In the aviation industry, complacency is not an option.

Despite a robust system of technologies, processes and layered defences, the industry continues to face many rapidly escalating risks. We need to be aware of how the risks are evolving and learn from the best practices of our peers.

Take terrorism; recent attacks on Istanbul's Ataturk Airport and Brussels Airport serve as grim reminders to enhance vigilance. With increasingly complex security issues to be dealt with, "Smart Security" and improved cooperation offer great potential to enhance aviation security.

Other emerging challenges, such as cybersecurity, global aircraft tracking and unmanned aircraft pose an additional depth of challenge. In particular, the prolific use of unmanned aircraft in the commercial and recreational arenas will eventually force regulators to address the safe co-existence of both manned and unmanned aircraft in the same airspace.

With air traffic expected to double by 2030, the industry has to find new ways to bring safety to a higher plane. In line with the Global Aviation Safety Plan, some new initiatives include the shift from a prescriptive to a performance-based regulatory framework, and a sharper focus on risk management.

Although highly technological, the complex aviation system is heavily dependent on humans. Using the PEAR (People, Environment, Actions, Resources) model approach to applying human factors in aviation, encouraging a positive security mindset and culture, and the power of collaboration are critical aspects that can further improve operational and management activities.

Besides experience, big data plays an important role in good decision-making in the aviation industry. Aviation could harness this powerful resource to facilitate predictive analysis and what-if trade-offs, especially in the area of air traffic management development and provision of meteorological data.

All these issues and more will be addressed through ten papers in this edition. I hope this Journal brings you new insights and inspiration thereby facilitating your contributing to the vibrant and fast-changing industry. I would like to express my appreciation to the authors and members of the Editorial Advisory Board for their contribution and guidance.

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### AIRCRAFT ACCIDENT INVESTIGATION

**A Global Safety Deficiency: False Glide Slope Capture Affecting Aircraft**

Mr Michiel Schuurman  
Assistant Professor  
Delft University of Technology, the Netherlands
Unmanned aircraft can be used for many purposes, such as delivery of goods, aerial filming, inspection and search and rescue. The operation of unmanned aircraft is becoming increasingly popular worldwide, including Singapore. While Unmanned Aircraft Systems (UAS) present many opportunities for beneficial uses, there are challenges in managing the risks associated with such operations. In 2015, Singapore enhanced its regulatory and permit framework to regulate the use of unmanned aircraft operations, with a view to mitigating the associated public safety and security risks.

This paper shares Singapore’s experience in the development and implementation of this framework, and the challenges faced in assessing various aspects, such as airspace usage, airworthiness and flight operations, and remote pilot competency, to ensure the safe operation of unmanned aircraft.
Mr Bensen Koh is Manager for the Unmanned Aircraft Programme Office in the Civil Aviation Authority of Singapore. He worked with the Ministry of Transport to set up the inter-agency Unmanned Aircraft Systems (UAS) Committee in 2015, and currently serves as the Secretariat of the UAS Committee’s Work Group 2 on UAS Policy and Regulations. Mr Koh works closely with internal and external stakeholders both within and outside the public service to support a balanced, sustainable and whole-of-government approach to UAS operations in Singapore.

Mr Charles Ang is Senior Manager for Policy & Rulemaking in the Civil Aviation Authority of Singapore under Safety Policy & Licensing Division. His responsibilities include formulating and implementing policies in various areas such as flight operations, air navigation services and air traffic controller licensing. He is also involved in the review of rules and regulations to ensure they are relevant, updated and consistent with the broader International Civil Aviation Organization’s Standards and Recommended Practices.

Mr Loke Zhao Dong is Deputy Manager for Air Navigation Services Policy and Planning Division in the Civil Aviation Authority of Singapore. His key responsibilities include formulating policies on airspace arrangement, civil-military cooperation and air navigation services provision to ensure a safe operating environment for air navigation within and around Singapore’s civilian aerodromes. He is also involved in international meetings on air traffic management and air navigation services.
INTRODUCTION

Unmanned aircraft, or more recently referred to as drones, have become affordable and accessible to the general public. Recreational flying of unmanned aircraft is fast gaining popularity. In Singapore, unmanned aircraft are used for purposes such as aerial filming and photography, inspection of infrastructure and facilities. Many more uses are also being considered by both the private and public sectors. If not carried out under proper regulation however, the operation of such aircraft poses a risk to aviation and public safety, especially in Singapore’s densely populated urban environment and busy airspace. The International Civil Aviation Organization (ICAO) defines UAS as “an aircraft and its associated elements which are operated with no pilot on board,” where “associated elements,” refer to other components of the entire system, including the pilot or autopilot, launching mechanism, data-links, and retrieval mechanism, in addition to the aircraft itself. Other terms used include Unmanned Aerial Vehicles (UAV) and Remotely Piloted Aircraft Systems (RPAS).

While UAS originated in and has mostly been used in the military domain in the past, the civil use of UAS has grown dramatically in the past few years. The public and private sectors in many countries have begun efforts to tap into the potential of the civil UAS market to enhance productivity and improve task effectiveness. Notably, early adopters include the oil and gas industry, as well as the building and construction industry. This is in part driven by the need to manage high manpower costs (due to shortage in manpower supply) and “dull, dirty and dangerous” jobs. The United States, United Kingdom, United Arab Emirates, Denmark, and China have all sponsored programmes or initiatives to support the use of UAS by government agencies.

Some of these useful applications include the use of UAS for aerial surveillance, safety inspections, search and rescue, 3D mapping and modelling, and delivery. Furthermore, as the technology develops, new UAS types will be created and innovative UAS applications will arise.

However, despite the great opportunities that UAS are able to offer, there are still many challenges and issues facing their effective adoption, especially in a small island State like Singapore with limited airspace and a dense urban environment. The foremost consideration is the safety hazard they may pose to manned aircraft operations. When a UAS flies near a manned aircraft; it can endanger manned aircraft operations by distracting
pilots or risk being ingested into aircraft engines. With roots in the military, UAS have long been used in and developed for conflict situations for intelligence gathering, hostile surveillance, and even air raids. Consequently, it should come as no surprise that the proliferation of civil UAS also raises some significant security concerns. Privacy is another issue that is often raised in conjunction with UAS, because of their great propensity for collateral intrusions of privacy, their ability to access high places, and a relatively low signature. Additionally, UAS requires the use of radio-frequencies, and this poses potential spectrum management issues in our dense and technologically advanced city. It is not difficult to recognise that issues related to the use of UAS are highly complex, given the great diversity of UAS types and configurations, and the diversity of the UAS ecosystems existing today.

ICAO is developing the Standards and Recommended Practices (SARPs) for cross-border unmanned aircraft operations and for the safe integration of such operations with manned aircraft operations. These SARPs, which are expected to be issued in 2018, will cover areas such as certification of the UAS, competency requirements of the UAS pilot and guidance on its operations. Recently, ICAO published the Manual on RPAS (ICAO, 2005), a guidance material which was developed over the past three years, with inputs from experts representing regulators, operators, manufacturers, pilot representatives, Air Navigation Service Providers (ANSPs), air traffic control representatives, accident investigation bureaus, human performance specialists, and surveillance and communications experts.

In Singapore, we have recognised that safety is but one aspect of the diverse risks that the proliferation of UAS presents across the public sector. As such, the Ministry of Transport (MOT) had set up an inter-agency UAS Committee that provides a “Whole-of-Government” platform to share experiences and solutions, and to chart a balanced and sustainable approach to UAS for the betterment of Singapore.

CONSIDERATIONS IN DEVELOPING THE ENHANCED UAS REGULATORY AND PERMIT FRAMEWORK FOR SINGAPORE

While ICAO continues to develop the SARPs for international UAS operations, and the Universal Avionics Systems Corporation continues its work to chart a balanced and sustainable approach for UAS operation in Singapore, there is a need to facilitate the operation of unmanned aircraft within Singapore in the interim. Clear rules on the safe and responsible use of such aircraft had to be quickly developed in order to mitigate the risks to aviation and public safety. Moreover, the general public, businesses and organisations, and recreational users of unmanned aircraft expect the Civil Aviation Authority of Singapore (CAAS), as the aviation safety regulator, to stipulate the safety requirements and provide guidance for the safety of their operations. Those who engage in commercial services likewise expect a reasonable level of regulatory control of unmanned aircraft operations.
In this regard, CAAS worked closely with other relevant government agencies such as the MOT, Ministry of Home Affairs (MHA), Singapore Police Force and Republic of Singapore Air Force to enhance existing regulations for Unmanned Aircraft operations in Singapore. With the Unmanned Aircraft (Public Safety and Security) Act 2015 and subsequent amendments (CAAS, 2015) to the Air Navigation Order in June 2015, an Enhanced Regulatory and Permit Framework was put in place as an interim measure.

Under this Framework, a permit regime has been introduced to regulate the operation of unmanned aircraft weighing more than 7kg, for business purposes, in the vicinity of aerodromes/military airbases or involving discharge of items/substances. The key considerations to address the safety risks posed by unmanned aircraft operations are as follows:

(a) Injury to persons and damage to property – Unmanned aircraft that are heavy are likely to pose a higher risk to aviation and public safety in cases of collision due to their mass and speed. Similarly, those that are used for commercial purposes are likely to pose higher risks as they operate more frequently, involve complex and difficult manoeuvres (e.g. carriage of load), and are often flown over crowded areas. Discharge of items/substances from an unmanned aircraft likewise can also pose safety risks to populace and property on the ground.

(b) Safety hazards to manned aircraft operations – Permits are also required if the unmanned aircraft operate within 5km of any aerodrome/military airbase, or above 200ft when beyond 5km. This is to ensure that unmanned aircraft operations are adequately separated from manned aircraft operations.

(c) Spectrum management – A permit is also needed for the use of non-approved frequency spectrums as defined by the Infocomm Development Authority (IDA) of Singapore, due to the potential hazard of frequency interference.

Two types of permits are issued by CAAS for the conduct of unmanned aircraft operations – the Operator Permit (OP) and the Activity Permit (AP). An OP is granted if the applicant is able to ensure safe operation of the unmanned aircraft, taking into account the applicant’s organisational set-up; competency of the personnel, especially those flying the unmanned aircraft; procedures to manage safety (including the conduct of safety risk assessments); and the airworthiness of the aircraft. An AP is granted for activities at a specific area of operation, which are of specific operational profiles and conditions. Permits (e.g. for flying over security-sensitive locations) from other government agencies may also be required, depending on the activity to be carried out. Table 1 summarises the circumstances under which permits are required under the Enhanced Regulatory and Permit Framework.

---

1 This is the government agency responsible for regulation of the information technology and telecommunications sector in Singapore.
In all the above operational scenarios, if the unmanned aircraft is flown indoors at a private residence, or indoor area used for the purpose of constructing or testing unmanned aircraft and accessible only to the persons involved, and the flying does not affect at all the general public, no permit is required.

Permits (e.g. for flying over security-sensitive locations) from other government agencies may also be required, depending on the activity to be carried out. Additional permits will be required if:

(a) There is discharging or dropping of substances/items from the unmanned aircraft;
(b) The radio frequencies and power limits used for operating the unmanned aircraft do not comply with IDA’s guidelines on radio frequencies and power limits for short range devices;
(c) The unmanned aircraft is flown over protected areas (i.e. security-sensitive locations gazetted as such and their immediate vicinity) or flown in Special Event Areas as declared by the MHA under the Public Order Act; or
(d) Photographs (including videos and live-streaming) of a protected area are taken using the unmanned aircraft.

The assessment leading to the issuance of the required permits uses a risk-based approach in the interim. Such an approach provides flexibility in assessing the diverse operations of UAS on a case-by-case basis.

Table 1 - *Circumstances under which permits are required for operating an unmanned aircraft*

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Weight of Unmanned Aircraft</th>
<th>Permit Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>For any purpose</td>
<td>More than 7kg in total weight</td>
<td>OP and AP</td>
</tr>
<tr>
<td>For any business purpose (i.e. Commercial activities or Specialised services) including if not Recreational or Research in nature</td>
<td>Any weight</td>
<td>OP and AP</td>
</tr>
<tr>
<td>For Recreational or Research</td>
<td>Not more than 7kg</td>
<td>No permit required. However, an AP (only) is required if the unmanned aircraft is flown outdoors: • in a Restricted or Danger Area; or • within 5km of an aerodrome/military airbase regardless of operating height, or above 200 feet beyond 5km of an aerodrome/military airbase</td>
</tr>
</tbody>
</table>
CHALLENGES IN FACILITATING UAS OPERATIONS IN SINGAPORE

Airspace: A Premium Resource
For a small island state, airspace is a premium resource. With increasing proliferation of UAS and rapidly growing civil air traffic movements at Singapore’s airports, managing the competing demands for airspace use becomes a challenge. Airspace has to be optimally allocated to the various users according to operational priorities and industry demands. For CAAS, a balanced approach to airspace management will become increasingly crucial to support the continued growth of manned aviation sector while facilitating the development of the rapidly growing UAS industry, without compromising aviation safety.

Aircraft Separation
In managing domestic UAS operations, CAAS, like many other ANSPs around the world, practices total segregation between manned and unmanned aircraft operations. Reasons for this are twofold: firstly, there is currently a lack of internationally-accepted separation standards and secondly, given that the UAS industry is in its nascent state and with the wide range of UAS available, the performance and capabilities of UAS are relatively ill-defined. This means that many unmanned aircraft are unable to comply with regulations designed for manned aircraft.

In light of these concerns, the risk for other airspace users is largely mitigated through separation with manned aviation. Unmanned aircraft in Singapore must be flown outside critical areas of flight operations, such as areas within 5km of aerodromes and aerodrome flight paths.

Airworthiness and Flight Operations
Unlike the maturity and reliability of manned aircraft technology, UAS technology is nascent and relatively less regulated. The absence of humans on-board the unmanned aircraft to steer the aircraft to land safely in the event of loss of control from the remote pilot or ground control station adds to the complexity of the assessment. In addressing these challenges, CAAS adopted a risk-based assessment approach. All potential risks, such as loss of control of the aircraft, failure of the flight control system, loss of line of sight and collision with properties and trees, have to be identified by the operator or user and substantiated with adequate risk mitigation measures. This is complicated by the diverse profile of operators or users, ranging from large entities with an established pool of expertise on UAS operations, to uninitiated members of the public.
Remote Pilot Competency and Licensing
In a similar light, there is currently a lack of standards or harmonised requirements on pilot competency and licensing. CAAS does not issue remote pilot licences currently, but instead manages the safety risks arising from a lack of pilot competency by assessing the remote pilot in three aspects, namely: knowledge, flying experience and skills. In assessing knowledge, CAAS reviews whether the pilot has adequate knowledge of the capabilities of the unmanned aircraft, knows the contingency measures to undertake, has attended any relevant training, including training on manned aircraft, and is familiar with aviation safety regulations relevant to aircraft operation. Experience is assessed based on the number of hours previously acquired on flying the unmanned aircraft, including that of manned aircraft, and past track records of unmanned aircraft operation. The skill of the remote pilot will determine whether the remote pilot is proficient and competent to operate the unmanned aircraft for the proposed operation and this is being determined through the conduct of a demonstration flight.

While CAAS has developed guidelines to assess remote pilot competency, there exists a certain degree of subjectivity which could potentially lead to inconsistencies in assessment in the long run. While remote pilots may declare that they have completed certain training by an unmanned aircraft training organisation, there is difficulty in ascertaining whether the knowledge is sufficient due to a lack of harmonised international requirements. Experience levels such as that of flying hours are figures declared by the remote pilot, which are neither officially certified by an approved training organisation, nor are they officially documented. The demonstration flight could only verify certain aspects of the skills possessed by the remote pilot for the specific operation and may not be comprehensive. Further studies would be required to better determine or assess remote pilot competency.

COMMUNICATION AND IMPLEMENTATION OF THE REGULATORY FRAMEWORK
To effectively implement the Enhanced Regulatory and Permit Framework, CAAS recognises the need for public outreach, awareness and education in addition to the promulgation of legislative changes. CAAS distributed to all households an advisory (in the form of Dos and Don’ts) on the safe and responsible use of unmanned aircraft for recreation and private uses (See Figure 1).

Additionally, posters were distributed to all educational institutions and hobbyist clubs. Noting that the use of unmanned aircraft very much started with the use of remote controlled aeroplanes and helicopters by hobbyists for recreational purposes, many hobbyists may not have the essential knowledge of civil aviation. Furthermore, any member of the general public could easily pick up such a hobby, given that such products are easily purchasable at retail stores. CAAS realised the need to communicate the safety risks to this group of unmanned aircraft users through issuing an advisory with easy-to-understand and captivating infographics to better advise them on what to look out for when operating an unmanned aircraft.
Figure 1 - Advisory on the safe and responsible use of unmanned aircraft for recreational and private use.

**DOs**

1. Know the characteristics of the aircraft and how to fly it safely
2. Ensure that the aircraft is safe for flight before you operate it
3. Fly only in good visibility and weather conditions
4. Keep your aircraft within your sight at all times
5. Ensure the operation of transmitting devices of the unmanned aircraft system complies with IDA requirements
6. Keep a sufficient distance from people, property and other aircraft (manned or unmanned)

**DON’Ts**

1. Don’t fly the aircraft over any crowd
2. Don’t fly an aircraft weighing more than 7kg (in total)
3. Don’t suspend, carry or attach any item to the aircraft, unless it is manufactured to hold the item
4. Don’t carry hazardous substances using the aircraft
5. Don’t drop or discharge any item or substance from the aircraft
6. Don’t fly where you may interfere with emergency service providers or over moving vehicles where you can endanger or distract drivers
7. Don’t fly the aircraft over or within restricted, prohibited or danger areas, including security-sensitive locations
8. Don’t fly within 5km of any airport/military airbase, or higher than 200 feet
A series of briefings for key stakeholders, such as operators of unmanned aircraft, hobbyists, recreational users and retailers, were also held to explain the new regulations and gather feedback pertaining to the regulatory update. This allows CAAS to further refine our rules and regulations in time to come.

CONCLUSION
The wider use of UAS in Singapore presents a complex combination of opportunities and challenges that cut across various sectors, as well as strong public sentiments expected to be divided along the lines of competing needs for increasingly limited resources (especially land and airspace), and that of safety, security and privacy concerns. The enhancements to the regulatory and permit framework and the guidelines are interim steps that would help to address immediate aviation and public safety issues, pending Singapore’s ongoing study of an appropriate framework to facilitate and promote the use of unmanned aircraft for public and commercial purposes. They also work to adequately address safety, security and privacy concerns, as well as ICAO’s developments on the SARPs for international UAS operations.

CAAS is also studying the more established UAS regulatory regimes of other civil aviation authorities and relevant organisational entities, and actively participates in international forums such as the ICAO RPAS Panel and the Joint Authorities for Rulemaking on Unmanned Systems meetings to track the technological and regulatory developments in the area of UAS. To be adequately prepared, States and international organisations will need to continuously monitor and adapt their policies accordingly as UAS technology and capabilities evolve.

REFERENCES


AVIATION SAFETY

PEAR Model Approach in Applying Human Factors to Enhance Aviation Safety

ABSTRACT

Everyone has their definition of human factors (HF) when it comes to aviation. Pilots think of the flight deck, avionics displays and controls. Engineers refer to accessibility and maintainability issues. Air traffic controllers may refer to the issues associated with vigilance and stress. Cabin crew must manage an aircraft full of humans, each with characteristics that are potential safety hazards. All perspectives, while specific, are correct in representing HF.

HF scientists/engineers have developed numerous HF definitions. The definitions are often supplemented with models, mnemonics, and acronyms. These techniques help users recall and consider the variety of HF that poses hazards in all aspects of aviation. This paper considers popular conceptual representations to explain and apply HF principles. The primary focus is on the mnemonic, PEAR. It stands for People, the Environment in which they work, the Actions they perform, and the Resources necessary to complete the job safely and efficiently. PEAR is generic across all disciplines of human performance and encompasses, as well as complements, many of the existing models.
Dr William Johnson (Ph.D. University of Illinois, 1980) is the US Federal Aviation Administration (FAA) Chief Scientific and Technical Advisor for HF in Aircraft Maintenance Systems. Dr Johnson’s experience includes over 35 years as a Senior Executive and Scientist in private and public engineering and airline companies before joining FAA in 2004. He is the top FAA executive responsible for research and development (R&D) and technical programmes related to human performance in maintenance/engineering. He is an Aviation Maintenance Technician and a pilot of nearly 50 years. Dr Johnson has delivered HF presentations in over 50 countries.
INTRODUCTION
The author, together with Dr Michael Maddox, Johnson and Maddox (2007) developed PEAR in the mid-1990s. Since that time it has become the prevailing international instructional method to introduce HF. The specific examples offered herein are particularly relevant to engineering/maintenance but are otherwise generally applicable to other areas.

