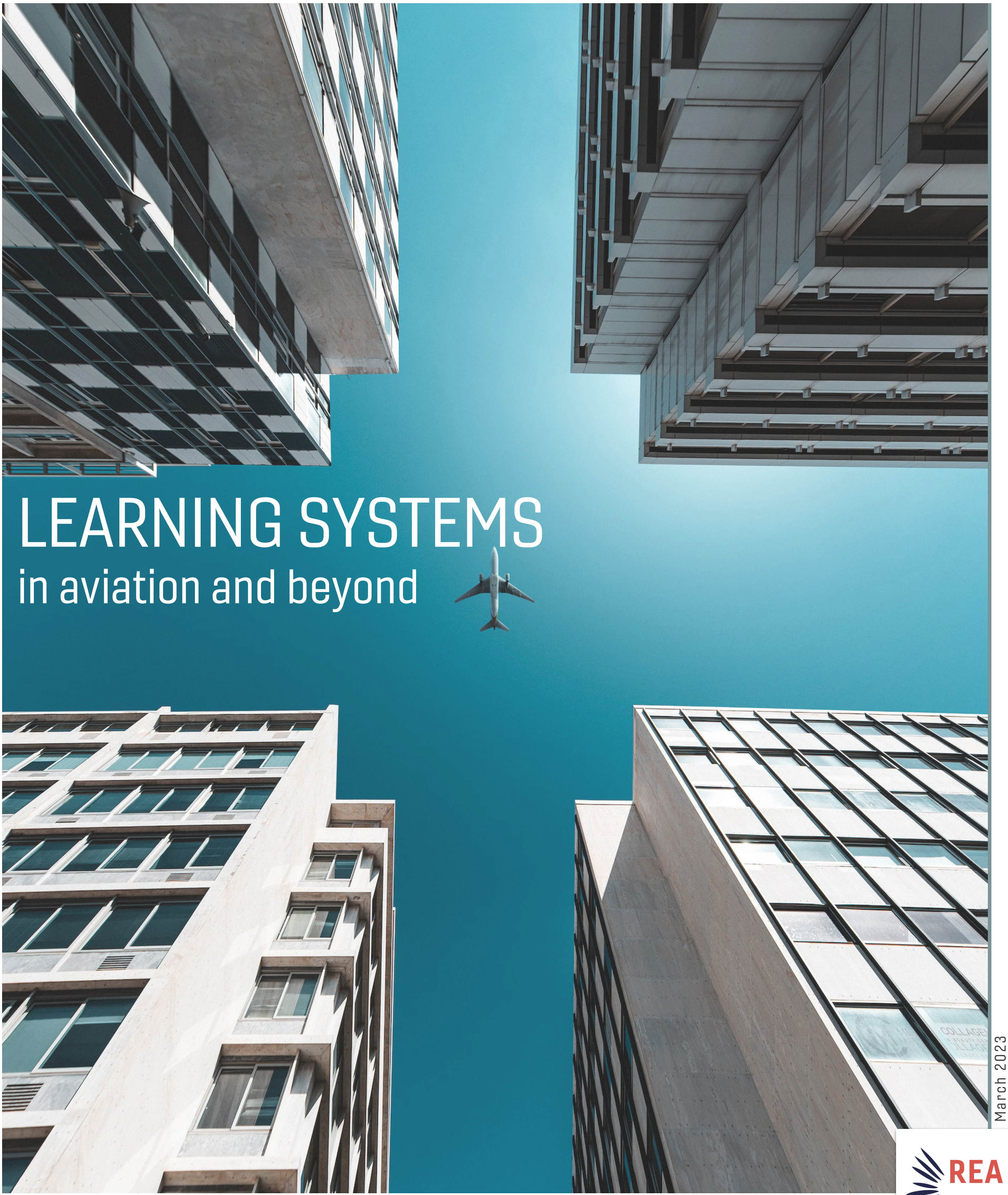
Newsletter14

RESILIENCE ENGINEERING ASSOCIATION



LEARNING SYSTEMS

in aviation and beyond

March 2023

REA

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FRESH DESIGN FOR RESILIENT IDEAS

The Resilience Engineering Association connects thousands of thought leaders, practitioners, and academics within the fields of Safety-I and II, Resilience and Crisis Management worldwide. Through our newsletter, our community is informed on state-of-the-art research, practices, challenges, and potential solutions for safe and resilient operations that span far beyond the individual, and delve into team, system, organisational, governmental, and societal issues.

Welcoming our redesigned newsletter, we celebrate its launch with a special issue dedicated to aviation, with guest editor James Norman.

And do not forget...

Registrations for the

10th symposium on Resilience Engineering

are now open!

Follow instructions on our website
For other interesting upcoming events on resilience and safety click here

Enjoy your Reading!

Lida Z. David

REA Newsletter Editor,
on behalf of the REA team

TABLE OF CONTENTS

Note from the guest editor
James Norman
p. 4-6

Can We Continue to Climb the Mountain in Ballerina Shoes?
Gitte Furdal Damm
p. 7-9

Are Black Swan Events Trainable?
Endre Berntzen
p. 10-11

Are We Learning All We Need for Resilient Performance?
Laura Maguire
p. 12-14

Two Views on Procedures
Tom Laursen
p. 15-16

A Multi-Domain View of System Management
James Burnell and Joji Waites
p. 17-20

Risk is Not as Simple as You Might Think
Ivan Pupulidy
p. 21-23

From Assessing To Enabling
Ron Gantt
p. 24-25

Organizational Learning Through Systems Theory
Shem Malmquist
p. 26-27

On the Logical Interdependency in Infrastructures: An Institutional Perspective
J. Yu, Hoon C. Shin, and Jeryang Park
p. 28-30

Resilient Organizational Learning Through Action Research
Torgeir Kolstø Haavik
p. 31-32

Developing Resilience in Commercial Aviation Pilots via Training Data-Driven Insights
Richard J Kennedy, Andrew CK Lim, David Owens
p. 33-35

Four Steps Towards Implementing Resilient Learning Systems in Aviation
Kristy Kiernan and Dave Cross
p. 36-37

Learning What Goes Well and Why at American Airlines
Nicholas Peterson
p. 38-39

Resilience and Psychological Safety: The Language of Learning
Leja Collier
p. 40-42

A WORD FROM THE EDITOR

James Norman, Ph.D

Welcome to Issue 14 of the REA Newsletter. Focusing on aviation, this edition sets out to explore two related constructs: learning systems for resiliency across domains, and using learning systems to capture Safety-II and resilience. Fourteen thought leaders from the resilience engineering and Safety-II community contributed to this edition, ranging from pilots, air traffic controllers, training experts, academics, and applied practitioners. They offer a depth and breadth of wisdom in their writing that I trust you will find valuable.

Aviation is both a fascinating and frustrating subject for resilience engineering.

On one hand, aviation folks have robust debates regarding high reliability (HRO) versus normal accident theory (NAT), Safety I versus Safety II, and so on. On the other hand, we have a near absence of accidents—a denominator of zero. Theorists like Cooper have vociferously raised the issue of a lack of empirical evidence to support the efficacy of theories such as Safety II. However, with such a lack of accidents, we barely have Safety I data to begin with. We are therefore left with a Gordian knot of trying to identify weak signals in Safety I incident data, or try to explore the variability in everyday work with robust Safety II data. Unfortunately, compounding the problem is that airlines operate at such thin financial margins that the resource allocation for Safety II is nearly absent, because it is not a regulatory requirement.

During the time our authors composed their pieces, a quartet of remarkable events took place in US aviation, pushing “resilience” into the headlines and discourse. Two of these events exposed organizational brittleness and collapse. Conversely, two revealed sharp-end performance success. Viewed as a composite, these events offer a timely background to the theme of organizational learning for this issue. Significantly, resilience (or the lack of it) was brought up numerous times in broadcast and print media, entering the public consciousness as it related to the aviation domain.

First, a Christmastime polar vortex delivered cold and misery to much of the US. Understandably, many airlines were affected. However, Southwest Airlines was unable to recover their operation for more than a week, stranding millions of passengers and prompting a congressional investigation. The reason? A network system that held insufficient slack for disruption, and a manual (yes, manual) system of rostering crewmembers. Southwest CEO Bob Jordan apologized to customers and employees, saying the company had “swiftly taken steps to bolster our operational resilience and was undergoing a detailed review of the events” (MSN, 2023).

Two weeks later, the antiquated NOTAM system imploded. Still based on 1920s teletype technology, the NOTAM system is used to notify pilots of the safety of flight information. It apparently collapsed due to a contractor deleting a single file in a database. This led to a temporary ground stop of all flights and cascading delays of more than 32,000 flights. The US federal government took notice, stating “the F.A.A. made the necessary repairs to the system and has taken steps to make the NOTAM system more resilient” (FAA, 2023). The chairwoman of the Senate Commerce Committee added, “the public needs a resilient air transportation system” (US Government, 2023).

Two days after the NOTAM outage, a Delta 737 was departing runway 4L at New York’s John F. Kennedy Airport (JFK), and conducted a high-speed abort after an American Airlines 777 incurred across the runway. According to the NTSB, the Delta 737 came within 500 feet of the crossing runway (NTSB, 2023). An automated alerting system called ASDE-X alerted the tower controllers of the conflict, which resulted in a call to abort the takeoff. While commercial aviation communication is still handled over analogue VHF radio signals, there was sufficient capacity at that moment for the tower to transmit the dire warning. The Delta 737 pilots had enough alertness, and the aircraft had enough engineering capability to stop immediately.

Finally, as a bookend, Southwest was again in the news. During low visibility operations at the Austin-Bergstrom International Airport (AUS), a FedEx 767 performed a missed approach at low altitude, overflying a Southwest 737 by less than 100 feet, according to ADS-B data. While this proximity has yet to be validated and the NTSB has not issued a preliminary report, this incident is profoundly concerning. The successful outcome of this event may have been due to technologies aboard the aircraft, including an Enhanced Flight Vision System (EFVS) and Mode-C transponder displays. It could also be attributed to something as simple as well-rested pilots who were at their best that day.

The preceding events may be bifurcated in this way:

The former two were blunt-end organizational failures that had been metastasizing for decades. When the system reached its limit, it was unable to provide adaptive capacity, and cascading failures followed. The boundaries for both the Southwest Christmastime fiasco and the FAA's NOTAM systems were in hindsight closer than previously imagined, due to lack of redundancies and reliance on manual systems.

The latter two events were sharp-end human performance successes, likely a result of decades of technological enhancements, training, and a bit of luck. When the human operators reached their limits, sufficient capacity was available to overcome the dire situations, even if such capacity was of mere seconds. Resilience was both a system property and an individual property in these latter cases.

The location of resilience was raised by Bergström et al. (2015) in a literature review of the topic, concluding that although resilience is usually conceptualized at the system-level, it has been better seen as an individual characteristic when empirically measured. It is therefore ironic that in the four aviation examples cited, (lack of) resilience was attributed to system-level failures, yet there was an absence of dialogue about resilience when it came to individual crew performance in JFK and AUS.

For this edition, we asked our contributors to explore how learning systems may be able to capture instances of resilience and learn in a double-loop fashion. Are our reporting systems designed to capture resilient behavior? Aviation is heavily prescriptive...think regulations, training, and compliance. Given the stellar safety record previously discussed, we may fall a victim to our own success in a self-perpetuating affirmation that "if it ain't broke, don't fix it." However, a credible safety management system demands we seek continuous improvement. And the healthiest safety cultures are generative, able to challenge assumptions and the status quo.

Our 14 contributors to the 14th edition have diverse and varied expertise, ranging from the theoretical to the applied. It is my hope that the remarkable effort our authors made will help to move the needle in the aviation industry, and beyond. It was encouraging to see the European Union Aviation Safety Agency (EASA) recently infuse its updated guidance with over 30 references to resilience. The altruistic effort of the Resilience Engineering Association's (REA) newsletter and annual symposia will bolster these efforts as well.

James Norman is a B-767 pilot and holds a PhD in Aerospace Science from the University of North Dakota, where he is a faculty member. His dissertation focused on voluntary reporting (ASAP) and the factors that promote and discourage reporting, comparing pilots, dispatchers, maintenance and air traffic controllers. In addition to line pilot duties, he works on behalf of the Air Line Pilots Association (ALPA), teaching risk management, safety management systems, and safety leadership in aviation.

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Can We Continue to Climb the Mountain in Ballerina Shoes?

Understanding Normalization of Adaptation in Aviation

By Gitte Furdal Damm

When I started flying some 25 years ago in Scandinavia, aviation seemed more simple. Getting a job in an airline usually meant that the career path could be secured for the next 30-40 years, and the industry was known for its beneficial terms and conditions. Working conditions were characterised by a sense of stability and predictability – permanent bases, fixed roster, familiarised route-net, fewer procedures and less automation. Training was associated with classroom sessions, social interactions over dinners and an occasional beer with the chief pilot, which paved the way for relationships across the system, to be built and nurtured over time. Although this might seem like a slightly romanticised and simplified version of the past, we find ourselves in another aviation reality today.

Aviation has grown in complexity and is today characterised by multiple uncertainties emerging from a constantly changing working environment that contains dealing with mergers, multiple Aircraft, Crew, Maintenance and Insurance (ACMI) wet leasing operations, adjusting to multiple national and organisational cultures, and a more distant management, where the chief pilot is known only by name rather than through personal appearance in the everyday operations. The level of social interactions associated with the past is more frequently replaced by online settings, computer-based training (CBT) and check-in happens at the gate of the aircraft rather than the crew room. What used to be a predictable job for 30-40 years is now replaced by contract employment and job expectancies of 2 to 3 years, before employees find themselves in a 'new' aviation reality.

