EUROCONTROL

Performance Insight

Future Challenges to Safety

Identifying potential safety risks in a changing ATM environment - and how to measure them.

Performance Review Commission

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Welcome to the first PRC Performance Insight publication!

Welcome to the first edition of the Performance Review Commission (PRC) Performance Insight in which we will inform you about relevant ANS performance related topics!

These are turbulent times for the aviation industry but the road back to normality is also an opportunity to make our ATM system better, to deliver improved performance when traffic returns. Although recovery will be challenging, the aviation industry has shown its strength and resilience before. It will, without a doubt, resume its important role in reconnecting families and business after the COVID-19 crisis. The COVID-19 crisis once again underlines the need for close cooperation and coordination and the importance of a proactive, harmonised network wide approach.

The first Performance Insight is on the new PRC niche project initiated in early 2020 - “Future challenges to Safety”. The project considers the future developments and complexity of the ATM system with a forward looking view on new emerging safety challenges. A PRC technical note on what this future work could be and how to establish it, is foreseen by the end of this year.

This publication aims to accompany this new PRC work and the development of a new safety performance framework. It provides some background information on the work with dedicated safety experts in the EUROCONTROL Member States, and other international organisations, at the PRC’s “Future challenges to Safety” workshop held on 29 June 2020.

In addition to a workshop, several experts and researchers were asked for their opinion from different perspectives. Their opinions are not necessarily those of the PRC but will serve as inspiration for further developing work in this domain. In that connection, the PRC wishes to highlight that the catastrophic impact of the COVID-19 pandemic on aviation will need to be addressed as part of the future challenges. The COVID crisis has pushed aviation industry to the limits of its safety performance by worsening existing hazards and creating new ones.

We hope that you enjoy reading this Performance Insight.

Performance Review Commission

Future Challenges to Safety: Identifying potential safety risks in a changing ATM environment - and how to measure them

Rationale and background

A primary responsibility of the ATM system is to control safety risks, although in practice developments are often dominated by changes made to improve capacity, efficiency and cost of the system.

ATM safety has improved over the past decades for many reasons, including better equipment, more efficient operations and additional safety defenses and mitigation tools.

However, any further improvement of current safety performance, and even maintaining the current levels, will be extremely demanding due to numerous technological and institutional changes in the future and rising levels of traffic.

"ATM safety has improved over the past decades - but there are challenges ahead"

Moreover, recent political priorities and calls for action raise several concerns and questions that would need to be addressed before they are officially accepted and implemented in any shape and form.

The Safety Challenge

As safety in aviation and in ATM is a priority, the challenges for European ATM stakeholders with any new developments and changes in operational concepts are:

(1) to determine what (potential) safety aspects are of concern;

(2) how these can be measured; and.

(3) what analyses are needed to ensure acceptable safety levels.

Safety analysts, experts and decision-takers have to carry out safety assessments of future operational concepts and changes, based on a large set of assumptions, statistically incomplete and sometimes maybe even biased evidence.

"How will safety be defined in the future?"

If future risks cannot be estimated with precision, it is questionable how safety can be ensured with traffic growth, operational and technological changes.

The Questions to be addressed

- What do we mean by safe in the future?
- How is safety being delivered in the operation in the future system?
- What will be the roles and responsibilities of different players in ATM?
- What are the implications of not having correct indicators to measure the future performance?
- How to demonstrate that the implementation of new ATM concepts and system designs are indeed 'safe'?

To address those unanswered questions, it is important to identify challenges to future safety in a changing ATM environment (what to focus on?) and how to measure them (what are suitable methods and tools?).

Being "safe" in the future system will be essential for survival in the industry.

Safety however should not be looked anymore in isolation, rather as the part of very complex system. We would need to take the interdependencies between safety and other Key Performance Areas (KPAs) into account, as it will be difficult or even undesirable to analyse safety performance in isolation.

The ATM community will have to look deeper into unanswered questions related to the future challenges to ATM safety.

So how should we measure future safety performance?

"Future challenges to Safety" workshop

To address these important questions, the Performance Review Commission (PRC) initiated a discussion with safety experts in EUROCONTROL Member States and other international organisations in early 2020.

The objective was to collect a wide spectrum of expert views on future challenges to safety and how to identify and measure potential risks in a changing ATM environment.

Building on this initial exchange, the PRC held a workshop on 29 June 2020 deepen the discussion.

Ahead of the workshop, the PRC asked participants to complete a survey to get their views on emerging safety challenges from the evolving ATM system.

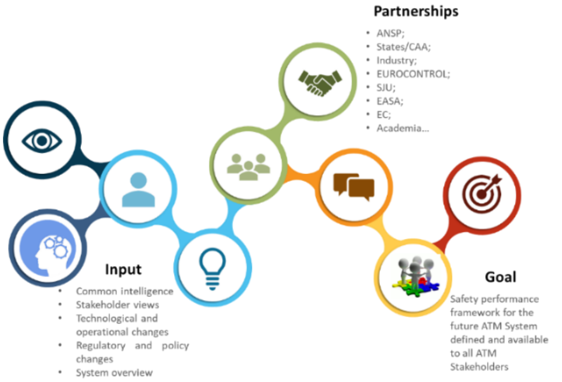
The PRC used this stakeholder input to categorize the main topics (automation, increased traffic, cyber security, big data, system thinking, new entrants, digitalization and human in the new system), which were debated in more detail during the workshop.

During the workshop, two additional categories for further discussion were identified: interdependencies and resilience.

The work by the PRC starts with an assessment of the pressures to deliver safety in a perspective way before developing and identifying the means and tools to assess the "post operational" impact.

Workshop should be seen as only a starting point in defining safety performance objectives/focus areas for the future ATM system. The Workshop itself should serve as a platform to collect intelligence about "what do we know" and "what is available".

A number of inputs, as well as possible partnerships that should take place, should be further considered in order to achieve the common goal and expected outcome, i.e. defining the safety performance framework for the future ATM system



Overall, this is an extremely complex undertaking but nonetheless a vital prerequisite for the measurement of safety performance in the future ATM environment

"There is a need for a safety performance framework that can address risks in the changing ATM environment""

Ultimately, the goal is to develop a safety performance framework that would support the implementation of changes (new concepts, technologies, and processes) in the future ATM environment.

In this context, it is important to highlight that the purpose is not to demonstrate that new ATM system designs are 'safe' which is the task of EASA and system manufacturers.

The PRC takes this opportunity to thank everyone concerned for their support.

Here is a hyperlink to the workshop documentation: (hyperlink – challenges to safety background note and ppt). Should you wish to comment on this publication, or to contact the PRC, please send an email to: pru-support@eurocontrol.int.

For more PRC products, please visit: www.ansperformance.eu. Watch this space for the next edition of the PRC's Performance Insight.

What others say…

It is the purpose of the PRC to ask experts to shed light from different perspective as inspiration to the ATM community and for the work of the PRC.

The following articles are the opinions of the authors. Their contributions are not necessarily the view of the PRC but serve as inspiration for further developing work in this domain.