METHODS TO CONSIDER HUMAN FACTORS AND HUMAN ERROR
There are a few very popular ways to generally characterise HF and human error. Below are suitable examples:

THE SHELL MODEL
The Software/Hardware/Environment/Liveware (SHEL) model was first developed by Edwards (1972) and modified by Hawkins (1987) when the second L was added.

Software, which in 1972 was not a widely-used computer term, referred to the non-physical, intangible aspects of the aviation system that govern how the system operates and how information is organised. Examples of Edward’s software were: rules, instructions, regulations, policies, norms, safety procedures, customs, practices, and collections of documents.

Hardware includes the physical elements of the aviation system, like aircraft (structures, systems, seating, etc.), operator equipment, tools, materials, buildings, vehicles, computers, conveyer belts, etc.

Environment is the context in which aircraft and aviation system resources operate, made up of physical, organisational, economic, regulatory, political, and social variables that may impact the worker/operator. Environment also includes work environments, like cockpits, cabin areas, ramp areas, and maintenance facilities.

Liveware is the human element in the aviation system. As SHELL evolved, one L represented the individual human while the second L represented the human working collectively with all other humans and parts of the aviation system.

The SHELL model was used extensively during the 70s and 80s for many Crew Resource Management (CRM) training programmes. It remains relevant today but has been replaced with other methods.

DR WILLIAM JOHNSON
Federal Aviation Administration, US
SWISS CHEESE MODEL
The Swiss Cheese Model (SCM) of maintenance error was developed by Reason (1997). The SCM is more about human error than about broad HF. Nevertheless, it is justifiably used in modern HF training, where students can understand and recall the concept.

Reason believed that most accidents could be traced to one of four failure areas:
- **Organisational Influences** – Resource management, organisational climate, and organisational policies.
- **Supervision** – Inadequate, planned inappropriate operations, failure to correct known problem, etc.
- **Preconditions for Unsafe Acts** – Condition of operators, personnel factors, and environmental factors, etc.
- **Unsafe Acts** – Errors and violations.

In the SCM, Reason represents the four failure areas with four slices of cheese. The holes in the cheese represent hazards while the solid cheese represents the defences against a series of failures. See a simplified SCM in Figure 1. The SCM has had a great impact on HF training and understanding. Searching for “the holes in the swiss cheese” has become a common expression and endeavor in aviation HF.

![Figure 1 - A Simplified SCM](image)

THREAT AND ERROR MODEL
The idea for the Threat and Error Model (TEM) came from Helmreich et al (1995) at the University of Texas. During the 1990s, TEM was widely applied to commercial aviation flight operations. The TEM team promoted the training for pilots to watch out for hazards that could lead to errors (threats), coming up with strategies to address these threats.

The TEM development team created the Line Operations Safety Audit (LOSA) process. LOSA is a process whereby a trained observer studies normal behavior, using a standardised method. The observer is a peer of those being observed, and hence this is also called peer-to-peer observation. TEM is used (Ma, et al, 2011) for the Maintenance LOSA observation process.
BOW TIE MODEL

The Bow Tie Model (BTM) emerged in the 1990s, developed by staff and consultants at the Shell Oil Company (no relation to SHELL Model), to identify and manage risk in the North Sea oil exploration operations. It has many of the same considerations as the SCM. Figure 2 shows a simplified BTM.

![Figure 2 - A Simplified BTM](image)

At the centre of the Bow Tie is a specific undesirable event or state. On the left side of the model, there are proactive (preventive) controls to minimise potential causes/hazards. The undesirable event at the centre is the trigger to determine the left and right sides of the model. The right side of the model represents potential corrective actions and mitigation from the undesirable event. Organisations have found the BTM to be very helpful in predicting potential system errors. The model is particularly conducive to “group think” sessions where knowledgeable personnel can collectively prevent or minimise potential hazards and anticipate or mitigate consequences.

DIRTY DOZEN

A discussion of HF training, models, acronyms, and pseudonyms would be incomplete without a mention of the Dirty Dozen. Dupont (1999) developed the Dirty Dozen concept in 1993 while he was working for Transport Canada developing HF training. The Dirty Dozen refers to 12 common pre-cursors to maintenance errors that lead to incidents and accidents. They would be called “hazards” in SCM, “threats” in TEM and “factors contributing to an undesirable state or event” in BTM. That is, they influence maintenance staff to make errors. In HF training the facilitator usually works with trainees to identify or design “safety nets” that would prevent or mitigate events resulting from one or more of the Dirty Dozen. Table 1 lists the Dirty Dozen, as shown in a HF training product from Lufthansa Technical Training as well as the FAA.

<table>
<thead>
<tr>
<th>The Dirty Dozen</th>
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<tbody>
<tr>
<td>1. Lack of Communication</td>
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<tr>
<td>2. Complacency</td>
</tr>
<tr>
<td>3. Lack of Knowledge</td>
</tr>
<tr>
<td>4. Distraction</td>
</tr>
<tr>
<td>5. Lack of Teamwork</td>
</tr>
<tr>
<td>6. Fatigue</td>
</tr>
<tr>
<td>7. Lack of Resources</td>
</tr>
<tr>
<td>8. Pressure</td>
</tr>
<tr>
<td>9. Lack of Assertiveness</td>
</tr>
<tr>
<td>10. Stress</td>
</tr>
<tr>
<td>11. Lack of Awareness</td>
</tr>
<tr>
<td>12. Norms</td>
</tr>
</tbody>
</table>
THE PEAR MODEL

PEAR, created by Johnson and Maddox (2007) around 1995, is the primary focus of this paper. The model, actually a mnemonic, was initially designed to be understood and used by the aviation maintenance and engineering audience. PEAR remains as the main HF training paradigm for FAA inspector training (Johnson, 2015b) and is also widely used by the Civil Aviation Safety Authority (CASA), Australia (Johnson, 2015a) training programme. The entire PEAR training can be downloaded from the training section of: www.humanfactorsinfo.com. PEAR is the basis for maintenance HF training at many airlines and maintenance, repairs and operations. For over two decades, the term “PEAR” has been used as a memory jogger, or mnemonic, to characterise HF in aviation maintenance. PEAR prompts recall of the four important considerations for HF programmes:

- People who do the job
- Environment in which they work
- Actions they perform
- Resources necessary to complete a job

In most cases, HF programmes are designed around the people in the organisation’s workforce. You cannot apply identical strength, size, endurance, experience, motivation and certification standards equally to all employees. The company must match the physical characteristics of each person to the tasks they perform. It must consider factors like each person’s size, strength, age, eyesight, hearing, and more, to ensure that they are physically capable of performing all of the tasks that the job entails. A good HF programme will consider the limitations of people and design the job accordingly. On the other hand, people are often the solution when machines cannot accomplish a task. For example, people are able to figure out the unanticipated complex troubleshooting not written into system software. People adapt where machines fall short in capability.

PEOPLE

HF programmes must focus on the people who perform the work. Programmes must address physical, physiological, psychological and psychosocial factors. HF programmes must focus on individuals, their physical capabilities and the factors that affect them. It should also consider their mental state, cognitive capacity and conditions that may affect their interaction with others (See Figure 4).

In most cases, HF programmes are designed around the people in the organisation’s workforce. You cannot apply identical strength, size, endurance, experience, motivation and certification standards equally to all employees. The company must match the physical characteristics of each person to the tasks they perform. It must consider factors like each person’s size, strength, age, eyesight, hearing, and more, to ensure that they are physically capable of performing all of the tasks that the job entails. A good HF programme will consider the limitations of people and design the job accordingly. On the other hand, people are often the solution when machines cannot accomplish a task. For example, people are able to figure out the unanticipated complex troubleshooting not written into system software. People adapt where machines fall short in capability.
Attention to the individual does not stop at physical abilities. A good HF programme must address physiological and psychological factors that affect performance. Companies must be diligent in not only pre-employment screening but also with continuing good physical and mental health. Offering educational programmes on health and fitness is one way to encourage good health. Many companies have reduced sick leave and increased productivity by making healthy meals, snacks, and drinks available to their employees. Companies should also have programmes to address issues associated with chemical dependence, including tobacco and alcohol.

Fitness for duty is an important aspect of the P in PEAR. The most common challenge is human fatigue. Fatigue Risk Management Systems should provide employee training as well as reasonable scheduling practices (Avers and Johnson, 2012 and Folkard, 2003).

Another People issue involves teamwork and communication. Safe and efficient companies find ways to foster communication and cooperation among the workers, managers and owners. For example, workers should be rewarded for finding ways to improve the system, minimise waste and help ensure continuing safety.

ENVIRONMENT – PHYSICAL AND ORGANISATIONAL

There are at least two environments in aviation maintenance. There is the physical workplace on the ramp, in the hangar or in the shop. There is also the organisational environment that exists within the company. A HF programme must pay attention to both environments (See Figure 5).

The physical environment is obvious. It includes ranges of temperature, humidity, lighting, noise control, cleanliness and workplace design. Companies must acknowledge these conditions and cooperate with the workforce to either accommodate or change the physical environment. It takes a corporate commitment to address the physical environment. This topic overlaps with the Resources component of PEAR when it comes to providing portable heaters, coolers, lighting, clothing, and workplace and task design.

The second, less tangible, environment is the organisational one. The important factors in an organisational environment are typically related to cooperation, communication, shared values, mutual respect, and the culture of the company. An excellent organisational environment is promoted with leadership, communication, and shared goals associated with safety, profitability and other key factors. At the same time, each employee must share the safety goal and be able to state their roles and actions to ensure safety. The best companies guide and support their people and foster a culture of safety. The author does not claim to offer the solutions to these organisational challenges in this short paper, but acknowledges that environmental matters are every bit as critical as the other elements in PEAR.

An example of programmes that have a notable positive effect on corporate organisational culture are the FAA’s Aviation Safety Action Program (ASAP) (FAA, 2002) and the 2015 FAA “Compliance Philosophy” (CP) (FAA, 2015), (Johnson, 2016). ASAP is a cooperative arrangement where the FAA joins with company management and its labour representation to report and correct errors as they occur. The result is a new level of teamwork that promotes non-punitive event reporting and clear communication to manage error and cost while ensuring continuing safety.
Contributing to the ASAP is the 2015 FAA CP. This philosophy balances reasonableness and enforcement action to ensure ideal regulatory compliance. A portion of the CP order says: “...When deviations from regulatory standards do occur, the FAA’s goal is to use the most effective means to return an individual or entity... to full compliance and to prevent recurrence. ...FAA recognizes that some deviations arise from factors such as flawed procedures, simple mistakes, lack of understanding, or diminished skills. The agency believes that deviations of this nature can most effectively be corrected through root cause analysis and training, education or other appropriate improvements to procedures...”

Portions of the CP refer to consistency, just culture, fairness and the interdependency among FAA to adopt the new philosophy in daily interaction with organisations and individuals. This philosophy will be paramount in promoting an enduring safety culture in both industry and government.

Figure 5 - Environment Factors in PEAR

<table>
<thead>
<tr>
<th>PHYSICAL</th>
<th>Lighting</th>
<th>ORGANISATIONAL</th>
<th>Size of company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>Sound level</td>
<td>Personnel</td>
<td>Profitability</td>
</tr>
<tr>
<td>Location inside/outside</td>
<td>Safety</td>
<td>Supervision</td>
<td>Morale</td>
</tr>
<tr>
<td>Workspace</td>
<td>Supervision</td>
<td>Labour-management relations</td>
<td>Corporate culture</td>
</tr>
<tr>
<td>Shift</td>
<td>Pressures</td>
<td>Crew structure</td>
<td></td>
</tr>
</tbody>
</table>

**ACTIONS**

Successful HF programmes must carefully analyse all the actions people must perform to complete a job efficiently and safely (See Figure 6). Job task analysis (JTA) is the standard HF approach to identify the knowledge, skills and attitudes that are necessary to perform each task in a given job. The JTA helps identify what instructions, tools and other resources are necessary. Adherence to the JTA helps ensure that each worker is properly trained and that each workplace has the necessary equipment and other resources to perform the job.

Many regulatory authorities require that the JTA serve as the basis for the company’s general maintenance manual and training plan. Often a manufacturer conducts JTA and prepares training objectives and material, thus minimising the necessity for extensive JTA by the airline or maintenance organisation.

Many HF challenges associated with the use of job cards and technical documentation fall under **Actions**. A crystal clear understanding and documentation of actions ensures that instructions and checklists are correct and usable. Increasingly, best success with adherence to technical instructions is driven by a corporate safety culture and peer-to-peer observation and pressure. Manufacturers are constantly working to clarify written procedures, keep them current, and deliver them in a format and medium that promotes effective and efficient use.

An interaction between PEAR and SCM shows how Organisation Influences; Supervision; Preconditions for Unsafe Acts; and Unsafe Acts affect the **Actions** of the PEAR Model. The TEM could be applied by determining what **Actions** are posing safety threats and how they must be managed.
RESOURCES
The final PEAR letter is “R” for Resources. It is sometimes difficult to separate Resources from the other elements of PEAR. In general, the characteristics of the People, Environment, and Actions dictate the Resources. Many resources are tangible, such as lifts, tools, test equipment, computers, technical manuals, and so forth (See Figure 7). Other resources are less tangible. Examples are the number and qualifications of staff to complete a job, the amount of time allocated, and the level of communication among the crew, supervisors, vendors and others.

Resources should be viewed (and defined) from a broad perspective. A resource is anything a mechanic (or anyone else) needs to get the job done. For example, protective clothing is a resource. A mobile phone can be a resource. Rivets can be resources. What is important to the Resources element in PEAR is that you focus on identifying the need for additional resources.

The Dirty Dozen lists “Lack of Resources” as one of the 12 most common contributors to human error. Often a lack of resources leads to improvisation. However the wrong scaffold, tool, procedure, or documentation, or qualified staff often contributes to errors and negative events.

SAFETY MANAGEMENT AND PEAR
All regulatory authorities require safety management systems (SMS). Regardless of the regulatory requirement, it makes good sense for an organisation to have a formal process that identifies potential hazards and their associated level of risk.

As part of the company’s SMS, policies must be established, hazards must be identified and mitigated, and the system must be monitored for acceptable levels of safety. An SMS must be formalised, documented, and become the key element of a company’s safety culture. The HF programme, exemplified by PEAR, provides methods for identifying and controlling many of the potential hazards within an organisation and should be an integral part of a company’s SMS programme.

PEAR is an easy means to remember the four key elements of any HF programme. Maintenance HF programmes do not have to be complex, expensive, or a burden to the organisation. Simply apply PEAR to identify HF issues and facilitate your efforts to develop and support your SMS.
WHICH MODEL IS BEST?

There is no best model, acronym or mnemonic. The one that works for the target population is best. Students and workers have to be able to remember the model so that it can be readily applicable to every day work. Models, acronyms or mnemonics are domain independent. What works for a flight deck can be used in a process control plant, a manufacturing facility, a medical facility or a construction site. Human error and the processes to address it are similar. These HF approaches work best in the growing number of environments where “safety culture” is more than a buzzword, but instead, an organisation-wide way of thinking, speaking, believing and behaving. At the same time the models, acronyms, and buzzwords can build and reinforce safety culture.

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AVIATION SAFETY

Performance-based Regulation – Are You Ready?

ABSTRACT

Civil aviation is an activity which carries very low levels of risk compared to almost all others in life. Despite this, public attention is drawn disproportionately to any accident, and so, as an industry, we must continue to improve to avoid public perception of safety concerns affecting the industry’s ability to grow. Prescriptive regulations, enforced effectively, have been the bedrock of the current level of safety achieved, and recently performance-based regulation (PBR) – as an additional safety layer – has been proposed and enacted into International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs). However, if under pressure from uninformed operators, untrained regulators introduce performance-based measures as an alternative to prescriptive regulations; then rather than being a safety enhancement, they risk becoming a degradation to civil aviation safety margins. Moving the burden of safety regulation and enforcement from the regulator to a conflicted operator is not going to enhance safety.
THE AUTHOR

Captain Martin Chalk is President of the International Federation of Air Line Pilots’ Associations (IFALPA), which represents more than 100,000 professional pilots from around 100 countries. IFALPA’s main role is to work with ICAO and other international organisations to develop and ensure harmonised implementation of SARPs in the global civil aviation system. Captain Chalk is also a senior captain with a large European network airline and has been flying in military, regional, short and long haul airline operations for over three decades.
AIR TRANSPORT CARRIES LEAST RISK FOR TRAVEL

Civil aviation has become an incredibly safe part of contemporary life. We regularly and frequently fly up to a 500-tonne aircraft, including 600 people and 200 tonnes of fuel, 12km above the world’s oceans and continents for up to 15 hours at a time, at temperatures of -70°C and wind speeds of up to 400km/h. However, for each passenger this remarkable event is safer than taking a bath and significantly safer than taking other forms of transport. Indeed, in the UK it is 12 times more likely that a person will die tripping up whilst walking, than from the worldwide risk of taking an airline flight.

Those who work and have worked in the civil aviation world should be rightly proud of this remarkable achievement, yet because of the remaining small number of high profile aircraft fatalities each year, public and passenger perception is not always positive. Airlines which have suffered aircraft losses will bear witness to the significant impact they have on profitability. Given the projected continuing positive growth rates in the industry, if we do not continue to work towards ever lower loss rates and higher safety standards, the resulting perception of increased risk will negatively affect the industry’s ability to grow.

Strong, thoughtful and evidence based regulation is one of the foundations of the success of civil aviation in turning its extraordinary challenges into mundane and remarkably risk-free undertakings. The current low level of risk in commercial air travel has been achieved by reflecting on all the possible causal factors of each accident and serious incident in order to identify and implement effective changes to the regulatory and operational environments. However, many regulators, led by ICAO, have concluded that the reactive approach alone is unlikely to result in significant further improvements to the current performance.

BUT HOW CAN WE DO BETTER?

In addition to the baseline, prescriptive regulations providing a minimum level of safety, a more dynamic, performance-based approach is advocated. Safety Management Systems (SMS), based on the new ICAO (2013b) Annex 19, are promoted as being an effective means of delivering a more nuanced and operationally responsive additional layer of safety; customised to suit each regulated entity and their operating environment. ICAO (2013a) advocates, in Document 9859 (Safety Management Manual), that “traditional data collection and analysis efforts, which had been limited to the use of data collected through investigation of accidents and serious incidents, were supplemented with a new proactive approach to safety. This new approach is based on routine collection and analysis of data using proactive as well as reactive methodologies to monitor known safety risks and detect emerging safety issues. These enhancements formulated the rationale for moving towards a safety management approach”.

CAPTAIN MARTIN ChALK
International Federation of Air Line Pilots’ Associations
When describing the necessary steps in developing this new layer of regulation, ICAO (2013a) is clear in paragraph 2.16 on a number of points;

1. “...requires that the existing prescriptive approach to safety be complemented with a performance-based approach.”

2. “The State and its product and service providers respectively should have a State Safety Programme (SSP) and an SMS in place.”

3. That baseline performance under the prescriptive system needs to be defined and analysed prior to the implementation of any performance-based elements to ensure that safety performance outcomes are better with the new regime.

4. System performance degradation must be addressed by “…modification of the performance-based requirement itself or, where necessary, restoration of basic prescriptive requirements.”

What is quite clear from this ICAO advice is that a performance-based regulatory regime is designed to be in addition to, and complement a prescriptive regime. How could an operator be required to return to the basic prescriptive requirements if these were no longer available or updated? Consequently, until the performance-based regime is comprehensively implemented, and successfully delivering better safety performance outcomes consistently; it is hard to see how it can be anything other than an additional investment in safety levels, available only to those with the capability to implement it.