The Normalisation of Adaptation

The world is constantly changing. More than ever, people employed within aviation (at all levels of an organisation) find themselves immersed in constant adaptations in order to keep up with the pace of change. They create the capacity to get the job done in a constant fight for survival. Going the extra mile and stretching a bit more, while dealing with the many uncertainties that emerge in the working environment seems to have created a normalisation of adaptation.

This goes unaddressed in training sessions, which are dominated by compliance and achieving standards often based on arbitrary measures. This normalisation of adaptation is invisibly patching up the system and making it work. It contains both the contributions that people make, as well as the trade-offs people have to make that seem to go unnoticed in the way airline training and opportunities for learning are designed.

It seems that both the understanding of work and training design in many airlines is based on obsolete thinking (e.g., Safety-1), where the human is seen as a liability and system "improvements" happen by fixing the people at the sharp end, and not the system. This approach lacks the robustness to deal with and learn from the ongoing changes and growing complexity that influence the system's performance and system learning. We may find the people working in the aviation industry equipped with ballerina shoes, as they climb the mountain of aviation complexity, afraid to cause disruption. The underlying assumptions on which aviation training is based have become saturated and are in need of an update.

> **“ ...training...is dominated by compliance and achieving standards often based on arbitrary measures...normalisation of adaptation is invisibly patching up the system and making it work. ”**

However, new regulatory winds are blowing on the mountain. They may demand a steadier foothold, which in turn requires more solid footwear. In early 2023, the European Union Aviation Safety Agency (EASA) published updated guidance on its aviation safety plan for the next three years. They state:

“As the aviation system changes, it is imperative that we ensure that human factors and the impact on human performance continue to be taken into account, both at service provider and regulatory levels. Resilience and a Safety-2 approach, where the number of intended and acceptable outcomes is as high as possible, shall be introduced alongside the Safety-1 approach.” (EASA EPAS, 2023, Vol. 1, p.43).

The Organisational Proficiency Check

People are part of the system, and not isolated from it. This, in my opinion, means that for learning to occur it requires a more holistic approach. Every six months European pilots are in the simulator for an Operators Proficiency Check (OPC) to check, train and improve their qualifications. Maybe it’s time to explore the possibility of an Organisational Proficiency Check as a recurring theme in an airline, not for the sake of an audit, but for the sake of constant organisational learning and improvement.

Features of this Organisational Proficiency Check could involve an update of the existing platforms available in an airline (e.g., CRM, SMS, OPC, Line checks, reporting system etc), where employees at all levels of an organisation would play an active role in redesigning these platforms. For example, this could involve setting up ‘learning teams’ that participate in the daily operation to feel the pulse of the airline, in the effort to constantly create and adjust the capacity and adapt the existing platforms to match the needs.

Perhaps most important to this process is challenging the underlying perspective that’s been dominating the aviation world (e.g., Safety-I), and improving upon this with a curiosity to create opportunities for learning by understanding the contributions and challenges from work-as-done, and by tapping into the practical wisdom present in an airline. These learning teams are thereby not experts or managers, but colleagues that work as collaborative links in an airline for the purpose of constant organisational learning.

Learning teams could for example ask questions like:

- How do we redesign the training platform to include learning opportunities, that tell us about how people adapt and make it work in everyday operations?
- What needs to be in place for people to proactively address concerns and potential signals of risks without the fear of retribution?
- How do we establish and nurture relationships across the system that benefit the organisation as a whole?
- What sort of human adaptive contributions are present in our system?

Incorporating learning teams in everyday operation could assist in a continuous effort of organisational learning and resilience. In the aviation world of compliance, it may be worth noticing that the regulatory winds seem to be changing here as well, encouraging more holistic approaches. EASA elaborates further that:

“Organisational resilience is a key factor in successfully managing safe operation, but there is scant regulatory guidance on how to apply the concept. Resilience comprises both a system’s ability to withstand disturbances, challenges and change, and to recover and sustain operations thereafter. The positive contribution to safety of each and every staff member is a key component in an organisation’s resilience” (EASA EPAS, 2023, Vol. 3, p.53).

I welcome these times of regulatory change that suggest broadening our perspective to include the system, and not just looking at the individual. We may find ourselves in need of new shoes which may hurt a little at first, and may even be a bit of a struggle to put on, but over time may provide the necessary comfort and support to climb the mountain.

Gitte Furdal Damm is a former pilot and has for the last 8 years been providing CRM and HF training as a consultant through her own company About Human Factors. She completed the MSc program at Lund University in Human Factors and System Safety in 2021, writing a thesis about resilient performance within aviation.

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Are Black Swan Events Trainable?

By Endre Berntzen

I once was told that aviation safety is like making moonshine: everyone knows when you are doing it bad.

In aviation, we find the types of professionals you would expect, the ones dressed in uniform making decisions on everything regarding your life for the next couple of hours. You expect the best service as well as the safest duty of care.

If I told you the opposite—that everyone involved is doing their best to make this unsafe —you would select a different airline or not travel at all.

Flying is a profession; it is a specialized task requiring certain skills and training. It also requires specific competencies to precisely navigate a steel tube through the air at high speed, surrounded by flammable liquid.

Our expectation is therefore a high level, or perhaps the highest level of safety. We take it for granted. Like moonshine – we expect the recipe to work. It is so safe that when something happens everyone jumps to quick conclusions - this must be an error (pilot error). In theory, high reliable organizations (HROs) have complex systems that work in symbiosis, procedures that are well-tuned and effective. Aviation is well-regulated and already has well-working concepts in place. Using the theory of resilience may then be seen as an add-on or something extra.

> **“ To enter the world of the Black Swan, we need to understand two elements: hidden interdependencies and brittleness. ”**

Pilots on an airplane shall never perform a task that they are not trained for – it’s where we build our competence and establish our culture. Culture is a buzzword and can be defined as “what you do when no one is looking.” When you operate there will be risks – how you deal with them can be different. Surprise in training, or Black Swans if you will, can be difficult to both facilitate and solve and need identification of when the resources required to solve the task is higher than the resources available. It can be achieved when the workload is high and there are added requirements in place – a situation that could approach negative training.

Applying a resilience perspective in training means adding knowledge of what type of resources you have available and how they can be applied. The most significant change we made when introducing this concept is the language. Instead of asking the 5 why´s - we simply ask “how come” or “what was it...” The idea is that pilots always have their attention on something. And when you understand what they need you will probably increase the resources available. The problem for many HRO companies is that there are weak leading indicators or lack of meaningful markers; what you are looking for are thin margins and small indicators.

To enter the world of the Black Swan, we need to understand two elements: hidden interdependencies and brittleness. You should look at job requirements in a specific order - starting with the rules, then going to technology, and ending up with training. The hidden facts of your work will then potentially expose brittleness. This is the point where performance starts to decay and higher risks in your operation begin to appear. We found the most effective way of studying this is by doing a work-as-imagined vs work-as-done gap analysis. You will not see the Black Swan if you do not know what to look for (e.g., hidden interdependencies and brittleness). New training concepts introduced worldwide seek to find these answers and introduce new rules and training concepts. The problem I find from a resilience perspective is that the introduction of these rules may introduce new complex clustering and the possibility of weak links. Since mapping your dependencies can be complex, you run a risk of missing important datapoints relevant to performance. In other words, you risk a higher degree of brittleness that increases your risk level because of very small indicators.

We find examples of this in everyday airplane operations. After an accident we often find investigators using “loss of situational awareness” in their reports. We can argue that this is not true, people always have their attention on something – we just need to figure out what, learn and then train. In Black Swan events, we could find that the crew has been (or not) exposed to a certain situation and the response to the threat is either too quick or too slow, and most likely a cascade effect putting strain on time management.

A specific example is the altimeter procedure setting in an airplane. Airlines have rules on how this should be set and if the airplane (technology) is either old or extremely modern the training is increased. If you are AQP, ATQP or EBT approved, you monitor pilot performance to check the effectiveness of the procedure. In your observational data, you may find that 3,8% of pilots are performing the procedure incorrectly and conclude that the deviation is statistically within your margins. However, looking from a two-person crew perspective, the deviations then double to 7,6% which is way above your expectations. From a normal perspective you would probably call the pilots for tea and biscuits and give them a reason to be proud (and perhaps walk out the door with Penny Benjamin – for all the Top Gun aficionados). Or you could flip the line of thinking – if your procedure is 100% effective you might have a bad culture, or if your procedure is a 100% ineffective you have a good culture. Why? The observation during LOQE or LOSA would focus on how the procedure is corrected and which pilot played the active role when corrected. At this point you are capable of, and knowledgeable enough, to know what to train.

Aviation is inherently complex and based on many unknown factors, yet still resilient enough to operate with the highest degree of safety. Working within the margins of safety, we should always question what our acceptable levels of risk are. Risk tolerance and training to reduce exposure to risks is complex.

Training for Black Swans is a marathon and not a sprint. Are you up for the task?

Endre Berntzen has been flying since he was 15 years old and has experience from the oldest four-engine Lockheeds from the 1950s to the newest technology of today's jets. Through his airline, he has led a number of research programs and has been involved in almost everything that has to do with the training of aircrew. He has extensive experience with ATQP and has assisted OEMs and CAAs in certification requirements of new and old aircraft. The most interesting study he has been involved in relates to the effects of somatogravic illusions and pilot training. In his spare time, he enjoys driving a 11.5 ton snowmobile and making ski tracks for cross-country skiers.

Are We Learning All We Need for Resilient Performance?

By Laura Maguire

Competency in performing a task is a minimum requirement that is assumed for workers in high-risk/high-consequence environments. Organizations utilize a variety of mechanisms to assess proficiency such as competency matrices, ride-alongs, peer review and coaching, refresher training, regular re-certification cycles, and performance reviews to assess technical skills. Many simulation-based assessments also include assessments of explicit skills in coordinating and collaborating for team dynamics.

While the knowledge and skills demonstrable in these processes are important, they are insufficient to account for resilient, adaptive performance. What is missing is the significant amount of knowledge learned outside traditional channels and expressed most noticeably during adaptive performances. In the literature, the concepts of shared mental models (Converse, Cannon-Bowers & Salas, 1993), common or mutual knowledge (Clark & Marshall, 1981; Krauss and Fussell, 1990) and common ground (Clark and Brennan, 1991; Klein, Feltovich, Bradshaw, & Woods, 2005) are well established, and were a central component of my own doctoral research. This article expands on this important component of workplace learning to suggest ways to enhance existing organizational learning systems.

The importance of the implicit

In modern work environments, practitioners face trade-off decisions, goal conflicts, and requirements to continually revise, replan, and reprioritize in the face of changing conditions (Woods, Dekker, Cook, Johannesen & Sarter, 2017). But the knowledge of these aspects of work, which is crucial for carrying out tasks and coordination across inter- and intra-organizational boundaries, is typically not made explicit in traditional training systems. Instead, it is left to individuals to uncover these requirements and put this knowledge into practice alongside the technical demands of their role.

In my doctoral research, studying software engineers resolving complex large-scale system outages, I discovered many different classes of knowledge that were used in responding to incidents (Maguire, 2020). The knowledge that aided not only timely and effective incident response, but also how to enhance current knowledge of system behaviour included crucial information about:

- the kind of organizational demands (including shifting priorities, new management, pressures & constraints for action);
- organizational and team priorities and how they tend to shift relative to different kinds of pressures as well as how quickly/slowly these shifts take place;
- goal conflicts and how those are typically dealt with;
- formal decision processes;
- informal decision processes or role-specific decision-making authority;
- when to use formal vs informal decision processes and the implications of each;
- who makes decisions in emergent situations and at what speed; and
- in complex, large-scale, interactive failures, who were the dependent units, and what were their role & function (espoused and actual).

In looking at formal job descriptions, training programs, and competency assessments there was little to no evidence that this contextual knowledge was recognized and valued for the central role it played in minimizing the impact and duration of the incident. And conversely - when it was absent- of the role it played in amplifying impact and extending the duration of the incident.

Contextual Learning

Practitioners often acquired this knowledge in an emergent, ad hoc fashion often initiated on their own volition. To many organizations, this process of establishing and maintaining common ground looks like slack in the system - inefficiencies to be eradicated. It is the casual but protracted conversation two residents have in the cafeteria after bumping into one another getting coffee. It is the equipment operators lagging behind after the morning meeting to talk about the difficulties faced on the jobsite the day prior. It is the investment made by an engineer to spend her lunch hour at another team's weekly meeting to listen in for any disruptions in their work that may impede her own team's efforts.

> **"To many organizations, this process of establishing and maintaining common ground looks like slack in the system"**

This learning becomes knowledge about how the system functions under different conditions and, to the practitioner, it enables resilient performance much in the same way expertise enables knowledge to be flexibly applied to novel problems (Feltovich, Spiro & Coulson, 1997).

Pre-emptively, the practitioner uses this knowledge to anticipate problems that interfere with their ability to carry out their work, proactively adapt their actions or gather more information to keep their options open, to recruit needed resources or secure access they may need in future. For example, a forest supervisor might know one of their tree faller's children is sick and may need to leave the jobsite quickly that day. They use this knowledge to assign them a location close to the road that allows for a quick and safe exit from the cut block that doesn't impede or endanger other nearby workers.