“Challenges to safety”, some reflections

Dr. Jean-Christophe Le Coze

Introduction

In this paper, I comment the background paper “*Challenges to safety*” produced by the performance review commission (PRC) for a workshop held on 29th June 2020. I do so from a safety research angle, situating the content of this document within current empirical, practical and theoretical developments in the field. I start with an empirical illustration in order to ground my analysis in a real case study. It is a short description which allows me then to introduce two challenges. The first is the importance of anticipating changes and the second is about thinking safety from a broad perspective, and not from a restricted one. I finish with the implications for ATM, indicating a recent study requested by the nuclear regulatory agency in France to show how such ideas slowly penetrate authorities’ practices and expectations.

The problem of change, an illustration

In a hazardous plant that I studied, several events challenged safety management. Within a short period of time in the same production department, an operator had his feet severely burned by a drop of hot liquid metal during an operation; a fire occurred which impaired production for several weeks after a young operator made a mistake and a leak of chlorine from a faulty valve required an evacuation of the building. These events, and other problems, triggered the need for an investigation that the health and safety manager of the plant commissioned. Managers of the plant wanted to find out about their problems, but they didn’t want to focus at an individual level of analysis.

They did not want a behaviour-based approach of the problem and believed that they needed a different type of explanation. They knew that beyond the mistakes made by individuals lied deeper issues to be discussed, explored and understood. A sociological study of their situation was performed. One which would not remain at the level of operators, working situations and supervision, but one that would investigate the system more broadly, including managers of other departments (e.g. maintenance, production, safety) but also the managing director of the plant, all of them within their social, political, corporate, legal and economic environment.

In a nutshell, the outcome of the study showed that the recurring safety events in the production department could be explained by the difficulty of finding adequate ways of organising in the context of many changes. Indeed, after many years of uncertainty about the future of the plant which led to a loss of experienced workers, a new owner bought the plant and invested massively to modernise it and to increase production targets. Modernising the plant meant reopening lines of production (which had been closed) while automating them further, but it also meant recruiting a new workforce, and adapting the structure of the organisation to the new production objectives.

These changes, intensity and timing, created multiple challenges that the production department (partly) failed to cope with. Automation created a new working environment which challenged the experienced workforce and careers’ evolutions. The new recruits had to be trained quickly to ensure flexibility of an increased level of production based on a fluctuating market. The new organisation structure of the production department created new roles but also interactions between people who were used to work in a different way before. Regulatory expectations because of the modernisation required a level of compliance which empowered new actors, creating new patterns of interactions. Unions were not absent in this picture, playing an influential role in the new context.

Once described, these changes, and the new patterns of interactions between artefacts and people that they created explained the safety events. Automation, recruitment of a younger workforce, new working arrangements (including structure of organisation) were more than the production management could cope with. It created weaknesses. The big picture remained however a blind spot for the plant's managing director. Rather than a strategic problem, his understanding of the situation was that it was more of an implementation problem in the production department (other production departments in the plant did not face similar problems). For some reasons which are specific to this case study, a thorough description by an external observer was needed for them to find, collectively, a suitable way out.

Because the complexity of these changes and their consequences were not sufficiently acknowledged, shared and analysed collectively by plant's people (managers, engineers, foremen, fieldworkers, union's members), they failed to find an adapted response to their problem. The key to understand the problem was to step back and decipher how the new patterns of interactions between the different actors within and outside the production department, in a context of strategic change, created multiple challenges that the actors failed to meet, collectively. The picture needed was a broad (or multilevel) one.

Two safety challenges

This simplified and summarised presentation of this case study introduces some of the challenges of safety. I discuss briefly two of them. As illustrated above, changes in the level of automation, changes in organisational structure, changes in regulation have an array of (sometimes subtle) consequences regarding practices of operators, patterns of interactions, of power distributions, of flows of information, all of which are key dimensions of safety. The nature, intensity, timing and potential combined effects of changes must be part of the safety risk picture. It is by paying attention to people's activities and how changes are likely to affect these activities that one can better anticipate. So, the first challenge is to anticipate the impact of changes on safety.

But, and that is the second challenge, these changes are not isolated ones and combine to produce complex patterns of interactions across a multitude of actors. To manage safety requires a certain understanding of such patterns of interactions in specific situations and contexts from a broad (or multilevel) perspective as illustrated above. Forty years of research in safety shows the relevance of describing and anticipating changes in combination, not in isolation. Most often however, such analyses are only made available after a major event, when accident investigation commissions produce their reports. It is obviously best to provide these descriptions and to act upon them beforehand when it is most needed, rather than after, when it is too late.

Of course, requirements for studying small or bigger organisations are not comparable, but changes in technology, tasks, structure, strategy and regulation which affect smaller organisations as presented above similarly affect bigger ones. Administrations and corporations such as NASA, BP or Boeing in the past or more recently are known to have failed to manage these complexities in specific historical, managerial, regulatory and technological contexts. But many others succeed.

Changes in ATM

The background paper, "*Challenges to safety*", by the performance review commission (PRC), cogently and legitimately addresses these issues for air traffic management (ATM) in Europe. Several changes are indeed introduced and commented: new organisational arrangements with a change of structure giving more power to the network manager (section 1.1); new level of automation and digitalisation through several prospects of including AI, algorithms and big data in ATM (section 1.2); new context of work for experienced air traffic controllers (section 1.3) and new regulatory configuration with a potential independent economic regulator (1.4). And the PRC adds "*safety however should not be looked upon in isolation anymore, rather as the part of a very complex system*".

In other words, in its document, PRC frames the two safety challenges introduced above: (1) how to anticipate the impact of several changes on safety (2) how to keep a big picture of these changes in combination, and not in isolation. A mix of cognitive engineering, user-centered system design and of sociology is expected in order to both anticipate and to keep this big picture in sight. Contemporary safety research indeed insists on the interdisciplinary nature of the field (Le Coze, 2019) but also insists on the need to strengthen the sociological perspective, particularly so in a context of unprecedented changes (Le Coze, 2020).

The idea that such safety challenges matter slowly penetrates regulatory thinking and practices of high-risk systems. In the nuclear domain, I have recently been part of a study of a large research and development administration, following a request by the French nuclear authorities. The request was that an independent, external analysis should be produced, looking into the organisation from a sociological angle, describing the multiple interactions which underpinned the safe (and unsafe) performance of this safety-critical system, in a context of strategic changes. Perhaps, considering the importance granted to safety in aviation, that ATM could be requested to reflect on its mode of operating and its future evolution in a similar way, starting with the background paper, "*Challenges to safety*" as an initial contribution to explore the implication of changes for safety.

References

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Le Coze, JC. 2020. Post Normal Accident. Revisiting Perrow's classic. Boca Raton, FL. CRC Press, Taylor & Francis.

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Loose coupling as a fundamental safety management principle: Recommendations for air traffic management

Prof. Gudela Grote, ETH Zürich

In air traffic management as well as many other complex high-risk systems, it has become apparent that safety management will succeed in the long run only if the basic tension between safety and autonomy is revisited. Loose coupling has been proposed as key to bridging the safety-autonomy divide by creating concurrently stable and flexible organizations (Weick, 1976, 1987).[1] Thereby, organizations can exercise central control for safe-guarding operations and local autonomy for managing the unexpected.