**SO ARE THE REGULATORS FOLLOWING ICAO’S ADVICE?**

The European Aviation Safety Agency (EASA) published a Report (EASA, 2014) on the implementation of what it called a “Performance-based Environment” (PBE). In this whitepaper, it was quite clear that it agreed with the ICAO analysis. In paragraph 5, EASA asserts: “PBR should not be mistaken for ‘deregulation’ or ‘absence’ of any binding or concrete rules. It is not a relaxation or substitute of the prescriptive system. Continued adherence to prescriptive rules remains a success factor in a PBE to meet the targets. However, introduction of PBR can facilitate the continuous improvement of aviation safety.”

However, when the report had been subject to consultation, and had become “Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (EUR-Lex., 2015) on common rules in the field of civil aviation…”, the first expected result was “framework for eliminating unnecessary/overly prescriptive rules; introduction of performance based rules identifying objectives to be achieved, but leaving flexibility as to the means for achieving the objectives; framework for adapting rules to the risk involved in the activity they regulate.”
The extra investment EASA intends to make in the “transition” is laid out in the financial impact assessment: none. That first framework target will receive no additional financing, and the entire package of EASA changes, which include the transition to a PBE involves just seven extra staff.

So is PBR a safety enhancement or an increased risk? A performance-based system, is designed to be an enhancement process, an extra safety layer which can only serve to improve safety margins in a nuanced, industry sensitive way. When it is implemented without the investment in manpower, training, understanding and sufficient preparation, however, a performance-based oversight regime may well be a significant risk to the safety levels achieved with the prescriptive system.

JUST CULTURE – A PREREQUISITE
Safety performance assessment needs to be set within the framework of a national (or regional) SSP which provides the framework and setting for operators’ SMS. All SMS rely on data, which can come from automatic monitoring systems such as Flight Data Monitoring and audits, but must be augmented by what is universally described as the most important source of data – voluntary safety reports. These validate and contextualise the automatically reported data, and so give the risk assessor the whole picture from which to draw appropriate conclusions.

As an example, if an operator or State programme identifies that aircraft are regularly landing deep onto a particular runway, the automatic data may only suggest that pilots are failing to control their speed in the final stages of the approach. We can inform and educate the pilots that stable approach criteria must be adhered to, but unless they are engaged in a vibrant and effective voluntary reporting programme, we may not learn that there are topographical reasons for late windshear, or that Air Traffic Control (ATC) have recently implemented a minimum speed until too late in the approach, or that the new Performance-based Navigation (PBN) approach has a steep section which pilots new to the approach mishandle, or a myriad of other reasons why this runway provokes this behaviour.

ICAO, as well as some national regulators, have emphasised the need for “big data” or good sources of data as a prerequisite for a functioning SMS, yet seem much more reluctant to provide advice, guidance or regulatory requirements as to how to achieve the “Just Culture” which underpins the reporting culture and therefore the functioning SMS. There are lots of descriptions of “Just Culture” as well as many similar definitions – but how does a regulator measure performance with respect to culture? At one end of the scale is the operator which punishes its key safety staff (such as pilots and engineers) for reporting things it does not want to hear (management failures, fatigue, lack of resources), and at the other end is the operator which provides such opaque or difficult access to feedback that it effectively dissuades key safety staff from further reporting. Both preclude a valid SMS.
Recent research in the UK points to reporting culture being a difficult area. Research for the UK Civil Aviation Authority (UK CAA, 2015) pointed to 3 major headlines:

• “The overwhelming majority of pilots were strongly committed to safety, and took pride in this. They felt that safety culture is at the heart of the job...”;
• “...everyone we interviewed thought that there was under-reporting”;
• That the reasons for under reporting were often influenced by the (potential) reporters’ belief that the report would not be viewed purely as a safety report, but had commercial, employment or disciplinary impacts, too.

REGULATORS NEED TO BE READY – WHAT ABOUT OPERATORS?
Operators have a number of competing interests in both the reporters, (key safety personnel, employees, costs, etc.) and the reports. Safety enhancements which come at no cost to the operator are much more readily accepted than those which may incur some or substantial costs. Consequently, analysis is biased. This “legitimate self-delusion” was identified by Coglianese, Nash and Olmstead (2002) who described it thus: “In other words, regulated entities may present or interpret their models and data in a way that makes it look as if their proposed approaches will perform well, when in fact a more disinterested examination would find problems with the analysis.”

This leads us to a structural problem with a PBR system; the very organisation which is responsible for the collection and analysis of the data is conflicted. Regulators are generally thought of as being responsible for safety first, with economic performance as a secondary responsibility. However much operators say that safety is their highest priority, economic performance and survival are normally much stronger drivers of their decisions. Transferring the responsibility for analysing data and implementing appropriate mitigations for hazards to the operator means losing some of the objectivity in safety decision-making. This conflict of interests affects not just the analysis of the data, but its availability and quality if reporters perceive a biased analysis.

“LEGITIMATE SELF DELUSION” IS NOT A BASIS FOR VARIATIONS
Significantly, “legitimate self-delusion” is not a basis for permitting variations to baseline prescriptive regulations. PBR only work to improve safety in aviation if they are IN ADDITION to the strong prescriptive regulations currently providing high levels of safety.

One mitigation for the conflict of interests inherent in an operator is a “Just Culture”. Eurocontrol defines this as “a culture in which front-line operators and others are not punished for actions, omissions or decisions taken by them which are commensurate with their experience and training, but where gross negligence, wilful violations and destructive acts are not tolerated.” Skybrary, run by Eurocontrol has a good description of the various
aspects of a “Just Culture”, and quotes James Reason, who described it as “an atmosphere of trust in which people are encouraged, even rewarded, for providing essential safety-related information – but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour.”

A “Just Culture” is therefore a product of the management style of the airline. It results from the reaction of the key safety staff as they believe, through experience, that management will seek to understand first, and punish only on those extremely rare examples where people acted deliberately outside the rules, reckless as to the outcome.

“JUST CULTURE” IS SQUARELY MANAGEMENT’S RESPONSIBILITY
So a “Just Culture”, crucial to the success of any SMS, is created by management, but is only effective when trusted and engaged with by key safety staff. How does a regulator test the belief and engagement? Volume of reports will not betray the quality of those reports. An absence of fatigue reports may be due to the absence of fatigue in the operation – or the lack of encouragement for, or the deliberate suppression of, such reports. A weakening of the link between licensing authority and licence holder damages the process, as does a lack of employment security.

CONCLUSION
In conclusion, before contemplating a move to institute any form of PBR or PBE, aviation regulators should:
• ensure they understand the additional layer concept of PBR – it does not replace prescriptive regulation and compliance, but is complementary to it
• examine whether they have the necessary extra resources to provide trained, equipped inspectors to cope with the additional competencies necessary to regulate and then check for compliance
• understand and test for a “Just Culture” based on a functioning and productive voluntary reporting system; trusted and engaged with by key safety personnel
• question how the airline or operator is going to separate safety decision-making from commercial decisions – minimising the conflict of interests inherent in the operator
• maintain a robust and comprehensive prescriptive system to guarantee the current high level of safety is not compromised
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AVIATION SAFETY

Risk Management Systems – The Journey from Dystopia to Utopia

ABSTRACT

In modernity, risk is ubiquitous; it presents itself all around us within our daily lives. Risk means different things to different people – everyone has their own propensity for risk, some greater than others. The aviation industry is perceived to be a risky business. However, in reality, aviation is a well-managed industry which keeps risk management and safety at the very heart of its operations. Notwithstanding, risk is often misunderstood or even misused as a tool for getting one’s own way.

Risk is best managed within a workable safety management system (SMS), tailor-made to each organisation. Yet, SMS can become wieldy or in some cases, overly simple, resulting in a document often referred to as the “safety manual”. In order to make sense of this supposed “black art”, ICAO issued a useful guidance document to assist airports in formalising their SMS.

This paper shows how Glasgow Airport introduced their SMS and maintain the system through a continuous improvement philosophy which builds on recognised international standards.
Mr Gillies Crichton is the Head of Assurance at Glasgow Airport with 28 years’ experience in the aviation industry. He was the key architect of the SMS and their business recovery plans. He oversees health, safety, environment, fire safety, risk management, business continuity, audit and resilience and led the Airport Crisis Management team during the 2007 terrorist attack. He also chairs the Transport Group for the West of Scotland Regional Resilience Partnership.

Mr Crichton holds a Master of Risk, Crisis and Disaster Management. He is also a Graduate of the Institution of Fire Engineers; Member of the Business Continuity Institute; Specialist of the Institute of Risk Management and founding Director and Vice Chair of the International Aviation Fire Protection Association.
INTRODUCTION
Risk is universal, and is frequently changing. Yet, unsurprisingly, the perception of risk varies wildly from one individual to another. Anthropological studies demonstrate that human nature has a multi-dimensional view of risk which gives individuals the opportunity to adapt to the depth and breadth of their personal ideologies. Therefore, risk becomes personalised; giving individuals the right to choose how much risk they are prepared to live with. Indicating risk means “[…] different things to different people and different things in different contexts” (Warner, 1992: p. 7).

When humans and machines come together to form a highly socio-technical industry such as aviation, it can exacerbate the risk argument significantly, adding to the nuances of multi-faceted risk and vulnerability within aviation. This perception of risk can be a key driver of the efficacy of risk management and, therefore, how these identified risks impact at an individualistic and collective leadership level within the boardroom (Pidgeon et al, 1992, p. 89).

This can be further exacerbated with the potential for groupthink (Toft and Reynolds, 2005, P. 8). It can be potentially seen, when powerful leaders in the boardroom lead their organisations into an illusion that they are somehow invulnerable to potential risks and the subsequent effects of significant incidents (Janis, 1972, p. 36).

SMS is a long-established method to ensure risk is managed effectively within an agreed framework. This framework can be easily developed to suit each individual organisation dependant on the size, context and complexity. There is no such thing as one size fits all.

WHAT IS RISK?
Risks are uncertain events that, should they occur, will have an effect on the successful running of the business and the ability to achieve strategic business objectives. This, whilst a simple theoretical reasoning, can be supported by looking at everyday tasks: Crossing the road for example, requires a degree of risk-taking.

Every individual has a differing appetite for risk and some may decide to cross the road with a vehicle 20 metres from them, whilst others may decide that this might pose too much of a risk. A risk to one individual may be seen as an opportunity for someone else. Take for instance, the same two individuals now being in a race where the prize is to win $1 million. The objective has now changed from simply crossing the road, to winning the prize. This adjustment in objectives can therefore be directly proportional to the increased propensity to take risks.
Often people can be heard saying “you would never catch me doing that”. In reality, just because something looks risky, does not mean that it always is. Ostensibly, people often measure risk at an inherent level (pre-mitigation) rather than at the residual level when the controls are in place and working effectively. Inherent risk therefore, is where there are no mitigations in place and there was nothing done to treat the risk. Residual on the other hand, is the level of risk which is left after the risk has been treated (control measures).

When it is unknown, or individuals or organisations are unsure of what control measures are in place, then assumptions are often made. This could lead to an unacceptable level of risk, which, gone unchecked, leads to significant consequential problems for an organisation. Conversely, some organisations who are extremely risk-averse, throw money at problems with an array of control measures, without fully understanding the risk and where it fits within their business objectives. This is often referred to as “gold plating”. Indeed, there is often a misconception that risks need to be eliminated when in reality, it only needs to be effectively managed to an appropriate level.

THE LAWS OF PROBABILITY
Perception of the risk of flying can be substantially heightened following high profile air crashes in which large numbers of fatalities occur. Media plays a part in delivering the bad news, and can quickly whip up the public into becoming risk-averse without looking at the holistic “picture”. This was demonstrated in the aftermath of the 9/11 attack when many American citizens avoided air travel and opted to travel by road. Consequentially, an estimated of 1,200 more road deaths ensued in the following 12 months compared to the previous period (Baggini, 2010).

In actuality, statistics showed that in the ten years up to 2013, there were an average of 500 passenger deaths per annum during commercial flights. In developed countries, the probability is therefore in the region of 1:25 million per flight. Put into simple terms, a child born today has a greater likelihood of growing up to become the prime minister of the UK; winning a Nobel Prize in physics; or winning an Olympic gold medal rather than dying in an aircraft crash (Gee, 2014). Indeed, out of all of the transport modes per million miles travelled (air, road, rail and sea), air travel is clearly the one that presents the least risk (Westcott, 2015).

![Figure 1 - Deaths per million miles travelled (2004-2014)](image-url)
However, Gee (2014) states that 2014 was an exceptional year for fatalities with no less than three fatal crashes in the same week: the Malaysian Airlines flight 17 shot down over Ukraine on 17 July saw 298 fatalities; TransAsia flight 222 crashed into buildings whilst attempting to land in Taiwan on 23 July, suffering 48 fatalities and; Air Algerie flight 5017 which crashed in Mali on 24 July, suffering 116 fatalities. This halted the five year trend of reducing fatalities; notwithstanding, the number of fatal crashes continue to reduce (See Figure 2).

Furthermore, despite the crash of the Germanwings A320 aircraft in the French alps on 24 March 2015, the Bureau of Aircraft Accident Archives shows that this being the 17th aircraft accident of 2015, is a vast reduction on the 33 for the same period in 2014. Indeed, despite 2014 showing an increase in the number of accidents, due to the increased passenger numbers, it still equates to less than five accidents per million departures; the lowest number since 1973 (Arnett, 2014, p. 4).

**MANAGING RISK**

Often, organisations tacitly take an esoteric view to risk management, with the thinking that “it is the risk managers’ job”. In fact, it is essential that this myopic view is discouraged as it is the organisation as an entity, that needs to embrace the management of risk. The risk manager as a professional in assessing risk is only responsible for undertaking qualitative and quantitative risk assessments which should then be passed to the wider organisation to make decisions based on the outputs of the assessments.

Previously, risk management can easily be seen as a key component in organisational decision-making which supports the organisation’s set objectives. In its broadest terms, it can be defined as a tool to assist organisational decision-making in reaching its business objectives. Put another way, it is simply effective business management.
However, during periods of austerity, boards may look to take greater risks than normal in an attempt to produce greater operating profits for their shareholders. The downside to doing this is that latent failures may be unwittingly built, which may manifest themselves several years later with catastrophic consequences. It is like black ice forming on roads, where the risk of the ice cannot be readily seen; nevertheless, the danger is real, it is no less apparent and is a killer if ignored, or not anticipated – in other words, appropriate control measures must be put in place to manage the risk.

Taleb (2007) describes another potential issue where risks are often ignored purely on the basis that something like that has never happened before. This is known as “black swan thinking” which sees risk takers believing that all swans are white and that black swans do not exist, because they have personally never seen one. Taking this stance, there are many issues which could easily manifest themselves within the aviation industry which have never happened before. In the case of the terrorist attack at Glasgow Airport in 2007, had that attitude been taken, the airport would not have reopened for business as usual in less than 24 hours. The mantra, “think what if, rather than if only”, stands true.

In managing risk, the tide of change is turning as the public become sensitised to disasters. Inevitably, there continues to be an increase in the number and intensity of disasters, even in the aviation sector. However, society needs to establish if it is reasonable to expect disasters to cease, especially as society becomes more tolerant to uncertainty (Lagadec, 1993, p. 12; Perrow, 2011, p. 291). Moreover, like risk, there is no universality to what may erroneously be deemed a disaster. For some sections of society, a simple accident may well be deemed a quasi-disaster, especially if it affects them personally.

The aviation industry can be arguably proud as one in which risk management forms part of its DNA. The introduction of systems, processes and procedures such as crew resource management, collision avoidance systems, enhanced ground proximity warning systems, just safety cultures and the investigation of aircraft accidents are just a few examples of risk improvements put in place to improve safety. Indeed, as previously stated, the number of aircraft-related crashes and consequently, the number of fatalities has decreased over the past ten years. However, from an airport perspective, one of the greatest steps forward in risk management was the introduction of the requirement to have an SMS in place.

SAFETY MANAGEMENT SYSTEM

In order for risk management to drive improvements in daily life and help organisations achieve their strategic objectives, it is best served through a risk-based SMS. SMS is often misunderstood as being a simple mono-directional, safety manual. In reality, SMS is by its very definition, a system which is cyclical in nature, and therefore, done correctly, it negates the need for a start, middle and end point – a continuum.

As harmonisation of standards continues to take effect across Europe, the European Aviation Safety Agency (EASA) has mandated the use of SMS at aerodromes “The aerodrome operator shall implement and maintain a management system integrating SMS” (EASA, 2014, p. 158). Indeed, EASA define SMS as “[…] a systematic approach to manage safety including the necessary organisational structure, accountabilities, policies and procedures” (EASA, 2014, p. 34).
Clearly, SMS is a key and important factor in managing risk and consequently, safety at aerodromes. Yet, it is important to note that organisations should use SMS to assist in managing their businesses, not merely because it is a mandate.

By use of a robust management system, it can be adapted to each organisation, depending on their organisational needs. Some organisations have exceptionally complex systems, whilst others are simple and easy to use. However, the system should fit the needs of the organisation and the amount of effort required to make it effective. These systems can be electronic, manual, or a combination of both.

SMS is not a tool to be used to manage risk; instead, it is a collection of tools which are used at the appropriate time and in the appropriate context. A useful analogy, therefore, would liken an SMS to a toolbox rather than a tool (ICAO, 2009, p. 7-1). The benefits of using this analogy, is that the assembled collection of tools are pulled together into one place having the added advantages:

- All tools found within a single place;
- Facilitates a collection of tools;
- Provides the correct tools for the job;
- Different tasks need different tools – tools and tasks are interrelated, not a one size fits all;
- The tools are readily in hand – a search is not required;
- Only trained personnel are permitted to use these tools;
- The toolbox can vary in size and volume;
- The toolbox protects the contents inside, keeping them safe and secure;
- Easily auditable – confirm all of the tools in the box are working as intended.

This demonstrates that an SMS can be adopted to suit individual organisations and help support their organisational objectives as a single, integrated and holistic system. Therefore, organisations which embrace a proactive SMS within a continual improvement philosophy will manage their risks in an effective and efficient manner.

With an effective SMS, it will assist organisations in their decision-making process and aid the development of setting strategies and identifying organisational objectives. Therefore, the SMS needs senior leadership buy-in from the outset. This is not to be understated, as many senior leaders needs to be convinced that good safety performance means good business performance.

Possibly, one of the reasons for the laissez-faire attitude is that there has been a focus and over-reliance on emergency planning for a long period of time. The risk profile of the aviation industry on the other hand, shows that whilst an aircraft accident is a catastrophic event, it is also becoming an exceptionally rare event when compared to other risks. Therefore, SMS has the ability to address the situation by taking an over-arching view by embracing enterprise risk, which can also encompass business resilience issues as part of the same system.
This was demonstrated during the floods in Southern England on 24 December 2013, which led to the closure of the North Terminal at Gatwick Airport on one of the Airport’s busiest days, with many passengers expecting to fly home for holidays (MacMillan, 2014 p. 4). Following a House of Commons Select Committee report into the event, the UK Civil Aviation Authority was given direction to ensure UK airports, especially regulated airports, had a level of preparedness for non-emergency type of events in which passenger welfare may be affected.

During the ICAO High-Level Safety Conference in 2010, a decision was taken to incorporate the common elements of the existing annexes into a single new annex. This included transferring or duplicating the safety management provisions from Annexes 1, 6, 8, 11, 13 and 14. Annex 19 was brought into force in 2013 (ICAO, 2013b). Notwithstanding, ICAO (2006) had previously issued guidance material by way of a safety management manual - Document 9859 (2006). This provided extensive guidance on the provision of SMS including the minimum requirements:

- Safety policy and objectives
- Management commitment and responsibility
- Safety accountabilities
- Appointment of key safety personnel
- Coordination of emergency response planning
- SMS documentation
- Safety risk management
- Hazard identification
- Safety risk assessment and mitigation
- Safety assurance
- Safety performance monitoring and measuring
- Management of change
- Continuous improvement of SMS
- Safety promotion
- Training and education
- Safety communication

**THE “MANAGING RESPONSIBLY” SYSTEM**

Glasgow Airport has a well-established and embedded SMS in place. This system, known as the “Managing Responsibly System (MRS)”, is an integrated management system encompassing quality, risk, safety, environment, asset management and business continuity. This gives the benefit of a single system with each strand of management feeding directly into the system.