In the midst of a crisis situation, this knowledge is applied dynamically with the practitioner calling forth contextual information that enables them to trace the loss or gain of additional capacity relative to changing events. For example, a software engineer without access to a critical database knows a member of the database team from their shared work in the employee resource group, and is able to text them asking for help during the incident response.

Retrospectively, this knowledge is used to help reconstruct contributing factors and make sense of seemingly discrepant system behaviours. When a lack of common ground or common knowledge contributes to difficulties in working effectively together, this can be taken as a signal that great cross-functional and multi-level interactions would provide a benefit. For example, a helicopter pilot experiences a near miss when transporting passengers from a staging area and invites the marketing and operations staff of the holiday operator to attend the debriefing, so they may identify potentially hidden barriers to understanding and ways to communicate hazards early and often to passengers.

Encouraging a continuous learning function

Organizations looking to develop learning systems to support this form of learning need to recognize its implicit value and enable mechanisms for it. While formal structures (weekly update meetings, townhall events, newsletters) may serve to capture some of this form of learning, the tendency towards repeated, managed, and structured information delivery is likely to be insufficient for developing relevant and ongoing common ground. In highly variable operating systems - like those of continuously changing distributed software systems - these mechanisms will lack the variability of information and the inability for practitioners to probe for information that is more immediately pertinent for their goals, purposes, and concerns.

Instead, more ad hoc and emergent interactions should be encouraged across internal and external organizational boundaries to encourage diversity of information flows. Workers should be provided training that highlights the importance of this form of learning and enables them to practice establishing and maintaining common ground both within their teams

and across different levels and roles in the organizations.

Cross-functional game days, simulations, or incident reviews consisting of complex, contextually-driven problems coupled with skilled debriefing that can reinforce technical and knowledge factors can assist organizations in learning for resilient performance.

Laura Maguire leads the research program at Jeli.io, where she studies software engineers as they cope with the cognitive complexities of keeping distributed, continuous deployment systems reliably functioning and helps to translate those findings into a product that is advancing the state of the art of incident management in the software industry. Her research interests lie in resilience engineering, coordination design, resilient systems control, and building tooling to enable adaptive capacity across distributed work teams. She was a researcher with the Cognitive Systems Engineering lab SNAFU Catchers Consortium from 2017–2020, working closely with large and medium-sized digital service companies to identify and support resilient performance within their engineering teams. Laura has a Master's degree in Human Factors & Systems Safety, a Ph.D. in Integrated Systems Engineering from the Ohio State University, and extensive experience working in industrial safety & risk management.

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Two Views on Procedures

By Tom Laursen

There are two very distinct and rather contrasting views on procedures and how the aviation system creates safety.

One view is that the aviation system would be safe if only humans, especially the operators, followed the rules. This belief is governed by the idea that following procedures equals safety. In this article, this view is called ‘**the adherence view.**’

A different view is that procedures are one recourse, amongst others, for human operators to respond to the inherent variation and uncertainty of the aviation system. In this article, this view is called ‘**the adaptive view**.’

> **"The adherence view’ is the language of compliance and non-compliance; ‘The adaptive view’ language is characterised by description, understanding and explanation."**

In this short article, I will highlight how operators respond to everyday uncertainty and variation within the aviation system. I argue that the use of phrases like rule-breaking and non-adherence to procedures can be substituted with other labels that are less pejorative and more useful if we are trying to improve the overall performance of the system through our available tools.

Adaptations

There is inherent variation and uncertainty within the aviation system, which aviation stakeholders are good at predicting. They spend considerable resources on predicting what can happen, but we will never be able to fully predict and anticipate all scenarios. Therefore, the aviation system has been designed to respond and adapt performance to these changes. The place where the largest number of adaptations are taking place is at the operator level. Operators can respond in real-time and make short necessary adaptations to the planned operation.

An example I have used in the past to describe the everyday necessary adaptations is the number of phone calls that Air Traffic Controllers (ATCOs) execute daily. The main purpose of phone calls between ATCOs is to coordinate smaller or larger changes to the planned operation. During an hour of work, an ATCO will make 10-30 phone calls to coordinate changes to the planned operation. There are, of course, procedures in place when ATCOs need to make phone calls. The procedure says that phone coordination needs to be performed when there is a revision to the planned operation. Coordinating what is beyond planned operation requires the operator to be sensitive to many subtle variations (requests for direct tracks, aircraft that can’t reach an agreed flight level because of performance, all kinds of revisions, etc.) in the situation. These variations often require real-time interventions from the operators.

Sidney Dekker says that ‘applying procedures successfully is a substantive, skillful cognitive act’. If operators followed rigid procedures, according to how they were designed, the aviation system would come to a halt very quickly. There is simply no way that the 10-30 phone calls per hour can be described in detail within the procedures. Despite that, there is a continued belief that rule-following equals safety. The aviation system is safe because it has been designed to be able to respond to the variation and uncertainty in everyday

operations as well as contingencies.

The need for change

'The adherence view' governs many of the processes that have been implemented as tools for managing today's aviation system. Taxonomies, incident reporting, risk assessment, proficiency checks, KPIs, and many more are tools that are based on the idea that any identified non-conformity (a social process where the people with the right to define the paradigm have the power) to the written word can be tabulated and counted to serve the process for safety improvements. This approach aligns well with excel sheets, quantifiable risks and checklists, and managing your organisation with reported numbers through a distant view of work. This method often generates misguided countermeasures.

In contrast to this approach, 'the adaptive view' is based on understanding context and the messy world of conflicting goals. This world is difficult to tabulate and understand without understanding the work context and cognitive processes that lead to performance. It's a world where organisational performance results from organisational preparation (staff numbers, equipment, airspace design, selection, training, etc.) and how human operators respond and adapt to everyday variations.

If we want to move towards an aviation system that is governed by 'the adaptive view', there is a need for change. We do not need to abandon 'the adherence view', but the balance between the two must change.

The language

Another difference between the two views is the language that is used. 'The adherence view' is the language of compliance and non-compliance. Most situations become digital and, therefore, can be judged to be either right or wrong. This judgment is done after something has happened. Our language to describe failure is very rich compared to our language to describe complexity and the positive system attributions of humans.

'The adaptive view' language is characterised by description, understanding and explanation. This is a language that allows us to understand the situations we describe. Through a language of understanding, it's easier to recognise the complexity involved in real work, which again provides us with improved possibilities to introduce useful countermeasures.

Some suggestions

Our suggestions to change the balance between the two views to improve the tools we use for organisational and industry decision-making are:

- Stop or be more careful with tabulation - use a qualitative approach to manage your organisation. Tabulation often leads to more procedures that lead to more tabulation of non-compliance.
- Managing organisations safely is about collecting multiple perspectives, and interactions between system elements. Not one truth.
- Learn to support the human capacity to adapt. It is a finite resource that must be monitored in the live environment to ensure sufficiency.
- Compliance is never a substitute for engagement.
- Learn to find the adherence/adaption sweet spot and adjust with system contextual changes to minimise the load on the human operators.
- When adding new procedures, trial them first to ensure they are stable enough to be helpful, especially in messy situations.
- View adaption as a chance to learn about what is going on.
- Learn from adaption to improve procedures.
- There is no such thing as a Root Cause.

Achieving improved performance and doing it safely is about supporting practitioners and other staff when they attempt to solve the variability of the aviation system both in everyday operations and contingencies.

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A Multi-Domain View of System Management

By James Burnell and Joji Waites

This article is written not just from an understanding of theory but with one foot in live operations across the aviation industry. To validate our thinking, we have drawn on what works and doesn't in live operations from the frontline operators' viewpoint. This has then been used to find and validate alternative coherent approaches that target areas where the current systems fail to support the operation. Exploring some potential learning improvements that come from conceptualising the system differently, we will open the door to using different types of data. The framework we introduce here draws upon the benefits of moving on from uncontextulised data only approaches, to adding varieties of contextualised data such as contextualised data at scale, or context rich narrative to improve our understanding.

We discuss some of the pitfalls of a single-domain view and, more importantly, the benefits of a multi-domain one. How does a multi-domain view allow us to create new ways to understand the management of uncertainty created by our modern complex adaptive systems? This includes the opportunity offered to balance worker adherence to rules with adaption to unlock the inherent resilience in our systems.

Background

As background for those unfamiliar with the aviation industry, the approach to learning and risk management is realised through a Safety Management System (SMS). Various types of reports or data are synthesised into largely uncontextualised data that is used to create objective truths for system improvements or corrections through linear risk management structures. An example of uncontextualised data could be the distribution of unstable approaches by location as detected by a Flight Data Monitoring (FDM) programme.

A Multi-Domain View

The alternative approaches we suggest here need to be intellectually scaffolded by one core concept: a shift in our perception of the system. This is a change in systemic conceptualisation from a single-domain system view to a multi-domain view. By domain, we mean a part of the system distinct enough to warrant its own paradigm of understanding, learning and operation.

The phrase coined by the statistician George Box, 'All models are wrong, but some are useful.', is helpful here to highlight why value is generated by a multi-domain approach. Value is found in one view over the other only because one model is likely to be more useful than another under a given context. To make the concept accessible, we have restricted this article to the two main domains organisations expect to manage in daily operations.

The Ordered Domain

The prevailing single-domain view to which we refer is that of the 'Ordered Domain' or Cartesian, 'system as a machine' view that has dogged western-world thinking for several centuries now, and we believe is stopping us all from moving beyond the asymptote of safety improvement. The ordered domain is where cause and effect are obviously and irreparably linked. We can learn and manage as if building or fixing a piece of machinery. Some refer to this as a "Taylorist" approach, where safety management can be deconstructed into constituent parts in a reductive manner.

The Complex Domain

The second domain, which is undeniably part of every system we operate beyond the merely mechanical, is the 'Complex Domain'. This is an easy concept to grasp, as it is how we experience our own lives outside the working environment. We would not intrinsically organise our lives through systems engineering, KPIs or standard operating procedures.

These complex parts of our system are dispositional (only disposed to repeat the same outcomes but in no way guaranteed to do so) and, therefore, subject to radical uncertainty, emergence, sensitivity to small changes, tipping points and other properties that we don't see in ordered domains. We do not propose to define and elaborate on these concepts here, however we consider it well worth the reader's time to get to grips with the concepts of radical uncertainty and emergence in complex adaptive systems.

> **"Complexity is, like gravity, a foundational property of the world and ignoring both generate similar results. – Professor Dave Snowden"**

To cement this idea, it might be valuable to highlight the other name for complex systems, which is **nonequilibrium steady state systems** which is much more intuitively descriptive of the challenges held within. It is also useful to understand that complexity is not a nebulous concept. It is a foundational property of our world, a world that would not exist without it. In essence, it means that the system's constituent parts adapt and change to one another, creating a higher-order output that is only discernible when the system is operating in its entirety, not by looking at the parts in isolation and extrapolating forwards.

Some Problems Created by the Single System View

We all agree that we must find a way to learn about what is happening in our operations in order to manage them appropriately. This is where ordered domain-only approaches create problems.

Learning and Data

The first problem. If you believe that the system is merely a machine to be fixed and perfected, any unwanted outcomes appear to be failures of that system or the operators of it. Therefore, any outcomes not amplified by unwanted consequences, say an accident or a serious incident, must be a system working well. This would make anyone question why we would learn from normal work.

This is manifestly not the case in complex systems, as highlighted above. They are dispositional, not causal. Hence, outcomes are always subject to variation at any time, so we must learn what the potentials might be. Most importantly, because it is a nonequilibrium system that does not necessarily regress back to the mean, we need to know where the adaptive capacities that stabilise the equilibrium are in order to ensure they are supported.

The mechanistic view leads us to suppose that our belief in stable cause and effect can successfully support the use of uncontextualised data as the sole source of learning. Uncontextualised data is data stripped of context and is then used to learn in context-rich environments, causing some of the potential operational failures we have seen in frontline operations. In the earlier example of FDM-derived unstable approaches, the data might show that some airports attract higher unstable approach rates than others but without the contextual information to explain why.

There are sound mathematical reasons for not using uncontextualised data solutions in context-rich environments, such as the curves used to describe distributions of events. When we stop using linear mathematics, such as Gaussian Distributions or bell curves, to describe the complex world and switch to far more domain-appropriate nonlinear Pareto distributions, we see a far higher likelihood of serious events, e.g. a 1-in-100 event becomes a 1-in-10 event. The next reasonable next question would be, 'If risks are more and potentially larger than we believe, why do we not see many more serious incidents and accidents?'. We believe this is because humans—a largely undervalued and overlooked form of resilience within our operations—adapt to a considerable amount more variation than is generally acknowledged.

A further problem with using uncontextulised data points is the enormous amount of possible linkages, which in classic fault tree analysis are used to build a picture of what is going on. The maths of using this uncontextualised data approach is that with 10 data points and 45 possible linkages, there are 3.5 trillion possible explanations of what is going on. It should be obvious that there are serious limitations to this approach in all but the most stable of contexts.

It is also the case that the output of any socio-technical complex system, such as an airline operation, beyond what has been safely ordered with standard operating procedures, is dispositional, or emergent. Looking at parts of the system to extrapolate potential outcomes is likely to be less effective than we might have first thought. It is akin to digging up and dissecting an apple tree to ascertain the taste of the coming autumn's apples—a fruitless approach.