Figure 1 lays out pathways for how mechanisms of loose coupling may operate. *Autonomy* is considered to drive *motivation* which in turn results in *safety-related behaviors and outcomes*. *Uncertainty* influences this process fundamentally by creating the need for loose coupling through concurrent requirements for stability and flexibility. It is important to note that uncertainty can stem from the environment within which an organization operates, but it may also be created from within the organization: unintentionally, for instance by non-transparent communication, or intentionally, for instance by introducing new work processes. Autonomy can take two forms, operational and higher order autonomy. *Operational autonomy* refers to the decision-latitude that actors have in fulfilling their tasks. *Higher order autonomy* refers to participation in decision-making on boundary conditions for task fulfillment, such as rules and procedures and very importantly also the use of technology as a way to replace or

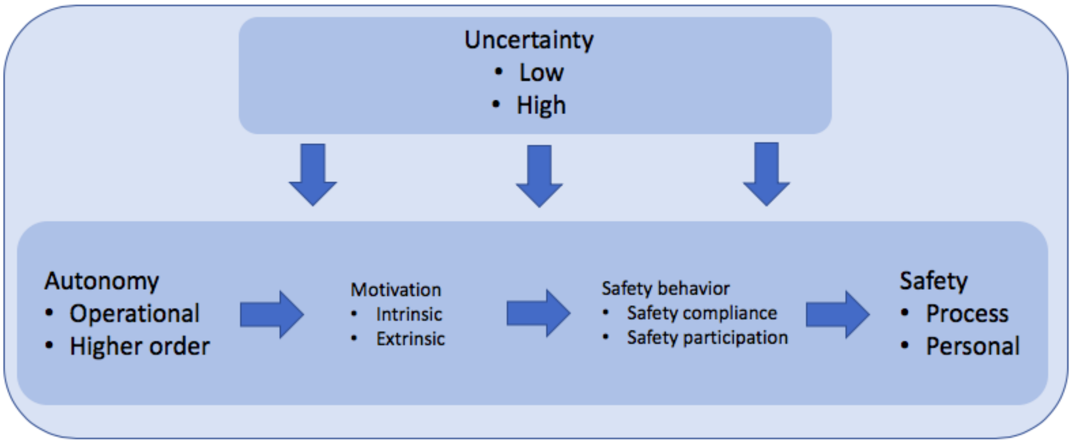

Figure 1. Framework for establishing loose coupling (from Grote, 2020) [2]

[1] Weick's concept of loose coupling is not to be confused with Perrow's (1984) use of the term. In Perrow's categorization of organizations, coupling is one of the two central dimensions (complexity being the other), ranging from loose to tight coupling based on the amount of slack in work processes. Perrow's concept of coupling therefore does not entertain the duality of stability and flexibility which is key to Weick's understanding of loose coupling. (see Perrow, C. (1984). Normal accidents - living with high-risk technologies. New York: Basic Books; Weick, K.E. (1976). Educational organizations as loosely coupled systems. Administrative Science Quarterly 21, 1–19; Weick, K. E. (1987). Organizational culture as a source of high-reliability. California Management Review, 29, 112-127.)

augment human operational autonomy. *Intrinsic motivation* is created by the task and its relevance for the actor, while *extrinsic motivation* results from external incentives such as financial rewards or social control. Safety behavior concerns *safety compliance*, such as following rules and procedures, and *safety participation*, that is active involvement in continuous improvement for safety. Safety as an outcome can relate to *process safety*, that is safe operation of the primary work processes, such as flying an aircraft or operating on a patient, and to *personal safety*, that is avoiding harm for the workers themselves.

From decades of organizational, job design, and safety research, some basic relationships among safety, autonomy, and uncertainty can be stated, which are the building blocks for mechanisms to achieve loose coupling[2]:

- High uncertainty requires operational autonomy and safety participation.
- Low uncertainty requires safety compliance.
- Operational and higher order autonomy create intrinsic motivation.
- A lack of intrinsic motivation needs to be compensated by extrinsic motivation.
- Operational and higher order autonomy support safety participation.
- Higher order autonomy supports safety compliance.
- Process safety requires more management of uncertainty than personal safety.

Mechanism 1. Worker participation in rule making.

Participation in rule making creates higher order autonomy, which increases process safety by helping workers to combine rote rule following and proactive rule adaptation in the face of uncertainty; and increases personal safety by raising intrinsic motivation.

Mechanism 2. Flexible rules.

Flexible rules offer operational autonomy by describing processes for problem solving rather than solutions and by setting boundaries for action rather than prescribing action. Thereby, personal and process safety are increased because mindful routines are established where rules concurrently operate as constraints and enablers of action.

Mechanism 3. Giving workers a sense of purpose through transformational leadership.

Transformational leaders give workers a sense of purpose by providing them with a vision for their work and empowering them to enact that vision. Thereby, leaders foster intrinsic motivation for tasks and behaviors that are not inherently motivating, such as safety compliance in relation to personal safety.

Mechanism 4. Paradox-savvy leadership.

Leaders who explicitly acknowledge the duality of stability and flexibility as a fundamental organizational paradox are more capable of managing the dynamic delegation of operational autonomy required for process safety.

Mechanism 5. Sensemaking.

Leadership grounded in sensemaking can raise awareness for stability and flexibility demands

[2] Grote, G. (2020). Safety and autonomy - a contradiction forever? *Safety Science*, published online first, https://doi.org/10.1016/j.ssci.2020.104709

in work teams and initiate the swift switches between central control and local autonomy needed for personal and process safety.

Mechanism 6. Shared perception of safety management (=safety climate).

Safety climate increases personal safety by creating intrinsic motivation through shared commitment to safety, which compensates for low operational autonomy.

Mechanism 7. Shared basic assumptions that promote safety (=safety culture).

Safety culture increases process safety by bounding operational autonomy through centralized norms.

Recommendations for loose coupling in air traffic management

Recent developments in air traffic management (ATM) triggered by initiatives such as Single European Sky and NextGen increase the complexity of highly interconnected and time-pressured operations among a multitude of actors both human and technological. Along with this complexity, actors are continuously exposed to high levels of uncertainty and the need to stay resilient in the face of unpredictable and unprecedented events. This situation heightens the importance of managing the tension between safety and autonomy, while also creating particularly demanding conditions because basic questions on the division of labor between central agencies such as Eurocontrol and local ATM service providers and between humans and technology are still unresolved. At the same time, this situation may be considered a major opportunity to explicitly build the new operations of ATM on principles of loose coupling. This could turn ATM into a showcase for a new generation of safety management systems.