This MRS is a 14-step process based on the Plan-Do-Check-Act (PDCA) model (See Figure 3). It ensures that enterprise risks are identified, assessed and optimally managed.
The system was cross-mapped against the ICAO Safety Management Manual (2009) to ensure all of the necessary elements of the SMS were covered (See Table 1). This demonstrates that the system is a “plug and play” insofar as the elements are ubiquitous; they cover all areas of the business and are interdependent of each other e.g. safety risk and environmental risk can be juxtapositioned within the same system. This joined-up thinking, therefore, goes a long way in addressing some of the socio-technical frailties which could otherwise put undue levels of risk onto the business.

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<td>Appointment of key safety personnel</td>
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As part of a five-year SMS strategy, Glasgow Airport undertook certification to four international standards. The MRS was cross-mapped against International Organization for Standardization’s (ISO) 22301 (Business Continuity Management), 14001 (Environmental Management), 55001 (Asset Management) and Occupational Health and Safety Advisory Service’s 18001 (Health and Safety Management) certifications. Currently, all of these standards are firmly in place within Glasgow Airport. Additionally, the MRS was used as the basis for a British Safety Council five-star audit which was achieved in 2013 on the first attempt – making Glasgow Airport the first to do so. This was then followed up in the same year by a British Safety Council “Sword of Honour” for excellence in safety management. Glasgow and Hyderabad Airports were the first airports in the world to achieve such an honour.

International standards are useful to assure businesses that the right levels of safety management are in place. Glasgow’s suite of ISO’s helps to focus the mind on doing the right thing for the right reasons, rather than purely pleasing the regulator. ISO 31000 (2009) is a relatively recent addition which sets out a very useful framework for risk management principles and helps companies to understand risk concepts and associated procedures.

Developing the MRS was relatively simple; however, implementing the system was somewhat more difficult. This was due to the myriad of old systems, spreadsheets, documents and other processes, which individuals have grown accustomed to over the years, that become personalised to them – they all had better ways of doing it. This was exacerbated where the documents were hidden away in personal folders or other areas accessible only to a few.

It is necessary, therefore, for senior leadership teams and heads of department to provide a clear steer towards the need for a single system. However, some of the heads of department required convincing, which brought in an added dimension of convincing them to assist in convincing others. The major benefits of having a single system were simple; it saves time, effort and duplication across departments.

In early days, heads of department would call or email the head of assurance to request a copy of a document, accident statistics, risk register etc. This required more time in training staff to use the system, which could otherwise be realised through self-service.

Each section of the MRS has a local operating procedure (LOP) in place which explains in detail, what is required and how it should be executed. The first LOP was essential to ensure that all of the documents including policies, strategies, processes etc. were all completed in a standard format, using an agreed nomenclature.

**DOES IT WORK?**

Year 2014 was an exceptionally important year for the city of Glasgow. A number of high profile events including the Commonwealth Games, Ryder Cup, MTV Europe Music Awards and the BBC Sports Personality of the Year saw an estimated 33 percent of the human population across the entire planet watch Glasgow on television during the year. Clearly, as the main entry and exit point to the city, Glasgow Airport played a key part in ensuring these events went off smoothly.
Ostensibly there was no need to develop a standalone planning and preparation system as the MRS has the ability to envelop these major events into the system. An “events” risk register was produced and incorporated within the Glasgow Airport risk register. Operational plans were produced, contingency plans addressing potential issues were completed, emergency plans worked out and both tabletop and practical exercises were tested with multi-agency partners. Such was the success of the MRS that not a single piece of adverse media was reported.

Yet, in the early part of 2014, the potential existed for massive passenger disruption. A major electrical shutdown of 90 percent of the campus had to be planned and implemented. This was due to the need to replace potentially faulty electrical switchgear required by the manufacturer as part of a world-wide safety alert. Again, the MRS was utilised to ensure that the outage went off without any disruption; similarly, not a single complaint or mention in the media.

Is this something new? The answer is clearly, no. The terrorist attack on Glasgow Airport in June 2007 highlighted to the world the robustness of the MRS. Scotland was generally thought to be exempted from terrorism. During the face of terrorism associated with Northern Ireland on the UK mainland, Scotland was never attacked. This potentially caused Scotland to take a narcissistic view to terrorism. However, Glasgow Airport had identified terrorism as a potential risk, hence, such plans was planned and tested. Consequently, following the attack, Glasgow Airport fully reopened for business as usual in 23 hours and 59 minutes after the attack took place. A true demonstration that risk managed within a robust SMS is not only good for business, but plays an essential component as well.

CONCLUSION

Clearly, risk means different things to different people and everyone has a differing appetite to how much risk they are prepared to live with. Risk is not something to be feared, indeed, it is something we live with on a daily basis. Yet, the risk term is often misused, especially when trying to convince another on the merits of a particular topic or project.

Risk, therefore, can only be properly analysed and deemed so, by having firstly looked at likelihood and consequences. Only then can an appropriate measure of risk be determined and demonstrated that failure to manage risk can lead to significant problems.

SMS helps us to understand risk better. Vitally, it should be remembered that an SMS is not a tool; it is a system to facilitate the vast array of tools which, used correctly, can aid decision-making and support reaching the business objectives through a philosophy of continual improvement.
REFERENCES


The US commercial aviation industry is a system comprising a complex array of subsystems that must work together effectively. Because these subsystems are coupled, changes in one subsystem can affect some, or even all, of the other subsystems. To continually improve safety, the industry uses a collaborative approach to accomplish “System Think” (ST) – an awareness of the impacts throughout a system of changes in any of its subsystems. The industry brings its key participants together to work collaboratively to identify and address potential safety concerns. This resulted in an 83 percent reduction in the US commercial aviation fatality rate in only 10 years. It also demonstrated that, contrary to conventional wisdom, safety improvements resulting from a collaborative approach can simultaneously improve productivity. A collaborative approach can also help other industries manage their safety risks more efficiently and effectively.
Mr Christopher A Hart is Chairman of the US National Transportation Safety Board (NTSB), having been nominated by President Obama and confirmed by the Senate in 2015. The NTSB investigates major transportation accidents, determines probable cause, and makes recommendations to prevent recurrences.

He was previously a Member of the NTSB from 1990-1993, and has held a variety of other legal and transportation safety positions. Mr Hart has a law degree from Harvard Law School and Master’s and Bachelor’s degrees in Aerospace Engineering from Princeton University. He is a member of the District of Columbia Bar.
MR CHRISTOPHER A HART
US National Transportation Safety Board

INTRODUCTION
The NTSB is a federal government agency that investigates accidents in all modes of transportation in order to determine what caused the accidents, and to make recommendations to prevent recurrences. This paper is about the power of collaboration to improve safety in US commercial aviation. The collaboration process appears to be very generic, and the aviation industry experience suggests that in theory it should be transferable to other complex industries that are engaged in potentially hazardous endeavors.

THE CONTEXT
In order to explore the transferability of the collaborative process, it is helpful to look at the typical structure of complex industries. Complex industries often involve systems that are made up of several interconnected and coupled subsystems. Because of the coupling, a change in one subsystem will often affect other subsystems. Moreover, the subsystems often include many high-tech aspects in which there is continuous innovation, which the industry must continually incorporate. In this context, if a mishap occurs, the cause is usually not that one subsystem was not working properly; more typically, the cause is that the interactions between the subsystems were not as anticipated.

Collaborative efforts can help enormously in mitigating such risks. For example, equipment manufacturers can bring in operators of the equipment they are designing, to inform the design of the human/machine interface. Manufacturers of large aircraft generally involve pilots during the design phase, which has greatly improved commercial aviation safety. This represents only one facet of a broader collaboration addressing the myriad coupled subsystems in commercial aviation.

The good news regarding complex systems, especially in industries that are engaged in potentially hazardous endeavors, is that their defences are usually sufficiently robust, that more than one thing must go wrong to result in a mishap. The bad news is that the interactions between the subsystems are often so numerous and complicated that when something does go wrong, preventing it from happening again may require several interventions at several places in an already complex system, as opposed to a simple or single intervention.

EFFECTS OF INCREASING COMPLEXITY
As increasing automation makes operations more productive, reliable and efficient, complex systems grow in complexity, increasing the possibility of human error. Investigations by the NTSB have shown that increasing complexity may increase the likelihood of human error in at least three ways: first, the more complex a system becomes, the more difficult it is to factor out tendencies for human error.
Second, increasing complexity increases the likelihood that operators, the “people at the sharp end,” as Reason (2000, p.768) describes it, will encounter situations that were not anticipated by the designers of the systems and subsystems. When an unanticipated situation is encountered, the operator must respond in the moment, often without any training regarding how to manage the event (because the situation was unanticipated). Moreover, because automation is generally becoming more reliable, the operator is likely never to have seen a given failure before, even in training. When the automation encounters an unanticipated situation or environment, a highly competent and well-trained operator may be able to salvage the situation successfully. If an operator of average ability cannot reliably handle it, sooner or later the situation will generate an undesirable outcome.

Third, increasing complexity increases the likelihood that operating “by the book” may not generate the best response. Highly competent and well-trained operators may routinely ignore “the book” in those situations because they have learned how to do it better. These improvements are commonly known as “workarounds.” If something goes wrong during a “workaround,” it is common to punish the operator for not going “by the book.” If “workarounds” are common, however, a more productive response would be to determine why common practice is not consistent with the “book” and then address the inconsistency, perhaps by revising the “book”, in the interest of safe and reliable operations.

The result of the increased likelihood of human error due to increasing complexity is that front-line workers who are highly trained, competent, experienced, trying to do the right thing, and proud of doing it well may still commit inadvertent human errors. In that respect, people are the greatest weakness in complex systems, because human operators will always be a potential source of error. However, people are also the greatest strength because they are the last line of defence, if the complex system fails to function as designed, or if an unanticipated situation presents itself.

Commercial aviation examples of the pilot’s importance during emergencies include the 2009 Hudson River crash in New York City, which resulted from a bird ingestion, and the crash in Sioux City, Iowa, in 1979, which resulted from an uncontained engine failure that irreparably damaged all three of the aircraft’s hydraulic systems.

The possibility of system failure and other unanticipated events, however slight, is the primary reason that automation will not replace humans in the commercial aviation system in the foreseeable future.

THE PARADIGM SHIFT

The challenge is how to make complex systems that include human operators work more safely and reliably.

Historically, one of the most common responses when something went wrong in the system was to punish the operator. The theory was that the operator was highly trained and had performed as trained, the undesirable result would not have occurred.
However, today’s safety experts are realising that punishing the operator usually does not solve the problem. Mistakes are by definition not intentional, so safety experts focus not only on why the operator’s action produced an undesirable result, but also on why the system allowed, or failed to accommodate, the operator’s inappropriate action. This allows them to determine how to improve the system.

For the operator, this does not amount to “get out of jail free card”. On the contrary, the operator is always ultimately accountable. However, instead of focusing solely on the operator, system issues should also be addressed.

The initial challenge, therefore, is understanding how complex systems behave. One suggested method is called “System Think (ST)”, i.e., understanding how a change in one subsystem of a complex system may affect other subsystems.

**SYSTEM THINK**
The commercial aviation industry accomplished ST by gathering representatives from all parts of the complex system together – including airlines, manufacturers, pilots, air traffic controllers, the regulator, and others – to collaboratively:

(a) identify potential safety concerns,

(b) prioritise those issues (because they will identify more issues than they have resources to address),

(c) develop solutions for the prioritised issues, and

(d) evaluate whether the solutions are
   (i) accomplishing the desired result, and
   (ii) not creating unintended consequences.

The programme, in which participation is completely voluntary, is called the Commercial Aviation Safety Team (CAST).

Understanding the system, however, is only the beginning of the challenge. Ultimately, the challenge is about understanding the interactions between the system and the human operators, in order to determine how to make them work together more effectively. The aviation industry is doing that by collecting, analysing, and sharing information about the human/system interactions. The data they are collecting includes automatically generated data from aircraft flight data recorders and air traffic control radar systems, as well as reports from pilots, air traffic controllers, and others, usually about near-misses.

The collaborative process has two objectives: to make the systems less likely to generate opportunities for human error, and given that human error cannot be eliminated, to make the system more able to tolerate error without undesirable consequences.
Another industry that is seeking to address these issues is healthcare. According to a report (Kohn, Corrigan and Donaldson, 2000, p.5) issued by the US Institute of Medicine, Committee on Quality of Health Care in America: “The focus must shift from blaming individuals for past errors to a focus on preventing future errors by designing safety into the system.”

The fuel for ST is information about what is happening every day on the front lines, including what is working well and what is not. One of the best sources of this information is the front-line work force. Because they engage daily with these subsystem functions, they often also have good ideas about how to make things work better. In order to obtain information from front-line workers, it is important to encourage them to report what is happening, and to assure them that, absent criminal or intentional wrongdoing, their reports will not be used against them.

When the front-line workers are confident that their reports will not be used against them, large quantities of data will become available. Then the challenge is for safety experts, with the help of sophisticated tools and processes, to transform that large quantity of data into useful information that can be used to identify potential safety concerns; prioritise them; develop interventions for the prioritised concerns, and evaluate the effectiveness of the interventions.

THE AVIATION INDUSTRY SUCCESS STORY

The collaborative process has worked very well in US commercial aviation. Although aviation was already deemed very safe in 1997, the CAST programme reduced the fatality rate, which had plateaued, by more than 80 percent in the first ten years, largely because of ST, fueled by proactive safety information programmes.

The process has been sustainable because it improved both safety and productivity, contrary to conventional wisdom that improving safety usually undercuts productivity and vice-versa. If that were not enough, one of the major challenges in complex systems is making intended changes without generating unintended consequences, and CAST has generated very few unintended consequences.

Last but not least, the CAST process accomplished this significant safety improvement mostly through voluntary compliance, without generating any new regulations. The industry was already highly regulated, and the way to improve it further was not through more regulations, but a better understanding of how to make all the subsystems and the people in the complex commercial aviation system work better together.

The moral of the story is a simple one: anyone involved in a problem should be involved in its solution. CAST ensured that this was the case.
BENEFITS OF COLLABORATION

Getting the industry to participate in CAST was a major paradigm shift. In most regulated industries, the regulator identifies a problem and proposes a solution. The industry often responds that the regulator does not understand the operational realities. Thus, the industry gives little credibility to the regulator’s identification of the problem, and even less credibility to the regulator’s proposed solution. Even if the problem was correctly identified, the proposed solution may not be the best way to resolve it. Hence, the industry often resists and delays implementing a solution, and when forced to, complies begrudgingly and half-heartedly.

A collaborative ST process, on the other hand, involves all of the industry participants in identifying problems and developing solutions. The result is a solution which enjoys “buy-in” from every participant because all participants’ perspectives were openly discussed and considered, and the participants understand each other’s perspectives. Consequently, the solutions are promptly and willingly implemented.

Equally important, if the solution needed further refinement, as often occurs in complex systems, all of the participants, because of their buy-in, are interested in tweaking the solution to make it work. The usual regulatory process provides no ability for tweaking. Collaboration yields solutions that are not only more effective and efficient, but also less likely to generate unintended consequences.

WHY IS COLLABORATION NOT MORE WIDESPREAD?

Given how successful this process has been, why is it not being used at the industry-wide level in more industries? There are several aspects to the answer: the need for a significant catalyst that stirs the players to action, and the need for incentives that outweigh the factors which challenge collaboration.

The Catalyst. The aviation industry created CAST because, as mentioned before, its accident rate, which had been falling rapidly for several decades, began to flatten out to a plateau by the 1990s. Meanwhile, the US Federal Aviation Administration was projecting that the volume of commercial aviation would double within 20 years. Doubling the volume of flying while maintaining the same accident rate meant that the public would see twice as many fatal accidents. Since anybody’s accident is everybody’s accident, and the public cares only about the number of events but not about the rate, it would have been a marketing nightmare for the industry.

The Incentives. The catalyst was important to get the process started, but the incentives that encourage participation are also crucial to keep it going. First, aviation mishaps, even minor mishaps, command intense media and political interest. Second, as mentioned above, anybody’s accident is everybody’s accident, so the entire industry engages in helping everyone prevent accidents. When an aircraft crashes, the public does not respond, “That was Airline X, I’m not worried because I’m flying with Airline Y.” On the contrary, crashes anywhere in the world can discourage people from flying. Third, airlines do not compete in field of safety, which enables them to liberally exchange information about what their safety concerns are and how they are addressed.
Challenges of Collaboration. The catalyst and the incentives must be sufficiently compelling to overcome the considerable challenges of getting industry participants to collaborate. For several reasons, that is not a trivial undertaking.

First, there is basic human nature, which is, “I’m doing it right. This complex system has problems because everyone else is doing it incorrectly.” Getting people beyond their natural “I’m ok, you’re not” thinking can be challenging; consider, on the personal level, two squabbling spouses who both say “I don’t need to go to the marriage counselor. You’re the one with the problem.”

In addition, the participants generally have differing and sometimes conflicting interests. For example, getting labour and management to come to the table together is often challenging. Many of the participants may be co-defendants in accident litigation, e.g., the manufacturer and the operator, and therefore focused in litigation on showing that the accident was the “other guy’s” fault.

The regulator is not normally welcome in the process, for fear that the regulator will use the information revealed for enforcement purposes. Conversely, the regulator may challenge the process for looking too much like a democracy – everyone decides what happens by majority vote – in a context in which the regulator, by law, is supposed to decide how best to improve safety.

The bottom line is that the collaborative process requires everyone to be willing, in their enlightened self-interest, to participate in the process to improve the overall system, rather than to think narrowly about only their own situation, on the basis that if the system improves, everyone wins. The important distinction is between ordinary self-interest, i.e. participating only for oneself; and enlightened self-interest, i.e. participating for the benefit of the system.

By analogy, successful athletic teams are usually those which see every player playing for the team, as opposed to trying to distinguish themselves as individuals.

A crucial ingredient to get all of the participants to think about the system is trust. All of the participants must trust that the other participants are working in the interests of the system, not just for themselves.

THE ROLE OF LEADERSHIP AND THE REGULATOR
Given the challenges of developing a collaborative process, strong leadership is crucial. Within each participating entity, leadership must do several things. First, leadership must demonstrate a commitment to improving safety, but that commitment must also reflect a clear recognition of the reality of human error, as opposed to demanding “no errors on my watch.” An intolerance of error does not mean it will not occur, it simply means it would be covered up.
Second, leadership must avoid falling into the “I’m ok, you’re not” trap by making it clear that improvements must occur not only with the front-line workers, but also at every level in the organisation, including the top. If the leader’s only solution is more training for front-line workers, that sends a polarising message that the leader has got everything in order, but the workers do not. Instead, leadership should make clear to the workers that improvement is called for at all levels.

Third, leadership must ensure that middle management’s performance metrics include safety. If the only performance metric for middle management is narrowly construed production/throughput, middle management will implicitly or explicitly discourage feedback from front-line workers about potential safety issues – especially if addressing those issues might interfere with narrow production or throughput goals.

Fourth, leadership must include labour from the outset in identifying and addressing the issues, as opposed to deciding unilaterally what the issues are and what the solutions should be. The latter is analogous to the situation described above in which the regulator defines the problem and tells the industry how to solve it. Ultimately the front-line workers have to implement the solution. They need to have a vested interest in making the solution work.

Fifth, leadership must ensure that everyone who is involved in the problem is collaboratively involved in developing the solution. That includes manufacturers, operators, regulators, and anyone else who is involved in the problem.

Last but not least, leadership must do whatever is necessary to generate the fuel for the process, i.e. reports from front-line workers about what is working well and what is not. Leadership must encourage and facilitate reporting by front-line workers; provide feedback to them so they will know that their reports are not disappearing into a black hole; provide adequate resources and make reporting simple and achievable on work time; and follow through with action on the reports to ensure that the workers know that their feedback is appreciated.

The potential win-win-win is enormous: Management is better informed about what is happening, labour feels more appreciated, and safety is continuously improved.

On an industry-wide basis, regulators are effectively the leaders, so to enable the collaborative process, regulators should do everything enumerated above. In addition, on an industry-wide basis, regulators have the duty of conducting enforcement against individual operators, but they should also emphasise the importance of system issues. Moreover, regulators must recognise that, while enforcement is an important tool for improving safety, overzealous enforcement can undermine collaboration, so they must carefully strike a balance between enforcement regarding egregious wrongdoing, while seeking improvement in response to inadvertent errors.
One of the regulator’s most important roles is to facilitate collection, analysis, and sharing of information by clarifying that, barring criminal or intentional wrongdoing, information provided by workers to proactive information programmes will not be used for enforcement purposes. Similarly, regulators should encourage the entities in their industry also to avoid punishment of their employees except in relation to criminal or intentional wrongdoing. Unless those steps are taken, front-line workers will remain reluctant to submit reports.

