Abstract Book Preview
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Critical Infrastructure, Resilience & Governance
A Capabilities Approach towards Prioritization of Critical Infrastructure Resilience

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In response to extreme weather events, terrorist and cyber-attacks, as well as other low-probability, high consequence technological catastrophes, recent policy directives and capital investments have exhibited a shift in priorities for critical infrastructure systems that emphasizes resilience. As a part of this resilience effort, the U.S. Department of Homeland Security (DHS) has identified 16 distinct critical infrastructure areas that are considered vital to the nation’s security, economy, and/or health and safety. However, there remains no articulated set of values that guides decision-makers about the prioritization of resilience investments towards one critical sector over another, which is particularly important in the event of a disaster.

To assess the order in which we value infrastructure, we must consider why we have infrastructure and what it does. At the most basic level, infrastructure is valued because it helps people thrive and prosper; Infrastructure helps individuals and households reduce costs, increase productivity, increases the quality of health and education services, as well as facilitates social cohesion. Thus, we argue that decisions about infrastructure priorities and investments affect not only national security and the economy, but also the lives and livelihoods of people as individuals and the collective. The failure of infrastructure to provide services can therefore restrict agency, prevent people from doing things they value, and undermine their ability to cope with threats. This view emphasizes that the importance of infrastructure is to provide critical services to the public and begs the question of what services are critical to meet basic human needs and the collective values of the public.

Our collective values are often written into law. For example, the Declaration of Independence and the US Constitution explicitly express what values we have as Americans and what we believe to be our inalienable human rights. However, these human rights require infrastructure to be realized, otherwise they are simply ideas. For example, the right to life cannot be achieved without access to clean water, food, and healthcare. Also shelter, freedom to assemble, and freedom of expression cannot exist without the technological platforms that make exercise of these fundamental human rights possible. Therefore, critical infrastructure can be defined as those systems that provide us with the capabilities to actualize our human rights and prioritization can be established via hierarchies of human development needs. This research examines the DHS designation of criticality from a capabilities perspective and argues for a capabilities basis for making distinctions between those systems that should be considered most critical and those that might be temporarily sacrificed.

*Speaker
The capabilities framework is particularly useful for prioritizing critical infrastructure systems at the collective level in a way that emphasizes the role that infrastructure plays in enabling people to thrive as well as adapt to all kinds of adverse events. It can also be applied at the community level, as a framework for guiding local policy and initiatives around specific value systems.

**Keywords:** critical infrastructure, human development, capabilities approach, human rights, criticality
Critical infrastructure resilience: Bridging the gap between measuring and governance.

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In this paper we review the current application of the resilience concept in the domain of critical infrastructure research and policy. The field of Critical Infrastructure research has traditionally focused on the protection and reliability of infrastructure systems in light of different causes of disturbances. Recently, a shift can be observed from a focus on the protection of critical infrastructures towards a focus on critical infrastructure resilience. We discuss the main differences between practice-based and attribute-based[i] approaches towards measuring and assessing resilience of critical infrastructure. We will address the underlying conceptualization and operationalization of (critical infrastructure) resilience and relate this to the state-of-the-art of Resilience Engineering[ii]. We discuss the implications of these different approaches with regard to their scientific merits and their practical applicability.

We will argue that both types of approaches have stronger and weaker points, but in general, the field of critical infrastructure resilience would benefit more integrative perspectives and multidisciplinary embedding. In particular for the governance of critical infrastructure resilience (both in terms of policy and strategies for increasing resilience of CI). Given the nature of the domain, with a large number of actors involved and complex networks of dependencies, increasing resilience is not something that is easily achieved. One of the main challenges for the governance of critical infrastructure strategies is the large, varied network of public and private stakeholders involved in combination with the connectivity, complexity and dependencies within the network of infrastructure systems. The existing approaches in the field of CI research generally have a rather narrow interpretation for resilience as the ratio of loss and recovery in the face of a disturbance. The performance-based approaches have a scientific orientation, but generally do not provide insights that contribute to the governance of CI resilience. Many attribute-based approaches provide some direction as to what type of capacities a system should strive for, but assessments are rather subjective and it does not guarantee that it constitutes sustainable capacity in changing circumstances. What is more, most of these approaches are targeting single organizations or infrastructure systems, while from a governance perspective it is relevant to address resilience at the level of the network or even at the societal level. As such, the field would benefit from an integrated, network-level, approach that is rooted in scientific knowledge, while at the same time providing insights that truly contribute to the governance of critical infrastructure resilience.


**Keywords:** Resilience Assessment, Critical Infrastructure, Governance:
From air to ground – Resilient strategies and innovation across critical infrastructures.

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In this paper we compare strategies and tactics for increasing resilience in four critical domains: aviation, power generation, healthcare, and oil and gas production. We explore similarities and differences between these domains and what these mean for the application of Resilience Engineering (RE). For example, we plan to answer the following questions: What does resilience look like in everyday operations in an air traffic control center, a power plant control room, and an acute care hospital? How does each setting anticipate, prepare and respond to surprising and novel events? Are there strategies that are uniquely suited to each domain, and why? To what extent is there overlap and are there opportunities for cross learning. Which strategies would work across domains? Which would not and why?

We will synthesize the current and emerging ideas to develop a set of RE themes, drawing from our respective practices and the work of international opinion leaders in RE (Woods. 2006-2016), Hollnagel, (2006-2017) and output from the recent European Project and Programmes. We believe that a set of themes is necessary to introduce RE to novices and to provide a structure for those who desire to design and operate resilient systems. As such, this paper will be part primer for the RE novice, and part "how to" guide for RE practitioners. The authors disclose a self-serving motive of learning from each other thereby building a richer toolbox for all RE practitioners. The themes will consider the challenge of implementation and thus be paired with innovation techniques that could be used to co-create robust solutions with end-users. The direct involvement of end-users aims to bring concepts closer to practical application and with the development of operationally valid tools or processes will help organizations and systems better understand everyday work, and prepare them to function in a resilient manner. This creates an opportunity for innovative thinking at all levels of the organization with respect to preparing for, and responding to novel and surprising events. Management innovation to mature resilience concepts gives room for unique and unorthodox approaches to unleash people’s thinking and attitudes; where everybody is pushed to consider useful solutions.

We have conducted systematic, structured literature reviews. There are salient concepts across the resilience literature in general, and specific concepts from RE in particular. These concepts are described by Hollnagel (2017)[1] as the "potentials" to anticipate, monitor, respond and learn; and, by Woods (2015) [2] as graceful extensibility and sustained adaptability, flexibility, diversity, work as imagined and work as done. Our work addresses the need to further develop

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these concepts into practical solutions and provides a way forward based on our practice and the input of end-users.

We will present the themes and the tools to support a paradigm shift to a resilience-oriented perspective based on RE and complemented by other relevant fields of research and practice.


Organizing Processes of Resilient Organizations.

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The definition of resilience which is most relevant for our examination of the interdependence between technical and human systems is that of graceful extensibility, which asks, “How do systems stretch to handle surprises?”[1] To assess an organization’s capacity for graceful extensibility, we borrow the notion of “agility” from the Command and Control Research Program (CCRP) within the United States Department of Defense[2] which defines “agility” as the ability to successfully cope with and/or exploit a change in circumstances. The CCRP’s goal is to transform how people in military and civilian contexts interact and pursue collaborative endeavors in the Information Age, and to identify the conditions and technologies which enable members’ organization, synthesis, and implementation of diverse knowledge. Organizations are considered agile if they can both recognize the dynamic nature of a situation and enact the appropriate response. An organization’s capacity for agility relies upon three dimensions:

1. Patterns of interaction—the willingness and ability of members to communicate.

2. Allocation of decision rights—the distribution of power to incur decision costs.

3. Distribution of information—the extent to which information is accessible and available.

The broadest enactment of these three organizational dimensions supports processes of both tacit and explicit knowledge sharing, the result of which is increased group tacit knowledge[3] and collective improvisation regarding the use and operation of technological systems, as well as self-organizing task clusters in the face of unforeseen change to which an organization must adapt. Enactment of resilience potential thus requires communication practices and protocols which are conducive to creating and sharing tacit knowledge, empowering members to act and make decisions on behalf of the organization, and providing access to and distributing information. Implementing and rewarding such communication practices often requires changes in organizational culture which reframe who and what is valued, redefine the self in relation to others and the enterprise, and identify and clarify individuals’ motivations for action.

However, a key limitation of the CCRP’s claims regarding components of organizational agility and maturity is that they have been developed and tested in one particular kind of culture—the United States military. In addition, graceful extensibility has not explicitly examined the influence of culture on the interplay between human and technical systems. What is therefore required is a test of how the three dimensions described above constitute culture in civilian multi-sectoral organizations, and the extent to which the ensuing culture supports the creation

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and transfer of tacit knowledge among groups. We test the hypothesis that organizations with greater group tacit knowledge can achieve greater graceful extensibility than their counterparts. In particular, we examine organizations which must confront uncertainty and surprise regarding technology and infrastructure systems.


**Keywords:** organizational culture, tacit knowledge, graceful extensibility, communication
Sustained adaptability: The transaction level.

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Recent advances in the study of resilience engineering have focused on discovering architectures that can sustain adaptability (Woods, 2015[1]). Tangled Layered Networks show ‘graceful extensibility’ in successful cases of sustained adaptability, that is, these networks have the ability to extend their capacity to adapt when surprise events challenge their boundaries. A key concept in this view is ‘adaptation’, which includes adjusting behaviour and changing priorities in the pursuit of goals. As surprise occurs continuously, units within the network constantly need to monitor their environment and regulate their resources, in joint coordination with other interdependent units in the network.

For both human and artificial systems, knowledge is one of the most important resources adaptive units can bring to bear. Any system that fluently applies knowledge in the service of goals operates at what Newell (1982[2]) has termed the ‘knowledge level’. At the ‘knowledge level’, the principle of rationality applies: if an agent (e.g., an expert) has a goal and knows that knowledge A will bring him or her closer to that goal, then the agent will choose knowledge A. As knowledge is always finite (principle of bounded rationality; Simon, 1955[3]), adaptation can only be local and perspectives of any unit in the network are bounded. In Newell’s (1982) terms, the ‘knowledge level’ is a radical approximation, that is, entire ranges of behaviour may not be describable at the knowledge level, but only in terms of systems at a lower level, i.e. the cognitive level.

However, if knowledge is finite, the only way for Tangled Layered Networks to show graceful extensibility is by aligning and coordinating across multiple interdependent units in a network, by shifting and contrasting over multiple perspectives, hence by extending the range of adaptive behaviour of other units. I will argue that this, in effect, calls for a different system level, right above the knowledge level, which I will call the ‘transaction level’.

At the transaction level, links are selected by agents (units) to attain transactions. Architectures for sustained adaptability need to be couched in terms of the transaction level, because of the fundamental limitations at the knowledge level. Unlike Munchhausen, we cannot attain graceful extensibility by pulling ourselves up by our own hair, that is, by using concepts from the level we are trying to explain. What this means in practice is that we need to study the links between the units in the network, the information flows between the links, and discover patterns in these flows. Whereas adaptation is a goal-oriented concept at the knowledge level, it needs to be described in terms of information flows at the transaction level. Resilience engineering needs to study, then, the ways these information flows can be optimized across the entire Tangled Layered Network. In this paper, I will present a number of examples of how this can

*Speaker
be achieved. This will be achieved partly by re-framing a number of classic disasters in terms of the transaction level, partly by recounting successful cases of sustained adaptability.

**Keywords:** Sustained adaptability, graceful extensibility, adaptation, system levels, networks
Resilience and Governance in Complex Temporary Organizations

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In complex organizations, no single individual has a complete understanding of the whole situation. Here, performance depends on seamless teamwork, which requires adequate organizational conditions driving a collaborative mindset, particularly in volatile and safety-critical environments. In complex temporary organizations, this effort competes with the participating permanent organizations’ objectives and is influenced by each organization’s unique signature[1], relating to for instance political pressures, pace and synchronization, as well as internal commercial targets, reward systems and commitments to other projects.

Temporary organizations are a growing phenomenon across many sectors. It refers to entities formed by multiple organizations, each contributing a part of the scope required to achieve the temporary organization’s objective. The inter-organizational dynamics differ from intra-organizational dynamics[2] since temporary organizations are also influenced by the permanent organizations’ internal motivations, e.g. how high is the specific project contribution on the internal priority list of the permanent organization? Moreover, the contributions may be (partly) subcontracted to other organizations which, in turn, may subcontract pockets to yet other organizations creating a constellation of mixed interests. The success of a temporary organization is influenced by the resilience capability at the point where contributions come together in design, realization and operation, as actors from different disciplines and from different organizations navigate through the situation together[3], adapting ‘work as imagined’ to the reality of work as it manifests itself while coping with the inevitable gaps on the seams between their contributions and their permanent organizations’ priorities.

This project has a special focus on the effect of the regulatory governance approach on the resilience capability in temporary complex organizations. While organizations become more complex, the regulator simultaneously increases the emphasis on rule compliance, which seems a counterintuitive move.