The mechanisms for loose coupling described above concern the daily operation of an organization and as such are also considered valid for any organization involved in ATM. Looking at existing recommendations from research that has been conducted on ATM and also existing practice in ATM, safety climate, safety culture, and transformational leadership have probably received the most attention. Accordingly, it would be important to address in particular participation in rule making, the option of relying more on flexible rules, and leadership that focuses on sensemaking and paradox when developing safety management further within single ATM organizations. Especially process safety can be improved through participatory rule adaptation, flexible rules that support mindful operations, and leadership that acknowledges the duality of stability and flexibility and establishes strong cultural norms as guideposts for local autonomy. Performance measurement would have to include new indicators, which need to capture social processes also, such as frequency and types of rule changes, frequency of speaking up during decision processes, and mentioning paradox in leader communication.

The much larger questions of redistributing responsibility between central and local ATM organizations and among pilots, air traffic controllers and various advanced technological systems are not directly addressed by the proposed mechanisms for loose coupling. However, these mechanisms can help guide the discussion as they describe conditions that should be established for the individual organizations involved in ATM. If, for instance, air traffic control will be more centralized, operational and higher order autonomy of local ATM providers needs to be recalibrated. Higher order autonomy should be strengthened then to allow local ATM providers to participate in ongoing changes at the central ATM provider. When core functions of ATM are increasingly allocated to technical systems, managing paradox becomes even more critical because humans can get caught in impossible tasks where they are held responsible for operations they have no control over.

By working towards implementing mechanisms for loose coupling already now in the individual ATM organizations, experience can be gained with new ways of handling the contradictions between safety and autonomy. Tools for performance measurement should be developed based on indicators that capture an organization's capability to concurrently create stability and flexibility in its operations. From these indicators, design criteria can be derived which can inform the much larger changes envisioned for ATM in Europe and beyond.

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Prof. Grote studies teams in a variety of high-risk settings and has developed theoretical and practical approaches to assessing safety culture and safety management in organizations.

Her work has been employed by hospitals, railway companies, commercial airlines and air traffic management providers, insurance firms, and regulatory agencies to improve training, rules management, assessment procedures, and system design. She has published her research in prominent outlets such as Journal of Applied Psychology, Leadership Quarterly, Ergonomics, Human Factors, Safety Science and BMJ Quality & Safety. She has served as Associate Editor for Safety Science and is on various editorial boards, including for Applied Ergonomics and Academy of Management Review.

Future ATM safety: What´s in a name?

Dr. Milena Studic, Skeyes

Safety paradigms

Debating about what safe(ty) might mean in the future is a tremendously challenging undertaking, knowing that there is no unanimous agreement about what we mean by safe(ty) today. While this topic has not been scrutinised during the "Challenges for safety" workshop, it is of upmost importance for the aviation community to start this debate. Here is why.

While the wider aviation community swears by the definition of safety as a "*freedom from unacceptable harm*" (e.g. ICAO Annex 19 defines safety as "*the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*"), it is clear that this understanding of safety has not evolved in parallel with the theoretical advancements in safety theory. This understanding today is often referred to as Safety-I, in contrast to Safety-II understanding that predominantly focuses on studying safe operation and how operations succeed under varying conditions. Consequently, the (aviation) safety community is often split between the two approaches – the former corresponding to the traditional ´outdated´ as opposed to the latter as the ´state of the art´ safety management approach. In reality, the two approaches are not mutually exclusive but are rather complimentary.

In line with its long tradition, there are plenty of well-established methods and techniques used for modelling Safety-I in contrast to Safety-II. Due to complexity and the limited empirical validity (Underwood and Waterson, 2013) of Safety-II when compared of the traditional tested Safety-I methods, there is big gap between the research and practitioner communities in application of Safety-II. This gap is widened even further by the existing legal frameworks that often promote a deterministic compliance mindset based on tabulation of 'errors' as opposed to actual understanding the past, present and future safety performance and learning from it.

This impasse in the evolution in safety thinking in practice can be attributed to both communities (i.e. research and practice). The Safety-II applications are still considered i) immature and (Underwood and Waterson, 2013): ii) resource-intensive, iii) require data that is not (always) collected and iv) rely on inadequate safety practitioners' knowledge. Similarly, the practitioners´ community is enthusiastically actively trying to embrace the evolution in safety thinking. But the trouble with that is that by doing so - they often take a reductionist view. For instance:

- Regulation (EU) 2017/373 is founded on a concept of a 'functional system', which in theory emphasises the need for a systems thinking approach. However, in practice – the ATM community does not entirely understand the meaning of a 'functional system' as such. The under specification of the concept in the regulation allows ANSPs to develop their own understanding of the term which varies between ANSPs. In addition, interestingly enough, the regulation does not stress the need to actually document and maintain a 'functional system' description which in itself defies the (assumed) systems thinking intent taken in the regulation;

- With the intention to move away from the purely reactive approach to safety management, the Regulation (EU) 2017/373 puts emphasis on "*reactive, proactive and predictive methods of safety data collection*" within the safety risk management component of a Safety Management System (SMS). Again, a great intent to introduce advancements in the safety science in the regulatory framework but with a catch. Firstly, there is a wide disagreement in the academic community about the actual differentiation between reactive, proactive and predictive safety risk/performance management. Secondly, this theoretically unclear differentiation has been introduced in the regulation without any further explanation, resulting in the same issues facing the concept of a 'functional system' described above. Thirdly, the International Civil Aviation Organisation (ICAO) Annex 19, 2nd edition and the 4th edition of Safety Management Manual (SMM) (Doc 9859), only discuss reactive and proactive methods of safety data collection, thus creating confusion amongst safety management practitioners.

However, the differences between Safety-I vs -II do not only lay in phenomenology (i.e. observable outcome of an event/occurrence) but also in aetiology (i.e. causes of an observable event/occurrence) and ontology (i.e. essential assumptions rooted in aetiology) of safety. Consequently, as a function of underlying assumptions, safety can be understood and managed as one or more of the following, as:

- an occurrence tabulation problem,
- a resilience problem (Hollnagel et al., 2006),
- a management system problem (ICAO Doc 9859, EU REG 2017/373),
- a systems theory and control theory problem (Leveson, 2011).

Safety as an occurrence tabulation problem

The general (ATM) safety community is still very keen on keeping track of various types of occurrences at a macro, meso and micro levels. At the micro level (i.e. unit) this does make sense but the issues arise at the meso (i.e. ANSP) and the macro levels (e.g. EU and world) given the occurrences are not always defined and counted in a same way (e.g. separation minima infringements vs. runway incursions). Furthermore, the higher the level of aggregation the more difficult it is to extract the actual safety intelligence from the data. A top-down approach that looks at trends is important for safety management but it needs to be complemented with a detailed bottom-up approach that would help make sense of the high-level trends. This however, is not always done at meso and macro levels.