Ultimately, regulators must recognise that compliance is very important, but their mission is reducing systemic risk in their industry. As CAST has demonstrated, if an industry is already heavily regulated, giving the regulator a “bigger stick” is probably not the most effective way to continue improving safety.

CONCLUSION

Safety programmes that improve the bottom line are more likely to be sustainable, and collaboration can help generate safety programmes that improve productivity while improving safety. The US commercial aviation industry collaboration success story is probably transferable, in whole or in part, to other complex industries in potentially hazardous endeavors that are seeking to improve their safety and reliability.

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*This article is in the public domain of the United States because it is a work of the US Federal Government under Title 17, Chapter 1, § 105 of the United States Code (as amended).*
AVIATION SECURITY

Aviation Security: Challenges and Priorities within the Airline Industry

ABSTRACT

When dealing with aviation safety, every accident presents an opportunity for learning and improvement, so a repeat of similar occurrences can be prevented. In aviation security, where human intention plays a role, past incidents and acts of unlawful interference must be seen in the context of risk management – and this requires examining a range of threats which may not have materialised yet. 14 years after 9/11, two main lessons can be drawn for the benefit of aviation security. Firstly, the current system is strong but also complex, being built from many layers of defence initiatives, many of which are relative to a past high-profile incident. The need to look ahead instead of looking back is one reason why airports and airlines are now promoting a new generation of passenger screening. This concept is called “Smart Security”, and integrates new technologies, along with other options for risk-based screening and process improvements.

Secondly, aviation security has been successful in building cooperation channels across borders in the last few years; but it must now take the same approach to building cooperation across disciplines. Recent events and emerging cyber-threats are indications that it will become increasingly difficult to draw clear lines of responsibility between aviation security, border control, information technology, safety, flight operations and air traffic management in the future. This highlights great potential for new or improved cooperation channels between disciplines.

Imagine a chess game, in which there can only be one winner. Each player not only constantly analyses how their own moves can help them reach their objective, but also considers the opponent and their future moves. When it comes to aviation security, what lessons can one learn from the past, to the benefit of the present and future? Should the priorities of the future be guided by the past at all?
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In her role, Ms Herbelles is part of the Airport, Passenger, Cargo and Security (APCS) regional team in Singapore and acts as IATA’s main contact point for Asia Pacific Security and Facilitation issues; helping deliver IATA’s initiatives in the region and ensuring that national regulations are adequate, risk-based and consistent with global standards.

Prior to this role, she coordinated the global airline industry’s Security and Facilitation positions from IATA’s headquarters in Montreal, and has also defended the European airline industry’s interests while working for the Association of European Airlines in Brussels. She has also trained with the European Commission’s Air Transport Directorate, Air France, the Spanish Airport Authority and with the world’s airport association, Airports Council International (ACI).

A French national, Ms Herbelles holds a Master of Air Transport Law and Management from Aix-Marseille University in France. She speaks French, English, Spanish and German. In her spare time, Ms Herbelles is a keen runner, having completed many half-marathons and two marathons in various countries.
AVIATION SECURITY: PAST LESSONS CAN HELP BUT CAN ALSO HINDER

Aviation security today is largely based on “past lessons learnt”. Examples abound: unaccompanied baggage has been re-screened since the Air India bombing in 1985; the cockpit door has been reinforced following 9/11 terrorist attacks; liquids, aerosols and gels (LAGs) were restricted on board after a terror plot was uncovered in 2006, and international air cargo security has been enhanced since another foiled plan involving printer cartridges in 2010.

The question is: is it our objective to prevent the attacks which happened in the past? To some extent, past events (successful or not) give a good indication of the shifting nature of terrorist paths, and the LAGs and printer cartridge plots were uncovered with the help of intelligence agencies. Today’s aviation security system is often compared to slices of Swiss cheese stacked on top of each other: risks are mitigated by a series of security measures that are “layered” onto one another.

This system is strong, but it is also complex. In addition to the several layers in place, from access control to aircraft checks and from screening of persons to screening of cargo, international harmonisation of security measures has not progressed in the same way that aviation safety harmonisation has. Beyond harmonising security measures at a minimum or baseline level prescribed by ICAO’s Annex 17 – Security, this same Annex also requires States to adopt a risk-based approach to security. In other words, States must tailor their security system to their individual environment, assessment of the risk, and tolerance to risk.

Unfortunately, security layers are often introduced after incidents, as a way to reassure the public that they will never happen again. It is difficult to discuss risk management in detail with the media and the public, therefore knee-jerk solutions that are directly related to the specific incident are often introduced, bringing people a sense of security. Few politicians, faced with a high-profile incident, have dared to express confidence in the robustness of their system.

The paradoxes of the “immediate solution” approach have come to light twice in the last few years: when the underwear bomber plot could not possibly have led to more intimate searches on passengers; and when the reinforced door procedures allowed a flight crew member to lock himself in the cockpit, as seen in the case of the Germanwings tragedy. Instead, recent incidents have shown that the extraordinary can and will happen. One cannot prevent attacks against aviation through a piecemeal approach. The lesson is that the system needs to be smarter, and that security cannot work in isolation from other disciplines.
RESPONDING TO FUTURE THREATS: SMART SECURITY

The aviation industry has witnessed firsthand the complexities and contradictions of the last decade of security rules, because it deals directly with passengers who struggle to understand these often intrusive rules. The passenger security screening checkpoint is an iconic part of this aviation security system. While today's checkpoint works, it does so at a great cost, operational complexity and to the detriment of many passengers who have become dissatisfied with queues and intrusive measures. Therefore, the passenger screening checkpoint is one key area where the industry is focusing its efforts – seeking to make the airport process more resilient and more customer-friendly.

Initially called the “Checkpoint of the Future”, the initiative started as an IATA project in 2009 before becoming a joint airport-airline (ACI-IATA) initiative renamed “Smart Security” in 2013. In September 2012, ACI, IATA and several States presented a Roadmap for the future of passenger screening which was adopted by the ICAO High-Level Conference on Aviation Security. Today, ICAO Annex 17 – Security continues to focus primarily on physical screening of passengers rather than on passenger pre-screening using available information. The industry, along with more and more States are testing new concepts that go beyond the baseline, with Smart Security providing an ideal platform for information sharing.

In addition to addressing risk-based differentiation, the ACI-IATA Smart Security initiative groups other crucial improvements into two more categories: technology and process. Smart Security also recognises that there will not be a one-size-fits-all solution: the approach is based on a menu of options which States and airports can choose to adopt where their risk, operations and resources warrant.

Since 2012, a Smart Security Blueprint has been developed. It lays out a number of innovative paths and techniques and how they are expected to evolve over time. Some examples include various ways of achieving risk-based differentiated screening, and the infrastructure needed to enable it. Also, advanced technologies for passenger and cabin baggage screening including next generation X-ray equipment, passenger security scanners, also known as body scanners or Advanced Imaging Technology (AIT), and stand-off Explosive Trace Detection (ETD). Solutions to enhance operational efficiency, including centralised image processing of cabin baggage X-ray images, parallel tray loading, and new options for lane configuration and automation, are also included.

A Smart Security Management Group has been set up consisting of five airlines, five airports and five government authorities (aviation security regulators and/or screening authorities), plus one representative each from ACI and IATA. This group meets regularly to provide high-level guidance and detail policy, technical and operational requirements.

For the past several years, various research activities and proof-of-concept trials have taken place in close cooperation with a selected group of airports, regulators and screening authorities, most notably at Smart Security partner airports: Amsterdam Schiphol, London Heathrow, London Gatwick, Doha Hamad, Melbourne Tullamarine and Dublin airport. The purpose of these trials is to validate (or, as it happens, invalidate) the innovative concepts listed in the Blueprint, demonstrate their benefits in terms of security effectiveness, operational efficiency and passenger experience, and test their operational viability in a real-life environment.
The knowledge gained and lessons learnt from trials and proof-of-concept implementations are collated into a comprehensive set of Guidance Materials that can be used to drive wider adoption of Smart Security concepts in other States and airports. After the initial issue in late 2015, these Guidance Materials will be frequently updated and amended to ensure that they remain in step with state-of-the-art security screening processes and technologies.

So how will Smart Security contribute to looking forward instead of backwards? For one, it is not focused on one particular threat. Risk assessment, which may take the form of behavior analysis, ensures that the system is deterrent and unpredictable to travellers. The concept recommends technologies such as AIT that are able to address a range of threats – compared to today’s ubiquitous archway metal detectors which only address the somewhat outdated threat of metallic items.

Finally, improving the processing of passengers through the checkpoint is a forward-looking effort. However, airports may not be able to keep up indefinitely, with increasing traffic growth. Global passenger traffic is growing by 5.9 percent each year, and by 11 percent in Asia Pacific. In some regions, new airports are being built that include spacious screening areas. By contrast, most existing airports are running out of space and will see customer satisfaction go down when these travellers are squeezed through the existing infrastructure. This is already starting to happen, with the latest IATA Passenger Survey showing that the most stressful touch point in passengers’ trips is security screening, with passengers’ tolerance for queuing times decreasing year after year.

FROM CROSS-BORDER COORDINATION TO CROSS-DISCIPLINARY COORDINATION

In the last decade, international coordination in aviation security has improved tremendously: a number of structures are in place for States to regularly exchange information, and in many cases the industry is actively consulted. In addition to the ICAO Aviation Security Panel and its Working Groups, and excluding industry associations, trans-national forums for discussing aviation security include, among others:

- ICAO regional security groups; including the Regional Aviation Security Coordination Forum in Asia Pacific and Cooperative Aviation Security Programme – Asia Pacific;
- Pacific Aviation Safety Office, whose core services include Aviation Security Asia Pacific Economic Cooperation’s Transportation Working Group and its Aviation Security Sub-Group;
- The ICAO Security Point of Contact network;
- World Customs Organization (WCO) Technical Experts Group on Air Cargo Security;
- ICAO/WCO Joint Working Group on Advance Cargo Information;
- The European Civil Aviation Conference ;
- The European Union’s Aviation Security Committee and its Stakeholder Advisory Group on Aviation Security;
- The European Union-United States Transportation Security Coordination Group.

In other words, opportunities certainly exist today for aviation security experts and decision-makers to exchange information across borders. Airports, airlines and pilot associations continue to attend global security meetings such as the ICAO Aviation Security Panel as observers, as they have done in the past. More recently, they have been joined by representatives from the Air Navigation Service Providers, the air cargo and express industries, aircraft manufacturers and
security equipment manufacturers. Within IATA, the Security Group ensures the airline industry maintains a global strategy and consistent positions on aviation security.

The groupings listed above have gone a long way in ensuring that all involved in the development and delivery of aviation security measures understand each other’s goals and capabilities, across different borders. IATA is a member or observer in many of the above-mentioned forums; where the main players are familiar with, and have a substantial understanding of one another, a range of viewpoints can be considered and the global aviation system can remain both secure and efficient.

In the future, aviation security will need to reach out, more and more, to agencies and colleagues whose main role and competency is not security, but safety, cargo or Information Technology (IT). Recent events have shown that as our defences against traditional acts of unlawful interference get stronger, future events might well be those that cross over between flight operations, safety, data, cargo and/or IT. Airlines will, more than ever, need to approach security issues in a multi-disciplinary way.

CROSS-DISCIPLINARY COORDINATION: THE EXAMPLE OF PASSENGER FACILITATION

Already today, a multi-disciplinary approach is in place, as can be seen from the way Aviation Security stakeholders cooperate with Facilitation experts. Certain Facilitation Standards in ICAO Annex 9 – Facilitation are labelled as “security-related” and are audited under ICAO’s Universal Security Audit Programme, requiring a coordinated approach between security and border control (mainly immigration, customs) authorities. This coordination is not only apparent in government structures such as the requirement for National Air Transport Facilitation Committees in each State. Many airlines also have a single Security and Facilitation team which ensures that both issues are properly coordinated.

CROSS-DISCIPLINARY COORDINATION: THE EXAMPLE OF CARGO FACILITATION AND AIR CARGO SECURITY

Cooperation between Security and Facilitation is also apparent in the field of air cargo security. The 2010 printer cartridge incidents led to an increase in air cargo security regulations. Of particular importance was the recognition of supply chain security, which pushes security controls upstream and outside of the airport – an area that was already regulated by Customs authorities. Aviation Security and Customs look at different, but interconnected issues: while in the past, Customs dealt mostly with the collection of Customs duties and combatting illicit smuggling, it has now extended its scope to cover trade security. For example, the WCO’s SAFE Framework of Standards to Secure and Facilitate Global Trade envisages that Customs should play a key role in securing and facilitating trade, including protecting trade against terrorism. Receiving electronic cargo information can be done before the aircraft’s arrival but also before departure: the latter is called Pre-Loading Advance Cargo Information, or PLACI. This concept can benefit Customs as well as Aviation Security – not to mention trade. Joint or aligned frameworks are appearing at the national level: e.g. the European Union and Australia are looking at parallel application processes for cargo businesses that seek both Customs and Security trusted statuses (respectively called “Authorised Economic Operator” and “Regulated Agent”). The same Customs/Security alignment is also emerging at a global level, with the welcome creation of a Joint Working Group on Advance Cargo Information between ICAO and WCO.
THE NEXT FRONTIER IN CROSS-DISCIPLINARY COORDINATION: THE EXAMPLE OF CYBER SECURITY

Through dedicated structures and mechanisms, industry and regulators have made great strides in bridging gaps between security and border control interests. These structures and mechanisms need to be replicated for other complex issues, where security plays only one part to a larger equation. One example is cyber security.

Within airlines’ organisational structures, IT teams have traditionally taken the lead in protecting systems which were considered as business-critical, such as reservation and financial systems. Countering online fraud has been a part of airlines’ IT security plans for some time. However, interest is shifting to the potential vulnerability of Air Traffic Management (ATM) or aircraft systems to cyber-attacks, with regulators focusing particularly on the risk - still assessed globally today as low - of a cyber-attack that would jeopardise the safety of flights.

Airlines need to address these distinct challenges in a holistic manner, looking at the range of cyber security threats in the same way that they manage risks to their physical assets: assessing the various IT systems, their criticality and each threat’s likelihood and impact before devising responses accordingly. This requires the bridging of expertise between risk managers, safety, flight operations, ATM and IT, which will not be easy due to the complexity of the subject.

One of IATA’s goals is to assist its member airlines in developing, implementing and enhancing their cyber security programmes. One tool that is at the disposal of airlines is an IATA Cyber Security Toolkit which recommends a risk-based, corporate approach to cyber security that is akin to Security Management Systems. Globally, most agree that aviation cyber security is likely to become more prominent over the next few years, so the learning and exchange process should start now. Just as aviation security has increased its cross-border cooperation by having forums providing for regular exchange of information, cyber security will require the development of forums that facilitate and promote exchanges between different businesses and agencies, within entities and at national/international level. Only then will a common language and a mutual understanding emerge, with a coherent strategy as the ultimate solution.

Platforms for cyber security dialogue have existed in industries such as banking, and they are starting to emerge in civil aviation. At the global level, a Civil Aviation Cyber Security Action Plan was signed by ACI, the Civil Air Navigation Services Organisation (CANSO), IATA, ICAO and the International Coordinating Council of Aerospace Industries Associations (ICCAIA) in January 2015, including a roadmap through which the signatories commit to cooperate on cyber threat and risk assessment; language and terminology; joint positions and communications to staff and to the public, and reporting of incidents. A high-level coordination mechanism was also established through an Industry High-Level Group which meets on a regular basis. Ad-hoc international events dedicated to civil aviation cyber security were organised in Paris in July 2014 and in Singapore in July 2015. Airlines are also tackling the cross-disciplinary challenge by getting cyber security on their Board’s agendas, running Cyber Risk Management Workshops and by putting the Security team in the lead for cross-divisional efforts.
For every business and every State, the challenge will be to set up structures that are not ad-hoc but are built into the routine structure. The cyber space is too dynamic to deal with an occasional review of risks and priorities. Moreover, the complexity of the subject means that ad-hoc workshops without a regular structure will bring value but will only scrape the surface. The key value that airline security managers can bring is to help businesses understand their risks. To deliver this value, they will need to understand, for example, how electronic flight bag content is uploaded; how pilots operate transponders, or which aircraft systems interact with each other. This steep learning curve is necessary and will benefit the whole company, putting cyber space in the overall context of protecting both physical and virtual assets.

CONCLUSION
The air transport industry is constantly looking for ways to innovate, modernise and improve itself; whether this applies to how passengers book their flights, how they travel through the airport, how the supply chain manages the flow of air cargo documents from origin to destination, or how security can become more effective and efficient.

IATA’s security priorities include Smart Security and cyber security. They have something in common: both are looking forward instead of merely trying to prevent what has already happened from happening again. There is an increasing realisation that aviation security needs to be two steps ahead instead of one step behind.

Some have compared safety to a science, and security to an art. To a large extent, the “art” of security will need to think outside the box over the next few years, not necessarily reflecting what is visible or known (i.e. past events, intelligence) as a realist painter would do, but reflecting trends and patterns in what would appear to the layperson to be unpredictable and incoherent – closer in the art world to what an abstract painter would do.

Modern art did not reach its peak in a vacuum. Instead, it was built upon centuries of traditional, often realist creations, and inspired by developments in society or through other disciplines. The same could be said of modern aviation security: it is not refuting decades of traditional approaches – projects like IATA and ACI’s Smart Security are actually building upon them. What aviation security needs to do more than ever, specifically with cyber security, is to leverage the expertise of other disciplines, becoming ever more in-tune with its environment and the challenges of modern times.

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AVIATION SECURITY

Aviation Security Human Factors: Towards A Positive Security Mindset and Culture

ABSTRACT

Aviation security is a critical pillar in the global civil aviation system. It comprises various components. These include the establishment of policies, regulations, security processes, measures, use of technology, communications and coordination, as well as continuous efforts to develop new approaches that mitigate new and emerging threats to civil aviation operations. One of the critical factors that determine the success of any aviation security regime is human factors (HF). HF form the core foundation of all aviation security regimes. When HF are weak, even the best possible security measures and technology will fail.

The key drivers of HF in aviation security are mindset and security culture. These two critical aspects of aviation security HF determine the attitudes, policies, behaviours and approaches of all civil aviation personnel – including the passengers – towards aviation security. With a positive security mindset and culture, all civil aviation stakeholders can make significant contributions to uphold the level of security in the global civil aviation ecosystem.
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Mr Lim had served as Vice-Chairman of the International Civil Aviation Organization (ICAO) Aviation Security (AVSEC) Panel from March 2009 to March 2011, and then as Chairman of the ICAO AVSEC Panel from March 2011 to April 2015.

He has also served as a member of the ICAO’s Secretariat Study Group on liquids, aerosols and gels (LAGs) (2007), Rapporteur of the ICAO AVSEC Panel working groups on Guidance Materials (2009-2011), Screening of Non-Passengers (2011-2012), and the development of the ICAO Comprehensive Aviation Security Strategy. In 2014, Mr Lim assumed the co-chairmanship of the ICAO-World Customs Organization Joint Working Group on Advanced Cargo Information. In April 2015, he took on the role of rapporteur of the ICAO AVSEC Panel Task Force on the security of remotely piloted aircraft systems. Within the Asia Pacific region, he continues to serve as Vice-Chairman of the Asia Pacific Economic Cooperation Aviation Security Experts Sub-Group.
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INTRODUCTION
Over the past three decades, States and civil aviation industry stakeholders have implemented many AVSEC measures to protect threats against airports, aircraft, and various other supporting services and facilities. These include security measures for air cargo, airline catering, fuel installations, aircraft maintenance, airport ground handling, and many more. At the global level, ICAO has also been actively working and promoting efforts on many fronts to enhance AVSEC standards and approaches worldwide, to address new and emerging security threats to civil aviation operations.