Exploratory data capture at industry partners of the dynamics and resilience in temporary organizations in different sectors allows for a discussion on cross-sectorial patterns, developing an understanding of how different sectors cope resiliently with the dynamics in temporary organizations under increasing compliance pressure. While TORC (Training for Operational Resilience Capabilities)[4] created an understanding of how resilience works within one organization, this paper aims to explore how resilience works between organizations engaging in a temporary complex organization.

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Health Care Systems
Emergency Medical Services: When Fatigue Becomes The Norm.

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BACKGROUND: Emergency Medical Services (EMS) routinely work at the very limit of their capacity due to growing emergency rooms visits and residents’ shortage. In this context, EMS workers are regularly asked to work more than 10 hours a day, on varying shifts and with short recuperation breaks. Two approaches can be used to reduce fatigue-related risk: reducing the likelihood a fatigued operator is working (i.e. fatigue reduction), or reducing the likelihood a fatigued operator will make an error (i.e. fatigue proofing). In Emergency Medical Services, formal risk control mainly focuses on reduction strategies such as reducing work hours while proofing strategies develops as an implicit element of the safety system. OBJECTIVE: Our purpose is to identify individual proofing and reduction strategies used by emergency residents and to investigate how they relate to fatigue, performance and patient safety indicators. METHODS: First, we conducted 4 focus-group sessions with a total of 25 EMS residents to elicit perceived consequences of fatigue and strategies used to cope with them. Focus group results were used to design a questionnaire assessing how often EMS residents personally used any of the strategies reported during sessions. Second, we administered the questionnaire to a larger sample and conducted a prospective observational study with a repeated within-subjects component. A total of 45 EMS residents participated in the study for a total of 400 shifts analyzed. We gathered sleep diaries, subjective sleepiness, reaction time, self-reported medical errors and performance ratings at different time point during both day and night shift using an android-based application. Sleep time and activity levels were confirmed using wrist actigraphy. DISCUSSION: We will discuss what can be drawn from our results in terms of individual and collective resilience processes with a focus on the potential for implementation of more formal processes at a system level.

Keywords: Fatigue, Risk, Resilience, EMS, Residency, Patient Safety

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Work-as-done to inform protocol development in the emergency department

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Introduction: The emergency department (ED) is a dynamic environment that requires providing timely care to patients of varying acuity. Many times, clinicians don’t follow protocol because it does not adequately represent their everyday workflow. This discrepancy results in the development of workarounds and/or unofficial protocols to communicate critical information or perform time sensitive tasks. However, varying protocols for tasks can disrupt one’s workflow, cause confusion and lead to errors impacting patient safety. The present study sought to use observations to identify tasks occurring in-situ as a source of evaluating work-as-done in the ED in order to identify opportunities to bridge the gap between protocols (i.e., work-as-imagined) and clinical work (i.e., work-as-done).

Method: Attending physicians at one academic institution were observed and workflow tasks were identified. Convenience sampling was used to select the physicians in the ED to observed. Data included a description of the task, who were engaged in the task (e.g., nurse, resident, technologist), and the location (pediatric or adult wing). Institutional procedures were reviewed for each task to identify whether relevant protocol was in place. For those lacking relevant protocol, the tasks annotations were categorized according to opportunities for protocol creation.

Results: During two attending physician shifts, 22 tasks were identified. 55% of the tasks were conducted by nurses, 23% were conducted by residents, 14% were conducted by radiology and 9% were conducted by other staff. There were 17 (77%) tasks identified as “Work As Done” (WAD) that did not have a formal protocol associated with the task. There were 5 (23%) tasks identified as Work As Imagined (WAI) that had a formal protocol associated with it and clinicians followed the protocol. Of the 77% WAD there are opportunity for protocol development related to continued patient care processes (53%), clinician administrative processes (29%) and clinician training processes (18%).

Discussion: A majority of the tasks identified in this study lacked associated protocol. Creating procedures for continued patient care processes, clinician administrative processes, and clinician training processes using work-as-done data will provide a chance to build resiliency into the work system. Developing procedures from the ground up (i.e., sharp end) rather than enforcing procedures that come from the top down (i.e., blunt end) will ensure that protocols can be flexible for performance adjustments and unexpected events when they arise. Next steps will

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include: 1) interviewing ED clinicians on their workflows for particular tasks, and 2) developing relevant and safe protocols alongside affected clinicians so that the protocols are an accurate representation of everyday work.

**Keywords:** work as done, work as imagined, emergency department, protocol development
Adaptation and implementation of the resilience Assessment grid in an urban emergency department

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SUMMARY
We adapted the generic Resilience Assessment Grid[1] to the emergency department (ED) context, and implemented a context-specific instrument to rate and monitor the everyday way an urban ED copes with the challenges and trade-offs that arise in risk critical work.

The context-specific instrument was derived from a series of dialogue workshops in a practice community of patients, care providers, support staff, and leaders. Workshops were based on the World Café strategy, and used statements from the generic Resilience Analysis Grid as a stimulus. Diagnostic statements were refined in monthly inter-professional departmental workshops for content and face validity, then used to plot a departmental resilience profile.

Through conversation and stories of everyday practice participants populated context specific examples of how the department and local healthcare system responds to what happens, monitors critical threats, learns from what happens, and anticipates what might happen.

The iterative work-in-progress of engagement and dialogue within a practice community using the generic Resilience Assessment Grid as a stimulus for dialogue and action has been generative in identifying gaps and actions to increase collective adaptive capacity. For example, statements about ‘vital signs’, thresholds and action plans have led to parallel work on the suite of operational metrics that practitioners and staff look at to get a sense of how the ED is operating. The ED Operational Vital Signs have been implemented locally in an hourly printout version, and an integrated electronic version is anticipated in the new few months.

Repeated application of the Resilience Assessment Grid over time demonstrates how the profile of a resilience potential develops and enables systematic monitoring and evaluation of specifically targeted efforts. The tool has been refined to create a context-specific strategic framework with face and content validity. The process created community, identified gaps, and has led to innovations and actions to increase collective capacity for manoeuvre. The ED resilience profile will continue to be iteratively mapped over time.

RELEVANCE FOR SYMPOSIUM
The process of adapting and implementing the ED context-specific Resilience Assessment Grid

*Speaker
has provided a space for practitioners, patients, and leaders to share in a conversation together about where we are and where we want and need to go. It has led to critical conversations about how patients are cared for safely in a complex clinical environment, and to consideration of how to adapt and respond to crowding while maintaining a safety margin and capacity for manoeuvre.

SIGNIFICANCE/TAKEAWAY

There was value in adapting the generic Resilience Assessment Grid to a local healthcare context in bringing a diverse group of clinicians, staff, patients and leaders together to focus on a systems view of complexity in everyday work. Industry and science can follow a similar methodology rooted in Appreciative Inquiry and complexity-based models of meaningful engagement to facilitate and foster a dialogue about how resilience potentials emerge and can be supported.


**Keywords:** Resilience Assessment Grid, healthcare, emergency department
Resilience: The Challenge of Maintaining Margin in Healthcare

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At first glance, safety practitioners new to the field of reliance engineering may automatically view Safety I as a reactive approach and Safety II as a proactive approach. This is understandable as Safety I often involves a response to an incident or adverse event while Safety II is concerned with adaptation and flexibility. However, in thinking more deeply about these concepts, this ”either / or” assignment is artificial and inconsistent with actual practice. We propose to discuss reactive and proactive approaches to Safety I and Safety II using safety events in healthcare (unsafe conditions, incidents and serious events) as exemplars. Constructs such as reactive and proactive are less helpful in understanding Safety I and Safety II and alternative frames may be useful.

In considering Safety I, root cause analyses, training, and creating policies in response to an incident are consistent with a reactive approach. Alternatively, implementing forcing functions and standardized rules to minimize variation can be a proactive approach to safety, albeit from a Safety I perspective focused on anticipated failures. (Vincent and Almaberti 2016)

However, we can also identify Safety II approaches that are both reactive and proactive. A reactive Safety II activity might include examination of ”normal cases” in association with unsuccessful cases of the same type. For example, when investigating cases in which spinal cord compression was missed, a large number of cases in which spinal cord compression was appropriately diagnosed and managed were also reviewed. A proactive safety II approach might include preparation of resources (personnel, equipment, processes) and margin in anticipation of a threat. Ensuring that personnel have the appropriate skill sets and familiarity with a system before they are required to function in the system is another proactive approach.

Perhaps a better differentiation is that Safety-I tends to restrict operators’ capabilities, Safety-II

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tends to expand them. The Safety II approach might better be when the operator is “poised to adapt”: possessing a deep knowledge of the situation, system and resources. (Cook, 2016) Alternatively, one might consider Safety II as “training for flexibility in the face of the unexpected rather than for specific threats” (Finkel, 2011)

RELEVANCE
Creating the space for resilience to occur requires that resources to facilitate adaptation are maintained at a level that allows for graceful extensibility (Woods, 2014) rather than constant “firefighting mode” (Schulman and Roe 2004). Ensuring adequate margin may be viewed as a radical philosophy in an era of “rightsizing” and Lean.

SIGNIFICANCE/TAKEAWAY
The consequences of insufficient resources for adaptation in the face of unexpected perturbations may not be immediately apparent. In fact, the system may continue to function adequately until a crisis challenges the system’s operations. In the case of healthcare, surges in patient census and unusually challenging patient conditions (e.g. ebola) represent regular and irregular threats to operations. Critical system failures may be precipitated by inadequate availability of resources necessary for system adaptation. Lack of sufficient margin to respond to perturbations may in itself be a latent or unsafe condition.

Keywords: margin, proactive, reactive, healthcare, safety II
What is a step in the right direction? The tradeoff between improving ideas and improving systems.

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We will be discussing, and perhaps debating, how to discern the true indicators of true progress in the larger safety and system performance communities with respect to adoption of Resilience Engineering concepts and precepts (i.e., “steps in the right direction”). There is a long and painful tradition of Resilience Engineering being misinterpreted, misunderstood, and co-opted into more mainstream theories, most notably Root Cause Analysis and the other theories that Hollnagel, et. al. has aggregated under the label of Safety I[1]. Ultimately, this has stunted the progress of Resilience Engineering specifically and of engineered system resilience in general. It also creates a difficult decision among resilience engineers as to how to direct their efforts: which of the updated, amended, or ostensibly brand new perspectives of system safety and performance should we support? Which should we tolerate because one or more aspects are better than the status quo? Which should we actively resist and criticize? Which should we co-opt and exploit, even if our interpretation does not match the original designers’? Perhaps most importantly, how should we approach the tradeoff between engaging in these activities to support Resilience Engineering and doing work to improve the resilience of a specific system?

We will discuss our recent efforts in applying Resilience Engineering in our respective health systems, and how recent large-scale safety initiatives from the Agency for Healthcare Research and Quality and the National Patient Safety Foundation may help and hinder our future efforts. As Associate Director of the MedStar Institute of Innovation as well as being an Attending Physician in the Emergency Department of the MedStar Washington Health Center, Terry Fairbanks directs how untoward events are investigated and advises the rest of the organization on how potential safety interventions should be designed and implemented. He also serves as an advisor to multiple healthcare safety organizations, helping them craft safety guidance to health systems in the United States. He will highlight the barriers that he has faced in bringing a Resilience Engineering perspective to his organization, and will discuss successes and failures in some of his recent projects. Mike Rayo will talk about his experience as an insider/outsider in his organization, with his primary appointment being in the College of Engineering but playing a consulting role in the Department of Quality and Patient Safety in The Ohio State University Wexner Medical Center. He will discuss how much of the language of Resilience Engineering concepts have adopted by more mainstream safety ideas like Root Cause Analysis, but the concepts themselves have not. He will discuss how it is important to look at the recommendations of a given investigation or guidance document, and compare them against the tenets of Safety I or

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Safety II. Even though our community has succeeded in including language that guides against blaming individuals and looking deeper into systemic issues, the lack of guidance on how to do this often leads well-meaning investigation teams to backslide into what is comfortable for them. He will also share his recent projects at Ohio State, and how he is slowly bringing Resilience Engineering to the consciousness of the organization through small projects that yield small, but notable, improvements.

The concept of resilience in surgical operations – from handling disturbances to coping with complexity, uncertainty and contradictions

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An established definition for resilience in health care goes as follows: ‘the ability of the health care system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required performance under both expected and unexpected conditions’[i]. This definition is in line with the generic definition of resilience and is therefore likely to reflect the typical safety-critical work contexts explored in the resilience engineering literature, such as the aviation or nuclear domains. In these work contexts operators usually engage in routine tasks or monitoring while challenge-defying performance is required during disturbances. It is then quite natural to connect the concept of resilience to disturbances and changes. However, the resilience engineering literature also suggests a clear difference between health care and other safety-critical domains in that health care commonly involves abnormal situations, not previsioned in the system design or procedures. For instance, Blocker[ii] has identified that non-routine events are extremely commonplace (it was observed that there are, on average, 56 distracting, undesirable, or unusual events per cardiac-surgery case). Overall, Clay-Williams and Braithwaite[iii] illustrate the actualities of health care by suggesting that it resembles wartime military aviation in requiring flexibility and in-situ decision making.