Safety as a resilience problem

In parallel with the evolution of safety thinking, the notion of 'resilience'[3] has grown in popularity and has increasingly been associated with 'safety'. Talking about the various definitions of Safety(-II), there is a particular one that equates safety with

[3] As there is no unanimous agreement about the definition of resilience, in this article I refer to the one coined by Hollnagel (2011) as " A system is said to be resilient if it can adjust its functioning prior to, during, or following changes and disturbances, and thereby sustain required operations under both expected and unexpected conditions" as it has been widely promoted within the ATM community through Eurocontrol (e.g. White paper on resilience (Eurocontrol, 2009), skybrary).

resilience (Hollnagel, 2014): "*Safety-II is the system's ability to succeed under varying conditions, so that the number of intended and acceptable outcomes (in other words, everyday activities) is as high as possible*". While intuitively this definition does make sense, according to the Safety-II school of thought, it leads to a range of follow-up questions: i) what is meant by success?, ii) what is meant by varying conditions? how do you identify them?, iii) does the entire system need to ´succeed´ for the whole range of varying condition or only a subset? if for a subset only, which criteria need to be met?, iv) should the intended and acceptable outcomes be considered at the micro, meso and/or macro levels?, v) what percentage of successes (as opposed to failures) can be considered as high or acceptable?

Here we need to start yet another debate: does Safety(-II) equate to resilience? The academic literature shows no agreement when it comes to this. For instance, Peñaloza et al. (2020), Ranasinghe et al. (2020), and Patriarca et al. (2018) advocate that resilience improves safety whereas Pariès et al. (2019) strongly argue against this. In my humble opinion, resilience does not necessarily equate to safety. For instance, in the past there were cases where an ANSP had a mid-air collision. At an organisational level, this ANSP was not safe (according to the Safety(-I) definition) but was resilient in terms of its ability to sustain required operations (under both expected and unexpected conditions) in the 5 years following a mid-air collision. In this example, resilience was defined in a very context specific way (i.e. resilience of what to what? (Carpenter et al., 2001)) at an organisational level within the period of 5 years. In that sense, resilience can be considered similar (if not identical) to robustness (Anderies et al., 2013). This type of resilience is referred to in the literature (Folke et al., 2010) as 'specified'. In contrast, resilience can also be understood in a more generic way – when it is referred to as 'general' resilience (Folke et al., 2010). More specifically, 'general' resilience can be defined as "*resilience of any and all parts of a system to all kinds of shocks, including novel ones*" (Folke et al., 2010). Societal resilience to COVID-19 is a great illustration of the concept of 'general' resilience. Because certain parts of the society could have been considered resilient (e.g. technological sector, cargo air traffic) and others could not have been (e.g. health systems in certain countries, passenger air traffic), it is rather difficult to conclude "*how resilient society was to COVID-19?*". Yet, for some reason, we hear a lot debates as to whether the "*ATM system has been resilient to COVID-19*" that tend to be rather subjective and without any theoretical grounding.

Due to the vagueness of the concept of resilience in the ATM domain, the concept is often limited to (Woods, 2015) i) resilience as a rebound, and ii) resilience as robustness. However, resilience ought to be understood in terms of (Woods, 2015) iii) graceful extendibility (i.e. how do systems stretch to handle surprises?) and iv) sustained adaptability over time. Points iii) and iv) are further discussed by Béné and Doyen (2018) through three resilience strategies: a) 'adaptation' (i.e. allowing change in the parameters in the control of a system), b) 'adaptive preferences' (i.e. allows adjustments and changing expectations) and c) 'transformation' (i.e. allows for a change in structure and functioning of a system).

Relying purely on empirical evidence, it would be possible to make a claim that the ATM community had become mature in bouncing back, resisting and coping with 'situational surprises' (Eisenberg et al., 2019) (i.e. known unknowns) but not very resilient in managing ‘fundamental surprises’ (Eisenberg et al., 2019) (i.e. unknown unknowns).

In summary, until we work out:

- what we actually mean by the functional ATM system (or come up with a different way of describing it) (refer to section Safety paradigms above),
- how we describe ‘specified’ and ‘general’ resilience within the ATM context, and
- how to describe and manage system ‘adaptation’, ‘adaptive preferences’ and ‘transformation’ (Béné and Doyen, 2018),

I am afraid that the ATM community will not be able to manage nor measure ATM system resilience.

Safety as a management system problem

Since early 2000, the ATM industry has been widely reliant on Safety Management Systems (SMS) to manage safety in a systematic manner. Having a SMS in place has its advantages in terms of creating solid prescribed foundations for managing safety but it does not guarantee that the actual safety is managed adequately. Pariès et al. (2019) refer to a SMS as a ‘syntax of safety’, as opposed to safety performance to which they refer to as a ‘semantics of safety’.

To account for this, the ATM industry has raised the need to measure the actual effectiveness of a SMS. Towards achieving this goal, two related indicators have been developed: Effectiveness of Safety Management (EoSM) and the Civil Air Navigation Services Organisation (CANSO) Standard of Excellence (SoE). And rightly so, EoSM has been included as a Key Performance Indicator (KPI) in Reference Periods (RP) 2 and 3 due to it proactive nature and ability to drive the right safety behaviours (e.g. continual SMS development). However, despite having the word ‘effectiveness’ in its title, EoSM does not actually measure how effective a SMS is but instead tracks the development evolution of a SMS against pre-established criteria. While the value of this indicator is sound and compelling for strategic ATM SMS development activities, there is still a room for an indicator that would establish a feedback loop between the SMS and safety performance.

In RP3, EoSM has been organised around 14 Study Areas (SAs) but in this article I will focus on: i) SA 5: SMS documentation, that focuses on compliance with applicable safety and regulatory requirements, and ii) SA 7: Risk Management Process, that looks into how risks are managed within a SMS.

Over the years the sheer number but also the content of regulations in the EU has exponentially increased. As a consequence, ANSPs are obliged to focus on safety compliancy as opposed to safety production. This focus in turn blocks a considerable amount of resources that organisations could be devoting to understanding the WHY of occurrences/trends/behaviours. And while compliance is beneficial to a certain degree, when extensive – it can be counterproductive and may actually degrade safety by promoting workarounds.

When it comes to risk management, ANSPs do not share the same perception of the concept of ‘risk’ nor of its identification. Unless ANSPs reach an agreement on this, no aggregation of risks should be allowed beyond the ANSP level (assuming that there is an agreement on the Unit level). Furthermore, the ATM community seems almost obsessed with numbers, including data collection, simple descriptive statistics, presentation of this data (e.g. dashboards), sharing and exchange of this data at the level of EU, Eurocontrol, CANSO and Functional Airspace Block (FAB). However, similar to the work on safety compliance – ANSPs are spending an enormous amount of time on the magnitude of available data without actually being able to extract much intelligence from it. To be able to advance safety, ANSPs need to be able to afford the right amount of resources to investigate in depth the drivers of certain trends. And a key to this is to include appropriate qualitative data into their quest.

Lastly, SMS is not the only management system on the block. The other quality management approaches somehow make the SMS compete with other management systems (MS) including the Quality Management System (QMS), Security Management System (SeMS), Business Continuity Management (BCM), Enterprise Risk Management (ERM), Compliance Management System (CMS) and Human Performance Management (HPM), to name a few. All these management systems, to a greater or lesser degree overlap with the SMS. This has created the following consequences in terms of safety management: i) safety is compartmentalised in the SMS box, strictly separated from other MS boxes, ii) a lot of duplication is created in all MS development and maintenance, iii) the emphasis is on MS instead of (safety) performance.