EVOLVING SECURITY THREATS AND MITIGATION MEASURES
Security threats to civil aviation operations continue to evolve. In turn, new security measures, including the development of new technology, security equipment and security processes have been developed to mitigate these threats. ICAO has also constantly been revising and establishing new SARPs under Annex 17 (ICAO, 2011), so that States and stakeholders will level up and focus their efforts on dealing with these security threats. In recent years, ICAO has also developed a Risk Context Statement (ICAO, 2013) that serves as a useful guide to all States on the security risks that needs to be addressed by all stakeholders1.

The development of new security procedures, measures and the use of security technology and advanced equipment are steps that certainly strengthen the security of the global civil aviation system. These are important on various counts: to address the security threats; mitigate security vulnerabilities and gaps; optimise the use of limited resources; and keep up facilitation and efficiency of airport and airline operations. Given the growing demand in air travel, which provides many wider economic benefits and spin-offs for States and stakeholders, security and facilitation must continue to be maintained at an efficient and effective level.

Globally, there is also greater use of security technology and advanced security equipment to protect civil aviation operations. This is driven by several factors. First, terrorist groups are becoming more sophisticated and innovative in their methods to attack civil aircraft and civil aviation facilities. Second, States and stakeholders need to cater to the demand for air travel and at the same time, provide for a high level of security and facilitation. Third, new technology continues to be developed that can be used by States and stakeholders to address the security threats faced. In addition, States and stakeholders across different airports also have unique and local circumstances, infrastructure constraints, cost and funding, as well as cultural issues that need to be considered, when implementing security measures at airports to meet the needs of security and facilitation.

Looking over the past three decades, it is evident how security threats, mitigation measures, new procedures and security technologies have evolved. For example, following the 1985 mid-air bombing of Air India flight AI182 from Montreal, Canada, to New Delhi, India, via London, UK. A bomb was found to have been introduced through the in-flight catering channel in Montreal, thus security measures at airport in-flight catering facilities were tightened and new security measures, such as strict access controls, were introduced.

In 1988, following the bombing of Pam Am flight 103 over Lockerbie, Scotland, which killed 259 passengers and crew, and 11 persons on the ground, ICAO (2005) introduced a new Standard that came into effect on 1 January 2006 mandating the security screening of all hold baggage. This led to the introduction of new methods for the screening of hold baggage, such as the 100 percent in-line hold baggage screening system at airports using explosive detection systems, and the use of explosive trace detection systems. Some States and airports also increased the use of explosive detection dogs, commonly known as “K9”.

Horrific attacks involving civil aircraft have taken several tragic forms: the attacks in the US on 11 September 2001; the “underwear” bomb attempt and threat to bomb the fuel farm at New York’s John F. Kennedy International Airport in 2009; the bombing of Metrojet flight 9268 over Egypt, and the mid-air explosion incident on board Daallo Airlines flight 159 in Somalia in 2016, using a sophisticated explosive device concealed in a laptop computer. The multitude of these attacks and their variety of methods clearly demonstrate the continuous evolution and challenges posed by new and emerging security threats to civil aviation operations.

HUMAN FACTORS IN AVSEC

However, the effectiveness of security measures and procedures employed by States and stakeholders, including the use of advanced security technology, are heavily dependent on HF. HF are a critical part of the entire security and facilitation process to deny and defeat threats to civil aviation operations. Without the human being to establish the necessary security policies, regulations, programmes, and to manage the security processes, measures, and to operate the security equipment, all civil aviation security outcomes and objectives would not be met.

The scope of HF in AVSEC management and operations are many-fold. HF are present in every layer of AVSEC, from the strategic to the final line operations. Two factors that are critical to helping strengthen the AVSEC management of States and stakeholders are: mindset and culture.

Having a positive and supportive mindset towards AVSEC and the critical role it plays in the global civil aviation system is a very crucial starting point amongst regulators and stakeholders. An organisation’s mindset towards AVSEC will determine the attitudes and policies that it takes towards AVSEC and all issues relating to security. An organisation’s mindset originates from the very top, with its highest ranking officer and the organisation’s leader undertaking security responsibilities to protect the State’s civil aviation operations.

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STARTING FROM TOP LEADERSHIP

Given AVSEC’s importance to the civil aviation system, it is imperative that its top leaders adopt a position to enhance AVSEC, in light of evolving threats to civil aviation operations.

The top leaders of regulators and stakeholders can also better appreciate each other’s concerns, and help air travellers appreciate the need for implemented security measures, which may cause some inconvenience.

A positive mindset adopted and demonstrated by the top leaders of civil aviation stakeholder organisations towards AVSEC and how AVSEC balances with facilitation, cost-effectiveness, development and meeting passenger and stakeholder expectations will certainly permeate down and create a positive AVSEC culture within the State’s civil aviation ecosystem. With top leadership support towards the need for good security, relevant personnel within each organisation can benefit from investment of new security equipment and processes to enhance and strengthen AVSEC security measures.

HIGH SECURITY AS A COMPETITIVE ADVANTAGE

It could be beneficial if the top leaders of civil aviation organisations consider in their mindset and culture that high security could be a competitive advantage, instead of viewing security as a “chore”, “problem”, or as a costly undertaking that brings little financial return. By viewing security as a competitive advantage, civil aviation regulators, airports and airlines could attract more passengers to use their airports and fly on their airlines, on the strength that they are secure. Passengers ultimately want to fly safely and securely from one destination to another.

The establishment and development of a positive and strong security culture are very important amongst civil aviation regulators and stakeholder agencies. The culture within an organisation reinforces its attitude towards AVSEC, and also sets the environment for all personnel on how important AVSEC stands amongst the priorities of the organisation. While an organisation’s culture is established by its top leadership, the rank and file play a critical role in perpetuating and influencing the attitudes and behaviours of the organisation towards the needs and implementation of effective AVSEC measures in addressing security threats.

If the civil aviation regulators, airlines, airport operators, airport agencies, security organisations, airport staff and even passengers adopt a lackadaisical attitude towards security, the security regime and measures will not be effectively implemented, and may not even be adequate. These will raise the risk and vulnerability of the State’s civil aviation operations to security breaches, compromises and terror attacks. On the flipside, if all civil aviation personnel view security as a core component of civil aviation responsibilities, they would be more willing to ensure that the security measures and processes to protect civil aviation operations are undertaken and periodically improved.

A positive security culture can also be a good source of influence to encourage all civil aviation stakeholders to view the needs of AVSEC seriously, and in its proper context and perspective. For instance, there are common security objectives that are shared by all stakeholders.
These include wanting to prevent and avoid any security incidents from occurring that would lead to human casualties, damage to infrastructure and property, disruption to business and operations, financial cost, and loss of passenger and business confidence, among others. If civil aviation regulators and stakeholder companies adopt the culture of wanting to help prevent and deny security breaches, compromises and attacks from occurring, these would contribute to the creation of a positive security culture across the domain and influence other stakeholder organisations, of the merits and benefits of doing the same.

A system of rewards can be considered as a form of encouragement for a positive security culture. Examples such as monetary rewards could be made to recognise proactive measures or actions that prevent security breaches of dire consequences, or even the loss of human lives.

GREATER SECURITY AWARENESS AND EDUCATION

Civil aviation regulators and security agencies can also conduct security awareness briefings and programmes on a regular basis, to educate all civil aviation personnel from stakeholder agencies, on the importance of AVSEC. This could include raising awareness on the critical function that AVSEC plays in the whole civil aviation system, its relevance to their organisation, to all civil aviation personnel, and how they can contribute to and keep up the level of AVSEC in their country, airport, airline and organisation. For example, if civil aviation personnel maintain consistent reporting with security authorities, acts of vigilance can help prevent a security incident or attack from taking place.

A key measurement of success is when civil aviation personnel are willing and happy to take ownership and responsibility to play their part to protect their agencies, and ensure the security of their civil aviation ecosystem. Civil aviation personnel from all stakeholder agencies can become the “eyes and ears” that could prevent a catastrophic security incident from occurring.

It would be useful for security authorities to consider avoiding punitive responses to false alarm reports made by civil aviation stakeholders, as well as by passengers and members of the public. This is especially if they had made reports on suspicious persons and articles with the intent of alerting the security authorities to take appropriate action to mitigate any threats. By taking an approach that would encourage such reports and alerts to be made early and timely, the overall security level at airports and on board aircraft would be increased. Such positive security culture involving all personnel from civil aviation stakeholders, passengers and members of the public can also serve as a useful deterrent to anyone who might have the intention of committing an act of unlawful interference against civil aviation operations.

THREAT FROM THE INSIDE

One of the most challenging emerging threats to civil aviation security is the “insider threat”. The “insider threat” is indeed dangerous as it would likely involve personnel who have access to sensitive areas of the airport and aircraft, access to security sensitive information, and those who have knowledge of the security measures, as well as the airport and airline operations. Such personnel who have the intent to commit acts of unlawful interference against civil aviation operations can be difficult to detect and identify. They could use their knowledge to circumvent an airport or airline’s security measures to assist and allow other perpetrators to carry out acts of unlawful interference.
In recent years, there have been AVSEC incidents which presented “insider threats” as the cause or conduit to acts of unlawful interference. For example, there has been suspicion that the crash of Metrojet flight 9268 was caused by the “insider threat” where explosives were planted onto the aircraft. As at May 2016, despite ICAO having established a Standard (ICAO, 2011), several countries have still not instituted 100 percent security checks on airport employees and their belongings as they enter the airport’s sterile areas, posing a clear vulnerability and access for the “insider threat” to civil aviation operations.

As such, one of the new and important challenges for all civil aviation stakeholders is to develop a culture within their organisation, which sees an intolerance towards any existence of the “insider threat”. It would be very beneficial if all civil aviation personnel would adopt a culture where they value the protection of their operations, such that they would be willing to report on any colleague who might be involved in suspicious activities that pose an “insider threat” to the operations. Such organisational culture that enables civil aviation personnel to muster the courage to report on suspicious activities carried out by their colleagues would go a long way in strengthening the overall AVSEC regime. This should be viewed in its proper context and from the larger angle of protecting innocent lives, as well as the security and integrity of the State’s civil aviation operations.

**JUST CULTURE**

A further step towards enhancing the AVSEC regime in States and amongst stakeholders is to have a “just culture” for security. Under this “just culture” approach, civil aviation personnel should be encouraged to own up and alert their superiors immediately, on their own volition, should they make a mistake or error that could have led to a security breach or compromise. The intent is not to invite an immediate punitive response but to quickly resolve the issue, address the security gap and ensure that the security of ongoing civil aviation operations are not affected. Under this “just culture” approach, civil aviation personnel who report on such mistakes and errors that could lead to a security consequence, should not be punished but the cause of the mistakes and errors should be examined to determine if they are systemic problems, human errors or technical glitches. The intent is to quickly identify the problem and plug the security gaps, and undertake the necessary actions to rectify the problem concerned. The civil aviation personnel could be sent for further training if necessary, and positive encouragement should be considered so that a culture of trust can be created, where people are unafraid to report mistakes and errors that can lead to major security compromises. This would certainly be better than a culture of fear, where civil aviation personnel would not report such mistakes and errors. The security consequences could be fatal.

**MINDSET AND CULTURE OF AIR TRAVELLERS**

The security mindset and culture of the air travellers are also an important factor to the overall management of security at airports and airlines. Given the global security climate and the increasing threat from international terrorism, it is inevitable that passengers will be subject to security screening, including on their check-in and hand carry luggage, prior to boarding a flight at the airport. As threats to civil aviation operations increase, more security checks at the airport as well as on the aircraft may have to be introduced, as seen in recent years. However, there is also a growing expectation that the airport authorities, airlines and security agencies, undertake all these new security measures in such a way that passenger and airport facilitation would remain efficient.
The need to manage the expectations of passengers and airport users is important, to realise that ultimately all stakeholders seek an environment where all can operate securely and go about their business free from the threat of disruption or harm. In this regard, if passengers and airport users develop a security culture of tolerance, where they understand that security measures and procedures are necessary to protect air travellers, it would also go a long way towards enhancing the security of the civil aviation ecosystem.

Under such a security culture, passengers would conscientiously avoid bringing prohibited items in their check-in bags, cabin bags or on their persons; follow instructions at security checkpoints; ensure that they have correct travel documents, and report anyone behaving suspiciously. These behaviours would contribute towards helping security personnel expedite the various security screening measures that the passengers have to go through, prior to boarding their flight. This could be a win-win situation for everyone and help strengthen both security and facilitation.

**CONCLUSION**

Ultimately, air travellers would like to enjoy air travel securely, efficiently and affordably. It would not be sensible to implement extensive security measures, many of which may well be unnecessary and incommensurate to the threat and risk at hand that would only cripple the civil aviation industry. Conversely, it is not acceptable to have a lax AVSEC regime that would lead to security breaches and compromises, where threats and vulnerabilities are exploited by terrorists or persons with questionable intentions and who wish to conduct acts of unlawful interference, which can also have the same negative effect.

To achieve a healthy balance among AVSEC, facilitation, efficiency and cost effectiveness, a positive security mindset and culture is necessary amongst all civil aviation stakeholders. They will need to recognise the challenges posed by security threats to operations, and be willing to work towards mitigating these threats sensibly and practically. This will go a long way in helping the civil aviation industry grow, innovate and offer all air travellers a secure and efficient global civil aviation system.

**REFERENCES**


This article is dedicated to the late Mr Victor Koh Dut Sye, former Chief of Apron Services, Civil Aviation Authority of Singapore (CAAS), who had taught me much about apron operations and the importance of HF, during my few years in CAAS’ Airport Management Division. This article is also dedicated to the late Mr Kang Huei Wang, who was also my former colleague in the CAAS and Head of the Singapore Aviation Academy’s School of Aviation Safety and Security, whom I had worked closely with on various AVSEC courses and programmes.
ABSTRACT

The relationship between Air Traffic Control (ATC) and Aeronautical Meteorological Services (MET) is one that continues to evolve. The provisions of ICAO Annex 3 no longer satisfy the requirements of current and future ATC needs. The introduction of new automated Air Traffic Management (ATM) systems necessitates a paradigm change in ATC operational methodologies, with consequent changes to the information and presentations which have traditionally been provided by MET.

To add to the complexity of this evolving relationship between the two functions, this rate of change is not necessarily one that is kept consistent internationally. This results in varying standards and levels of performance, which are often directly related to the resources of individual States or ATC and MET service providers. This situation brings familiar challenges to the International Civil Aviation Organization (ICAO) and its Global Air Navigation Plan (GANP), as well as pilots and controllers in their desire for a common set of worldwide standards and practices.
Mr John Wagstaff has been a familiar figure at ATM and MET meetings in the Asia Pacific region for many years, for his role as an Asia Pacific Representative of the International Federation of Air Traffic Controllers’ Associations (IFATCA).

In his career spanning more than 40 years in ATC units, he has worked at several locations around the world including the UK, Middle East, Africa and Asia. His last 20 years were spent working with Hong Kong ATC – initially at the fondly remembered Kai Tak Airport, and then later at the new Hong Kong International Airport.

After many years of frontline operational work in the control tower, approach radar and en-route area control, he moved on to operations planning and airport development. This included preparations for the overnight transfer of all ATC services and aircraft operations in Hong Kong from the old airport to the new airport, during the early hours of 6 July 1998.

In 2013, his retirement gave him a new start in life, at a new location: Thailand, bringing him also into a new role as an Aviation Consultant. His work included tasks involved with both the expansion of current airports, and the development of new airports. In 2015, he returned to Hong Kong to assist with the development of their third runway and passenger concourse project. His “re-retirement” is currently delayed “due to ATC”.

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CAN WE GET ALONG?

In the aviation world, we must all cooperate as allies, and not fall into adversarial habits. However, and understandably so, each party is bound to keep their own priorities, and methods of attaining the common goals of enhanced safety and improved efficiency.

For instance, when you mention “MET” to a controller, they might readily provide a list of their grievances concerning their own experience of MET services. Examples include:

- Events caused by an inaccurate forecast;
- MET responses to questions like “when will the visibility improve?” being answered with vague, non-committal responses;
- Why a tower controller would want a 30-hour forecast, when their primary concern should focus on what will happen in the next couple of hours.

MET could counter these arguments by stating that they are following Annex 3 requirements.

However, despite times where disagreement is experienced by either party, there should always be mutual respect expressed through listening and understanding the other party’s reasoning.

Parties who do not find themselves on good terms with one another, however, will rarely talk and meet. When they do, they would instead be eager to express only their own viewpoint, and not pay attention to the other party. Thus, at the end of the discourse, they could part ways feeling dissatisfied. When both parties are insistent on their own views being right, nothing can be achieved.

How did the tense situation between ATC and MET develop?

- Is it because of the rules – are ICAO and World Meteorological Organisation (WMO) to blame?
- Is it due to the training – are the Air Navigation Service Providers (ANSPs) and MET organisations at fault?
- Did this originate from the difference in methods developed by either service providers – is it a problem of traditional practice?

There is neither a single nor simple answer.
The “modus operandi” of these usual suspects could be interpreted as follows:

**ICAO AND WMO**

**Annex 3 “Meteorology for International Air Navigation”**. This document contains 180 pages of detailed information, but only one page (page 10-1) which relates to ATC. Paragraph 10.1.1 states, “The associated aerodrome meteorological office or meteorological watch office shall, after coordination with the air traffic services unit, supply, or arrange for the supply of, up-to-date meteorological information to the unit as necessary for the conduct of its functions.” This statement clearly indicates the need for coordination between MET and ATC, and it should be clear enough that the document was written by meteorological experts, for meteorologists.

**Document 8896 “Manual of Aeronautical Meteorological Practice”**. This document contains 157 pages of detailed information, but the only references to ATC relate to the provision of MET information (Significant Meteorological Information and wind shear warnings) to ATC for onward transmission to pilots. This is another document written by meteorological experts for meteorologists.

**Document 9377 “Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services”**. This document contains 133 pages of information to be provided by MET to ATC, the communication and coordination between MET and ATC, and the different MET requirements of ATM services. This document is written by meteorological experts for meteorologists and controllers. It is unfortunate that few controllers have heard of or seen this document, and even fewer know of its contents.

ICAO holds regular MET/ATC meetings for collaboration and consultation – the Asia Pacific Regional Office in Bangkok annually organises four meetings to promote MET/ATC coordination. In 2015, a joint session of the MET Asia Pacific Air Navigation Planning and Implementation Regional Work Group (APANPIRG) Sub Group and ATM APANPIRG Sub Group meetings was arranged to provide a wider audience for the development of improved cooperation between the groups. This year at the Asia Pacific MET Requirements Working Group (MET/R WG) meeting, one of the Draft Conclusions included the request for appropriate representation by ATM experts in the MET/R WG. Similarly in the recent Asia Pacific Air Traffic Flow Management Steering Group (ATFM SG) meeting, a joint session was held with the MET APANPIRG Sub Group. At this meeting it was noted that Annex 3 did not fully address the needs of ATFM and the ICAO Regional Office stressed the importance of the active engagement of the ATFM community in the work of the MET/R WG.

In meteorology, WMO is the overall global authority whereas in aviation, ICAO is the equivalent. Therefore, aviation meteorologists have two “masters”. Unfortunately, the WMO Commission for Aeronautical Meteorology (CAeM) and ICAO only meet approximately once every eight years. This will thus contribute to the slow progress of coordinating between MET/ATC at the highest level.
However, on a positive note, both parties have agreed to establish the Aviation Research Development Panel, to develop MET products for ATM to meet the Aviation System Block Upgrades (ASBU) programme timeline during their last meeting in June 2014.

TRAINING
The ICAO Annex 1 requires the air traffic controllers’ training syllabus to include knowledge of aviation meteorology, and at some airports, ATC staff receive additional training to conduct MET observations. Although there are some meteorologists equipped with strong background knowledge of aviation, others have acquired the relevant understanding of it through their work experience. There is no international requirement for meteorology personnel to be given additional training in aviation, or the effects which forecasts and observations present to ATM and aircraft operations. Thus, this begs the question: does a service provider require knowledge of how their information is applied?

- Can a forecaster relate visibility to Visual Flight Rules (VFR) criteria or CAT II/III operations?
- Can they associate a rapidly changing pressure gradient with the effects on aircraft altimetry and ATC operations?
- Do they understand the differing meteorological requirements of a Tower Controller, a Terminal Controller and an En-route Area Controller?

Forecasters and observers providing an aviation meteorological service do not require specialised aeronautical skills, but they do need to understand what information the different ATC units need and how the controller uses that information.