Indeed, changes and disturbances seem to be so common that the line between so-called ‘expected’ and ‘unexpected’ could become blurred. Similarly, in some health care settings, in surgery especially, one could see that it is not primarily so that a ‘change’ or ‘disturbance’ would be something that interrupts the ‘normal’ course of operations. Instead, the surgical operation itself is a huge ‘disturbance’, introduced by the surgical team, which has to be managed and controlled, while each patient is different in terms of anatomy and disease status. Furthermore, in the context of complex surgeries, the guidelines are fairly incomprehensive and unspecific, and they entail scientific uncertainty[iv]. There is also always present a contradiction: the aim is to heal a disease while at the same time minimal damage should be introduced.

In this view, resilience in complex surgical operations is not so much about system’s ability to function despite disturbances and changes (although they are relevant), but it is more about handling a complicated process despite the lack of exact scientific knowledge, the variability and complexity of human bodies, and the contradicting aims.

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**Keywords:** resilience, health care, surgery
”Disaster” Anticipation, Response & Recovery
Supporting resilience management through guidelines: Specifying the nature of the guidelines, development process and essential components

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H2020 project DARWIN aims to build resilience management guidelines to support organisations in developing and enhancing their resilience in the context of crisis management. During the first 6 months of the project, a vast review of associated literature, standards and operational documentation, as well as interviews of practitioners, was undertaken. A significant number of requirements were identified to guide the subsequent development of the DARWIN guidelines. Those requirements included especially conceptual requirements that captured resilience management capabilities the guidelines should address. However, the requirements did not specify the nature of the guidelines, i.e. the object of design, in order for them to be useful. The development of such object is a typical ”ill-defined” problem, i.e. corresponds to a problem for which there is no clear end goal, nor clear path to a solution. The nature of such problem is further complicated by the typical scope, scale and complexity of the domain of crisis management for which the guidelines are developed. The paper describes the iterative discovery process that took place in order to define the nature of the guidelines, to establish a development process and create an initial version of the guidelines.

The context is that of organisations that already have a number of processes and tools in place to support their management of crises (e.g., preparation activities, contingency plans, procedures, learning activities). As a result, the guidelines are positioned at a meta-level: they provide a perspective on these processes and tools grounded in research and practice on resilience management inspired by the fields of Resilience Engineering and Community Resilience.

The guidelines are constituted of three essential components:

• The building blocks are the Concept Cards (CC). CCs propose specific interventions in order to develop and enhance the resilience management capabilities captured in the conceptual requirements. CCs are at the heart of the guidelines development process described in this document; they are built and revised by incorporating operational perspectives.

*Speaker
• The guidelines build on the Concept Cards by organising and relating them, because the resilience management capabilities they refer to are not independent. A central component of the guidelines in a conceptual map that organises the CCs; it is used both for knowledge representation and development purposes.

• A knowledge management platform facilitates the development, management and future use of the guidelines. The platform offers opportunities to reconsider common views on the nature of guidelines, their necessary evolution and their multi-faceted, multi-purpose content.

The guidelines’ development follows a 4-step process established to be collaborative and iterative, and to include operational input early and as often as possible. The process changed and solidified during the course of the task as a result of the evolving understanding of what type and content of guidelines would be useful to develop and of how to produce such guidelines while fulfilling the various objectives of the project. Finally, the paper describes current results, achievements and limitations associated with the initial version of the resilience management guidelines.

**Keywords:** resilience management, guidelines, design, development, discovery process, knowledge management
Situated and participatory development of a collaborative technology to improve the resilient performance of disaster risks management.

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The Information and Communication Technologies (ITCs) designed to manage the risks of disasters presents restraints concerning the generalization of its use for they do not account for the diversity of disaster risks, the culture, the language, and the users. The current article discusses the issues related to the disaster alarm and alert system, the communication and coordination of actions referring to the disaster which occurred in 2014 in the neighborhood of Mãe Luíza in Natal- RN, Brazil. It also presents a situated and participatory development model of an application created to be used by populations vulnerable to disasters, civil defense and protection agents, and volunteers in the management of disaster risks. It was verified in the aforementioned disaster that the local alarm and alert system happened through word-of-mouth and the agents did not have anticipated access to the images and certain information of risk areas. The communication between the population and the public agents involved was not very agile, which contributed to increase the uncertainties and hampered the proper decision making, the coordination of the response actions and the performance of actions in due time. Because of that, the risks increased and the population had more difficulty to leave the risk areas in an early and quick way. It was noticed that the community had not been prepared to act in situations of risk and disaster, though they acted before and during the disaster specially, even in an unprepared way and without an integrated coordination. In some discussion forums the community pointed the need to improve the alert and alarm communication as well as the communication among the agents and the population and the action coordination. In order to accomplish that, it was suggested the creation and use of an application for mobile phones at low cost. There are several studies and researches which refer to the contribution of ITCs for that purpose but so far it has not been identified any device which has adopted the situated and participatory method of development or that refers to the focused population and location. The application is being developed with the participation of the neighborhood population and public agents, thus considering their accumulated knowledge and experience.

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The aim is to provide potential users with information on the risk of disasters, receive alert and alarm warnings and also guidelines on how to evacuate areas of risk safely. It is also foreseen that the application will have the following functions: social and demographic information, risk mapping, garbage mapping, disabled people, elderly, children and adolescents mapping as well as physically challenged people and their homes, the possibility of communication among users and the access to first aid procedure tutorials, the possibility to coordinate emergency actions and etc. The next steps expected are the usability test and the test and validation during a drill to be performed in the neighborhood. It is intended to use the application to contribute to the improvement of community resilience and also the city of Natal in face of disaster risks.

**Keywords:** disaster risks management, resilience, participatory design, situated action, collaborative technology, information and communication technology
Resilience at scale in mass casualty response(I): The Formosa fun coast fire, June 2015.

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The fire at the Formosa Fun Coast Park, Taiwan, had started because of a flammable, coloured powder was sprayed from a stage onto the audience around 20:30 Saturday June 27 2015. Nearly 500 young people were burned, of which 200 burned seriously and 15 had died. Five hospitals were selected in our study for understanding how the hospitals responded to the needs from casualties and provide safe care for the injured. There are one public regional hospital, two government-owned but private operated hospitals (one medical centre and one regional hospital), one private regional hospital, and one missionary hospital (medical centre). This accumulated 144 burn patients. The proposal is to discuss the resilience characteristic of the public regional hospital at the first and intermediate moment of accepting the casualties.

The ED of the public hospital has average 66 patient visits at 8:00-22:00, and 37 visits at 23:00-7:00 per day. They have 3 acute beds and 20 general beds. Two shifts of physician care and three shifts of nursing care are scheduled per day. One internal medicine physician and one surgical physician are allocated for each physician shift; six nurses plus one nurse practitioner are assigned for each nursing shift. 30 burn patients were transferred to the hospital during the accident. They were injured around 10 - 50% of total body surface area (TBSA). They arrived in two waves: 21 patients came in every 2 minutes from 22:04 to 23:06; 8 patients came in every 3 minutes from 23:32 to 23:56; 3 were in serious conditions. The last patient came at 00:20.

The communication about how many patients could be transferred to this hospital was not clear between the Regional Emergency Medical Operation Centers(REMOC) and the hospital especially within the first 2 hours after the disaster. Although the number of transferred patients was far more than the hospital’s expected based on their current capacity, the hospital performed professional responses to this event. These responses were categorized into two groups: common adaptations and special adaptations. Common adaptations indicate those changes that were commonly performed in emergency rooms elsewhere when a disaster broke out. Special adaptations are those changes acted differently from other hospitals while facing the same scenarios, because of particularly limited capacities in the organization.

The study identified major five common adaptations and six special adaptations. The hospital pulled out their surge capacity by these adaptations to provide necessary care for the injured. It is a particular resilience model for a public regional hospital.

*Speaker
Keywords: FORMOSA FUN COAST FIRE, MASS CASUALTY
Improving urban infrastructures resilience using conceptual models: Application of the "Behind the Barriers" model to the flooding of rail transport system.

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The vulnerability of guided transport systems facing natural hazards is a burning issue for the urban risks management. Experience feedbacks on guided transport systems show they are particularly vulnerable to natural risks, especially flood risks. Besides, the resilience concept is used as a systemic approach for making an accurate analysis of the effect of these natural risks on rail guided transport systems.

In this context, several conceptual models of resilience are elaborated for presenting the various possible resilience strategies applied to urban technical systems. One of this resilience conceptual model is the so-called "Behind The Barriers" model based on the identification of four complementary types of resilience: (i) cognitive resilience, linked to knowledge of the risk and the potential failures; (ii) functional resilience, representing the capacity of a system to protect itself from damage while continuing to provide services; (iii) correlative resilience, that characterises the relationship between service demand and the capacity of the system to respond; (iv) organisational resilience, expressing the capacity to mobilise an area much wider than the one affected.

The purpose of this paper is to offer an application of a resilience conceptual model, the "Behind the Barriers" model, relating to a specific urban technical system, the public guided transport system, and facing a particular risk, a flood hazard. To do that, the paper is focused on a past incident on a French Intercity railway line as a studied case. Indeed, on June 18th and 19th 2013, the rise of the level of the "Gave de Pau" river, located in the municipality of Coarraze, caused many disorders on the intercity line serving the cities of Tarbes, Pau and Lourdes. The latter is knowing as one of the world’s most important sites of pilgrimage and religious tourism. Among the disorders caused by the flooding, about 100 meters of railway embankments were collapsed. With a constraint to reopen the line before August 15th, reinforcements were studied in order to stabilize the railway embankment. During the works, substitute shuttle service was set up, providing services between cities.

This French past incident is studied through the "Behind The Barriers" model:

i. cognitive resilience: what was the level of knowledge of the stakeholders concerning the flood hazard?;
ii. functional resilience: what could be done in order to maintain the railway service between the cities?;

iii. correlative resilience: what was the operator’s response about the service demand with respect to the capacity of the railway line to ensure service?;

iv. organizational resilience: what was the mobilization of the impacted cities, the impacted French department, the National authorities... on a wider scale than the flooded area in order to restore the line?

The paper gives the main conclusions of this study and shows that resilience conceptual models such as ”Behind The Barriers” are relevant and powerful frameworks to understand damages on critical infrastructures due to natural risks.

**Keywords:** Risk, Resilience Conceptual Model, Rail Transport system, Flooding
Unreasonable expectations? Examining the use of public tolerance levels as critical infrastructure resilience targets

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Maintaining the minimum acceptable level of service as well as the rapidly restoring full services are two components of critical infrastructure (CI) resilience that are particularly pertinent during disasters[1]. However, no consensus currently exists on what should be the minimum level of service or restoration time. For actors that meet public needs, such as CI operators, the general public’s expectations and tolerance levels should be considered. Furthermore, going beyond basic needs and meeting expectations helps to maintain a good reputation in times of crisis[2]. While an "expectation gap" between what services the public expect CI operators to provide after a disaster and what CI operators are realistically able to deliver is a recurring theme in the literature[3] [4], few of these studies have empirically investigated what members of the public expect in relation to CI during human-made and natural disasters. As such, this paper provides new insight into CI resilience by examining public expectations of CI operators during and after disasters. It does so by drawing on key themes that emerged from a review of the literature on public expectations of CI and presenting results from an online questionnaire-based study (N=403) of disaster-vulnerable communities in France, Norway, Portugal and Sweden. Regarding the minimum acceptable level of service and recovery time, questions were asked for two sectors: water and transportation. Respondents were asked about the acceptability of four below normal service levels for each sector and also about the amount of time they would be willing to tolerate said disruption (from "years" to "not at all"). The paper provides empirical evidence that suggests that the public are willing to tolerate reductions in the level of service. When it comes to duration, the public appear willing to tolerate a reduction for either "weeks" or "days," or "weeks" or "months". The willingness to tolerate a disruption seems to be linked to the amount of inconvenience a given disruption would impart. This suggests that the expectation gap in terms of service provision may not be as wide as was found in the literature review, especially considering that information provision has been found to lead to more reasonable expectations[5]. As such, once known, the public’s expectations and tolerance levels can indeed be used to establish targets for the implementation of resilience by CI operators.

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**Keywords:** critical infrastructure resilience, resilience targets, expectation gap, public expectations, minimum service levels
Contribution of local government to disaster resilience: toward an assessment method

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Despite floods, sacking, shaking, burning, bombing, irradiation or poisoning most of the cities of the world have survived and are still existing [1]. During centuries, cities were, on the one hand, the symbol of protection for people living inside, symbol of order and rationality with police, administration, rules and justice as symbol of control over nature. On the other hand, cities have to cope with specific hazards such as fires, famines, epidemics and natural hazards such as earthquakes or volcanic eruptions [2]. The industrialisation led to the disappearance of famines and most epidemics and man-made risks such as fires are nowadays considered as accidents and no more as disasters. Nevertheless, industrialisation caused the emergence of megacities and consequently increased the interconnectivity between industrial systems, which led to the emergence of new types of disasters such as systemic risks.