Safety as a systems theory and control theory problem

Within the context of control and systems theory, safety is explained as a "*state of dynamic equilibrium by feedback loops of information and control*" (Leveson, 2004). Similarly, unwanted outcomes result from the inadequate control or enforcement of safety-related constraints on the development, design and operation of a system (Leveson, 2012).

But what is the actual relationship between safety (-I or -II) and control. Do they equate? A simple answer to this complicated question is: No, not really. Well, it actually depends on the system in question. It could be asserted that for systems that we know well and where uncertainties are reasonably low (Wildavsky, 1988, Hoekstra et al., 2018), a control theory approach could be used on its own to manage safety effectively. However, problems arise in the situations of low predictability and/or weak knowledge (Wildavsky, 1988, Hoekstra et al., 2018). A perfect example of this is COVID-19, where to make system work (safely) – it was paramount to afford to the system certain traits of resilience such as learning, self-organising and adapting to change.

The safety vs. control debate becomes particularly interesting within the context of Artificial Intelligence (AI)/ Machine Learning (ML). Herein, AI/ML applications will be able to act autonomously, without following a set of pre-determined set of instructions, by learning from experience (European Commission, 2020). However, careful consideration needs to be placed on data requirements that would feed this learning process. In the ATM domain, for instance, a lot of qualitative data (e.g. human performance) are not recorded and such crucial information will not be fed in the AI/ML 'black box-effect' algorithms. This in turn may affect safety of services by continuously altering systems characteristics and creating conflicting conditions, that can potentially tip the system beyond the safety boundary.

Conclusion

In this article, I have tried to note different avenues worthy exploration towards identification and addressing future ATM safety challenges. Assessing safety performance in the future will strongly depend on approach(es) to safety ATM community take(s). Instead of trying to win the debate in terms of Safety-I vs -II, resilience vs. control, SMS vs. safety performance, how about we take a step back and try to understand which (combination of) approach(es) would work best for which functional system elements, context, dataset and level of granularity? There is no such thing as a perfect approach but maybe they could be combined in a way that would expand the scope, customise and optimise existing ATM safety performance management activities. Let´s join forces to write together the remainder of the future ATM safety challenges story!

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Views on what is considered to be the most important element for the future evolution of the safety performance framework

Riccardo Massacci, SESAR Joint Undertaking

The year 2020 will be remember as the 'Annus horribilis' for the aviation industry. The COVID pandemic crisis, which outbroke in Europe back in March, put under critical pressure the whole aviation sector and triggered several cuts and job losses in other sectors which relied on a solid transport industry.

Despite the exceptionality of such an unprecedented crisis, it is not the first time that the aviation sector faced harsh challenges over the last two decades. Indeed, after the 9/11 events in 2009, the entire world went through one of the major financial and economic crisis in the modern history which affected nearly all industries across the globe. Nevertheless, as air traffic significantly bounced back in the following years, it became clear how hard and inefficient can be to manage robust traffic growth in a fragmented ATM context. In the recent years, the raise of environmental concerns, followed by public protests around the globe, put again the aviation sector under the spotlight of media and public regulators.

Back in 2012, the European Commission enforced a performance regulation with the aim, amongst others, to effectively reduce environmentally harmful emissions. In parallel, the SESAR Joint Undertaking, which was set up in 2007, was given the mandate to promote, develop and industrialise research initiatives and innovative solutions, in particular in the environmental and capacity area. In 2008, the Clean Sky Joint Undertaking, a public-private partnership between the European Commission and the European aeronautics industry, was launched to coordinate and fund research activities to deliver significantly quieter and more environmentally friendly aircraft.

Nevertheless, despite these massive efforts, the road to complete the transition from a carbon based air transport industry to a fully integrated green aviation industry is still long and winding.

But what about safety? Safety is very often given for granted, perhaps supported by the evidence of very limited number of incidents and accidents in Europe over the last years. This factual datum however, masks the difficulty to quantitatively correlate monetary investments in safety with the likelihood of potential hazardous events. Indeed, given its immaterial connotation, a cost-benefit analysis for a safety related investment is hardly quantifiable in monetary terms.

Keeping in mind the above-mentioned limitations, it is not surprising that the area of cost-efficiency, capacity, environment and safety were the main political picks in the past. These four elements symbolise a different facet of the same aviation system and are highly interconnected between each other.

As reported in common dictionaries, a system is defined as '*an assemblage or combination of things or parts forming a complex or unitary whole*'. An ATM system is based on a combination of several stakeholders that act and interact in a regulated manner. In such a system each stakeholder pursues its own interest (e.g. cost reduction, timely arrival, reduction of CO2 emissions, provision of capacity in a cost-effective manner, reduction of route charges etc..) but remains highly interconnected and dependent on each others' choices.

Given the high number of stakeholders operating in the aviation sector (airlines, ANSPs, airports, States, MET institutions, regulator, militaries, passengers etc..) and their different scopes and objectives, it is intuitive the level of complexity and competitiveness in which these entities operate.

For instance in a context of traffic growth, a strict application of cost-efficiency measures by an ANSP (for instance a reduction in technological investments) likely increases the exposition to safety risks for the ANSP itself, other centres and airlines. Lack of investments might also trigger reductions in airspace capacity, eventually contributing to spread traffic demand across environmentally inefficient routes. This adds unexpected capacity pressure on other air traffic control centres and environmental and cost-efficiency pressure on airlines.

It is unquestionable that any performance improvement in an area might trigger positive or negative variations in others, depending on the nature of the intervention and level of correlation between these areas. Nevertheless, from a pure economical perspective, what really count is the overall change of the business value of a system, pre and post intervention.

The following example describes a potential increase of business value in a win-win situation in which an intervention in the area of cost-efficiency would have likely determined a positive chain effect on the overall system. Back in 2019, the Belgian upper airspace (controlled by MUAC) recorded its highest-ever traffic. This undoubtedly penalised local airlines whose flights departing from Belgian airports were capped at lower levels to avoid regulated sectors in the upper airspace (mostly occupied by overflown traffic). Furthermore, this continuous congestion was definitely a major cause for an increase in complexity, workload, stress amongst ATCOs and certainly incidents. A modulation of charges – i.e. an application of different route charges between lower (controlled by skeyes) and upper airspace (controlled by MUAC) - would have contributed to push traffic away from the most congested sectors in the upper airspace. The taking of this decision would have therefore increased capacity in the upper airspace for flights climbing from lower sectors (i.e. benefitting from more cost efficient altitudes) and would have contributed to the reduction of CO_2 emissions. The negative impact on traffic shifted on longer routes would have been null or minimal since only transoceanic or long haul flights would have been cherry picked first (the overall impact on these flights is irrelevant). Finally, the national state would have not reduced their revenues thanks to the principles regulating the modulation of charges itself.