To resolve these issues, some ANSPs work closely with their MET services and provide briefings or information to explain how controllers use MET products, and the importance of accurate and timely data. Unfortunately, this scenario is all too rare. MET personnel in many locations still have no comprehension of the importance of their products to the aviation sector; and to exacerbate the matter, have misconceptions of how their products are used.

HISTORY
The origins of the understanding of meteorology and the art of forecasting can be traced back 2,000 years to reports made by Aristotle in 300 BC, regarding the concepts of weather. The early Chinese civilisation was also known to have produced tables and records based on cyclical weather events. Advance two millennia, and by the beginning of the 20th Century, a number of regional meteorological observation networks have been established to assist mariners with their international voyages.

In 1903, the Wright brothers knew that they needed wind power to generate the aerodynamic lift of a wing and they selected Kitty Hawk, North Carolina, as the location for their initial trials. It provided them an open expanse of flat land with regular breezes that were strong enough to generate the lift, but not too strong to physically damage their fragile craft. In the following 100 years, a strong bond was formed between pilots and meteorologists. This has resulted in a global network of comprehensive MET services and products tailored for pilots and airlines.
By comparison, ATC is of a more junior entity and it is one that had been until recently content to utilise the MET information provided for pilots. Things started to change with the rapid increase in the number of flights and the need for a better and more sophisticated global ATC service. With the inception of the ambitious Next Generation Air Transportation System (NextGen) project in the US in 2003 and the Single European Sky ATM Research (SESAR) programme in Europe in 2004, the concept of transforming ATC into ATM with advanced automated systems was created.

In response to the ICAO GANP, a number of other countries around the world have announced the development of automated ATM systems, which will also require improved levels of meteorological information for the efficient and effective management of aircraft.

**ATC TO ATM**

The new automated ATM systems are very sophisticated. They allow increased numbers of aircraft to be handled with greater efficiency and improved levels of safety, whilst reducing controller workload. However, even with such advanced technology solutions, statistics have shown that over 70 percent of airline delays in the US are caused by adverse weather conditions. Therefore, the requirement for specific MET information for ATC will become even more critical as controllers interact with the new systems in the strategic, pre-tactical and tactical stages of the ATM process to resolve traffic situations involving adverse weather.

Our MET colleagues are scientists – they revel in columns of data; they love complex charts full of isobars and frontal systems – the more information they have, the happier they are!

Controllers, by comparison, would seem more like “ordinary” people – they need enough information for them to assess the impact of the weather, but not too much to overload the picture (both visually and mentally); simple colour coding to indicate the severity of any event; relevant information on critical or bottle-neck locations in their area of responsibility; and most importantly, the data provided as graphics, diagrams or displays that are easily assimilated. In the ATM environment, the controller needs accurate and timely information that is based on the requirements of each ATM function – Tower, Terminal, En-route area and Flow Management.

**TODAY AND TOMORROW**

ICAO Document 9377 “Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services”, was published in 2010 and Chapter 7, “Meteorological support to the ATM system”, contains the following statement: “The provision of meteorological information will be an integral function of the ATM system. The information will be tailored to meet ATM requirements in terms of content, format and timeliness.”
Full marks to ICAO for producing a very concise and comprehensive statement on the need for MET and ATC to work together in the ATM process. If marks could be allocated to MET and ATC organisations around the world based on their plans for the implementation of the above guidance material, a few organisations would receive high marks, others awarded mid-range marks, but regrettably, many organisations would probably be scored very lowly.

The good news is that things are changing.

Although the NextGen and SESAR projects are over-running their original timelines, good cooperation and coordination between ATC and MET have already been established in each undertaking and new MET products are already being provided, which benefit the current operations of the respective ANSPs and provide a good basis for evaluating the new systems.

At some other locations around the world, individual ANSPs or units are collaborating with their local MET provider to produce new and innovative services and products for ATC to enable the benefits of new ATM systems to be fully utilised.

At the ICAO/WMO CAeM meeting in June 2014, the decision to form the Meteorological Panel (METP) was a positive step in achieving the ICAO Document 9377 statement goals.

In the first meeting of the METP a number of tasks were defined, including:

- Development of MET information specific to supporting ATM in the terminal area related to ASBU Block 1 and Block 2;
- Development of aeronautical meteorological information to support gate-to-gate ATM operations;
- Inclusion of aeronautical meteorological information in the globally interoperable ATM system through System Wide Information Management.

The creation of the ICAO Aviation Research and Development Panel was another milestone in MET/ATC coordination. It reviews the different MET products and services that are currently being provided at various busy international airports, and the development of new products for implementation in the future. The information will be collated to produce guidance material which will include a number of best practices to assist MET organisations around the world to meet the ASBU targets.

ICAO is made up of 191 Member States and sets the worldwide aviation standards and practices. However, due to the administrative process in developing new practices, getting them approved for worldwide adoption frequently takes a frustratingly long time. When ICAO does promulgate a new procedure, the implementation rate is far from uniform throughout the world – a few countries comply with the majority of requirements, some countries comply with many requirements, others comply with some requirements, whilst a few have difficulty complying with even a limited number of requirements.
This situation is reflected in the provision of MET services to ATC and pilots throughout the world, and is frequently an indication of the resources a State provides to its MET and ATC organisations. Therefore, it is inevitable that the better developed or more prosperous countries would be the first to experience changes in MET services. Indeed, some have already established new MET services whilst others are actively developing new MET products. It is good that some MET organisations and ANSPs are proactive instead of waiting for ICAO and WMO to provide the new standards. They have taken the initiative and are actively communicating and coordinating to explore ways and means to work together to provide upgrades and improvements to the service currently being provided.

**CONCLUSION**

While ATC and MET may not be the best of friends at every airport and control centre around the world, there are optimistic signs that each side realises the importance of collaboration, thanks to improved communication and cooperation at high levels as well as operational levels.

Although controllers and pilots aim for 100 percent accuracy in their work, weather still remains an elusive and unpredictable factor for both parties. Similarly for MET, forecasts can never be perfect and observations can rapidly become outdated because of the dynamic nature of the elements. However, the provision of accurate and timely information on current and forecasted events by MET will remain the primary requirement of every controller.

**REFERENCES**


*This paper is based on a presentation given by the author at the Aviation Weather Seminar held at the Air Traffic Management Research Institute (ATMRI), Singapore in April 2015.*
Harnessing the Power of Data Revolution for Air Traffic Management Development

ABSTRACT

The power to process a widening range of data has grown exponentially. Just like homeland security, healthcare, finance and retail, the ongoing data revolution offers promising potential for Air Traffic Management (ATM) and aviation. Data analysis can enable better decision-making and offer new insights and solutions. This paper will share some nascent aviation data projects within the Asia Pacific region.

While data analysis is about the “how”, it is equally important for us to understand the “what” that is involved. What is the vision for future ATM? If ATM is to play a strategic role in aviation development, and not merely the tactical operations of separating aircraft, ATM needs to make the smart choice of harnessing the power of this data revolution. However, while there are new solutions on the horizon, the old challenges to ATM remain. ATM development across national boundaries is inherently conservative. There is no guarantee that there will be pervasive data sharing in ATM-related processes.

The key to unlocking the power of data use in ATM lies with setting the right policy framework for international cooperation. The World Meteorological Organisation (WMO) places a high priority on the free and unrestricted exchange of meteorological data. States and WMO recognise that weather systems and patterns are not isolated, and can cross national boundaries. They have very explicit policy enshrined in Resolution 40 adopted by the WMO Congress. The aviation community needs to recognise that data sharing is a global public good. The Organisation for Economic Cooperation and Development (OECD) calls it an infrastructure resource. The best assurance of pervasive data exchange is an international compact through International Civil Aviation Organization (ICAO) that resolves to achieve a data-driven future through collaborative effort.
Mr Soh Poh Theen, Deputy Director-General (Air Navigation Services) of the Civil Aviation Authority of Singapore (CAAS), is responsible for directing the provision of air navigation services. He also oversees the development of new systems and airspace management, and is actively developing Singapore into a Centre of Excellence for ATM. He is a member of the Air Traffic Management Research Institute (ATMRI) governing council and a member of the MITRE Asia Pacific Singapore governing board. He is also a member of the Industry Advisory Panel at the Nanyang Technological University, School of Mechanical and Aerospace Engineering.

Before joining CAAS, he was Director, Air at the Ministry of Transport, where he participated in the formulation of various air transport policies and air hub development strategies. In particular, he was part of the team that planned and implemented the corporatisation of Changi Airport.

Mr Soh started his career in the Republic of Singapore Air Force (RSAF) in 1984. He held various senior command and staff appointments in RSAF and the Ministry of Defence, including Commander of the Air Force Systems Brigade, Head of Joint Plans in the Joint Staff, and Commanding Officer of the E2C Squadron. He was also the Director of the National Security Coordination Centre and set up the National Security Coordination Secretariat in the Prime Minister’s Office to achieve a whole-of-government approach to emerging threats.
INTRODUCTION

Long before Big Data became fashionable, data has played an instrumental role in decision-making. Today, the power to process information is growing exponentially. The forms of data that can be fused have equally grown, including data that is sourced internally as well as externally. We are at the threshold of what is called the data revolution.

While technology has advanced, the goal remains to turn information into insights. This paper looks at how this new power of data can be used for better ATM. The issue is not technology, but rather, the key to unlock the potential of data may lie in policy direction. Smart choices need to be made, when it comes to ATM. The first smart choice is in ensuring that decisions are made based on facts and driven by data. This is crucial in helping Air Navigation Service Providers (ANSPs) make smart choices.

An OECD report on data sharing in 2014 has called data an infrastructure resource. Akin to physical infrastructure like roads, rails and telephone network, data is an infrastructural resource that provides the underlying foundation for some downstream productive activities. It can be used as an input into a wide range of goods and services. It is also consumed non-rivalrously over a range of demands. One organisation using a set of data does not deprive another organisation’s use of the same set of data. It can be used by an unlimited number of users for an unlimited number of purposes. In fact, one’s use of the data can generate entirely new scopes of uses for the original set of data. Data-sharing is the new network infrastructure.

Data analytics is now being used in homeland security, healthcare, banking and business, to name a few prominent examples. Some police departments in Los Angeles are using predictive analytics to identify geographically-based “hotspots” so that more resources can be deployed at the right places. Banks use data science to improve fraud detection. Retailers are making use of data analytics of customer interactions to provide better product offerings and pricing.

It is about time for the ATM world to also leverage on the power of this data revolution.

ASIA PACIFIC EXAMPLES

To some degree, the Asia Pacific region has seen notable examples of data application within its ATM functions. The challenge with aviation lies with its cross-border nature. To fully exploit the benefits of data, a multi-national effort is needed. The following are examples of “baby steps” coming from the Asia Pacific region. They are potential building blocks to wider and more powerful use of data.

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SAFETY DATA SHARING THROUGH ASIA PACIFIC RASG

ICAO has created regional aviation safety groups (RASG) to enhance aviation safety for different regions. Singapore and the MITRE Asia Pacific Singapore (MAPS) have worked with the Asia Pacific RASG to initiate a pilot project for a regional data collection, analysis and information sharing system for aviation safety. The integration and analysis of safety and operational data such as air traffic control and flight data could potentially uncover safety vulnerabilities or hazards that would otherwise not be detected.

Singapore first initiated a feasibility study of such a regional project through MAPS. The study showed that a regional data collection, sharing and analysis system could achieve safety improvements in the Asia Pacific region. However, unlike the Federal Aviation Administration’s Aviation Safety Information Analysis and Sharing system, the Asia Pacific system involves multiple jurisdictions, and requires more work on fundamental issues like governance structures, funding models and data confidentiality. Following the initial study, Singapore continued with a demonstration project with MAPS to show the potential benefits while addressing the concerns of data sharing.

ASEAN TRAFFIC FLOW MODELLING AND SIMULATION BY ATMRI

In 2014, the Association of Southeast Asian Nations (ASEAN) established an ASEAN ATM Modelling and Simulation Function, made possible through the ASEAN Air Transport Integration Project, and supported by the European Union. The initial phase saw the setup of the ASEAN modelling and simulation function by the ATMRI in Singapore with the help of Eurocontrol.

More importantly, ASEAN will share air traffic data at periodic intervals and analyse it using the expertise provided by Eurocontrol and ASEAN member States or ANSPs. The first set of ASEAN air traffic data was collected in December 2014. More data will be collected to help determine the current traffic demand baseline for ASEAN. More can be done in the next phase, leading to air traffic route structure enhancement in the region.

ASIA PACIFIC COMMON REGIONAL VIRTUAL PRIVATE NETWORK

The idea of data exchange is not limited to the purpose of offline analysis, there are also operational applications. The common data network for the Asia Pacific region, known as the Common Regional Virtual Private Network (CRV) is another example which will enable efficient data flow for operations in the future.

The idea of CRV was first proposed at the Aeronautical Telecommunication Network Implementation Coordination Group of the ICAO Asia Pacific Air Navigation Planning and Implementation Regional Group. This change was motivated by the difficulties of upgrading the Aeronautical Fixed Telecommunication Network (AFTN), which was established in the 1950s, to Aeronautical Telecommunication Network (ATN). However, the progress for ATN has been slow for various reasons, including the need for bilateral circuit arrangement and upgrades between States. Today, many Air Traffic Services (ATS) related messages such as flight plans and Notices to Airmen are still being exchanged over AFTN. More critically, in order to support future ATM concepts like System Wide Information Management, a common regional Internet Protocol based data communication network service is required.
A unique two-stage procurement process was implemented to select a single regional Communications Service Provider. To emphasise the importance of the CRV, the pioneer States had a signing ceremony at the Asia Pacific Directors General Civil Aviation Conference in Hong Kong in November 2014. The CRV operation is expected to commence in 2017.

THE “WHAT” BEFORE THE “HOW”

Data use and analysis are about the “how”. Before going too far on the “how”, a more basic question has to be asked: what are we trying to achieve in ATM through the better use of data? Data is a means to an end but what are we trying to achieve? It is necessary to know the “what” before pursuing the “how”.

To understand the end goal, it is necessary to go back to the critical missions of ANSPs. To fully appreciate the vision of what future ATM should be like, it is necessary to imagine the likely trajectory of ATM development and in particular the two extreme ends of the spectrum of ATM futures – of centralised control and self-managed air traffic.

The best example of centralised control can be found in air force operations. Air force operations believe in centralised control and decentralised execution to produce unity of efforts. They call this command, control and communications, or C3 for short. In air force operations, C3 is central and pivotal. The equivalent in civil aviation is ATM. From this perspective, ATM can be viewed as more than a tactical operation to help achieve separation between different aircraft. ATM is strategic in orchestrating all airborne activities in the skies. If the vision is for ATM to be central to civil aviation operations, ANSPs need to make some important smart choices.

At the other extreme, ATM can be totally laissez-faire based on an autonomous agent approach. There is minimum control from the ground. Real-time and complete information is provided to the aircraft and they have total situational awareness to operate independently. Airborne aircraft will self-organise and achieve optimal operations by themselves. The assumption is that if an aircraft is aware of the traffic within its immediate environment, it can make effective separation decisions. With enough knowledge of traffic en-route and at the destination airport, pilots can even make flow management decisions, for instance, by adjusting the speed of the aircraft. This is the concept of autonomous flight known as free-flight. This is the extension of Visual Flight Rules (VFR) to all airspace. ATM as we know it today will then have a minimal role.

This discussion of the two extremes is not to suggest that the reality is either of the above but to highlight the contrast to help clarify dilemmas and sharpen our visions of the road ahead. Realistically, the current and future problems in aviation would require ATM to play a more centralised control role. ANSPs should play more than a tactical role of aircraft separation. There are expectations from various stakeholders on ANSPs to solve many of the problems of traffic growth and capacity imbalance. To do so, ANSPs have to play a strategic role. If ANSPs want to move in this direction, they need to be aware and make smart choices.
NEW SOLUTION, OLD CHALLENGES
However, there are some fundamental differences between air force operations and civil aviation that limit the development of the latter, especially in ATM.

Air force operations are unified and centralised. In contrast, the provision of ATS is by nature a cross-border matter and involves many entities. In certain places, there is still a tendency to equate ATS to the control of airspace leading to a nationalistic stance on ATM. This is a very misguided view that can do much harm to the growth of air transport. To make matters worse, every ANSP has varying capabilities and motivations to improve. Most ANSPs are monopolies with little motivation to change. There is little or no competition for the provision of ATS in most parts of the world. Hence, civil ATM is, more often than not, fragmented.

As a result, ATM modernisation tends to be incremental and its progress moves at a glacial pace. The track record of some of the aviation initiatives does not give much confidence that free flow of aviation data sharing across borders will happen easily. Data sharing is likely to face the old challenges in ATM modernisation. Even within individual organisations, there are difficulties implementing free flow of data. According to a survey by the Economist Intelligence Unit (2012), almost 60 percent of companies stated that “organisational silos” are the biggest barrier to using data for decision-making. Larger firms have reported more data silo problems than smaller firms. If this is true for companies, one can imagine the magnitude of the challenge for cross-border data flow. Data analytics is a powerful tool that can help find a needle in a haystack. However, the problem is that before we can use this tool, we need to agree to have a haystack to begin with. A critical mass of data is needed before any insights can be derived from it. It is of no use if data is not being shared.

The international civil aviation system centred on ICAO is heavily shaped by a legal mindset, as opposed to an engineering or entrepreneurial mindset. To some degree, this is understandable as the current international aviation system was shaped during the post-World War II years, and thus heavily influenced by nationalism. Sovereignty was a big concern back then. In addition, issues of aviation safety have implications on liabilities and culpabilities which have legal implications. Both these driving forces favour legalism, and such an ethos can dampen the pace for innovation. To overcome this, the solution may have to start at the policy level first.

Civil aviation and ATM can potentially operate as a cohesive network, but tight coordination is required. Coordination across boundaries among different entities is a huge challenge. The starting point to better data sharing and utilisation may well be the right policy framework for international cooperation.

TOWARDS INTERNATIONAL DATA POLICY FRAMEWORK
The Asia Pacific data sharing and analysis projects mentioned earlier are all works in progress. There is no guarantee that they will be successful or for how long they will take before results are achieved. The biggest stumbling block to harnessing the power of the data revolution may well be policies, especially those at the international level. The best assurance is an international agreement that resolves to achieve pervasive data sharing to enhance aviation safety and efficiency.
In this respect, one could learn from other organisations that already possess similar systems. One such organisation that has for decades practised cross-border data sharing is the WMO. Like ICAO, WMO is also a specialised agency of the UN. While ICAO focuses on the implementation of aviation standards and regulations, the WMO places a high priority on the free and unrestricted exchange of meteorological (MET) data. In fact, data exchange is foundational to WMO. Through their World Weather Watch Programme, WMO members have a structure to share MET data in real or near real-time to supplement their national data for forecasting purposes. Besides this, specific climate data such as Greenhouse Gas emission is also collected by dedicated WMO World Data Centres.

How did the WMO achieve this? States and WMO recognise that weather systems and patterns are not isolated, and can cross national boundaries. They have very explicit policies enshrined in Resolution 40 adopted by the WMO Congress. Through Resolution 40, members agreed to share meteorological data and products on a free and unrestricted basis. More significantly, they also agreed to provide to the research and education communities, free and unrestricted access to all data and products exchanged under the auspices of WMO.

There is a case for ICAO to consider a similar policy through a resolution of the ICAO Assembly to explicitly state a policy of cooperative arrangement for data sharing. Civil aviation shares the same cross border characteristic as weather. There is a need for the aviation community to recognise that the provision of data offers a global public good. As mentioned, like infrastructure, the consumption of data is non-rivalrous. The outcomes from its use can benefit more than one group of countries or all countries. The problem with public goods is that they are often under-supplied. At the national level, the government normally steps in to provide the public goods. At the global level, it is more challenging to decide who should play the role of a global sovereignty. UN-specialised agencies like ICAO and WMO are the next best alternatives.

If aviation is able to develop its data sharing capability, many tangible benefits can be reaped. Safety is one area but there can also be sharing of data for operations. Air traffic flow management can be realised across States and regions on a global scale, and with greater predictability of air traffic, better capacity planning can be performed to increase airspace utilisation. With the data resource, aviation research and development can discover new insights and offer breakthrough thinking in aviation.