Managing

A common management misconception is that management interventions are a binary choice between fixing the system with system-level interventions, or by individually fixing the human that created a poor outcome by not complying with the rules or making errors.

A multi-domain view allows us to see the complex system as dispositional, always ready to create new outcomes regardless of structure, freeing our managers to try many new approaches to creating interventions to support the resilience vital to contend with such systemic context variations. Risk management can now be dealt with at multiple levels and with a fractal approach (by this, I mean broken up by different conceptual areas and not just scale, e.g. safety management is not the same when looking at Edinburgh-based crews as Copenhagen-based crews).

System change is also a significant concern when viewing issues from the frontline. The foremost problem, as we see it from a resilience engineering viewpoint, is implementing changes with the belief that the system will create an output that is stable across time and outcome. This has two consequences. The first is the obvious lack of ability to spot impending emergent issues created by our own interventions. The second is that beyond the sight of current learning approaches, this methodology of change consumes the most significant form of operational resilience in our systems. Our workers are left to control any unintended consequences of these interventions to stabilise system outputs, which absorb this finite adaptive capacity.

In summary, the ordered domain approach incentivises the creation of context-free global solutions in context-rich fractal environments, as opposed to potentially creating many methods and tools that could be combined to create systems of action coherent with the local context.

Some Benefits of Multi-Domain Approaches

Given that we are all comfortable with the ordered system approaches, the following paragraphs relate to possible differences that support risk management within the complex parts of our systems.

Learning and Data

In the complex parts of our systems, such as the parts where humans operate, we would advocate an approach to learning grounded in the belief that context is the most important element of any data collected.

Making sense of what happens within complex domains differs greatly from ordered domains. The uncertainty created by the interacting and adapting system elements that create the output means the system is immune to accurate modelling and prediction. The good news is that, as humans, we naturally evolved to work within this uncertainty and are well-attuned to the context-rich narrative learning approaches needed to determine what is going on.

As we move into the complex domain and possible contextualised data solutions, we must switch to abductive approaches to reasoning. Abduction, sometimes called the science of hunches, is just this. This allows us to hold multiple coherent ideas of what might be going on so this is no longer about which ideas are objectively right or wrong, but which might be contextually useful.

Therefore, the upside of learning from a contextualised approach is that we can better understand what might be going on, leading to more coherent methods of system management.

Possible Contextualised Data Learning Technique

One example of a narrative-based data learning technique we could use in an airline setting might be to use the informal network structures between airline crew. This is, not to replace current approaches, but to augment them. In the complex parts of our operation, we can now imagine adding learning structures below the level of the formal systems of SMSs. These would be capable of amplifying weaker signals through informal network interactions while being more targeted.

The problem with formal learning structures such as airline SMS is that they inherently restrict the type, and quantity, of data that flow through them. Both by design and because of the levels of trust or understanding the participants have of them.

Worker culture or social heuristics (ideas that form group patterns of behaviour) are the main driver of crew behaviour beyond the vagaries of human decision-making. This means that mapping this culture creates leading indicators of safety, where compliance to a fixed system is a lagging indicator and arguably an ineffective one at that.

To ensure the informal networks are of sufficient density, airlines could carry out any variation of social network stimulation to reengage these. Based on the fleet structure or crew base size, crews would need to be networked within an appropriate number of degrees of separation from each other. This is quickly and efficiently achieved, and the operation will become safer even without formal learning as information flows are facilitated.

When these networks are in place, it is relatively simple to tap into the data stream with an appropriate data collection approach that does not allow gaming of the question, maintains epistemic justice and is seen as non-jeopardy by the participants. The correct process here is the collection of contextualised data at scale using any suitable available commercial collection software or carefully considered in-house approaches to narrative databases. We could take a lead from one of the schools of sense-making and anthropologists who have been working with the knowledge of complexity from the start.

These collection methods can be used to highlight any desired topic or used for trending. It would also support a complexity-coherent theory of change. As context changes, though, company initiatives or otherwise, we could be proactively monitoring to catch unintended consequences, which, as it stands, are only retrospectively picked up when consequence amplifies poor outcomes. This approach also allows KPIs to become vector measures of change of reality and aid system management rather than hinder it.

Managing

Now that we can have a multi-domain approach to learning and data, a significant benefit becomes the freedom to manage the system of uncertainty with a more coherent approach.

If we are to hold multiple potential truths at the same time, we can test ideas for usefulness. This can be done through safe-to-fail experimentation to avoid unintended consequences of a system that we now know to be dispositional. As we now know, the outcome of all possible interventions in any complex system cannot be truly seen until the system has run through all iterations. Still, with context rich data approaches, changes can be monitored, and poor outcomes safely dampened if needed.

> **“ ...our systems are significantly more fragile when airlines make changes to the operation without a complexity-safe theory of change backed by contextualised data learning. ”**

The lack of the need to ascribe an objective truth also allows us to practice greater epistemic justice within worker communities and improve safety culture. The use of social network stimulation further cements this culture of sharing and discussion, both improving safety, data collection and trust as the workers see their issues being addressed without undue delay.

We can create interventions that include whole systems of action across multiple levels and areas of the operation, creating contextually appropriate responses to fractal problems at any scale.

We can also anticipate that this approach will give us the ability to directly influence a significant source of undervalued resilience. This can be achieved by supporting our frontline staff through a good understanding of the system dynamics and maintaining the balance of ordered parts to complex parts. In other words, the balance of adherence to adaption. If unbalanced in either direction, it may significantly erode the adaptive capacity of the humans who keep our context-rich systems safe and efficient in the face of the uncertainty and emergence generated by complexity.

We will finish with a concern borne out of bitter experience. We now know that when changes, such as improvements in safety or efficiency, are made to nonequilibrium steady state systems we risk unwanted consequences. From experience, we see that our systems are significantly more fragile when airlines make changes to the operation without a complexity-safe theory of change backed by contextualised data learning.

The scope of this article limits our ability to discuss this in more depth. Still, we would advise some further reading on theories of change, coherent and safe, for complex adaptive systems, such as the Vector Theory of Change from Professor Dave Snowden.

In summary, although we have only touched the surface of the potential approaches to this inherent uncertainty, we believe that it is possible to see that a multi-domain approach could have many potential benefits and allow new approaches to safety that give us a chance to break the declining returns of current linear reductionist methods.

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Captain James Burnell is a pilot and safety rep based in Edinburgh with the UK airline easyJet. He supports the British Airline Pilot’s Association (BALPA) in creating and promoting safety theory. James has a strong interest in generalist learning, cutting across many scientific fields with the aim of improving the safe management of humanistic systems.

Risk is Not as Simple as You Might Think

By Ivan Pupulidy

Recently there has been a lot of talk about “Zero.” The zero-accident philosophy is interesting and a noble goal; however, we need to ask is it attainable and that means we also must ask. “What happens if we fail?” The concept of zero is built on an idea that all accidents are preventable, and, in hindsight, we can build causal chains that suggest that they are. When we explore this issue through the lens of complex systems, we recognize the presence of uncertainty along with the lack of ability to fully predict what will happen. Following the logic of this argument, we can see that if a worker knew in advance that they would have an accident, then it is reasonable to assume that they would avoid that outcome by doing something different. The reality is that they don’t know what will happen.

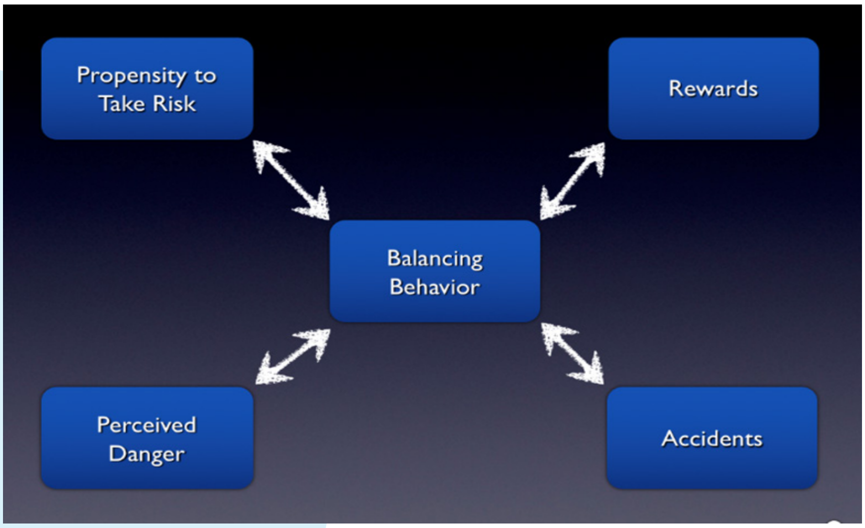
So, what does risk mean to operators?

Risk is more than a simple model of hazard coupled with duration of exposure, or probability times severity. Interacting with hazards is a complex human activity that is influenced by a number of key human and system features—a point missed by most post-incident investigations. Commonly when something goes wrong, our assessment of field risk management is strongly influenced by hindsight bias. Couple this bias with the emphasis of many current models of investigation which are designed to attribute cause to the disposition of those closest to the work . This means that behaviors and actions are often attributed to the disposition of the operator, which frequently leads to the judgment of action described as the “bad apple” theory. This model is challenged by complex systems research.

Any review of incidents must include situational attribution. This approach focuses attention on the influences or performance-shaping factors that exist in the work environment. There is a concerted effort to place actions and decisions in context. From a risk perspective, we need to understand how people related to the risks in the working environment and understand the normal tendency of people to normalize the risks associated with day-to-day operations. Normalization of risk is a term developed by the author during a Learning Review in the USFS. There had been a fatality tree strike and it became clear that the team of firefighters did not normalize deviance, as had been suggested by a team member. Rather they had normalized risk and fallen into a routine that made them more vulnerable as the system delivered the unexpected.

Professor John Adams has developed a risk diagram that helps us understand these risk relationships.

Adams views the reaction to hazard exposure (risk) as a balancing behavior, where influences pull toward risk exposure or



Adapted from John Adams, Risk (1995)

away from risk exposure. This is consistent with real-world operations – when, for example, a pilot senses or perceives the risk to be increasing, they naturally build margin into the operation, thus pulling away from risk exposure. In this model, balancing behaviors are influenced by four major categories: accidents, perceived danger, sense of reward, and propensity to take risk.

Propensity to take risk is a function of the individual's inclination toward risk-taking. For example, during a recent training session, I asked participants to tell me a story about a time they took a risk, that in hindsight they would not do again. A US Forest Service Smoke Jumper[2] reflected for a few moments and then replied, "I am not much of a risk taker, I am thinking about open ocean kite surfing, backcountry skiing and my other favorite hobby of Canyoning." This quote demonstrates at least three things; first, this person's propensity to take risk is probably higher than most. Second, they have difficulty relating risk to the things they love to do (a form of normalization of risk). Third, they did not even consider their job, jumping from a plane to fight fire, one of their high-risk activities.

The sense of reward is related to systemic and individual/personal rewards. Rewards can be institutionalized, such as awards or medals. They can also be systemic in terms of compensation such as pay and overtime. Rewards can also be individually developed, for example a firefighter responding to a vehicle fire, who sees a sign on a car that says "Baby Onboard" will likely take more risk to potentially save the at-risk child.

The term accident refers to the perception an operator or worker has regarding the severity of an adverse outcome. This works hand-in-hand with perceived danger, which refers to the perception the operator or worker has of the likelihood of an event occurring. Together, these two factors influence how the worker or operator perceives the overall risk in the system. It is very similar to the severity part of the probability and severity equation.

Normalization of Risk

Through a systematic review of US Forest Service accidents, the author uncovered the phenomenon of "normalization of risk"[3], which occurs when risk is accepted as a normal part of operations. In most cases, risk (like drift) is gradually accepted until it seems normal[4]. Normalization of risk is a common aspect of long-term human interaction with risk, regardless of any calculation of risk. The review of USFS accidents showed that the longer a system seemed safe (no accidents) the greater the amount of risk firefighters accepted.

Any risk management program has to consider all four of the influences/perceptions above to change the way that workers interact, accept, manage and deal with risk.

Hope for change can be recognized in tactical aviation operations where the environment consistently delivers uncertainty. Pilots in tactical operations are still subject to the normalization of risk; however, when a situation is recognized as novel there is a natural increase in risk awareness and experts move toward deliberation and become more risk-averse.

Stuart and Hubert Dreyfus of UC Berkeley conducted research that helps us to understand why the recognition of anomaly or novelty is so important[5]. Their research points to the system's expectations of performance based on experience or expertise. They demonstrated that novice practitioners abide by a rigid adherence to rules or plans, have little situational perception and demonstrate limited discretionary judgment. When we contrast this with expert performers, we see a very different set of qualities. The expert no longer relies on rules, guidelines, or maxims, has an intuitive grasp of situations and applies analytic approaches only in novel situations. This last line is key to understanding how and why tactical pilots tend to be more deliberative during operations and thus tend to be less apt to normalized risk. When the system delivers an anomaly, tactical pilots are influenced to make sense of conflicting information, learn in the moment, and adapt or innovate solutions.