Resilience appears as a new paradigm for disaster management, with new expectations such as considering potential systemic or global risks, extending the scope of disaster management stakeholders including citizens and civil societies, increase capacities to respond to unforeseen situations, etc. In this document, definition of resilience provided by UNISDR will be used as reference: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions [3]

Improvement of cities disaster resilience requires the interaction between two approaches. The first is a top down approach, according to which governments are expected to design proper disaster resilience mechanisms such as regulation and inspection regimes, and assign tasks to each level of responsibility. The second follows a bottom up approach, where local governments, citizens, communities, business, non-profit organisations share tasks to increase their risks culture and capacities to prevent, respond and recover from their occurrence [4]

This paper aims describing activities dedicated to the development of a methodological guideline aiming at assessing and enhancing the performance of local governments in the context of disaster resilience, which is easy to handle and applicable by all types of cities. The proposed methodology aims at representing the diversity of works and projects conducted in the context of city resilience to disasters by integrating different methods developed throughout Europe, the United States, Australia and New Zealand into one integrated approach.

The paper is structured into three main sections. The first section is dedicated to the description of the resilience of cities towards disasters and to the role of local governments within
disaster management. The second section outlines the results of the analysis of existing tools for resilience assessment for cities. The last section presents the first version of the solution for supporting the management of the contribution of local government to societal resilience to disasters and first lessons of its experiment.

**Keywords:** Disaster resilience, local government, assessment method
Resilience in Power Systems
Sociotechnical Networks for Power Grid Resilience: South Korean Case Study

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Despite broad engineering efforts to make power grids resilient to all hazards, maladaptive blackout response practices continue to exacerbate isolated failures into systemic losses. Power grid resilience understood by engineering experts focuses on designing robust infrastructure systems to reduce the probability that customers will lose access to electricity. In contrast, blackout response is organized by public administration experts focused on system rebound via policy and protocols to coordinate crisis response to unforeseen infrastructure losses. Together, robustness and rebound practices do not produce resilient power grids, as the large-scale, cascading power failures that overwhelm automatic controls and security constrained operations also overwhelm bureaucratic processes for information-sharing and decision-making established before the crisis. In fact, engineering and public administration approaches to resilience are often established absent from each other – the physical limitations of electric power transmission are not considered in response protocols and crisis management roles are not reflected in robust design. We argue that these isolated practices will continue to produce brittle infrastructure systems, and that blackout response must advance beyond robustness and rebound towards sociotechnical concepts that integrate infrastructure design and crisis management together.

This work uses network science to measure how misconceptions of built infrastructure and their management systems influence sociotechnical resilience in power systems. Network science has emerged in both power engineering and public administration disciplines as an important tool for identifying critical infrastructures that cause emergencies when failed and human interactions that dictate emergency response. We believe that the similarities in modelling and analysis across both disciplines signify the potential for corresponding social and infrastructure networks to mutually inform one another. Specifically, corresponding networks can reveal the mismatches between engineering design and public administration that cause maladaptive blackout response by quantifying: (1) biases in identification of critical infrastructures for failure protection activities, (2) the disconnect between organizational authority in normal operations and coordinated crisis response settings, and (3) which organizations may be more impacted by cascading failures. In this work, we study these three blackout response issues in the South Korean power grid. Network analysis is accomplished by developing corresponding infrastructure and social networks, applying statistical methods to reconcile conflicting interpretations of network models, and generating social networks associated with cascading infrastructure losses. Results demonstrate that separate understandings of engineered infrastructure and organizational coordination do not match those in sociotechnical practice – regions with few power grid infrastructures contain

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those most critical to grid protection, organizations with the most decision-making authority do not broker crisis management information, and few organizations are more adversely affected by cascades than others.


**Keywords:** Electric Power Systems, Critical Infrastructure, Network Science, Sociotechnical, South Korea
Resilience activation and liminality during the Fukushima Dai Ichi nuclear power plant accident

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This article will focus on the definition of the model of resilience activation (Powley 2009) and more specifically on the phase of liminal suspension. The goal is to test this model and to evaluate its contributions and limits. The testimony of Masao Yoshida, the manager of the Fukushima Dai Ichi nuclear power plant during the accident, that was held during official hearings on July and August 2011 (Guarnieri et al. 2015) will be used to test the model and achieve our goal of evaluation.

According to Edward Powley (Powley 2009), resilience activates when organizations confront threats, challenges, or unexpected emergency situations. It defines an organization power to resume, rebound, bounce back, or positively adjust to untoward events. In order to understand this process and how individuals and collective are able to overcome the trauma caused by a crisis in their organization Powley presented a three-phase model. The Resilience Activation model (Powley 2009) considers that three key moments are necessary for an organisation to overcome a trauma: liminal suspension aims to restore the psychological, emotional and relational balance of all of the actors in the system, compassionate witnessing aims to restore social order and relational redundancy aims to restore the balance between the organisation and its environment. About this model we paid specific attention to the first phase: liminal suspension and, more broadly, liminality. In Powley’s work (Powley 2004; Powley and Piderit 2008; Powley and Cameron 2008; Powley 2009; Powley 2013), liminality deals with the unknown, death, transition to a new life. This step is characterized by ambiguity, fear, danger and risk. Nor ranks nor status exist anymore. Individuals have to transform towards a new identity and new norms of relations in order to reconstruct themselves. Liminality is situated between two statuses; it is a moment of renewal that introduces change.

The first section of the article will be dedicated to the presentation of the concept of resilience activation and of the liminal suspension phase as Edward Powley defined them, and to their confrontation with Resilience Engineering concepts and models. The second section will propose an illustration based on the study of Masao Yoshida’s testimonies related to events that occurred within the Fukushima Dai Ichi nuclear power plant from 11th to 15th March 2011.

Keywords: Resilience activation, Liminality : Fukushima Dai Ichi

*Speaker
Resilient Interdependent Power and Water Systems Using Machine Learning

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The U.S. bulk electric power system is regulated to maintain strict reliability standards. Power utilities use Supervisory Control and Data Acquisition (SCADA) tools and detailed power system models to estimate states throughout the electric system. Grid operators—e.g., electric utilities—that act as balancing authorities use this information for internal reliability operations and to communicate with neighboring balancing authorities for increased reliability and prevention of cascading failures. The U.S. water distribution system is not as well-regulated. Reliability standards for water distribution systems are driven by bottom-up organizational management or by public utility commissions at the city or state level. The reduced amount of U.S. regulation can be seen in the number of infrastructure managers—76 grid operators that act as balancing authorities compared to 4277 water system managers that maintain their own operational standards. Utilities of the future will operate their systems with increasing data resolution which will decrease costs of operation, improve operator understanding of system state, and decrease response time to system faults or failures. Access to more data is beneficial for utility operation and improves communication between utilities and organizations. This study introduces data sharing techniques between power and water SCADA systems to characterize, understand, and operate interdependent infrastructure systems. Contingency analysis is employed to monitor the potential effects of component faults or failures across infrastructures. Water systems do not have metrics for reliability comparable to power systems—e.g., area control error—therefore contingency analysis of interdependent power and water systems is a concept yet to be realized that has implications for tomorrow’s smart cities. Deep neural networks (DNN) are developed and applied as a contingency response tool for the interdependent system modeled herein. DNN’s are useful tools to approximate binary and/or continuous nonlinear functions for which there is no direct solution—e.g., interdependency between nonlinear power systems and nonlinear water systems. For a given interdependent network topology, we use machine learning tools to understand continuous perturbations or strict failure of components for systems-wide contingency analysis. Smart tools and methodologies such as machine learning algorithms can enable new paradigms for the resilient operation of interdependent infrastructure. This article demonstrates the use of machine learning algorithms for contingency analysis of an interdependent power system modeled in OpenDSS and water distribution system modeled in EPANET.

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Keywords: resilience, machine learning, electric power, water distribution, interdependence, infrastructure, neural networks, GPU
Supplementation of the risk analysis of fire in the main transformers of the Itaipu binacional hydroelectric power plant with resilience engineering elements.

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Serious accidents in critical infrastructures, although rare, cause significant social and economic impacts in their area of influence. The Itaipu Binacional Hydroelectric Power Plant, an organization with such characteristics, must avoid accidents throughout its operational cycle, even if a ”normal” accident rate is expected due to the high risk factors and complexity inherent to its operation. In order to succeed in avoiding them, a line of study considers important an evolution in safety management: formerly reactive, based on the retrospective analysis of accidents and ”what goes wrong”, now proactive according to Resilience Engineering (RE), which is based on the variability of normal operation and therefore ”what goes right”. By this approach, this article aims to propose a method to supplement the traditional risk analysis of fire in one of the main installation power transformers with elements of ER, by inserting proactive elements based on the experience of the team in a risk analysis based on the statistical failure analysis. It is justified by the socio-technical importance of the installation, by the constant technological changes and by a process of technological upgrading of all control, supervision and monitoring systems of its generating units and substations, making essential a proactive approach of operational safety of the plant. Considering the structured opinions of the operational staff and the precepts, techniques and heuristics of RE, indicators and action plans were proposed to increase the operational safety of regular work.

Keywords: operational safety, power plant, risk analysis

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Modelling organizational learning from successes in the nuclear industry.

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During the past decade there has been a growing interest in utilizing lessons learned from successful experiences to ensure safety in high-risk organizations. For example, the Safety-II approach to safety management emphasizes the understanding of how things go right. In our ongoing study we aim to provide insights into how successes can be identified and utilized for learning purposes in the nuclear industry. We conducted a literature review into the concept of learning from success and two empirical case studies at Nordic nuclear power plants to identify successes, lessons learned, and the learning practices utilized. Data collection consisted of interviews, document analyses of event reports and field observations.

Drawing insights from existing theories, we modelled the findings from our study from the perspective of organizational learning and knowledge management. The purpose of this exercise was to understand how learning processes are utilized in the context of successes in a high-risk organization, what special considerations might be necessary to take into account when facilitating organization learning from successes and what practical tools exist that can support this effort.

We identified four learning-related phases from our data. The first phase – identification and acquisition – serves as the starting point for a learning agent. Within our study, we found three types of means through which success-related information can be acquired: identification of own successful decisions and actions; actively retrieving success-related information by asking from colleagues, reading reports, analysing databases, or conducting investigations; and receiving success-related information through listening to storytelling or participating in trainings. The second phase relates to creation of the lesson. Characteristic activities of this phase are, for example, providing a salient starting point and structure for analysis or reflection, encouraging finding positive aspects within adverse situations and ensuring that the right lessons are learned in order to avoid confirming risky habits or creating organizational drift. The third phase is about storing the success-related knowledge. Storage can take many forms: it can be explicitly codified in systems, or tacitly embedded in individuals or culture. The stored knowledge can then be, in the fourth phase, either utilized in practice or communicated actively to others. The existence of easily accessible communication channels is of relevance in ensuring the effectiveness of active communication of success-related knowledge.

In this paper we will describe the results of this modelling exercise in further detail and provide examples of practices that may facilitate learning from successes in each of the phases based on

*Speaker
our observations from the empirical case studies. In addition, we will present generic types of information flows that illustrate the routes along which success-related information (e.g. lessons learned) may get passed in the organization. This can help pinpoint the processes and practices that facilitate organizational learning from successes. Finally, we will discuss how such a modelling exercise can benefit practitioners working in high-risk industries aiming to develop their organizations so as to learn more effectively and systematically from successful experiences.

**Keywords:** organizational learning, learning from successes, knowledge management, nuclear industry
Resilient power plant operations through a self-evaluation method

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An important aspect in system resilience is the quality of work practices. Assumedly, in nuclear power plant operations, being able to consider situations interpretatively provides good basis for handling various kinds of challenges, that is, with consideration to various information sources and with profound understanding of the plant dynamics as well as in dialogue within the operator crews[1]. This implies that developing training for developing work practices could enhance system resilience.

Certain challenges have been identified in the existing training practices at a specific Nordic power plant site: the crews would need opportunities to witness and exchange the practices with the operators of other crews for the proliferation of good practices between the work shifts. The current safety procedures also dictate operator activity very specifically – capability to handle new kinds of situations is not therefore efficiently developed in the emergency training where these procedures are applied. Exchange and creation of good work practices along with opportunities for more ‘freeform’ simulator try-outs for more profound understanding of the plant dynamics would be beneficial. Some of the challenges might reflect the nuclear domain’s safety critical and hierarchical nature – generally, transition from training where learners are ‘passive objects’ to ‘active and critical subjects’ would be necessary[2].

For enhancing simulator training, we generated a self-evaluation method that aims to dissemi- nate good practices by the means of guided dialogue among the operators. It consists of 1) personal evaluation, 2) group evaluation and 3) inter-group learning. The data collected for this study represents the first two phases. Two questionnaires were constructed for evaluation in first two phases, including simulator task performance related open-ended questions and statements with rating scales. The group discussions (phase 2) were recorded for data collection and analysis.