In such a complex business environment, it is undoubtedly challenging to provide a regulatory model, which could fit for all stakeholders. However, the example described above proves that this indisputable complexity should not limit the efforts of the major stakeholders to adjust the intrinsic distortions of today's ATM system, in particular in the wake of the COVID 19 outbreak.

The IATA recently published that more than 20 million jobs are at risk if governments do not take concrete action. The pressure on the ATM infrastructure to apply digital technologies to become more cost efficient, resilient and scalable to fluctuations in demand for air transport has never been higher.

Indeed, the current infrastructure is the result of historical operational and technical evolutions, primarily conducted at the national level, where each air navigation service provider optimises its resources and capacity locally (silo approach).

The objective of the Airspace Architecture Study (AAS) is to support the transition from a static, rigid but safe "manageable" vertical ANSP model towards a fully integrated service oriented one. This will lead to more interfaces, SLAs, different actors, more complexity etc. This likely scenario has certainly consequences that new safety cases, hazards will have to be dealt with. There is no doubt that the way we deal with and monitor safety today will have to evolve in function of all this as well.

However, the shift from a pure local ATC perspective to a fully integrated ATM concept is slowed down by several factors. The fragmentation of the European ATM system, exacerbated by lack of political impetus, is a clear obstacle. The timing for development and deployment of innovative technological solutions coupled with the certification of safety and security-related procedures and infrastructures are amongst the most critical reasons for the slow uptake.

The use of obsolete and non-interoperable technologies does not support the implementation of a dynamic capacity management system on a large scale. Furthermore, it limits the exploitation of potential new forms of air vehicles – in particular drones and air taxis for urban air transport - that are more autonomous and use digital means of communication and navigation. Cyber security, which currently has a lower profile at this stage, will remain a major challenge from an ATM safety viewpoint.

For this reason, an efficient use of big data is a paramount step towards full automation of the European ATM system and an optimisation of resources and results at systemic level. However, it is understood that such a Copernican revolution cannot be achieved without a full involvement and commitment of all major stakeholders.

To conclude, there is a strong need to pro-actively engage main stakeholders, in particular states, into the implementation of a performance oriented air traffic management system in which safety plays a pivotal role. On the other hand, a sound commitment to developing, implementing and exploiting new technologies is a 'conditio sine qua non' for delivering a more efficient, resilient and safer European sky in the future.

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Future safety challenges for ATM – the future of change?

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Change is nothing new to societies, communities and organisations, indeed humankind. The imperative for change will be different and varied, nevertheless change is discussed, expected, resisted, vaulted, desired as well as postulated and even longed for. This is a facet of the way that humanity organises itself for numerous worthy and for some unworthy reasons. Today, globally, society has seen (or had), and no doubt will continue to have, a need to embrace and confront the change that COVID19 induces and requires. Change is a concomitant of the way we live.

In the way that safety is undertaken and conceived in ATM, has ATM embraced change or is the status quo sufficent? In which case, does the status quo serve the needs of understanding and sustaining safe and effective production in future ATM operations and organisations?

ATM has for decades lived with some change as well as the promise of change. However, some of these changes promised in ATM has simply not materialised or has endured implementation times spanning decades. Consider the history of CPDLC from its roots in ADSEL and DABS in the 1970s and stuttered and faltered implementation many years later as Datalink Services, or the changes that have been implemented into operations through Mode S DAPS for example. Much change has been implemented and has contributed significantly to sustaining the European aviation network and the growth in density and traffic aviation services. Still more has failed to reach the operational environment. Today ATM finds plans abruptly halted as a result of events in March this year, leaving an uncertain future. A different form of change – radical rather than incremental and by nature a surprise.

Radical change refers to change as 'fundamental rethinking' (Al–Mashari and Zairi cited in McAdam, 2003). Elsewhere, radical change has been described as 'dramatic and revolutionary change', 'discontinuous change that requires upside down thinking', or 'non-linear, complex radical change' (McAdam, 2003). The consequences of such radical change may lead to a qualitative and/or structural change to an organisations way of organising itself, requiring organisations (as well as communities and society) to reappraise their structures, processes, or business models. This goes beyond incrementalism and incremental approaches to organisational and technical change. McAdam argues that an underlying assumption of the operations and organisations in incremental change remain unaltered: the focus is on enhancing efficiency. In many respects, ATM has experienced near continuous incremental change. Not however, radical change.

Preceding COVID 19, the discourse around ATM included both the need for, as well as the practicalities of, radical change. The justifiable challenge to the accepted wisdom and philosophy of the way that ATM delivers air traffic services and developed to embrace both technological innovation new methods and concepts of operation. Radical change was considered, contemplated even the subject of research but opposed by the incremental change status quo. The ramifications of these are debated and alluded too even today. SESAR has engaged in numerous research projects that have advanced the knowledge that we have of the philosophy, principles and dynamics of ATM in the broadest sense. There is a different understanding of the dynamics of the ATM network and the numerous performance aspects. How do these contribute to a fundamental shift in the philosophy of the provision of ATS that serves the various and disparate needs for optimal operation?

To some dissenting voices, this understanding will not be sufficient, or enlightened, to challenge the long-established hegemony of ANSPs in the aviation system. The digitisation of work systems and the growth of network increases the pressure for real radical change in ATM in a belief that. The demands have been growing and the challenge and dissent growing even more (ATM Policy Institute, 2017).

The nature of the changes hypothesised and that are significant foundations the ATM Master plan are percieved as radical and are presented as radical through the technologically driven optimism of the benefits to be gained. To what extent are these developments radical in the sense characterised above?. Radical change is dependent on questioning the ‘restrictions of the taken for granted’ (Alvesson and Willmott). Some dimensions of the ATM Master Plan are consistent with how radial change is conceived, others less so. An ATS service will need to be provided continuously for example. This dictates incremental approaches towards implementation, nevertheless it is appropriate to explore what freedom there exists to transcend this. Global air traffic will not pause to allow structural reform of the ATC environment to take place as their new business models and modes of operation need to be implemented The future role of the human and the control and management of airspace users and operators are all elements of the ATM system that have been recognised and proposed as in need of change. These propositions are perceived as radical by some but may be essential to provide and sustain a path to both the continuous growth of aviation as well as being agile to accommodate new markets and business models. What is the inertia for such changes?

There are undoubtedly elements of the characteristics of radical change for ATM in the future. The tendency for ATM to regress to incrementalism when arguing for radical change is a phenomena that remains a strong possibility.

Safety has been one of the given’s or universal truths of ATC and ATM since its creation it can be argued. An incremental approach to safety has characterised the manner in which safety has evolved, although there are notable examples of innovation in safety within ATM with varying degrees of success.

The challenges that ATM faces in the future can be framed in terms of the nature of the change that it confronts. In one sense incremental but in fact, in actuality radical. What are the implications for Safety In future ATM when faced with radical or incremental change?