Most organizations under-rate the importance of sensemaking in favor of demanding adherence to rules and developing rote knowledge through training. These are, of course, important qualities and they work as long as the system delivers the expected. When organizations develop the capacity to accept that complex systems deliver the unexpected our definition of resilience has to change. The capacity for sensemaking, learning and innovation becomes a cornerstone of a resilient system. This resiliency is dependent upon the people in the organization and their ability and freedom to innovate in anomalous situations. This form of resilience was demonstrated during the ditching of Cactus flight 1549 and during the Qantas flight QF32 uncontained turbine failure. In each of these cases the system controls were not enough to allow for a safe outcome. The crews had to innovate. Resilience may go well beyond constructs of decision-making and, as in the two cases just mentioned, it may be represented as testing ideas to see what fits the situation.

> **“Normalization of risk is a common aspect of long-term human interaction with risk, regardless of any calculation of risk.”**

In summary, the more routine the operation is perceived to be, the more likely the operator will be to normalize risk. Forcing operators into routine responses can make operators more susceptible to normalization of risk and therefore, the more apt they are to accept higher levels of risk exposure. All workers operate in an environment that delivers unpredictable situations and this can be leveraged into the development of capacities in the workforce designed to improve sensemaking, learning and improvisation skills.

Conclusion

Risk is not a simple issue. There are deep underlying conditions and factors that influence how people act in the presence of risk. Some of these factors are related to the disposition of the individual, but most are related to the system of work and the environment. As pilots, workers and managers, we have to consider all these conditions if we want to manage risk. Professor James Reason wrote, “We cannot change the human condition, but we can change the conditions under which humans work”[6]. This strongly points to the need for organizations, leaders and operators to become more aware of conditions and the influences that exist in normal work environments and to begin to manage those conditions, rather than magically expecting that people will change to suit an imagined work environment[7].

Simply admonishing people to “try harder” or, as some leadership have said, “take no unnecessary risk,” creates hollow guidance in the face of complex situations. Rather than these simple platitudes, we must endeavor to increase the capacity of our personnel to make sense of conflicting information and situational anomalies. This was once a key aspect of Crew Resource Management – perhaps it is time for us to consider how we can help our people to understand the nature of complex adaptive systems and what different skills are needed to operate with the highest margin of safety that is practical for each given situation.

There is no zero-risk option.

Ivan Pupulidy retired as the Director of the U.S. Forest Service Human Performance, Innovation and Organizational Learning Division. Ivan developed and implemented the Learning Review, which is designed to improve how large and small organizations respond to accidents and incidents. The team led by Dr. Pupulidy is credited with facilitating the improvement of risk management skills and fostering a culture of learning in the US Forest Service.

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[1] This is referred to in academic literature as Dispositional Attribution or the Fundamental Attribution Error.

[2] Smokejumpers are wildland firefighters trained to parachute into fires. Their primary mission is fire suppression and with the speed, range, and capacity of their fixed-wing aircraft, smokejumpers are capable of quickly delivering as few as two or as many as 12 firefighters with equipment and supplies, directly to the fire in a single trip.

[3] Pupulidy, I.A. The Transformation of Accident Investigation from Finding Cause to Sensemaking. PhD Thesis, Tilburg University, Netherlands, 2015.

[4] Adams, J. (1995). Risk; Routledge: Oxen, England, 1995.

[5] Dreyfus and Dreyfus in, Flyvbjerg, B (2001) Making Social Science Matter, Cambridge University Press

[6] Reason, J. (2000). Human error: models and management. BMJ, 320(7237), 768–770. https://doi.org/10.1136/bmj.320.7237.768

[7] The recognition and mapping of performance shaping factors is a major part of the Learning Review Process which is designed to build understanding of the context of decisions and actions to answer Prof. Sidney Dekker’s question, “Why did it make sense for people to do what they did?

From Assessing to Enabling

By Ron Gantt

A few years ago I was lucky enough to work with a construction client that was interested in trying some different things with their safety assessment process. They were required to do one by upper management, but were frustrated with the traditional approaches that were often more 'check the box' and typically culminated in an argument between the site personnel and the assessor as to whether a finding was a "2" or a "3" in their four-point scale of importance. They were looking for something fresh. Something that would leave the project teams feeling understood and supported, rather than judged.

In talking through what they were looking for with the client's team, we decided to try out a process that we took to calling an "operational resilience summit." These summits were designed based on two key realizations. First, the client realized that safety issues do not exist in a vacuum. Instead, things like hazards, risks, violations, and 'errors' are side effects of everyday work. Put another way, these safety issues emerge from the system of work within and surrounding the organization. Therefore, the organization wanted to focus on those things that they are doing to create successful work.

It turned out that this was not hard to identify. The organization already had ten "success factors" that it identified as important for creating a success project. These were things like: having a solid operational plan; a good relationship with their customers; adequate resources; and fostering a high-performing team within the project.

So, rather than the safety assessment looking only at how the site is managing safety, what if we shifted the question to how the organization is setting up the site for success? Then the lessons from the process wouldn't just live at the site level, but would provide a feedback loop to the whole business unit.

For example, those who worked to create bids for their jobs or who were involved in the scheduling or design often rarely visited the sites. As a result, they never got feedback on how realistic their bids, schedules, and/or designs were. Leaders would help develop plans for jobs, but when things did not go according to plan, it was viewed as a local problem, not a system issue. As a result, success and failure were typically viewed as a result of either the people at each site performing well or poorly, and/or good or bad luck. But the organization was designed to create the conditions for success at each site, specifically by using those success factors. If those were the basis for the assessment, couldn't we create the opportunity for learning to flow beyond the site level so that each job makes the organization, not just the individuals, smarter?

The second realization that guided the creation of the summit was the idea that every instance of work is an outcome of the system of work surrounding it. This is to say that any one time that a person does a task, that instance emerges from the system it is embedded in. Furthermore, these instances of work are variable and, to paraphrase David Woods, systems work as designed but rarely as intended. Therefore, the system we were trying to assess was (1) changing all the time, and (2) not working the way we thought it was. Its properties were emergent.

As a result, the team decided a checklist approach wouldn't suffice. Instead, we could gather stories about how work was happening and use those to infer how the system of work is actually working. From there, we could start to see how the success factors are actually playing out, good or bad. We could see sources of brittleness or precarious success, where people were working for cross purposes, the system was stretching close to its limits, or where a strategy that appeared to be working was actually introducing new vulnerabilities to changes. We could also discover sources of resilience, where the people had developed useful or innovative ways to achieve success in the face of project challenges.

This obviously creates challenges, because checklists are seen as easy to implement and easy to measure. Story-gathering is much messier. In going this route, the organization opted to forego the ability to compare sites in any sort of reliable way. They couldn't say that this site's stories are 40% better than the other site's, for example. However, the stories resonated with them because, not only are humans attuned to storytelling instinctually, but it also gave them something tangible to do. If I tell you that one site scored 83% on the latest assessment, you are left with more questions than answers. Is that good? Is that bad? If it is good or bad, what should you do about it? There is a lot of analysis that must be done before you get to the point where you can do something about it.

But if I tell you that at one site, we heard stories about how work crews had to wait around for an extra 40 minutes each day just so the crew ahead of them could finish their work because of a bottleneck in getting the right tools, now you have some tangible areas that you can explore and make changes on that touch many areas of the organization. And because the people who do this work are helping us gather these stories, those people are engaged in helping create improvements. As a result, even though it is hard to quantify (but not impossible in all cases), it was easy to point to specific improvements that resulted from this process.

"...a checklist approach wouldn't suffice... humans are attuned to storytelling instinctually..."

Based on these realizations, the team developed a basic process to pilot. We would have a summit team composed of people from outside the project (e.g., people from other projects, people involved in the project design and scheduling, safety personnel, etc.). However, we also wanted this to be a collaborative experience, so we also invited project personnel onto the team.

The summit began by gathering stories. Most team members went out in small groups (2-3) to the project to engage directly with frontline workers and ask questions about how they felt the work and the project was going. Another small group stayed in a conference room and had listening sessions with project foremen, engineers, and leadership.

In all cases the conversations centered around gathering stories. If someone said the project was going well, we would ask for an example of where the person thought it was going well (and similar for those who said it wasn't going well). The team then came back together and shared the stories they heard. The team then would engage in what is basically a group coding session, where they described how the success factors working (or not) in practice in the stories. The focus at this point would be on identifying lessons learned that could be shared (and how), actions for the project to implement to shore up sources of resilience or manage sources of brittleness, and associated actions for the business unit to better support this and future projects.

After a pilot project at one project, team members agreed that the project was a remarkable improvement over traditional assessments. People from the project reported that they felt supported because we weren't there just to point out what they did wrong. People from outside the project reported that they learned things that could help them in their own projects or scopes of work. Leadership was amazed at how much they learned that could help them better support projects. The organization is now iterating on the summit to see how it works on different sizes and types of projects and how it can be scaled to other business units.

There were numerous lessons we learned along the way, but the most important is that by simply shifting the focus a bit away from assessing safety and towards how we can enable the successful completion of work we can not only improve safety, but other organizational outcomes as well.

Put another way, we improve work to improve safety, rather than the other way around.

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Organizational Learning Through Systems Theory

By Shem Malmquist

In a statement that captures the concept of resilient performance, astronaut Frank Borman was quoted as saying that "a superior pilot uses his superior judgement to avoid situations which require the use of his superior skill" (FAA, 2008). In a chapter of Advancing Resilient Performance (Nemeth & Hollnagel, 2022), Carroll and Malmquist (2022) proposed some approaches to increasing the resilience of pilots, but is there a way to do the same thing with an organization?

There are two different aspects to creating a resilient system. The first is to design the system such that the need for extraordinary performance by individuals is not required (implementing the superior knowledge). The second is to empower the people in the organization to do what they need to do in order to ensure that the outcome stays within the margins of desired performance (superior skills). Too often organizations exhibit neither of these, not learning enough to have superior knowledge and using Taylorist approaches to management that only serve to constrain their people to scripted responses that are only effective when the script matches the situation. Unfortunately, the real world is too messy for this to work consistently, although it does provide for reliable performance within the narrow scope of the design of the scripts. Note here that computers are always limited to scripted performance and hence can never be considered resilient.

Broadly defining safety as the prevention from unwanted outcomes opens a pathway to applying safety and causality models to problems such as monetary losses and impacts to the brand as well as to damage to property and loss of life. It has been shown through system theory that safety is a control problem (Leveson, 2011). Here "control" is not intended to mean micromanagement and strict scripting of behaviors. The Taylorist approach to management is only effective for those problems and scenarios we have imagined in advance, and so incorporated into the methods.

> **"Building in...resilience requires first recognizing when assumptions are not matching reality."**

Instead, control here refers to the type of more broad control that can be seen in the work of air traffic control (ATC). Contrary to public perception, ATC only controls the aircraft to the extent it is necessary to prevent collisions with other aircraft. Similarly, a good manager will not be micromanaging their employees, but rather providing boundaries for the employee to keep them from doing something unsafe (safety in this context just means preventing an undesired outcome). Obvious examples of this might be controls (rules) for policy and procedures, such as about conflicts of interest or sexual harassment in the workplace, a violation of which would always be harmful to the organization. There are also controls to meet regulatory requirements, such as limiting what equipment can be inoperative on an aircraft and still be legal to fly. With this type of control there can potentially be operational pressure to violate as they can negatively impact reliability. Another type of organizational control is training programs, where people are trained to perform a certain function. It is important to recognize that adequate control requires both the ability to control the behavior of the component (hardware, software, human) being controlled, as well as adequate feedback so the controller can track the behavior of what they are controlling and modify their control as required to ensure that the desired outcome is met.

System theory considers the entire socio-technical system, including hardware, software, and human behavior as affected by social, psychological, and environmental factors. Through the application of system theory, it has been demonstrated that there are only four ways that a control can be unsafe:

1. A needed control action is not taken.
2. A control action taken that should not be.
3. A control action is done too soon, too late, or in the wrong order.
4. A continuous control action is taken for too long or too short a period of time (Leveson, 2011).

When applied to the examples above. If a control to prevent conflict of interest is not implemented, or if a control is implemented too late, a serious problem can occur. Similarly, a training program can be ineffective (or worse) if not implemented properly. Clearly, not training can be unsafe, if training is flawed, then training is unsafe (see American Airline's training that contributed to the loss of AA 583), training done too soon or too late, and also training done for too short a period of time, all could result in a hazardous scenario.

Another unsafe control action would be by management providing too much constraint on an employee. Imagine a customer service agent (CSA) at a large airline where some outside event has resulted in hundreds of canceled flights. If management provides too much control the CSA will never be able to satisfy the customer. Although this would appear to lower costs for the management in the short term, it would cause damage to the brand. Clearly, there needs to be some control over what remedies the CSA can offer, but micromanaging will likely be harmful. A better control here is adequate training. The same concept can also be applied to the hiring and monitoring of personnel, providing early identification of problems. Equally important, feedback is critical at every level. If the management can get feedback on problems, they can address them.

The key here is to identify the controls and the assumptions carefully, and then match these against actual performance. Castillo (2019) outlined an approach to use System Theoretic Process Analysis (STPA) to identify unsafe control actions and use them to identify scenarios that could lead to hazards. The method has been shown to be effective at identifying factors that are missed using traditional hazard analysis methods. These are then mitigated through the design policies, procedures and training. Actual performance metrics are captured to find additional scenarios not previously identified. These are then mitigated, and the process started again. This approach can be used across an organization to improve operations.