The focus of analysis is on operator crews’ reflections on the simulator tasks. In short, reflection here means talk where the operators are analysing or commenting on themes prompted by their simulation experience or by the self-evaluation guideline. Reflection is expressed as uncertainty or doubt, dilemmatic speech, expressions of challenges, evaluation or questioning, and expressions of feelings[3].

As a preliminary result, reflection was quite abundant in the broad sense, consisting of more than a half of all discussion. In this sense, we could say that self-evaluations were efficient in enhancing operators’ reflection: they involved dialogue and reflection among operator crews about

*Speaker
their own work practices and capability in emergency situations. However, it is not certain how these contribute to the interpretativeness in actual work practices.


**Keywords:** resilience, training, nuclear power plant operations, work practices
Assessing Resilience
FRAM to assess performance variability in everyday work: Functional resonance in the railway domain.

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Modern trends in the field of safety analysis of current socio-technical systems suggest developing an integrated view on technological, human and organizational aspects of the system. The traditional safety assessment techniques might become ineffective, since they generally evaluate only linear causal dependencies, based on the principle of decomposition, failing at identifying transient and dynamic interdependencies. The Functional Resonance Analysis Method (FRAM) aims to fill this gap, as proved by several FRAM applications in different industries and organizations, even at different operational levels. FRAM aims to define complex systems looking at their functional aspects rather than their physical structure. Therefore, it shows how systems actually perform in everyday work, adapting their functioning to deal with the variability of current operating conditions.

This paper shows the possibility of enhancing the traditional FRAM structure by a semi-quantitative framework in order to increase its applicability for the analysis of complex systems. This innovative framework consists of defining numeric scores for variability, quantifying in a particular scenario the effects of interactions among functions. In addition, rather than static and deterministimc values, it assigns probability distribution functions to the scores, mixing them by the aid of Monte Carlo simulation. The distributions, based on Subject Matter Experts’ judgments and historic data, if available, allow measuring variability of performance and subsequent effects in terms of critical functional resonance. This semi-quantitative framework allows isolating the critical functions and the critical links among functions, considering non-linear and transient interdependencies.

Furthermore, this paper explores the possibility of combining the Monte Carlo framework with a framework based on different abstraction layers, to make more evident and readable the model itself, maintaining a systemic functional perspective. Once addressed the criticalities and related them to different levels (operational, tactical, strategical), it would be possible to decide the priority for future mitigating actions. The illustrative case study takes advantage of SMEs and several accident reports in the railway domain to analyze specific accident data, according to a resilience engineering perspective, clarifying the application of the proposed frameworks based on FRAM.

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Keywords: Safety assessment, Resilience, Functional resonance, Monte Carlo, Abstraction, SME.
A stamp based task and organizational analysis to improve aircraft ground handling safety.

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The research work proposed for presentation as a paper is an output of a research project investigating aircraft ground handling safety based upon the systems theoretic accident model and processes (STAMP)[i]. The work consists of (1) a task analysis of the aircraft ground handling process and (2) an analysis of the organisational setup of aircraft ground handling companies in support of the implementation of safety control actions in the aircraft ground handling environment.

The task analysis (1) consists of a functional decomposition and was initiated by means of line observations following the various input-process-output (IPO) flows occurring in aircraft ground handling operations in order to functionally characterise the controlled process of aircraft ground handling to the highest level of detail (the third level of a functional hierarchy). Collected data were then reported in the functional flow block diagram (FFBD) format and clusters of functions determined at the second level of the functional hierarchy; the latter were then further clustered together to determine the first level of the functional hierarchy. Second and first level functions were also drawn in the FFBD format. The task analysis was continued with the identification of the safety control actions[ii] enforced over second level functions, as documented in the IATA Ground Operations Manual (IGOM). The task analysis was conducted with the aim of characterising the aircraft ground handling process both horizontally - with respect to the informational transformations that occur through the several IPO flows - and vertically - with respect to the safety control actions that have to be implemented to maintain safe performance. The task analysis has led to a detailed horizontal and vertical characterisation of the aircraft ground handling process and to an improved understanding of the differences between functions - the informational transformations that occur within a process - and safety control actions - the precautions or conditions that must be satisfied to perform a function safely.

The organisational analysis (2) is being conducted by means of an on-line survey distributed to aircraft ground handling operations managers and aiming to depict the consistency in the implementation of safety control actions and feedbacks at three control levels within aircraft ground handling companies: the corporate over operations management control level, the operations management over line employees control level, and the line employees over aircraft ground handling process control level[iii]&[iv]. The survey is being complemented by twenty semi-structured interviews to aircraft ground handling operations managers; the interviews are focussed on safety

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performance enablers and inhibitors, as well as on possible status quo improvements, across the three levels of control detailed above and within five control dimensions in aircraft ground handling companies: the quality system, the training system, the safety culture, the supervision system, and the operations design system. The interviews are being transcribed and are being coded for analysis based upon the control loop taxonomy of STAMP:

- controller (and related control action generation and system model);
- control action(s);
- controlled party; and
- feedback(s).

The control loop taxonomy of STAMP is being applied across the five different control dimensions and the three different levels of organisational control, and based on whether the themes refer to enablers or inhibitors of performance and whether they refer to the status quo or possible improvements. The organisational analysis has been undertaken with the aim of identifying - regardless of any specific safety control action directly exercised over the aircraft ground handling process - both enablers and inhibitors of safety performance within the organisational setup of aircraft ground handling companies. The aim is also to identify possible (additional) improvements for organisational redesign based upon the STAMP model of accident causation. Early transcript coding exercises are allowing the deployment of the – generic – control loop taxonomy at three aforementioned levels of control and across the five aforementioned control dimensions; an aircraft ground handling specific taxonomy is also emerging from the transcript coding exercise that is linked to the generic taxonomy: a theme is coded with both the code pertaining to the applicable category of the control loop taxonomy and with a nominal phrase summarising the theme. As an example, the recurrent theme of IGOM’s adoption by aircraft ground handling companies is considered as an enabler of safety performance (+) occurring within the operations design system (ODS) that classifies as a corporate over operations management (CO) control action (CA) representing the status quo (SQ) and therefore generically coded as +ODSCOCASQ. The same theme, however, is also being specifically coded as ‘IGOM’s adoption by corporate management’.


Lessons from the design of a Resilience Engineering based socio-technical system diagnostic method

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This paper aims contributing to the application of resilience concepts and precepts to the design of operational methods and tools with presenting and discussing lessons learned from a collaborative process involving researchers, railway experts and operational agents designing and experimenting a method for analysing socio-technical system resilience performance. First part of the paper aims describing the key phases of the process followed. Starting from the Resilience Analysis Grid (Hollnagel 2013) two prototypes has been successively specified, designed and experimented. For each of these six phases, the context, the methodology and the results obtained will be presented and commented. Second part of the paper will be dedicated to the discussion of a set of lessons learned from this process. Lessons will be related to theoretical concepts, method scope, performance model, data collection and analysis and experiments.

Keywords: Resilience Analysis Method, Railway, Lessons learned

*Speaker
Tracking the emergence of resilience: The role of complexity

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Resilience in complex socio-technical systems (CSSs) takes a wide variety of forms – e.g. proactive, reactive, organizational, individual, team, etc. Nevertheless, little is known on the origins of resilience, which is usually regarded as an emergent phenomenon arising from dynamic interactions between several factors. While this “emergent” perspective is correct, it does not explain how fundamental system characteristics interact to generate resilience. In this paper, we discuss the role of complexity attributes in the emergence of resilience. We build on a previous work[1], which has proposed four categories of CSSs attributes: a large number of dynamically interacting elements, a wide diversity of elements, unexpected variability, and resilience. Figure 1 (see word file) presents a model of the interactions between the attributes.

However, each of the four groups of attributes has a number of dimensions, thus making the relationships displayed in Figure 1 an oversimplification. For instance, diversity of skills of the workforce can interact with resilience in a very different way than technical diversity of materials and equipment. In order to go further in this analysis, we propose a framework (Table 1 - see word file) that shows how some dimensions of the CSSs attributes interact with the four potentials of resilience systems[2]: anticipation, monitoring, responding, and learning.

In this paper, we report an empirical test of some of the propositions implicit in Table 1. This test was carried out in a construction site, by: (i) applying a questionnaire to workers and managers, so as they could point out the extent to which complexity attributes were present; (ii) interviewing workers and managers, in order to spot perceptions about the construction site’s complexity; (iii) describing the four sub-systems that form the socio-technical system under investigation (i.e. technical, social, work organization, and external environment); and (iv) conducting a resilience assessment, by using the Resilience Analysis Grid2(RAG). Data from (i), (ii) and (iii) were cross-checked with data from (iv), thus setting an empirical basis to discuss Table 1.


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Can artefacts be analysed as an agent by itself – Yes or No: what does Hutchins ‘how does a cockpit remember its speeds’ tell us

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Hutchins’ paper ‘How a Cockpit Remembers Its Speeds’ (Hutchins, 1991), emphasised the unit of analysis in exploring the processes and knowledge structures that underpin the activity of a socio-technical system. The context in which artefacts are situated is implicit to understanding socio-technical systems and their underlying processes. Analysts undertaking explorations of socio-technical systems are confronted with an analytical dilemma: where to begin to frame the exploration to derive appropriate and relevant questions to ask. One approach is to explore the interactions between system elements (sub-systems) that comprise flows of information or tasks within the work system.

Resilience engineering has an interest in the interactions between sub-systems. These dictate and influence the availability of sources of resilience that can be drawn upon in exploiting the systems adaptive capacity escalation in response to performance variability as well as the consequences upon other system elements.

Resilience engineering conceives these interactions through the work-system and strategies that are employed when deploying sources of resilience, reconfiguring & adapting the work system. Hutchins investigated this through conceiving the cockpit as a joint cognitive system: how a work-system observed and remembered the speeds by which the aircraft operated. In turning non-observable properties of system performance into adaptive strategies, Hutchins offers the RE community a potential way to study the work-system.

FRAM is proposed as a tool that provides the means by which a work-system can be explored taking system and functional perspectives of the work-system. It is acknowledged that FRAM has limitations. Some relate to the definition of the system of interest. Of more relevance is the question that the FRAM model is built to explore.

A FRAM study was undertaken of the Hutchins’ 1991 work-system and three pilots who flew

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the DC9 provided the domain knowledge to produce an ecologically valid FRAM model through interpreting the documentation and procedures that shape the work system. The FRAM study modelled the joint cognitive system of the flight deck for the specific phase of flight that Hutchins examined – the descent phase, from top-of-descent to final approach.

It is widely recognised that developing an understanding of the work system is an essential preparatory stage. FRAM produces a view of how sources of resilience can be deployed with an assessment of their properties, but some other analytical mechanisms outwith FRAM are required to yield a structured approach.

By using a structured approach, knowledge of the suitability of FRAM to explore a work system previously studied could be assessed, and the results compared. Especially, Hutchins’ interest in exploring beyond mere human agents that can alter the focus on other units of analysis that might otherwise be overlooked. FRAM analysis might not need some of these emergent units of analysis and could describe performance variability without these additional constructs.

The paper will report what was undertaken, the understanding gained and results drawn with a comparison made with Hutchins paper and usefulness and utility of specific preparatory steps before building a multi-layered FRAM model.

**Keywords:** RE, Sources of resilience, FRAM, socio, technical systems, work system, cognitive artefacts, Joint cognitive systems, system properties
Methods and Analytical Frameworks for exploring adaptive capacity

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As the interest in Resilience engineering grows, so does the need to have operationally viable methods that can be applied to provide meaningful assessments of resilient performance. A methodology that is accessible to a community of practitioners that are unlikely to have extensive background theoretical knowledge of the concepts of Resilience Engineering is sought.

In two SESAR Projects, development of a methodology to assess resilient performance as part of a larger safety assessment method was undertaken iteratively. The resulting RE method was integrated into the Safety Reference Material, it being mandatory in the SESAR safety assessment methodology to assess whether a project will benefit from an R.E. assessment of the designs used in SESAR operational concept development projects that exploit the potential of new technologies.

Taking the earlier derived RE method, it was applied on two new operational concepts for further development. Following the first of these applications, a critical review led to recognition that derived RE method required further development with a change of emphasis.

In order to understand adaptation and resilient performance in work systems, which was the objective of the assessment methodology, it was decided to use an understanding of the strategies that are enacted as work-as-done that are employed in managing and responding to surprises and the underlying philosophy of the adaptation. This focus required that the potential features of the operation, the sources of resilience and resources drawn upon, the way in which escalation can take place, the trade-offs that are faced and the means by which the work system can return to some stable state were understood. The consequences of these adaptations are elicited therefore, from the knowledge of those who undertake the work in real world settings.

The methods and techniques to understand resilient performance - by exploring the adaptive

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properties of the work system and its associated consequences - were explored and a methodological framework developed. The methodology was developed from critically reviewing available methods, selecting those to use drawn from systems thinking techniques, knowledge elicitation and other methods that provide the means to carry out meta-analysis. These were then applied on three new concepts for ATM system development, in an analytical framework including several methods that have been employed in studies of resilience, and some that had not.