As noted above, ATM has demonstrated a desire for radical change as characterised above but tended to incrementalism. Is this a consequence of a naturally conservative approach to implementing change? Or and effect of being bounded by regulatory structures? These are undoubtedly potential reasons for incremental approaches (or responses?) to large scale change. However, if the nature of the change in ATM is discontinuous then incremental approaches will act as a barrier to progress. There are those in project engineering who do take the view that ‘safety’ (however it is conceived) is a hurdle to be navigated to achieve successful implementation.

Humankind ability to improve the human condition in the twentieth century has been described as ‘so often going awry’ (Scott, 1998). In Scott’s view, High modernism a ‘particularly sweeping vision of how the benefits of technical and scientific progress might be applied in every field of human activity’. The transforming benefits that science and engineering brought in the 19th and 20th century changed social structures and created different societies. Such changes, radical changes, are characteristic of technological determinism and ´the rational design of work and social order, the increasing control over nature (human nature)´ (Scott, 1998, Wears, 2014, Zuboff, 1984). A common thread that conjoins these threads is that of scientific management as introduced and developed by Taylor - ‘the man who emerged as the chief symbol of the rational approach to management’ (Zuboff, 1984).

Within the safety discourse, Taylor is recognised and acknowledged as making a significant contribution (Wears and Hunte, 2014; Dekker, 2019) to the foundations of safety science. It is argued that safety management today retains an affinity with the principles of scientific management as espoused by Taylor. The need for Taylorism (and the work of Gilbreth, although philosophically different) was a response to the change that industrialisation enabled. Leading to the need to increase production through ‘productivism’ that was achievable through the belief in the potential gains that technological innovation in the design of work systems could bring.

Zuboff observes that ‘the logic of Taylorism took hold, the substitution of machine power became the obvious method of increasing the speed and volume of production’ (Zuboff, 1998). The changes to industrial work settings beget changes to social order and structures, changes in the nature of the knowledge that operators and practitioners have and hold and that society values. Knowledge and experience that has its place in industrialised work settings, but less so as a response an consequence of the nature of the change. Is there a need for this in industrialised work systems that are highly integrated human-technology systems? Technical rationality, Wears and Hunte (Wears and Hunte, 2014 citing Dekker et al 2013) identify as creating a belief that a better, safer more predictable world; a controllable world, not just a manageable world, is achievable. A belief that it is argued here is similar to one that ATM in Europe holds today.

If this sounds familiar to the ATM community it should not come as a surprise. The SES ATM master plan envisages a work system where technology facilitates changes in the role and function of human actors. In some cases, changes in the nature of human agency as well as potentially new paths for the responsibilisation of human actors. New business models are postulated.

A cornerstone of safety management today is the Safety Management System (SMS). Can this be conceived as an instrument of authoritarian high modernism?

Safety management systems that have emerged through ICAO as an aviation standard exemplify this approach, presenting as rational approaches to the “management” of safety. Li and Guldenmund (2018) consider the purpose of a safety management system and identify that control and compliance are fundamental characteristics of such systems. Entirely consistent with the ideology of authoritarian high modernism. High modernism is seen as influencing and shaping safety (Wears and Hunte, 2014) amongst other attributes of organisational praxis, in their case Healthcare.

Can safety be reduced to a suite of metrics and indicators that identify the specific areas of organisational praxis requiring intervention to achieve a desired safety performance? Questions emerge when considering the real characteristics of radical change in ATM and the prevailing philosophy used in ATM safety. The substantive changes that are expected to alter the nature of ATM mean increasingly conceiving ATM as a non-linear system, becoming both more intractable and complex. Are the tools of authoritarian high modernism conducive to understanding safety in such systems? Does safety materially alter in such systems?

Radical change driven by the desire to exploit the potential of technological and scientific progress is a trajectory of change in ATM. Technological determinism is a perceived reality for some in ATM. The role of the human in the system - ATCOs and ATSEPs for example – has long been a subject for research and conjecture, for discussion and tension. It might be given that the thrust for change to social structures and organisational values is technologically driven and can influence and shape the professional identities of actors in the ATM system. Such changes can lead to unwelcome consequences for some, a perceived cost for improving society by others.

What of safety? If, as has been asserted, foundational aspects of Taylorism that influenced safety science continue to shape the classic safety paradigm which prevails in ATM in Europe, then it begs the question; Is this too a continuation of high modernism? With its belief that this technical and scientific progress will yield substantial and potentially transformational new benefits. As well as rational approaches that seek the reassuring solace of standardisation, today's safety paradigm is based on the formal procedures, metrics and indicators of rationalism itself.

What is safety in these terms? What does safety mean?

A consistent thread of contemporary safety science is that of the nature of organisations and their characteristics in terms of a social-technical system. Substantive structural changes may well inevitably flow from the innovative and visionary changes that the ATM Road Map seeks to introduce.

It is anticipated that ATM of the future, as seen through a social-technical prism, will become more complex than the ATM system of today.

Is the safety management system equal or appropriate to the challenge of what is proposed as radical change? If the SMS is an exemplar of the classic safety paradigm of learning from events and making changes, of control, – perhaps through new procedures, enhancing redundancy, training practitioners etc, will orthodox safety thinking meet the needs of society to achieve safer operation?

It is anticipated that ATM, as seen through a social-technical prism, will become more complex than the ATM system of today. New actors and stakeholders, new forms of aviation operator e.g. spaceflight operations, new business models and forms of ATM infrastructure reliant upon software engineering will all contribute to introducing uncertainty and potentially contribute to the comforting linearity that ATM has long enjoyed (for the most part!) changing to a system that is characterised by non-linearity and less dynamically stable?

Definitions of Safety in aviation abound 'freedom from unacceptable harm' for example or the ICAO Annex 19 definition ICAO

Annex 19 defines safety as "the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level'.

Do these definitions of safety fit with the nature of the ATM system as we see it today – characterised as it is as a complex social technical system.

Arguably serviceable – but barely so. There are events that cannot be understood through the mindset of safety thinking that has changed incrementally and begins to lag behind the complexity of the emerging operational and business environments that future ATM is expected to adapt and change to become?

Will counting and categorising event types and manifestations of safety as constructed through SMS processes then attributing and refining causal factors meet the needs of sustaining safe production in the ATM sense in its future state? For example, the interdependencies that can come to the fore in organisational praxis and the trade-offs that are inevitably required to balance these competing objectives in not just the operational elements of ANSPs but the whole of the organisations activities as well as the external influences that need to be reconciled as well.

This is not to propose that there is no use for classical safety processes, arguably there is a need for the knowledge that it brings. However, the knowledge and understanding that is required to manage safety in the future demands more than this.

Safety and safety thinking in ATM needs to move beyond incremental change and evolve radically by challenging the well-worn and well-trodden practices and philosophies of the past. . As argued above, and as seen in other domains, high modernist frameworks for managing and controlling organisations to achieve safe operation. Is this suite or equal to the challenge of radical change that ATM was, until March 2020, pursuing or on the cusp of.

If ATM has been on the cusp of 'radical' change for many years, then the time is right for safety thinking in ATM as well as the philosophy of safety that is the foundation for safety per se to change too. Radically.

Let's begin with asking the question 'what is safety'? A question that the answer has been taken for granted for far too long.

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