This process will also identify human performance that goes above and beyond. Most of the duties carried out in aviation are repetitive in nature, so can be scripted, but there are times that require a novel response (resilient behavior) by people in the organization to enable it to respond to unexpected problems. Building in such resilience requires first recognizing when assumptions are not matching reality, which can be a consequence of inadequate hazard analysis at the outset, or changes over time that render the initial assumptions invalid. In this way the process can result in organizational learning. Feedback to the organization, both formal and informal, will therefore make processes more efficient and thereby affect the bottom line positively. Systems thinking will also help an organization to diversify its lines of thought and challenge assumptions.

Aviation is an incredibly interconnected system, and oftentimes it is equally valuable to generate questions as it is to propose answers when it comes to organizational learning.

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On the Logical Interdependency in Infrastructures: An Institutional Perspective

By David J. Yu[1],[2], Hoon C. Shin[1], and Jeryang Park[3]

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It is well known within the field of resilience engineering that interdependencies of components within infrastructure networks can greatly affect system-level resilience because of their influence on how localized failures might cascade through the system (Yu et al., 2020). Interdependency is defined as "a bidirectional relationship between two infrastructures through which the state of each infrastructure influences or is correlated to the state of the other" (Rinaldi et al., 2001).

It has also become common knowledge within the field that such interdependencies can take various forms, including physical (the state of each infrastructure depends on the material output from or the state of the other because of a physical linkage between two or more infrastructures), geographic (parts of two or more infrastructure networks are co-located or in close proximity), cyber (the state of an infrastructure depends on information generated by information infrastructure), and logical (two infrastructures affect the state of each other via human decisions) (Rinaldi et al., 2001). These four types of infrastructure interdependencies, especially the physical and geographic forms of it, have been an active area of research among researchers and practitioners.

The goal of this short article is not to simply reiterate what is already known, but rather to highlight and make the resilience engineering community aware that, among the four types of interdependencies, the logical type is potentially the most critical one, and often under-appreciated by many.

Logical interdependency may also be the least studied and the least understood among the four types. Perhaps the physically invisible and intangible nature of such logical relationships makes it harder to detect and study them. Nevertheless, as we shall show in this communication, this gap in knowledge is a paradox to us since human decisions and rules prescribing them are omnipresent and influence almost every aspect of infrastructure operation. When rule-mediated human decisions underlie operation of two or more infrastructures that either knowingly or unknowingly require coordination (think pilots and ATC), logical interdependency is potentially present.

Few mention the importance of logical interdependency and address how a shift of demand between two infrastructures with the substitutable service (e.g., road and rail) can be conceived as an example (Petit & Lewis, 2017; Petrenj & Trucco, 2014). However, we argue that this misses the point we raised above: rules, procedures, or norms that infrastructure operators use to govern their decisions during normal and emergency modes can generate logical interlinkages. It is critical to see that human decisions around infrastructure operation are not made in vacuum. Those decisions are structured and constrained by agency-level rules and plans that have been codified, e.g., operational manuals and emergency plans of dams and hydroelectric power stations (Garcia et al., 2022). Such rules, generally referred to as institutions by scholars who study how rules shape human interactions and thus outcomes (North, 1990; Ostrom, 1990), can fundamentally shape how two or more infrastructures can affect one another through human decisions.

An example of rule-mediated logical interdependency is how operational rules at a dam and hydroelectric power plant are often interlocked. Most multipurpose dams are operated according to a set of rules known as "rule curves" that specify how much water should be released or stored and when to achieve a balance among flood control, water supply, and power generation (Garcia et al., 2022). These rules prescribe a range of water storage levels at some temporal resolution according to seasonality, water demands, and weather forecasts.

For example, under extreme precipitation and heavy inflow of water, a dam's flood pool can exceed a certain elevation (e.g., 750 feet) and the dam's operator is required by rule to make water release at a certain rate (e.g., 4500 cubic feet per second). When this happens, the hydroelectric power plant and its operator are required by another rule to fully open its plenum tainter valve and fully close its turbine value (so as to not disrupt or slow down water release from the dam). How well the rules are designed reflects local realities. Whether operators of the two facilities conform to the rules can greatly affect the states of these two facilities, flood outcomes, and subsequent decisions. This particular rule-based interlinkage can be represented as a network (actors and facilities as nodes and rules connecting them as edges) as shown in Figure 1. Systematic analysis of operational rules and network analysis of how various actors and infrastructure components are linked by such rules may generate insights about potential logical interdependencies in a complex infrastructure network.

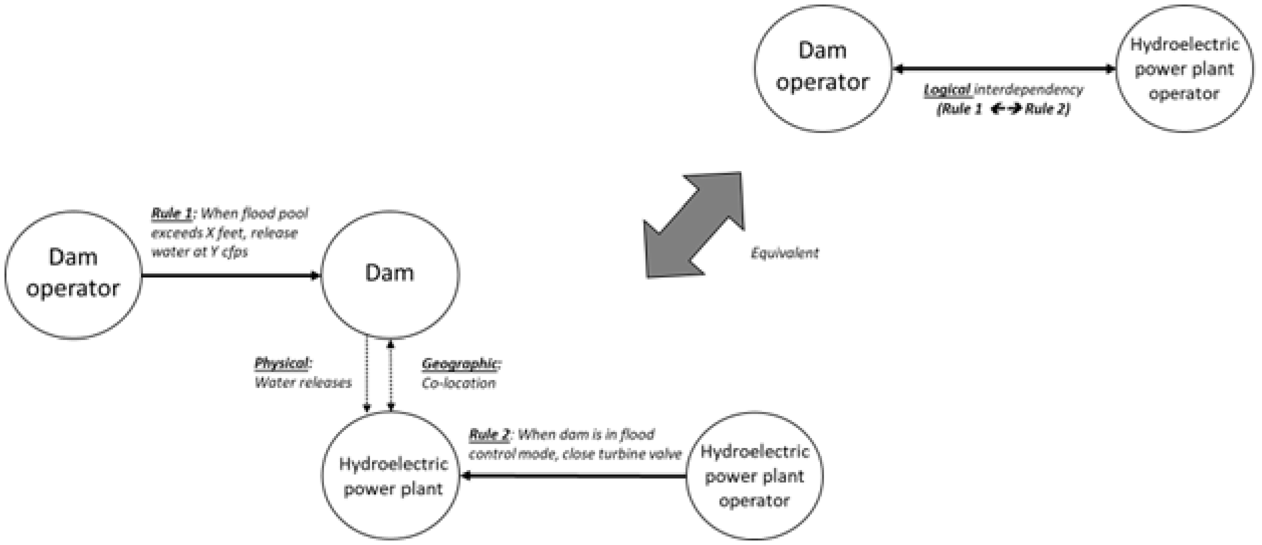

Figure 1: Network representation of logical interdependency between dam and hydroelectric power pant

One could argue that this example of dam and hydroelectric power plant is actually a case of geographic interdependency (because these two facilities are co-located) or physical dependency (water releases from the dam become inputs to the hydroelectric turbine for power generation). But we would like to bring attention to the fact that even in such geographic and physical linkages, there likely exists another set of rules that have been codified upstream at the agency-level to prescribe how operators should handle issues associated with co-location and input-output exchanges of two facilities. More generally, such rules like these act as a "glue" that brings together heterogeneous infrastructures and defines their protocols of interaction. Thus, logical and other types of interdependencies and risks associated with them are all significantly shaped by how operational rules and plans are designed (e.g., absence of rules, rules are present but a loophole exists, rules are present and well-designed but operators do not conform to them, etc.).

We suggest that more research is needed on the systematic analysis of 1) rules and plans governing human decisions on infrastructures and 2) how nodes of infrastructure networks (various actors, built and technological components) are connected by such rule-mediated edges (rules that tie nodes above). This should be an active area of research in the field of resilience engineering because of the omnipresence of such rules and their influence on human decision-making on infrastructure outcomes. Also, the original definition of logical interdependency by Rinaldi et al. (Rinaldi et al., 2001) could be updated – FROM dependencies that exist between infrastructures caused by human decisions that do not belong to the physical, geographic, and cyber types TO dependencies caused by human decisions and rules regulating them that occur either independently or in conjunction with other types (physical, geographic, and cyber) of dependencies.

For this new research agenda to advance, a systematic approach to analyzing operational rules and norms of infrastructures are needed, requiring an interdisciplinary approach and tools that encompass the study of institutions and governance and network science (Anderies et al., 2004; Eisenberg et al., 2017; Olivier, 2019). Aviation is well suited for such inquiry, as it encompasses commercial entities (airlines), regulators (civil aviation authorities), research and design (manufacturers), and many other stakeholders. By understanding logical interdependencies, we may further enhance our knowledge of resilience engineering as it relates to human decision-making.

David J. Yu is currently an Assistant Professor at the Lyles School of Civil Engineering and the Department of Political Science, Purdue University. He is also part of Purdue's Building Sustainable Communities cluster. His research centers on using a multi-method approach as a tool to systematically study the resilience and sustainability of human-dominated complex 'model' systems (infrastructure-dependent coupled natural and human systems) that captures key elements of actual governance arrangements, engineered and natural contexts, and human behaviors observed in the field. His research involves two interactive processes: 1) based on observed phenomena, define key hypotheses and contextual factors upon which to design and conduct behavioral and modeling studies, and 2) analyze results to develop generalizable insights and inform policy and planning. David brings diverse knowledge sets together to engage in this research: resilience thinking, human behavior, collective action and the commons, dynamical systems theory, and experimental economics.

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Resilient Organizational Learning Through Action Research

By Torgeir Kolstø Haavik, Norwegian University of Science and Technology (NTNU)

How do you build and maintain resilience in organisations operating in risky environments?

The importance of understanding what characterises everyday work and what 'makes work work', as well as being able learn from the whole spectrum of events from success to failure, is well established in the field of Resilience Engineering.

However, although the resilience literature says much about characteristics of work at a theoretical and conceptual level – I'm thinking about the substantial vocabulary describing work-as-done, adaptations, variability, ETTO and much more,– describing and analyzing this in organisations can be a challenging research task. It is often difficult even for many practitioners, safety managers and managers themselves, in the very same organisations, to describe and merge these concepts with the existing concepts and vocabularies dominating their organisations. And even if they do so, it is still challenging to fold them into the practice of work, the practice of safety management, and the practise of leadership in a meaningful and useful manner.

> **"...learning is an investment, and organisational knowledge – and indeed resilience – are qualities with a limited shelf life, and are in need of continuous fostering"**

On one hand, one could think of this as surprising, since resilience vocabulary describes (at a conceptual level) what people are actually doing when they are performing their everyday work, or finding solutions in the face of challenges. On the other hand, what people do and how they think and talk about what they do are two different stories. In that regard, one can find a source to explore the distinction between work-as-done and work-as-imagined, as well as a source to the conceptual difference between tacit knowledge and explicit knowledge.

As researchers of resilient performance – and researchers of sociology of work in general – we approach organisations and the people who constitute them with more questions than answers. This is also known as an inductive approach. We want to learn how they organise their work, how they produce and carry out their procedures, how they adapt to situational circumstances, and how they learn. Further, we can draw general insights out of such studies, and we can also collaborate with the same organisations to help them improve, succeed, and sometimes merely to fail better. We can help, we can provide advice and tools, but in the end, improvement is ultimately something that must be fostered by the organisations themselves.

One way such collaboration can find application and promote advances in organisations and science is trough action research. In action research, researchers and practitioners work together in search of improvement. With a resilience perspective and approach to action research, we have powerful methods and tools for improving organisational performance and gaining new research insights at the same time.

I would like to use an example an ongoing research project I am conducting together with my colleagues, that aims to strengthen the resilience of the fire management organisation on passenger and cargo ships.

The shipping industry works hard to strengthen fire management on such ship types, and a particular area of interest is in improving work processes, procedures and design solutions. In the project, the Functional Resonance Analysis Method (FRAM) lent inspiration to a process where a ship's crew got together in workshops and described in detail the work (in terms of functions) that they carried out in a simulated fire drill that they had just completed. For every little operation (function) they had carried out, they were asked to describe the particular conditions that contributed to shaping the operation. They were also asked to use both their experience and their imagination to describe different conditions that could have coloured, boosted, hampered or even prevented the operation. This produced a perspective and an understanding of their own work practices – explicit knowledge of work-as-done – that they discussed and scrutinized among themselves.

The next day the crew were asked to bring their newly acquired perspective to their own practices in yet another simulated fire drill, after which a debrief workshop provided the opportunity to reflect critically on their work, procedures and design. From here, they were prepared to think actively about improvements in a way that they usually did not have as much time nor inspiration to do. Those improvements could be ideas for new types of fire drills focusing on identified learning needs, or improved design solutions for materials or systems that are integral to maritime fire management.

This project is an example of how insights and concepts from Resilience Engineering can be operationalised into structured means for organisational learning, in this case using the FRAM. The crew expressed that they found the process very useful, but that that it would be difficult to follow up on a regular basis; in the maritime domain, a serious constraint is finding time to undertake such exercises and the ambition to go further than just checking off the list of required safety work. However, it has to be acknowledged that learning is an investment, and organisational knowledge – and indeed resilience – are qualities with a limited shelf life, and are in need of continuous fostering. Investing in resilience is also about prioritisation. The time and resources spent on proactive activities as the one described here will in the long run still be subordinate to the cost of accidents. It might even make work more interesting!