The RE assessment methodology evolved into an analytical strategy that was subsequently used by domain safety practitioners, who operationalised the methodology.

A step by step process evolved that included building an understanding of the work system in preparation for a workshop; the output being captured as visualisation of the current and proposed work system. This formed the basis for an eventual functional synthesis of both current and envisaged work systems. A workshop was used as the principal means for exploring resilient performance of the current operation and the future design.

This paper discusses and reports the evolution of the RE assessment methodology, critically reviews the methods employed, the analytical strategy derived and discusses the results achieved

**Keywords:** Adaptive Capacity, RE, Methodology, methods, adaptation, graceful extensibility, work, as, done, work system, RE assessment methodology
Organizing Team Resilience
Safe Mooring Operations: A functional approach to routine work?

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This paper is an enquiry into mooring of merchant vessels. Much can be learnt by understanding routine work rather than analyzing an accident as an isolated event to the depth of details. The severity of an isolated accident tells us much less about how a system functions than frequent undertaking of routine work except that in the case of latter we lack a vocabulary and method. Unfortunately, this is how we understand most accidents and hence fall into a negative framework of shaming and blaming the people and ‘fixing’ the system. What follow is more controls, procedures and barriers none of this of much practical value if we fail to understand how routine work is performed. This paper introduces a method and a vocabulary to make sense of routine work through firsthand experience of an accident of the author.

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From resilience to routines and back: Investigating the evolution of work adaptations.

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SIGNIFICANCE PROBLEM
No socio-technical system is fully pre-specified: people always fill in gaps. This is a sign of resilience: the ability to adapt to changing circumstances to meet production and safety expectations. However, when teams do the same task multiple times, teams do not only respond to their current conditions. Teams also replicate parts of what they have done before; they also have a path dependency. Our research has explored the space between variation and replication in performing a task, the formation of a routine, and the change of routines. METHOD To investigate this, we studied both blast crews in mines and power line crews. Both blast crews and power line crews do safety critical work and have (partly) interchangeable roles within crews. We conducted fieldwork for a total of seven weeks (usually with 12-hour shifts) across different crews and different locations. The fieldwork consisted of observation, as well as semi-structured interviews about what people would do in different situations. The focus was on:
• How different actions followed each other
• Differences and similarities between different instances of similar tasks
• Differences and similarities within crews, between crews and between locations
• Historical changes in how people would have addressed similar problems

RESULTS SO FAR
While the literature often described routines as repeating patterns of actions, we found considerable variation in the patterns of actions. However, we did find consistency in ‘in-between-states’ towards the completion of the goals and meaning given to the environment. Practitioners used different actions, different orders of actions, and different resources the reach the same state. The idea that there was an ideal pattern of actions did not fit, instead, crewmembers acted opportunistic by using what was available. For some isolated tasks, some crew members in one crew could show certain patterns more often than other crew members did, but crew members were not aware of these differences nor did these differences have any noticeable effect. However, crewmembers would correct each other on differences in in-between-states created, even if the created states were functionally as good. The standardisation of in-between-states created recognisable markers of task progress and made incidental deviations stand out. The standardisation also allowed for team ‘cultures’ to form, where crews had their own symbols and associated meaning.

While there is replication in routines, routines are not completely permanent. Routines can

*Speaker
evolve quickly, even without crewmembers explicitly instructing each other. One change often creates the conditions for the next change. Elements that facilitated change included: goal feedback, varying task conditions, exchanges of practitioners between crews, and a semiotic system that supports coordination of new goals and constraints.

CONCLUSION
The actions of a team can quickly change if the environment changes. However, there was consistency in the problem understanding, a division of the problem space into sub-goals, and the semiotic system. To these sub-goals, there is freedom how these are reached. These elements are carried over through between enactments and show permanence between enactments but can change over time.

**Keywords:** routines, long term adaptation, team resilience, semiotics
Improving team resilience by supporting mindful cooperation awareness.

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Background
Resilient teams are able to adapt to dynamic working conditions (Rankin, Lundberg & Woltjer, 2014). This ability emerges from cooperation of team members. When the same people work together over a longer time period, team specific patterns of cooperation evolve, triggering mutual expectations among team members. These patterns and related expectations reflect cooperative adaptations to dynamic working conditions. They foster team resilience and are a part of a teams’ collective (embedded, see Lam, 2000) tacit knowledge.

Collective tacit knowledge evolves from the cooperation of different team members and hence from the interaction of different individuals’ tacit knowledge. Such, it incorporates individual tacit knowledge regarding local adaptation strategies, which has (unconsciously) settled in over time. Sometimes these strategies do not entirely comply with official guidelines.

Over time, team members individually and often unconsciously develop expectations regarding the cooperation within the team. These expectations as well as their mutual compatibility are key elements of both, of the collective tacit knowledge as well as of distributed situation awareness (Salmon et al., 2009). A lack of systematic cultivation of such collective tacit knowledge may cause disruptions in cooperation, e.g. in case of staff fluctuation. New team members unfamiliar with the team specific cooperation patterns may base their actions on official guidelines and standards while, at the same time, long-time team members behave according to the patterns that settled in over time. This can lead to an incompatibility in mutual expectations causing disruptions in cooperation and finally reducing team resilience.

Developed and pilot tested method
In close cooperation with Swiss NPP’s a method was developed and piloted that supports systematic cultivation of collective tacit knowledge. The method supports the elicitation (Nonaka & Takeuchi, 1995), the sharing and the cooperative handling of collective tacit knowledge as well as of potential uncertainties emerging from incompatible mutual expectations. Such, the team members’ cooperation awareness is enhanced, incompatible expectations are revealed and disruptions in cooperation can be prevented.

The method incorporates three parts: a pre-job workshop, a post-job workshop and a sys-
tematic exchange of tacit knowledge and mutual expectations during job execution. The three parts build on one another supporting stepwise deepening mindful cooperation awareness.

**Result of pilot test**

The pilot showed that the systematic fostering of cooperation awareness enables an ongoing monitoring of mutual expectations and uncertainties regarding cooperation thereby making explicit individual as well as collective tacit knowledge. Such, incompatibility in mutual expectations can be anticipated earlier and proactive measures can be taken to avoid disruptions in cooperation. Furthermore, team members become more mindful regarding success-relevant aspects in cooperation which normally are often not taken into account. Thereby they are also empowered to recognize conflicts between being resilient and ensuring compliance in the cooperation at an early stage. Furthermore, a regular application of the method supports an organization to learn from tacit knowledge based local adaptations. The method as well as the results of the pilot will be presented in detail in the paper.

**Keywords:** team resilience, collective tacit knowledge, cooperations awareness, mindfulness, mutual expectations, local adaptations
Innovation resilience behaviour in team work.

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In this paper the focus is on the sustainability of people at work. This means that workers need to remain healthy, employable and vital and resilient (have the ability to bounce back from adversity). Remaining healthy, employable and vital, asks for human resilience at work or for workers’ ability to bounce back from adversity (Demerouti, Bakker, Nachreiner & Schaufeli; Hobfoll, 2011; Salanova, Schaufeli, Xanthopoulou, Bakker, 2010). This contribution is project- ing that starting point on teams and on a specific type of work, namely carrying out innovation projects. There is much debate about the failure of innovation and of projects. We explore what team environment can help to reduce such failures, and whether such environments – that we call mindful infrastructures – enable teams to be more effective and successful. For this purpose we look at teams from other context, namely teams of High Reliability Organisations (HROs). HROs deal with high risks but hardly ever fail. Such organisations – like nuclear plants, aircraft carriers, fire brigades and surgical operation rooms – develop highly reliable team behaviours, which they label as ‘mindful’ and ‘resilient’ (Weick & Sutcliffe, 2007). We transfer this kind of team behaviour to the context of innovation management and brand it as ‘innovation resilience behaviour’, the ability to bounce back from critical incidents that may cause innovation projects to fail, and to ensure the team stays on track to achieve its project goal (Oeij, Dhondt, Gaspersz & de Vroome, 2016). Can innovation teams benefit from the experience of HRO-teams?

Literature:


Keywords: resilience, teams, innovation, mindful organising, project
Opportunities for synergies between Resilience and a positive Work Organisation

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Opportunities for synergies between Resilience and a positive Work Organisation

Twenty seven companies in seven European countries participated in a research on the implementation of the Zero Accident Vision (Zwetsloot et al 2015). Though most of these companies explored several innovative ways to improve safety, none of the 27 companies explicitly referred to the concepts of resilience engineering or high reliability. In a survey it was confirmed that there was still a clear opportunity to further improve in this area.

Nevertheless these ZAV companies seem to develop their organisational capacities in the direction of more resilient companies, which enjoy higher reliability. They developed their capabilities for monitoring, anticipation, and learning, (known to be relevant for resilience, (Hollnagel et al. 2006 and Hollnagel 2011). There was a high ‘individual commitment to zero’ from managers and workers, they developed the alertness to hazards and risks, and scored high on ‘safety empowerment’. In some companies the people were ‘invited to challenge their supervisors’. These capabilities seem to be aligned with respectively preoccupation with failure, sensitivity to operations, deference to expertise, and reluctance to simplify (capabilities know to be important for High Reliability Organisations, Weick & Sutcliffe 2007).

Several companies adopted the broader Zero Harm perspective, while most others recognised it is a future challenge to broaden their preventive efforts towards Health and/or Wellbeing at work. This will stimulate them to address the work organisation.

In resilience engineering deviations in processes are regarded as normal. In the research on work organisation and wellbeing at work where deviations are called ‘demands’ the worker has to deal with, that is also the case. Therefore there seems to be plenty of opportunities for synergies between resilience, the implementation of a broad Zero Harm concept, and the promotion of wellbeing at work.

Goldenhar, Williams and Swanson (2003) showed a correlation between several work organisation factors (e.g. job demands, job control, job uncertainty, training, exposure hours, and job tenure) and safe work practices in construction, and Glasscock et al. (2006) found similar results in farming. Bergh et al (2014) found a correlation between psychosocial risk factors and hydrocarbon leaks on offshore platforms, whereas Ramvi (2003) showed a correlation between the quality of the psychosocial work environment and commitment to safety at work at two different oil installations in the North Sea. According to Chan (2011) fatigue is the most critical

*Speaker
accident risk factor in oil and gas construction. A meta study by Nahrgang et al. (2010) showed that job demands and resources relate to safety outcomes.

Positive psychology (with its focus on ‘resources’) seems not only relevant for ‘work engagement’ but is also likely to be relevant for resilience and the safety 2 concept (Hollnagel 2014). Grøtan et al (2017) pay much attention to the role of ‘resources’ for increasing resilience capabilities.

It is therefore important to explore synergies between resilience, reliability of production, and a positive work organisation, i.e. to include work organisation factors in the practices of resilience engineering.

**Keywords:** resilience capabilities, work organisation, wellbeing at work, positive psychology
Resilience Engineering, Definition, Modeling & Methods
A practical workshop-based method for resilience engineering

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Under the premise that a more resilient operation is better able to be safe and efficient, this paper presents a pragmatic approach for analysing the resilience of future air traffic management (ATM) operational concepts and improving their design. The approach uses a workshop with operational experts as a central element and follows five steps. The last two steps use key new elements specific for this approach; the first three steps are used in other safety methods as well, but are adapted to better support the last two steps.

Step 0: Scoping - Planning and outlining the work to be undertaken.

Step 1: Describe operations - Building an initial understanding of the work-as-done in current ATM operations and of the way that future ATM operations are expected to be done.

Step 2: Varying conditions - Identifying a list of expected and unexpected varying conditions in the current and the future ATM operation.

Step 3: Adaptive capacity - Identifying the strategies that operators use when they are dealing with these varying conditions, and analysing the adaptive capacity of the current and future ATM operations. The strategies are acquired in a workshop session with air traffic controllers, pilots, supervisors and other experts. A narrative description of the available strategies, the decision-making process of when to use which strategy, the coordination required, the need to adapt each strategy to specific circumstances, and insight into how the strategy is acquired, i.e. through education or through practice and experience, provide input to understanding the resilience of the operation.

Step 4: Improve resilience - Deriving recommendations for strengthening the resilience of current and future ATM operations. In a workshop session, the operational experts involved in Step 3 identify improvements at the levels of design, management, operation and key performance areas such as safety, capacity, environment and cost-benefit. After the workshop, complementary design improvements are identified through analysis of all the material collected so far.

The approach is illustrated through application to an air traffic management (ATM) operational concept that uses Aircraft Surveillance Applications System (ASAS) for sequencing and merging of aircraft towards an airport. Output is an evaluation of the resilience of the operation, and the identification of a range of recommendations for the design of this operation, such that its resilience can be improved. This output has been used to further develop the ASAS sequencing and merging concept.