To some degree, ICAO has started to move in this direction. At the High-Level Safety Conference held in Montreal in early February 2015, there were extensive discussions on the topic of safety information protection. Unlike weather data, aviation data has the additional complication that they may be linked to liability issues, especially if accidents or serious incidents are involved, leading to punitive actions against individuals or organisations. This explains the much greater resistance to data sharing in aviation. The topic of safety data protection is meant to address such concerns. Agreement on data protection must first be in place before there can be a free flow of data. The next step could be a resolution from ICAO on the policy of data sharing. This should not be limited to just safety data but to operational data for efficiency improvement. A special provision should also be made for such aviation data to be made accessible by approved research establishments.
The International Air Transport Association (IATA) and Civil Air Navigation Services Organisation can help nudge ICAO in this direction. IATA already has a platform for global aviation data collection and analysis through their Global Aviation Data Management (GADM) programme. This taps on an extensive data source to enable data-driven evaluation of trends in air transport and occurrences of safety incidents. IATA’s GADM demonstrates how a global model for data gathering can be achieved for safety. ICAO can broaden the scope of such data works to a global repository that collects aviation data for use in operations and development works.

There will certainly be challenges in building such a large scale data sharing platform. Infrastructures must be built to act as data source nodes supported by a robust telecommunications network. There will be threats of cyber-attacks and potential exploitation of free data by commercial entities for profit-making. Detailed protocols will have to be developed once an international consensus is achieved.

CONCLUSION

Just like the other sectors, the on-going data revolution offers promising potential for ATM and aviation. If ATM is to play a strategic role in aviation development, and not merely the tactical operations of separating aircraft, ATM needs to make the smart choice of harnessing the power of this data revolution. While there are new solutions on the horizon, the old challenges in ATM remain. ATM development across national boundaries is inherently conservative. The key to successful pervasive cross-border data sharing and utilisation is in the right policy framework for international cooperation. The best assurance is an international agreement through ICAO that resolves to achieve a data-driven future together.

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This paper is based on a presentation given by the author, at the World ATM Congress held in Spain in March 2015.
A Global Safety Deficiency: False Glide Slope Capture Affecting Aircraft

ABSTRACT

A serious incident occurred at Eindhoven Airport, the Netherlands in May 2013. A Boeing 737-800 performed a go-around while using the Instrument Landing System (ILS) and automatic flight systems. The flight crew reported a false glide slope capture as the reason for the go-around. At first, the occurrence report did not gain much attention, but as the investigation progressed, it identified a safety deficiency on a global scale.

Following flight tests conducted by the Dutch Safety Board (DSB), a potentially serious weakness in the automatic flight systems logic used for capturing the ILS glide slope was identified. The result of this logic was a rapid pitch-up upset, which could potentially cause an aircraft making its ILS approach with automatic systems engaged, to stall. As the investigation continued, it was established that various aircraft types and models from different manufacturers used the same logic, and were thus affected.

Following this discovery, DSB published a worldwide Safety Alert (SA) to update the aviation community. The SA was re-published all over the world. The DSB finalised the investigation with recommendations in two final reports. The first report (DSB, 2014a) covered the event “Stick Shaker Warning during ILS Approach Eindhoven Airport”, and a second report (DSB, 2014b) explained the pitch-up response of aircraft and examined the issue on a global scale.
THE AUTHOR

Mr Michiel Schuurman was a Senior Air Safety Investigator for DSB from 2005 until August 2016. His key responsibilities at DSB included conducting accident investigations, performing accredited representative duties, analysing flight recorder data and other electronically recorded data. Currently, Mr Schuurman is an independent consultant in the field of aviation safety. He is also an Assistant Professor at the Aerospace Engineering Faculty, Delft University of Technology (TU Delft), the Netherlands. In the Structural Integrity and Composites Group, he is responsible for teaching Forensic Engineering course.

Mr Schuurman holds a Master of Aeronautical Engineering from TU Delft. He was trained in accident investigation at the National Transportation Safety Board (NTSB) training centre, US, and at Kirkland Air Force Base, US. He also received technical training on various types of aircraft, including Boeing and Fokker.
HOW IT BEGAN
On 31 May 2013, a Boeing 737-800 received radar vectors for the approach to the active landing runway at Eindhoven Airport. During the approach, a 30-knot crosswind at 2,000 - 3,000 feet on base leg and a tailwind on final approach contributed to the aircraft being closer and higher to the runway than normal. The influence of the crosswind and tailwind on the flight path remained unnoticed by both the air traffic controller and flight crew. At approximately 1,300 feet, the Captain informed the First Officer (FO) that it was very unlikely that a successful landing would be possible, and that they should prepare to make a go-around.

At approximately 1,060 feet and 0.85 nautical miles (NM) from the runway threshold, the aircraft pitched up rapidly at 3 degrees per second while both engines N1 increased from 30 to 90 percent automatically in order to maintain the selected airspeed. Finding this behaviour unexpected, the Captain called for a go-around. The aircraft pitch further increased to approximately 24.5 degrees nose up and the stick shaker warning was activated. Almost at the same time, the take-off/go-around button was pushed by the FO and the autopilot was deactivated. The aircraft was levelled and a second approach was flown to the airport where it landed safely.

At first, the occurrence report did not gain much attention, but after reviewing the flight and radar data, an investigation was initiated. As the investigation progressed, two main questions were formulated. The first was to determine the cause of the pitch-up upset while flying the ILS glide slope with automatic systems engaged. During the investigation, DSB became aware of four similar pitch-up upset incidents. This led to the second question of how current and implemented safety management systems (SMS) dealt with previous pitch-up upset occurrences.

BACKGROUND
Similar Events
The fact that four other ILS false glide slope-induced pitch-up occurrences were identified during the investigation prompted DSB to perform a detailed database search for such incidents. A database search of the Occurrence Analysis Bureau, the Netherlands, revealed one case, which was already identified by DSB.

In France, there was one reported pitch-up upset case – an Airbus A340 at Paris Charles de Gaulle, experienced a pitch-up from 1 degree to 26 degrees in 2012. This incident was investigated by the French Bureau of Investigation and Analysis for Civil Aviation Safety (BEA). In the final stages of the investigation, DSB was informed by BEA that a similar pitch-up upset occurrence had been reported by an operator to Airbus. This occurrence pre-dated the A340 pitch-up upset.
A database search in the US performed by both the NTSB and Boeing yielded no similar incidents. By contrast, a search and analysis of the National Aeronautics and Space Administration (NASA)’s Aviation Safety Reporting System (ASRS) database revealed that 57 occurrences were reported between 1998 and 2013 where “False Glide Slope” was mentioned in the narrative.

For statistical purposes, ASRS attributed a problem to each event. The ASRS assessment of these events is not definitive, but the database suggests that human factors and navigation facility equipment played a major part. For the investigation, DSB analysed these ASRS events in more detail, and found that a distinction could be made between glide slope events from “Above” and “Below” the 3-degree glide slope (See Figure 1). The analysis shows a difference in assessment of the contributing factors. In cases of “Above” 3-degree glide slope events, the database suggests the problem is mostly related to the flight crew. But does this reflect what is really going on? What do we know about the ILS glide slope antenna?

**Figure 1 - ASRS Database Overview Problem Description Above and Below Glide Slope**

![Figure 1 - ASRS Database Overview Problem Description Above and Below Glide Slope](image)

### ILS Glide Slope Antenna

The ILS is a navigational aid used worldwide to facilitate the approach and landing of aircraft. ILS is a ground-based radio wave system providing both lateral and vertical guidance to aircraft at airports in any weather condition.

An aircraft either follows a standard published instrument approach, or is given directions (i.e. radar vectors) from Air Traffic Control (ATC) to the ILS coverage area, where localiser and glide slope signals would be transmitted to its systems for it to make an automatically guided landing. An ILS can consist of the following ground based components:

- Localiser transmitter – which transmits the lateral guidance signal
- Glide slope transmitter – which transmits the vertical guidance signal
- Marker beacons – which transmit vertical signals
- Distance measuring equipment – which transmits a signal for distance away from a fixed point, usually the runway threshold
The glide slope antenna is situated on one side of the runway touchdown zone. The centre of the glide slope signal is arranged to define a glide path of approximately 3 degrees above touchdown ground level. The glide slope receiver on the aircraft measures the difference in the depth of modulation of the 90 Hz and 150 Hz signals, similar to that of the localiser. For a standard 3-degree glide path, the relative signal strength of the “Fly Up” (150 Hz) command and the “Fly Down” (90 Hz) command is equal (Null).

Five types of glide slope antenna systems are used worldwide. Three of which are imaging type antennas referred to as Null Reference, Sideband Reference, and Capture Effect or M-array (See Figure 2). The two non-imaging type antennas are the Endfire and Waveguide. The non-imaging type antennas were excluded from the investigation because they are infrequently used. The M-array antenna is most frequently used at airports worldwide.

**Figure 2 - ILS Glide Slope Imaging Type Antennas**

![ILS Glide Slope Imaging Type Antennas](image)

**THE KEY OUTCOMES**

**ILS Glide Slope Flight Tests**

The DSB conducted flight tests to measure the ILS-signal field characteristics of the M-array antenna. As the Sideband and Null Reference antennas were not available in the Netherlands, these were measured by the Federal Aviation Administration, USA, at the request of NTSB. An ILS flight test plan was formulated and flown into the Netherlands and USA by several different specialised aircraft normally used to certify the ILS for operational use. The ILS flight test data was subsequently analysed by DSB, and the ILS signal characteristics were determined.

The first false glide slope type is defined as a False Null. This glide path resembles the normal 3-degree glide slope signal (null), but is actually either at the wrong location in space or has a steeper angle. A False Null signal will result in an aircraft having a higher than normal descent rate. The second type of false glide slope that can be distinguished is the Signal Reversal. This Signal Reversal is “unstable” as the ILS signal changes from “Fly Down” to “Fly Up”. When the autopilot is engaged in the appropriate mode, the “Fly Up” signal will result in a command to pitch-up the aircraft.
Both Null Reference and Sideband Reference antennas have one characteristic signal field which was identified through flight tests. Several measurements on the M-Array antenna showed that it did not have one unique signal field but two fields depending on the operational configuration. Therefore, the M-Array antenna system can have two different fields.

In summary, the measurements performed on the three imaging type category ILS Glide slope antenna systems revealed two different slide slope signal characteristics (See Table 1):

a. Signal reversal sometimes occurs at an approximately 6-degree glide path angle.

b. Signal reversal always occurs at the 9-degree glide path angle.

**Table 1 - Overview Measurements ILS Glide Slope Image Type Antennas**

<table>
<thead>
<tr>
<th>ILS glide slope antenna system type</th>
<th>Glide path angle [degrees]</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0 - 3</td>
</tr>
<tr>
<td>Null Reference</td>
<td>↑</td>
</tr>
<tr>
<td>Sideband Reference</td>
<td>↑</td>
</tr>
<tr>
<td>M-Array 1</td>
<td>↑</td>
</tr>
<tr>
<td>M-Array 2</td>
<td>↑</td>
</tr>
</tbody>
</table>

↑ GS signal “Fly Up”  ↓ GS signal “Fly Down”  Null glide path  R Signal reversal

Accessible information for the aviation community and understanding of both flight crew and air traffic controllers did not make a distinction between two types of false glide slope − False Null and Signal Reversal. As a result, the false glide slope phenomenon was not fully understood.

Furthermore, there was no information available to pilots (charts or other) on which ILS antenna type is used at the airport. Contrary to published information available, a “Flag” (warning) will precede a false glide slope but during flight testing, no “Flags” were recorded or displayed on the flight instruments.

Based on these results and other similar events in the past, a SA was published by DSB (2013). The SA warns pilots of a potential hazard when ILS approaches from above the 3-degree Glide Slope are performed in auto flight, resulting in unexpected and severe pitch-up upset. Following the SA, the industry and several aviation authorities worldwide have taken actions to prevent a recurrence.

For example, the European Aviation Safety Agency (EASA) announced that its experts in Flight and Avionics have reviewed the SA and the recommendations in the BEA report of the Paris Charles de Gaulle 2012 A340 incident. A Safety Information Bulletin (EASA, 2014) was issued to officially inform the European aviation community and highlight the issue.
Certified Volume of Operation
ICAO mandates that all types of radio navigational aids available for use by aircraft engaged in international navigation shall be subjected to periodic ground and flight checks. Ground measurements cannot completely assure the quality of the signal-in-space due to the effects of terrain, man-made obstructions, radio frequency interference, and reflective surfaces such as snow, water and other aircraft. The use of specially equipped aircraft, precisely positioned (laterally and vertically), is the only effective method of evaluating a signal-in-space or instrument flight procedure. Flight inspections certify instrumental approaches and ensure that an aircraft at the lowest authorised altitude is safe from ground obstacles.

Flight inspection is traditionally based on inflight measurements of the signal-in-space produced by air navigation systems on board a calibration aircraft. During flight inspections, the 3-degree ILS glide slope signal is inspected in different ways, including at a prescribed flight offset, to verify a valid 3-degree glide slope signal.

The inspected area is normally situated between 0 and 10 NM from the runway threshold and approximately 35 degrees left and right of the runway heading (localiser). The ILS antenna system is checked and if required adjusted at least once a year.

The measurements to determine the glide slope field as performed in DSB investigation were not part of a normal flight inspection, which is performed on the 3-degree glide path. Above an angle of 5.25 degrees, the glide slope field characteristic is not required by ICAO regulations to be inspected (See Figure 3). This means that when flying above the 5.25-degree glide path, the aircraft is flying beyond the reliability threshold, which is certified and periodically checked by flight inspection. The pitch-up upset events were all flying in the area above the 5.25-degree glide path.

Aviation Safety Management System
The occurrence at Eindhoven Airport and the subsequent four similar events gave rise to the question: why did aviation SMS not identify the ILS glide slope signal reversal as a potential serious safety deficiency?
ICAO mandates all Contracting States to implement a State Safety Programme (SSP) wherein aviation organisations are required to establish SMS. SSP and SMS are complementary to each other. The European Union (EU) adapted the ICAO requirements for safety management in two Regulations (EU, 2012a and 2012b). In some cases, this regulation pre-dated the events described in this investigation. The overall SMS structure for all organisations is based on the following four components (See Table 2), also known as “pillars of the SMS”.

<table>
<thead>
<tr>
<th>Pillars of the Safety Management Systems</th>
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<tr>
<td>Safety Policy</td>
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<td>Management Support</td>
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<td>Responsibilities and Authorities</td>
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<tr>
<td>Safety Assurance</td>
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<td>Process Evaluation</td>
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<td>Safety Performance Monitoring</td>
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<td>Safety Risk Management</td>
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<td>Proactive Hazard Identification</td>
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<td>Risk Assessments and Control Measures</td>
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<tr>
<td>Corrective and Preventive Actions</td>
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<td>Process Evaluation</td>
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<td>Safety Performance Monitoring</td>
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<td>Safety Promotion</td>
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<td>Safety Communications and Culture</td>
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<td>Safety Training</td>
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</table>

Individual Level – Operators
The level of development and implementation of SMS depends on the size, nature and type of operation. Depending on the number of aircraft and destinations, an operator can have thousands of flights per week with hundreds of safety reports being filed. All these safety reports must be captured, assessed and analysed to identify risks, and for deciding if further investigation and corrective actions are necessary.

Operators rate occurrences using a risk identification matrix as part of SMS methodology. The combination of severity and probability of the occurrence results in a total safety risk assessment. Depending on the level of safety risk, mitigating measures are required. In the matrix, three different levels of safety risk can be distinguished:
1. Intolerable – mitigating measures should be taken
2. Tolerable – mitigating measures could be taken
3. Acceptable – no measures are required

Following the risk assessment process, the operators assessed the pitch-up upset events as tolerable and an internal investigation was initiated. During the internal investigations, hazards and barriers related to the occurrence were identified. Thereafter, recommendations were formulated to prevent reoccurrence. However, the internal operator reports did not fully identify the cause of the pitch-up upset as false glide slope reversal.

National Level – Occurrence Databases
The objective of the national occurrence database is to identify and monitor safety performance within the State. The type of safety data to be collected may include accidents, incidents, non-compliance or hazard reports. The data are statistically analysed to identify safety deficiencies and to enable effective decisions to improve safety. The following report (See box) from the national occurrence database system in 2011 was received from the Netherlands’ Occurrence Analysis Bureau:
CAA-NL Occurrence Database Report
Title: Go-around due to Unstable Approach
Date of Occurrence: 12-2-2011
Summary: Aircraft became high, above glide slope, on ILS approach RWY 06 AMS. Believe aircraft at one point eventually picked up a false glide slope, during go-around stick shaker activated, pitch lowered in response to this. After go-around another successful approach and landing to RWY 06 was made.

This occurrence report shows that reference is made to a stick shaker and a false glide slope but no additional data is available. No factors explaining why the aircraft gained altitude are identified; only the result: after go-around a successful landing was made. This does not allow the reader to ascertain the essence of the false glide slope characteristic and the associated autopilot response.

SMS methodologies were applied and resulted in data being captured in the mandatory state occurrence databases and individual operators’ SMS databases. However, the investigation indicated that due to event coding and insufficient detail in the event descriptions, the complexity of the occurrence was not identifiable.

The initial mandatory reports in the involved State’s occurrence database were not always appended with the results of the follow-up investigations conducted by the operators. Furthermore, the root cause of the events was not identified during the operator’s investigation. The result was that due to the absence of valuable additional background information, the possible detection of a safety deficiency in the future became remote. As the investigated SMS are mainly driven by statistical analysis, a limited number of reports are statistically insignificant and on that basis no action was required.

Despite SMS methodologies and previous investigations, the reported pitch-up upset incidents occurred in airspace, which is not part of the ICAO certified ILS volume of operation. None of the parties identified this latent safety deficiency.

This investigation has shown that despite the implementation of SMS, the global aviation system was unable to “connect the dots” when related serious incidents occurred. On a national level, occurrences are analysed mathematically and the identified risk indicators are monitored to serve as the present safety state. As shown in this investigation, the unidentified or misidentified indicators which in some cases are mathematically insignificant, but nevertheless important, are not dealt with in current SMS occurrence report analysis methodology. This shows that new techniques and information sharing strategies are required to be embedded in SMS to search for and identify latent safety risks at present and in the future.

The large amount of reports and information available has meant that the current implemented SMS occurrence reporting analysis framework, using mathematical methodologies and assessments, might be reaching its potential limit for safeguarding safety.

It could be argued that a more holistic systems approach in risk identification might be a way to supplement current SMS occurrence report analysis methodology in the future. As an example, in the fourth quarter of 2013 the Flight Safety Foundation and MITRE...
announced collaboration in creating Transform Global Aviation Analytics. The background to the collaboration was given as the complexity of today’s global air navigation system; the analysis of diverse types of data is essential to establish the correlation of multiple attributes accurately, which in combination has the potential to identify systemic vulnerabilities that elevate safety risks. This is an example of a possible approach in addressing the safety challenge of the future.

**CONCLUSION**

In conclusion, the pitch-up upset events were reported to the European national occurrence databases and the voluntary NASA’s ASRS database. Analysis of similar events found in several databases suggests that aircraft pitch-up upsets have occurred with a variety of aircraft types from different manufacturers. The pitch-up upsets were attributed to ATC equipment failures and human factors and included in national and international databases for future analysis.

The root cause of the pitch-up upsets was not identified by databases, SMS and internal operator investigations. New insights were gained only when the ILS glide slope signal characteristics were closely examined by DSB investigation. A “reversal of knowledge” was required to identify an issue resulting in aircraft pitch-up upsets.

Despite SMS methodologies and previous investigations, the reported pitch-up upset incidents occurred in airspace which is not part of the certified volume of operation. None of the parties identified this latent safety deficiency.

The SMS risk management pillar to proactively identify risk needs to be addressed to identify potential future safety issues. The implemented SMS and its methodology have certain flaws which can be improved. Enhancement can be made through a holistic approach of using knowledge, experience and data to identify potential safety issues which have not yet occurred.

As a result of the investigation, DSB formulated six recommendations. The recommendations focus on changes being implemented in the short and long term in the areas of training, operational (stabilised approach criteria) and technical measures to prevent recurrence.

Furthermore, DSB made recommendations to enhance current occurrence reporting and analysis and took measures to achieve the goal of the system to identify potential safety deficiencies in a timely manner.

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DSB. (2014b). *Pitch-up Upset due to ILS False Glide Slope*.


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