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Haavik has studied organizational and societal resilience through a number of research projects, in domains such as offshore oil & gas (integrated operations), aviation (professional competence/airlineship), health (surgical teams and simulation), maritime (professional competence and firefighting resource management), and pandemic preparedness and response in municipalities and states. A growing research interest is addressing sustainability dimensions of societal resilience, to strengthen the political dimensions of societal resilience in research areas where politics, science and technology are deeply intertwined – for example climate change.

Developing Resilience in Commercial Aviation Pilots via Training Data-Driven Insights

By Richard J Kennedy, Andrew CK Lim and David Owens, Civil Global Training Organization, CAE

The Approach to Commercial Aviation Pilot Training

The commercial aviation industry has entered the second decade of its journey to transition from so called 'Maneuvers-Based Training' to 'Competence-Based Training and Assessment' (CBTA). Historically pilots have been evaluated on their ability to perform a given exercise to a level of mastery (e.g., rejected take off, go-around, engine failure, etc.). This contrasts with the CBTA paradigm, where pilots are instead presented with situations in training that are highly challenging and require a mixture of technical and non-technical skills to demonstrate resilient flight operations.

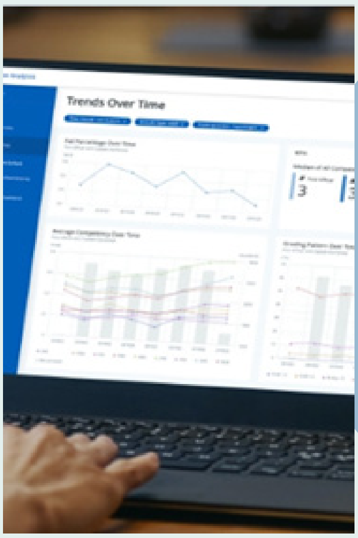
The current approach to developing resilience in flight crews is thus focused upon training and evaluating 'good performance' during stressful or unexpected situations. This approach requires the pilot to demonstrate competencies including effective leadership, situation awareness, knowledge, decision-making, problem-solving and communication which can then be applied to similar situations and exercises to that being assessed.

The principal means for training for resilience include simulation, case studies and even role-playing exercises that are designed to mimic the real-world scenarios

1. Simulator Telemetry Data

- Helps instructors detect parameter exceedances which would not be possible to monitor from the instructor seat.
- Supports the instructor in providing effective de-brief to pilots based on objective data.
- As the technical competencies are best evaluated through telemetry data it allows the instructor to focus more of their effort on evaluating the non-technical competencies.

2. Telemetry Data Analytics



- Provides the means to tailor training content based on objective training data.
- Facilitates insight into how a particular fleet / experience level of pilots responds to challenging situations in a training environment.
- Provides evidence for good performance, and mastery of specific competencies, as well as identifying where performance could be improved.

helping flight crews to develop the ability to adapt to unexpected events, maintain focus and composure under pressure and work effectively as a team. Furthermore, debriefing and reflection sessions after each training session will review what was learned and how this learning can be applied in the future.

When evaluating performance, the approach however needs to encompass both Safety I and Safety II philosophies, and thus:

- Focus upon things that go right as well as avoiding that things go wrong.
- Encompass all possible outcomes over only adverse outcomes.
- Incorporate holism and emergence over decomposition and identifiable causes.
- Consider performance adjustments and variability over bimodality.
- Treat humans as resource over humans as a hazard.
- Allow continuous anticipation over reactive response.

Data-Driven Performance Evaluation

The key question is therefore what actually constitutes good performance of commercial airline pilots and how can we measure its various elements within a flight training environment? In other words, “What A Good One Looks Like” (WAGOLL) requires unpacking and, to that end, there are two main sources of training performance data that are available:

- The performance evaluations performed by the training instructor(s).
- The data which can be extrapolated from the training device.

Performance evaluations are based upon the CBTA paradigm described previously whereas telemetry data is essentially the in-situ collection of measurements or other data at remote points and their automatic transmission to receiving equipment for monitoring.

With a focus upon the second source listed above, Figures 1 and 2 further describe the type of telemetry data that is obtained from the Full Flight Simulator (FFS) and how this data may be analyzed to provide insights on the performance of the pilot.

CAE Rise™ is a technology based-upon Full Flight Simulator (FFS) telemetry data enabling data-driven insights into the performance of pilots for the range of challenging situations that are presented in a flight training environment. The system consists of a tablet computer application and cloud- based analytics engine that uses the telemetry data to provide instant feedback to the instructor of outcomes relevant to the application of procedures and flight path management.

Rise allows operators to benchmark their performance against wider industry whilst providing data-driven insights that can be used to tailor training programs. A graphical example of the data-driven insights from by Rise is provided in Figure 3.

Calibration of Data: Instructor Grading vs Exceedance Rates

3. One Engine ILS Approach Example

When calibrating evaluations, comparison of independent sources of data will provide confidence of the quality of the grading data. Having different sources of data available to the training manager, allows a comparison of Instructor grade sheet data with simulator telemetry data of exceedances and deviations from SOPs.

An example of the use of data is the comparison of instructor substandard maneuver grades with the telemetry exceedance and error rates. One case, highlighted in Figure 4 is for a TCAS Event. In terms of instructor evaluations, this can be seen to be graded “less than standard” at around 2 % of the time. However, the telemetry data indicates an exceedance of agreed tolerances or SOP errors for around 20% of the time.

The TCAS Event example above contrasts with “Go-around – At Minima, One engine inoperative” case. With 7.7% of Instructor Grade lower than standard compared with 7.8% of Telemetry Exceedance, it is an example of near perfect concordance between the Instructor Evaluations and telemetry data.

Summary and Conclusions

This paper has described the evolution of commercial aviation flight training towards a full Competency-Based Training and Assessment (CBTA)-based paradigm. In the CBTA paradigm, both Safety I and Safety II perspectives are equally important. In order to support assessment and evaluation, it has been shown that data plays a crucial role. As well as providing insights on performance, instructor grading and simulator telemetry data can be compared to provide confidence in the quality of the assessments.

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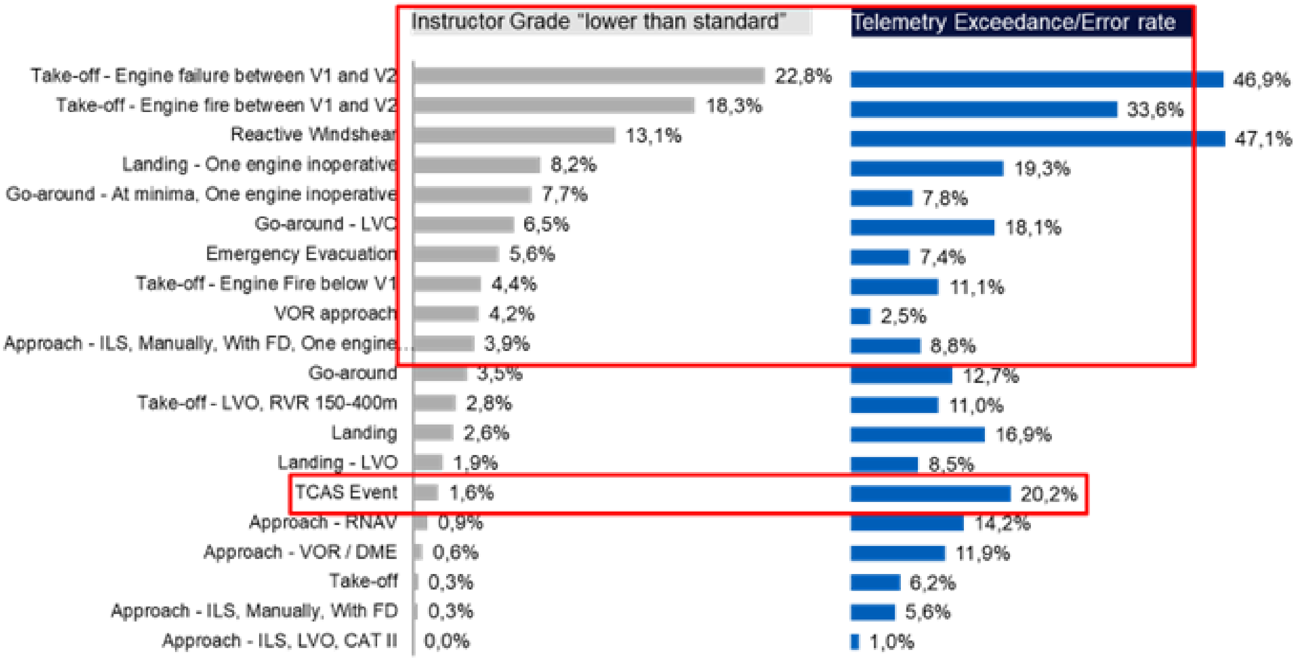

Four Steps Towards Implementing Resilient Learning Systems in Aviation

By Kristy Kiernan and Dave Cross, Embry-Riddle Aeronautical University

Learning from mishaps and near-mishaps is a time-honored tradition in aviation. From “there I was” stories told in military ready rooms to case studies reviewed in formal training, aviators have long recognized the value of learning from each other’s mistakes. But what mechanisms do we have in place to learn from, individually and organizationally, and highlight what we do right?

In an effort to understand resilient performance, we conducted a study and asked professional pilots to describe routine yet unexpected events, and to explain their thoughts and actions in handling these situations. Of the four cornerstones of resilience, anticipate, monitor, learn, and respond, the behavior most commonly observed was learning. This was broken down into individual informal learning from peers or experience, and organizational learning from formal training.

In the vast majority of interviews, informal learning was ad hoc, based on personal networks, and not supported by any institutional structure. Common generic answers to the question “Did you share this event with anyone afterwards” were, “It wasn’t a big deal”, “I was just doing my job”, or “Not really, I just talked about it with the first officer afterwards.” In other words, when unexpected events were safely handled through the application of formal or informal learning there was no venue for that information to be shared through existing data collection mechanisms, nor was it necessarily thought worthy of sharing. If we want to create learning systems in aviation to foster resilient performance, we have to tackle these problems.

First, we have to socialize the ideas behind resilient performance. Just as among healthcare practitioners, pilots are typically receptive to the tenets of resilience, as they recognize intuitively that their behaviors contribute positively to safety beyond just not making mistakes. However, aviation lacks a standard vocabulary for discussing resilience. Part of the success of threat and error management is the clarity and ubiquity of Reason’s Swiss cheese model. Resilience does not yet have a simple visual model with as much explanatory power. The verbal equivalent is Marit de Vos’ metaphor that we have been learning about marriage by only studying divorce, but we have yet to capitalize on that memorable description. At every opportunity, we should be talking about resilient performance, using a common vocabulary, and helping pilots value the “routine” work they do every day that builds system resilience. Pilots can only report events that they recognize as valuable, and for which they have a vocabulary.

Second, we have to collect the right data. American’s Learning Improvement Team, discussed elsewhere in this newsletter, and Cathay Pacific’s Operational Learning Reviews are excellent examples of collecting the right data. In addition to observational data, our own research has shown the value of debrief-style interviews for collecting data on resilient performance. Captain Leja Collier describes this in her piece for this newsletter as well. Industry and academia partnerships can be helpful in developing systems that are tailored for the needs of specific organizations.

Third, we need to analyze data the right way. We have long collected Flight Operational Quality Assurance (FOQA) data, which records dozens of flight parameters for every flight every day in commercial aviation. However, what we look for in that data is exceedances. Can we instead look for occasions that identify underlying resilient performance? We also collect thousands of voluntary safety reports every month through the Aviation Safety Action Plan (ASAP). These reports have traditionally been analyzed through a threat and error management model, but increasingly, NASA is working to identify evidence of resilient performance in these reports. NASA’s Brian Smith is developing a lexicon that will allow automatic filtering of submissions to identify keywords associated with resilient performance.

Fourth, we need to develop structures to support both formal and informal learning.

Formal Organizational Learning

Formal training programs can incorporate the framework, terms and hallmarks of resilient performance to socialize the concepts among pilots. Simply introducing these ideas in multiple venues – initial and recurrent training, captain upgrade training, newsletters, and safety promotion literature, will help familiarize pilots with the concepts of resilient performance.

Informal Individual Learning

Two pathways exist to support informal learning: one is to codify it into formal learning, for instance by creating a success-based reporting structure similar to what exists for reporting errors; another path is to provide more opportunities for informal learning to occur. In a recent Safety First article, Airbus highlighted the importance of debriefing, particularly as it can reinforce resilient performance. The customary “good flight, no problems” leaves much opportunity for learning on the table. Several airlines, including RyanAir, All Nippon, Delta, and soon American, provide debrief tools that use flight data to allow crews to observe their own actions immediately after the conclusion of a flight. United Airlines encourages crews to reflect on positive performance using a “what went well and why” debrief after every flight.

However, effective debriefs need structural support. One extremely helpful method would be to actually pay pilots to debrief, rather than rely on the professionalism and good will of the pilot workforce. For example, extending five minutes of pay during post-flight to provide a debrief or submit a safety report would likely provide the psychological buy-in pilots would need. Providing opportunities for pilots to engage informally on professional matters would not only support resilient performance and strengthen safety culture, but build pilot engagement and affinity, which, according to Oliver Wyman’s 2022 Flight Operations report, is an area of increasing concern for flight operations management.

This is a daunting list. However, the task becomes much more manageable when we consider first the minimum elements which are required for learning from resilience, both formally and informally. Rather than wait for a perfect solution, we can take concrete steps now to support individual and organizational learning.