*Speaker
The workshop sessions supporting Steps 1-4 have been designed to address all aspects of resilience, yet such that resilience engineering jargon is avoided as much as possible and the participants can express their views in close relation with their own operational experience. The operators in our workshop were very positive about the approach, which allowed them to explain all the things they do to make ATM safe, rather than getting blamed for some rare and difficult situations they were not able to completely solve given the circumstances. Resilience appears to be something they encounter in their everyday work.

**Keywords:** resilience engineering, method, workshop, air traffic management, future operations, practical, application
Towards an operationalizeable definition of resilience.

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Background: The concept of resilience is becoming widely used by many industries where safety and security is crucial for success. Often, resilience is being regarded as a homogenous concept, valid to be applied on individuals, organizations, government and even societies equally well. Unfortunately, this popularity led to rather diffuse definitions that are sometimes difficult to operationalize. In this paper, we present a definition of resilience that can be used in CD&E Experiments regarding socio-technical systems.

Method: Principally, there are two different approaches to a definition of resilience. The typological (or deductive) approach is often referred to because of its intuitive accessibility. There are several drawbacks to this perspective of which the inherent ambiguity is probably the most significant one. Following the typological approach, it is well possible that a completely non-resilient system shows a typical resilient response behavior, while, on the other hand, a truly resilient system may show a degrading performance that has nothing in common with a typical resilience performance curve. The taxonomic (or inductive) approach may overcome some of these problems but is not as intuitively accessible as the typological one. However, in this paper we focus on the taxonomic approach and limit the scope of our work to the definition of resilience in socio-technical systems.

Results: We refer to resilience as a property of systems only to emerge in a state of overload. Overload occurs, as soon as performance requirements (R) exceed the response capabilities (C) of a given. Therefore, overload can be formalized as C/R < 1. Furthermore, resilience is defined as the capability of a system to stay productive in an overload state and to overcome the overload state through adaptation. We identified several principles (we call them "resilience adapters") that enable the emergence of a resilient reaction, such as fractality, T-shapes or recombinability. Additionally, we found that a resilient reaction can be separated in a degrading phase and an adaptation phase, where each phase utilizes different resilience adapters to generate a resilient reaction.

Conclusion: In this paper, we will propose an operational definition of resilience in socio-technical systems. Some fundamental principles we had found to enable the emergence of resilience will be presented and the pros and cons will be discussed.

Keywords: resilience, definition, framework, adapter, fractal, overload, phases, operational, CD&E, socio, technical, military

*Speaker
Experiences and lessons from developing RE Methodologies

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A growing critique of the Resilience Engineering (RE) community is that RE is too theoretical for practical use. The SESAR project included two projects developing an RE assessment method. These concluded with it being mandatory in the SESAR safety assessment methodology to assess whether a project will benefit from an RE assessment in the design, evaluation and validation process for new ATM system designs.

The first SESAR-RE project established a theoretical position and then developed a method for exploring resilience, validated on a new SESAR ATM concept design. The derived method used workshops, interviews and observations of simulations with operational personnel as the means to explore resilient performance by addressing work-as-done of the current and expected future operation with eight RE principles as a guide.

The second SESAR-RE project applied this method too other SESAR projects—initially Multiple Remote Towers. As a result of this application, the assessment method was determined to require change. The focus in the method changed to operationalising adaptive capacity within the safety assessment.

Candidate methods were identified that were applicable for exploring the sources of resilience, the strategies employed in managing surprises as well as nominal work.

A further iteration was undertaken, including the application of an RE method by two Air Traffic Management safety assessors, well versed in the techniques and philosophy of classic safety techniques. Integral in the RE assessment method is a workshop with those actors who are determined to be system actors, thus sources of resilience can be identified and the consequences of drawing upon them derived.

The objective was to integrate an assessment of resilient performance into the safety assessment of the project under study. The two safety assessors were trained in the method and
then undertook and facilitated the workshop analysis and results, supported by project team members. The two assessors developed a coding schema that supported the eventual acceptance of hitherto hidden safety implications of the design.

In the course of undertaking the research the tension between the approach of research scientists to RE and Safety-II and the safety community immersed in the classic safety background and who are part of the community of intended users of the RE method needed to be navigated.

RE results and narratives therefore need to emphasise the added value that they can bring to not only safety but to effective system performance and within resource constraints. The two practitioners recognised the value that RE can bring to safety assessment, that it may even replace traditional safety approach. These are discussed and the implications for RE practitioners argued.

This paper shares the experiences of a project where the objective was to operationalise RE, discusses the issues that arose in terms of RE theory, methodology & politics, proposes the means to navigate these based on the experiences that the RE team had, the principal lessons learned and proposes suggestions for the RE community to embrace in the pursuit of ensuring RE moves from theory to practise.

**Keywords:** Methodology, Adaptive capacity, Safety Assessment, SESAR, RE
Agent-based modelling and mental simulation for resilience engineering.

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ABSTRACT
Agent-based modelling and simulation (ABMS) is an approach for modelling complex systems by describing the behaviour and interactions of a collection of autonomous decision-making entities, called agents. The overall system behaviour emerges as a result of the individual agent processes and their interactions. ABMS provides a highly modular and transparent way of structuring a model, thus supporting systematic analysis, both conceptually and computationally. An agent-based model of a sociotechnical system describes the performance and interactions of its constituent human operators and technical systems working in an operational context. ABMS offers the possibility to combine a large variety of models for expressing the behaviour and performance variability of the interacting agents in a sociotechnical system.

We present ABMS as part of a generic cycle for resilience engineering (RE), including scoping, description of operations, identification of varying conditions, analysis of adaptive capacity, and improvement of resilience[1]. In support of the adaptive capacity analysis, there are two ABMS phases: qualitative ABMS and quantitative ABMS. Qualitative ABMS includes the development of a qualitative agent-based model and it uses this model for reasoning on relations and dynamics of agents’ states. The qualitative model development includes the identification of agents and their interactions, and the determination of model constructs as a way to describe the behaviour of agents in an operational context. Reasoning on the basis of the qualitative model is called ‘mental simulation’ and it is used to explicitly identify agents’ interactions and to reason about the development of performance variables given particular varying conditions. Quantitative ABMS includes development of a formal model, software implementation and computer simulation.

The approach will be presented in detail for aircraft runway approach operations using conventional systems and an advanced aircraft surveillance application system. We will show by this air transport case that ABMS is a detailed analysis approach for studying resilience of sociotechnical systems that offers a flexible range of model constructs enabling representation of the work-as-done in the system. The agent-based perspective fits well with usual views on elements of a sociotechnical system and it naturally couples states and behaviour of the agents.

Preference for an oral presentation

The research on ABMS for RE was published in a journal[2], but is has not yet been presented at a conference. We’d like to discuss this innovative approach with researchers at the
REA Symposium.

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Keywords: agent, based modelling and simulation, air transport
Time Dynamics of Adaptive Capacity

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SUMMARY OF THE PROPOSAL / ABSTRACT
We have previously presented empirical observations of a expression of resilience – adaptive cross-coverage in an emergency department1. In this paper we focus more deeply on analyse the resources that support that adaptive capacity as they have developed over time, following an approach first developed by Ekstedt and Cook2.

RELEVANCE FOR SYMPOSIUM
Resilience engineering has been rightly criticised as speaking of systems but focusing most attention on individuals3. This paper moves beyond descriptions of resilient actions by individuals to identify resources at different levels of the system that enable those actions4; the resources that allow the system to be poised to adapt, even though it may not have (yet) been called on to activate those adaptations. We pay particular attention the temporal character of those resources2, some of which have accumulated over long periods of time, spanning at least 7 orders of magnitude in time from the moment of resilience expression.

SIGNIFICANCE/TAKEAWAY
Resilient performance in a moment of crisis or opportunity is more than just extemporaneous improvisation, but depends on long-standing pre-existing properties of the system. Because they are long-standing and may not often be called on, they risk being taken for granted. Frequent small events using these resources tends to keep them in mind, while long periods of apparent normality may lead them to decay, be subverted to other goals, or be inadvertently damaged by organisational change.

Our observations suggest that studying detailed paths of particular resilience expressions in hopes of emulating, replicating, or ”operationalizing” them is not likely to be successful, for two reasons. First, it is dependent on resources and investments made long before they are called on, and likely for purposes unrelated to the current moment of crisis or opportunity. Second, any particular expression is also dependent on a constantly changing matrix of contingencies, so the same path is unlikely to ever be repeated exactly. Attention should instead be focused on the resources called upon, how they are recognized, how investments in them are defended and maintained, and how practitioners recognise the degrees of freedom available to them.

REFERENCES

*Speaker


**Keywords:** capacity to adapt, time dynamics, emergency departments, health care
Infrastructure, Safety & Resilience
Four questions about safety

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In this paper we focus on the issue: what is resilience engineering? a theory? A methodology? A way of thinking? A code of behavior?
To answer, we analyze four questions:

- The ontological question: what is safety?
- The epistemological question: how do we know safety and how can we measure it?
- The methodological question: how do we make safety?
- The ethical question: who and why should assure safety?

During the Eighties some disciplines such as biology, ecology, neurology, genomics and others that had to cope with complexity found themselves in a ”gridlock” because the ineffective approach of the reductionist paradigm. Complexity became a ”buzzword”. New ways of looking at the reality emerged: attention to the relationships rather than the single components, levels of observation rather than a neutral point of views, interaction, integration and retro-action between systems, history of the organism rather than a snapshot of ”now and here”. Many scholars such as Edgar Morin focused their research on the development of a new paradigm. His path towards the foundation of reality went back till the Big Bang, to detect which are the fundamental law of nature, verifying if they are applicable to the biological world as well. The amazing, systematic work of Edgar Morin (but also other authors, like Fritjof Capra, to mention one) is illuminating because he places complexity as a way of thinking. Today we can benefit of this new paradigm, translating the concepts belonging to the philosophy of complexity to our socio-technical systems.

Resilience engineering is an approach that adopts most of the basic principle of this philosophy. However, as a meta-cognitive effort, how can we place this approach compared to others, namely Reason’s model, Normal Accident Theory by Charles Perrow, or the Man-made Disaster Theory by Barry Turner?

The paradigm is enough to avoid accidents as a set of good practices, or it is simple a way to understand why past accident happened? Is it a way to interpret safety, and hence responsibility, accountability and liability? Is it a guideline for a correct statement of a safety culture

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in an organization?
Before answering to these questions, a step back is necessary, to find out the foundations of this approach. The analysis of safety is propaedeutic to the definition of resilience engineering. Four questions have to be addressed in order to enhance the awareness of this approach: what is safety? How do we know safety? How do we make safety? Who and why should we assure safety?

**Keywords:** safety, resilience engineering, ontology of safety, epistemology of safety, methodology of safety, ethics of safety, safety models, complex systems
The embracement of risks. How to make sense of 'resilience' for public and industrial safety?

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'The capacity of a system, enterprise, or a person to maintain its core purpose and integrity in the face of dramatically changed circumstances' (Zolli & Healy, 2012, p.7 )

The avoidance of risk to ensure safety and security should not be the primary goal of a community or organisation because that could undermine the primary processes of living in a community or working for an organisation. Safety and security is something that often develops indirectly as a result of involvement. It is under these conditions that a community or organisation will be more resilient. The ‘simple, local and diverse’ as advocated by Zolli & Healy (2012) resonates as a response to the state-centred view on public safety and the tightly coupled and complex system in industrial safety. In order to be flexible resilience is sceptical of a central and hierarchical organization of safety and security. Furthermore resilience does not shy away from risk because risks offer all kinds of opportunities and gains. In a similar fashion as cost-benefit analysis resilience understands the management of risks as a trade-off between efficiency vs. fragility and inefficiency vs. robustness (Zolli & Healy, 2012). The logic of resilience has however less to do with predictability as it seems to be a fundamental preparedness no matter what.

Public safety is basically about living together as citizens. Crime and nuisance can be a problem for a community. Industrial safety is basically what organizations have to do in order to make sure that employees return home safely. In every type of organization accidents can happen because of work processes and human error. How to prevent both types of safety and security problems? How about giving people living in a community more responsibility and giving employees working for an organisation more discretionary power? I believe a community police officer and a line manager could learn from one another in how to change human behaviour and create conditions to do so. By focusing on active citizenship in a community and safety culture within an organisation I would like to discover how increasing resilience would work to promote safety and security within both communities and organisations.

The purpose of this study is to create an exchange of strategies used in the world of public safety that has been increasingly discussing its concerns in terms of resilience and industrial safety which has been discussing the concept of resilience for many years. I would like to connect recent talk about building resilient communities with the work of resilience engineering. What can both communities and organisations learn from each other in terms of best practices and policy transfers? I think municipalities and corporations can benefit greatly from a cross-fertilization between the domains of public safety and industrial safety. However there

*Speaker
are crucial differences between the mentioned social systems making the application of resilience rather problematic. This paper will also emphasize the limits of a catch-all term such as resilience. When does it stop making sense?

**Keywords:** resilience, risk management, public safety, industrial safety
Creating foresight and resilience in emergency care through real-time operational ‘vital signs’ and predictive analytics

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Foresight to anticipate and respond flexibly and effectively to changing and unknown conditions is a critical measure of resilience. Forecasting operational demand, with ongoing reassessment and calibration with real-time data, may facilitate foresight in anticipating resource needs to match capability and demand.