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Dave Cross has been an instructor with Embry-Riddle’s Worldwide Campus for over 20 years. He lives about an hour south of Denver, CO, which gives time for skiing and flying when not teaching. Dr. Cross teaches subjects ranging from math, research, aeronautical science, safety, and statistics, at both undergraduate and graduate level. Previously, Dr. Cross flew as an airline pilot throughout the world. He has flown as a First Officer on the Boeing 727, 757/767, 777, and 787, and as Captain on the B-757/767, B-737 and Airbus 319/320. His research interest is in conflict management, online education assessment, and teacher-student feedback. When not stuck in the office, flying, genealogy, scuba diving, and skiing take up his other time.

Learning What Goes Well and Why at American Airlines

By First Officer Nicholas Peterson

American Airlines and the Allied Pilots Association established the AA/APA Learning and Improvement Team (LIT) in 2019 as a proof of concept. The task was to develop a method for collecting data from normal flight operations where no unwanted or undesired outcomes were encountered.

SMS Integration

Aviation safety has always studied incidents and accidents, and applied lessons learned as preventative measures to ensure those instances were not repeated. As aviation became safer, these events decreased in number and the vast majority of operations were not studied at all. But to understand how the system is working, good or bad, it must be looked at it as a whole, studying both success and failure. LIT was designed to be complementary to the other AA SMS programs to help the airline learn from operations. Support and funding for LIT exists at the highest levels within AA management as demonstrated by the growth from a team of two to the current 20 between 2019 to 2022.

There are currently four main data streams collected by LIT:

- direct flight observation
- pilot interviews
- surveys
- learning teams

To date, more than 340 AA flights have been observed by LIT “Learning Navigators.” Navigators also conduct interviews, or “Shop Talks,” with pilots discussing a variety of topics. Shop Talks help the airline gain insight into how its pilots think and why they make the decisions they do. LIT has also placed a survey within the AA Professionalism, Leadership and Mentoring (PLM) course. This survey asks current, experienced captains several questions in an effort to transfer as much knowledge and experience as possible to new AA captains and first officers.

In December 2022, LIT debuted its first two Learning Teams in Miami and Austin. LIT Navigators facilitated individual discussions on a variety of operational challenges with more than 130 pilots and what considerations those pilots had when trying to operate within those challenges. To date, LIT has observed or had direct contact with over 1200 pilots and gathered data on how everyday work is done by these pilots. The data is shared internally during monthly AA safety meetings as well as the above-mentioned PLM course and Recurrent Human Factors (RHF), a course every pilot must attend annually as part of recurrent training.

One of the challenges facing LIT is how to present the data it collects, given that the data looks quite different from other data presented within an SMS. Significantly, because LIT highlights normal work that didn’t result in an incident or accident, that data may be perceived as less stimulating or important because nothing bad happened. Additionally, LIT data is more qualitative than quantitative making it more difficult to analyze. These issues create challenges in demonstrating why it is important to look at all outcomes, not just the undesired ones. In reviewing normal work, it is hoped that over time the airline can begin to detect weak signals. These can be difficult to detect if they are not significant enough to result in unwanted outcomes. Despite these challenges, LIT has become a valuable program to AA because it is able to capture data that was not available in the past, simply because there was not a program designed to capture it.

The Four Potential Model

LIT has gained some fascinating insights that would not have been possible prior to its creation. For example, during flight observations, LIT captures data in four “Potentials”-the potential for the pilot to do something positive. These four potentials are **Learn**, **Plan**, **Adapt** and **Coordinate**. Each potential consists of several proficiencies that can be observed by a LIT Navigator. By observing these proficiencies, the airline can begin to understand what actions and adaptations pilots make in their dynamic and changing environment. What is remarkable is that many times pilots are unaware of these accommodations they are making as they are doing them instinctively based on years of experience. In capturing proficiencies, the airline can learn more about the human contribution to safety and what pilots are doing to keep the operation safe.

Currently, AA is experiencing a significant loss of experience in its pilot workforce due to the FAA mandated retirement age of 65. This has caused the time for a first officer to upgrade to captain to fall from above 15 years to below three years. While there is no way to compress 15 years of experience and knowledge into three, efforts must be made to facilitate this knowledge transfer. LIT data has shown that captains are almost four times as likely to ask the first officer for input in decision-making than first officers ask captains for input. These decision-making skills are essential for a captain to possess and LIT data is being used to help the airline and its captains prepare first officers for command. To help improve the captain and first officer information exchange, LIT has added content to the PLM course to educate captains on how best to utilize their first officers and to mentor them for the future.

The focus for LIT in 2023, besides continued data collection, is to intently review the data collected thus far, discover what it contains, present findings to both AA safety and its pilots, and continue the journey of learning what goes well, and why it goes well.

First Officer Nicholas Peterson is a member of the American Airlines Learning and Improvement Team (LIT) and the Allied Pilots Association Deputy Chair, Learning and Improvement Team. A graduate of Purdue University with a B.S. in Aviation Technology, Nick began his airline career with Chautauqua Airlines. During his twenty-six-year airline career Nick has flown J31s, Saab 340s, Embraer 145s, B757s, B767s, B777s and the A320 family for a variety of airlines including Chautauqua, America West, US Airways, All Nippon Airways and American. Nick has been working in AAL safety since 2015 and with LIT since its inception in 2019.

Resilience and Psychological Safety: The Language of Learning

By Leja Collier

As an airline captain and aviation human factors specialist, two concepts in the last ten years have captured my professional curiosity - resilience and psychological safety. I was equally interested and skeptical of both. Were these merely buzzwords? Or was there something meaningful here?

I was introduced to resilience after a hiatus from human factors work in 2015. The pause was due to a job change. Once I had spent some time learning a different airplane and organization as a new hire pilot, I returned to safety work. I asked mentors and friends what the leading edge in human factors was. The answer was resilience.

Language is my favorite data source, so I asked some questions: "What do you mean by resilience? Please tell me more."

"Through mastery, we can improvise."

To learn more, I was told I needed to talk to Shawn Pruchnicki at the Ohio State University's Department of Aviation (now Dr. Pruchnicki – Congratulations, Shawn!). Shawn introduced me to resilience engineering and the anticipate, monitor, respond, and learn framework. He also joined me on an industry panel in 2018 called "Training for the Unexpected: A Focus on Resilience." Shawn was our first panelist and provided the foundation for the discussion. Other panelists included Terry VanHoose, a safety award winner; Lou Nemeth from CAE; and Alaska Airlines' Brad Donaldson.

Here's a link to the panel hosted by the Air Line Pilots Association.

Panelist Terry VanHoose and his first officer won the Air Line Pilots Association's Superior Airmanship Award in 2015 for their performance during a dark and stormy night. They were dodging thunderstorms and experienced a loss of instrumentation and unreliable airspeed. We had Terry participate in the panel because we often dissect events that went wrong. Here was an opportunity to learn from something that went well.

Terry provided my favorite takeaway from the panel. When asked, "How do we train for the unexpected?" Terry answered, "We get really good at the expected."

Through mastery, we can improvise.

Brad Donaldson built on the concept of mastery. He discussed Gary Klein's "Intuition at Work" and Recognition Primed Decision Making. Alaska Airlines has leveraged that work to encourage pilots to build their experience in five different ways. The first is to read and research. Policy and procedure knowledge is essential. We can also learn from others' experiences through safety publications. The second tenet of Alaska's learning model is to challenge yourself. We get good at what we repeatedly do, and that can leave us stale as learners. For example, I jokingly call myself a "Day-Trip-Diva" because I like to fly turns up and down the west coast of the US. This schedule is great for sleeping in my bed but bad for challenging myself. The third tenet is to practice deliberately. To accomplish this, Alaska encourages their pilots to practice using different combinations of automation. It is an intentional growth strategy.

Alaska's fourth and fifth steps to building pilots' experiential "tool kits" are briefings and debriefings. Alaska Airlines has championed a threat-forward, interactive, and scalable crew briefing. It begins with threat identification by the pilot monitoring. The pilot flying then discusses the plan and considerations for the plan.

Resilience Framework for a Flight

The four-dimension resilience framework created by Erik Hollnagel can be used in the planning and execution of a flight in a cyclical process. Crew briefings and debriefings can be used as anchors to the cycle.

Anticipate

In the flight deck, we use preflight and approach briefings to anticipate threats, mitigations, and a plan of action before the highest workload segments of the flight. This is also a chance to prime ourselves for potential contingency plans should our plan not execute as anticipated (departure contingencies: rejected takeoff, single-engine departure procedure, and return to the field).

Monitor

Once the plan is being executed, we shift to monitoring. How is our plan going? Is our aircraft on the intended flight path? Is our fuel state consistent with the dispatcher's plan? How are aircraft systems functioning? Is the weather as forecasted or improving/deteriorating?

Respond

We anticipated some potential contingencies. As the flight progresses, we may need to respond with one. If we encounter an unanticipated threat, we may need to improvise. Pilots do have some guidance in response to unexpected threats. From the high-level prioritization “aviate, navigate, and communicate” to a more structured and airline-specific response, including delegation of tasks. Who will fly and talk to Air Traffic Control? Who will manage the event – from running the checklist to communicating with the company, passengers, and flight attendants? These structures make non-normals indicated by ECAM, EICAS, or Master Caution systems a fairly routine response. Often, the more mundane unanticipated threats like a runway change lend to response challenges because we are less intentional about roles and responsibilities.

Learn - Debriefings

Once we are back on a stable path or at the gate, it is an excellent opportunity to discuss how everything went. We learn from the process. Did we execute our plan? What did we do well? What could we do better?

Anticipate, monitor, respond, and learn - repeat as necessary.

Psychological Safety

Psychological safety is a newer concept to me. I learned about it last Fall from a fellow doctoral student, Kimberly Perkins. If you've heard about psychological safety, it's possibly thanks to Google. Google studied their teams and found psychological safety as the key to high-performance teams. An article in 2016 about the study created a new buzz.

“What do you mean by psychological safety?”

Psychological safety allows team members to take interpersonal risks. Amy Edmondson introduced it as a team learning concept in 1999. Edmondson has five conditional elements to psychological safety: leader behavior, group dynamics, trust and respect, use of practice fields, and organizational support. Some of the results of psychological safety are speaking up about mistakes, requesting feedback, trying new things, and job satisfaction.

Psychological safety plays a role in anticipating threats. Is everyone comfortable speaking up about their perceived threats for the flight? Or does an experienced leader silence the threat by anchoring the conversation? Alaska's initiation of the briefing by the pilot monitoring identifying threats is a way to ensure a plan or person doesn't anchor the discussion.

What about the additional risk we bring to the flight deck? Performance is not binary – either good or bad. It is more like a bell curve. As two of my favorite scientists remind me (Dr. Immanuel Barshi of NASA and Dr. Jeffery Schroeder of the FAA), 50% of the time, pilots are operating below their average. If we recognize we are working sub-optimally but still fit for duty, is it safe to bring it up?

Psychological Safety and Monitoring

A lack of first officer assertiveness is a common finding in safety events with the captain operating as pilot flying. If we only focus on transmitting the message (speaking up), we miss 50% of the communication. Captains listening to initial alerts of speed and altitude excursions is just as important to first officer assertiveness. Supporting speaking up with “good catch” is another way to encourage monitoring.

This area of the resilience framework can use some work specifically in “how we monitor” as organizational and industry structural support. Monitoring is not just what has our focal visual attention, but sometimes that is what gets critiqued.

Responding to a threat also has elements of psychological safety. Some of the structures in place are encapsulated by Edmondson’s aspects of group dynamics and organizational support. Responses may not go well when there is a lack of clear roles and responsibilities.

Learning from all operations

Creating an environment for learning is psychological safety. Debriefing is one way to accomplish learning from all operations. Psychological safety is necessary to be open to that feedback as a team.

Conclusion

One interpretation of the sixth generation of Crew Resource Management is CRM as risk management and resilience. There may be some benefits to thinking about psychological safety as well. It is a team learning concept that can enhance flight deck resilience. As I map CRM concepts to Edmondson’s elements of psychological safety, I see some areas we can improve upon. One is the use of practice fields. I think Alaska’s five-step plan for gaining experience is something airlines should consider.

The other thing I recently read was Airbus’s resilience model showing competence and confidence as foundational. As I later thought about the psychological element of trust and respect in the flight deck, confidence made an impression. Building trust can be difficult with an interchangeable flight deck team, often of short duration. It is made more difficult with perceived inexperience due to a lack of confidence in ourselves and our teammates. I remember my first flight as an airline pilot. It was not a psychologically safe place, but the captain was correct with some heavy-handed mentoring at the time. The one thing I needed to do was to continue to show up and get experience.

Another mentor recently reminded me that we gain trust slowly in drops and can lose it quickly in buckets. While building that trust, we can certainly be respectful of each other. Our teammates often know something we don’t, and we’ll never learn what it is if you don’t do your part in facilitating a psychologically safe environment.

Leja Collier is an airline captain currently qualified on the Boeing 737. Her additional type ratings include Canadair CL-65, McDonald Douglas DC9, and Airbus 330. Collier is a safety advocate and human factors specialist. She is pursuing a Doctor of Philosophy in General Psychology from Grand Canyon University, specializing in Performance Psychology. She has a Master of Aeronautical Science Degree with an emphasis in Human Factors from Embry-Riddle Aeronautical University. Airbus awarded her a Leadership Grant to apply to her studies.

Newsletter14
RESILIENCE ENGINEERING ASSOCIATION

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