The nature of emergency care is to expect the unexpected, and to provide timely response to acute illness or injury. However, the capability to take on new work is limited by crowding and lack of organizational foresight. Mismatch between demand and capacity contributes to prolonged length of stay and adverse patient outcomes, including mortality and hospital admission. This ‘falling behind the tempo of operations’ - a classic pattern of decompensation in complex systems - is an everyday pattern in an urban ED.

Operational ‘vital signs’ are real-time metrics that offer an estimate of incoming work, completed work, and work in progress, with the purpose of matching capability/capacity to demand. Key operational metrics that emergency care practitioners use to understand how the department is working are: 1. Total number of patients – metric of crowding; 2. Number of patients in the waiting room – metric of access block; 3. Number of CTAS 2 patients in an unmonitored space – metric of acute resource matching; and 4. Number of patients waiting to be seen – metric of incoming work. Added to this suite of indicators is the evidence based metric of mean ED length of stay – metric of work in progress. These 5 ED ‘vital signs’ are meaningful real-time operational metrics, but are not easily accessible in one place. We have implemented an hourly electronic printout of these indicators to facilitate proactive system response, including surge response, patient movement, and progress chasing. Further work on electronic data visualization and threshold linked action plans is underway.

Prior efforts to model ED operations have used a variety of mathematical models, but forecast modelling is challenged by the dynamic, state-dependent, and nonlinear nature of inter-actions and interdependencies in the ecology of a complex adaptive system. We are using high dimensional administrative data for all patient visits to six EDs in an urban Canadian health region from April 1, 2014 to March 30, 2016 to build a data-driven predictive model by adapting published methodology. This includes rolling average, LASSO, and K-nearest-neighbour (KNN).

*Speaker
By comparing the prediction errors (mean squared error) of those methods, we have found the LASSO predictions to be the most accurate. The average performance of LASSO is comparable to the best prediction error in the literature. We are working on improving the prediction error by exploring other learning-based prediction methods, such as random forest, and nonlinear state-space reconstruction method.

Forecasting operational demand facilitates foresight in anticipating resource needs to match capability and demand. Moreover, it fosters dialogue with stakeholders from community and acute care, and contribute to awareness and anticipatory actions. Data-driven changes are anticipated to lead to improvements in length of stay and patient outcomes.

**Keywords:** predictive analytics, operational metrics, healthcare, emergency department
Focusing on success: A safety-II approach on operational maneuvers in the Itaipu binacional hydropower plant.

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Serious accidents in organizations with critical infrastructures, such as the Itaipu Binacional Hydroelectric Power Plant, although rare, cause important social and economic impacts in their area of influence. Therefore, they must be avoided even if a "normal" rate of accidents is expected because of the risk factors and complexity of the operation. This dissertation presents an investigation on the conditions that lead to accidents in the operation of Itaipu Binacional under the proactive approach of Security II management according to Resilience Engineering (RE). It is based on the variability of the normal operation and, therefore, "in the many things that go right", in contrast to the traditional and reactive view of Safety-I, based on the retrospective analysis of accidents and "the few things that went wrong". After a review of the literature on the requirements, principles and themes of Security-II, finding inspiration on the FRAM method and on the structured opinions of the operational staff, it was studied the normal operation and variability of four typical operational maneuvers selected by operators within four quadrants of a periodicity-complexity matrix. The results indicated that the same variabilities influence the operational steps, regardless of the complexity or the periodicity of the maneuver. A comparison between the analysis of the variabilities in normal situation and the reports of the four operational failures occurred between 2006 and 2015 indicated that success and failure come from the same source, and that some variabilities such as "maneuver environment", "necessity to confirm the maneuver steps" and "situations that take the attention of the operator" act decisively in virtually all maneuvers. The results were discussed with the team members who proposed the necessary adaptations to increase the operational safety of normal work from the RE perspective.

Keywords: safety, ii, operational maneuvers, power plant

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Resilience in Aeronautics and Space Systems
Flexible procedures to deal with complex unexpected events in the cockpit.

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Modern flight crew operate in an environment with multiple detailed procedures to cover critical abnormal events, and with systems that are automated and highly reliable. Complex and unexpected events without a clear procedure or systems solution are rare, and may thus present a challenge to the crew in knowing how to assess the situation and decide on a course of action. However, unexpected events still occur, and can in some cases be complex, which may adversely affect the crew’s ability to react and deal with the event. An example of this is the engine explosion that occurred on Qantas Flight 32 leading to a multiple systems failure. The accident exemplifies how an experienced flight crew initially try to apply procedures as required, but eventually needed to adapt their response to the situation that they faced and be flexible in the application of the procedures.

In the recently completed ”Man4Gen” EU project the flight crew’s ability to respond to unexpected events was investigated in a series of simulation experiments, with an aim to identify strategies to assist the crew in dealing with complex situations with multiple system failures. Initial experiments with 20 crews were used to identify strategies applied by different crew in dealing with situations where no single procedure was applicable and thus required a certain amount of problem solving and decision making. The experiment scenarios included complex unexpected events, such as a bird strike that caused problems on multiple engines. The aim of these scenarios was to create a situation with multiple conceivable options for strategies of how to cope with a problem, where there was no single correct strategy based on normal operating procedures. The findings were then used to develop a guide in the form of a flexible procedure that would assist crews in responding to events for which there was no single, clear, procedure. This flexible procedure was evaluated in a second set of experiments in a simulated operational environment with 18 crews from several international airlines.

This paper describes the development and evaluation of the flexible procedure based on the strategies that were applied by operational flight crew responding to unexpected and complex events in flight scenarios. The outcome of the initial experiments identified the strategies and competencies that were most beneficial to the resilience of the crew in the experiment scenarios. It is these strategies – problem solving, decision making, leadership, communication – that

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formed the basis of the separate steps in the flexible procedure. The result focuses on three phases to manage time criticality, manage (un)certainty, and finally to plan for contingencies and changes. These phases were translated into steps in a procedure that can be used by flight crew to assist them in responding flexibly and therefore to a variety of events. This forms the basis of the discussion of how training procedures can be used to assist resilience in the cockpit, rather than forming a barrier to it.

**Keywords:** Aviation, Flight Crew, Flexible Procedure, Unexpected, Training
Conceptual and computational modelling of coordination mechanisms in air traffic management.

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The commercial air transportation system comprises many different interacting with each other human actors, such as pilots, actors in Air Traffic Control (ATC) centers, at airlines and at airports. The effectiveness and efficiency of coordination and communication between these actors is essential for achievement of the very high safety records of modern commercial air transportation.

Commercial air transportation is a highly regulated system where the coordination procedures for human actors are well defined up to a certain procedural level. However, in practice non-nominal situations occur for which the set of existing procedures fall short, as a result of which human actors coordinate informally in a partially improvised way. Evidences exist that such an improvised coordination is often successful in practice.

Understanding of generic coordination mechanisms and their breakdowns in sociotechnical teams has been a long-standing challenge, in particular in the areas of human factors and social sciences. A few theories and conceptual frameworks were proposed to describe and explain coordination in teams. However, formal, systematic modelling of coordination in sociotechnical teams is still very limited; strengths and weaknesses of such approaches are not well explored.

In this paper we elaborate coordination processes in ATM using three existing modelling tools: a conceptual model of joint activity (Klein et al., 2004), a conceptual co-ladder model of coordination (Chou et al., 2000), and a formal framework for multiagent situation awareness relations (Blom and Sharpanskykh, 2015). These modelling tools address coordination at different levels of abstraction ranging from abstract conceptual to detailed formal. In the paper we demonstrate how these modelling tools can complement each other, and how by integrating them in a unifying framework a more profound understanding of coordination mechanisms can be achieved. We illustrate this framework by elaborating an ATM scenario, in which multiple non-nominal hazardous situations occurred, and the actors needed to coordinate with each other to handle these situations. A special focus of this study has been on coordination mechanisms related to maintaining common ground, identification of loss of common ground and its repair. Common ground refers to pertinent knowledge, beliefs and assumptions that are shared among the ATM actors.

Based on the elaborated coordination model we developed an agent-based simulation model, which was used to study the dynamics of coordination mechanisms in different variants of the
ATM scenario using ‘what if’ simulation.

Among the identified mechanisms that help maintaining common ground among actors in ATM are: acknowledgement/readback of a plan or activity, comparison of expected states attributed to other agents with the observed behaviour of these agents, requesting/providing information when state certainty is low or outdated, reasoning based on communication among other agents involved in the joint activity, group discussion and exchange of stances of agents about disputable issues.

The proposed approach and the identified coordination mechanisms related to common ground could be used to improve training of actors in ATM. Another possible application is in automated support facilitating coordination in ATM. Such automated systems could alert actors when a possible loss of common ground is detected.

**Keywords:** coordination, air traffic management, agent based modelling and simulation
Resilient decision making in the cockpit: Does it work?

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This paper evaluates a novel complex situation management strategy for flight crews in civil aviation. This strategy has been developed and evaluated in the EU-funded research project Manual Operations of Fourth Generation Airliners (Man4Gen), which investigates crew recovery capabilities in modern airliners. Based on exploratory simulations earlier in the Man4Gen project, the strategy attempts to provide crews a method to assert themselves effectively in complex, unexpected and ambiguous situations. Nestled within the philosophy of resilient operations in an increasingly complex operational context, the strategy will guide crews where conventional procedural resolutions and brittle and fall short. The design process of this strategy is detailed in a related paper by Field, Mohrmann and others, also submitted to the REA.

The Man4Gen project investigated whether introducing this new strategy would in fact result in increased performance. This experiment enlisted 17 Airbus A330 & A320 type-rated crews from various airlines and challenged them in a carefully refined scenario providing a complex energy management issue and an emergency diversion in bad weather. An important scenario element was the perceived (but not actual) time pressure. Crews were evaluated on 30 distinct challenges and risks to be managed throughout the scenario involving both engine management and navigation. These performance metrics would then be compared to a behavioural analysis which observes whether crews performed the strategy’s steps, and in which order. This comparison would be able to conclude whether applying the strategy as design actually leads to an increase in situation management performance.

Performance analyses (ANOVA, 0.05 level) revealed that the original test groups (trained vs not trained) did not exhibit strong group distinction in performance, but rather featured an overlapping spectrum of performance. As the strategy only served as an intervention to introduce higher performance, the crews were regrouped into high and low performing crews. The new groups featured low within group variance, and high between group variance. The subsequent temporal behavioural analysis observed the actual detailed steps of the strategy, as well as the abstract level of strategy’s philosophy. Analysing their behavioural trends revealed that there were distinct differences in the behavioural patterns of high and low performing crews. Performance increase correlated with stricter task sequencing along the strategy, not skipping steps or revisiting past steps, as well as increased use of the latter half of the strategy (managing uncertainties and contingency planning). At an aggregate philosophy level, the analysis reinforced the effect of strict sequence, expediting time management and taking time for contingency management.

This study concludes that the Man4Gen situation management strategy does indeed provide

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crews with effective guidance when addressing complex and ambiguous scenarios. In this way, this strategy is a concrete attempt to operationalize resilience theory in an industry which is becoming increasingly challenged by complexity which often trumps brittle Taylorist approaches to threat and error management. By engaging the human ability to learn, understand and anticipate, this strategy leverages the human asset in the cockpit, and sets an example for further operationalization of resilience theory.
Using the rag to assess international space station organizational resilience.

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Understanding high risk work settings from the viewpoint of resilience engineering (RE) requires methods that enable the researcher to successfully collect and analyze data, then provide well-founded findings and recommendations. We report on our experience using one RE method, the Resilience Analysis Grid (RAG)(Hollnagel, 2011), as part of an assessment of the organizational resilience of the role the U.S. National Aeronautics and Space Administration (NASA) plays as a partner in the International Space Station (ISS) Program. Two events led to the study. Each occurred during the performance of an extra vehicular activity (EVA), or spacewalk, outside of the ISS. In both cases, water was observed to accumulate in an astronaut’s helmet. In the second instance, EVA 23, it became evident that the accumulation of water in the space suit’s closed system could become life-threatening and the spacewalk was terminated. In response to recommendations from a mishap investigation board (MIB, 2013) report of the EVA 23 incident, the ISS Program Office invited the NASA Engineering and Safety Center (NESC) to assess how the agency handled this and similar situations, in order to improve its work processes. The NESC organized a team comprising five human factors specialists, working within NASA as civil servants or contractors, and two RE specialists from outside NASA. The team leader selected the RAG as the tool to analyze NASA system performance using EVA 23 as a case study. The team used the four RAG cornerstones (anticipate, monitor, respond, learn) to structure data collection, analyses, and findings. The team:

• Reviewed artifacts to learn actions that have and are being taken in response to recommendations from past mishap investigations and incident reports,
• Conducted a series of interviews with crew members and mission control center operational and engineering staff members
• Observed several groups at Johnson Space Center during 3 spacewalks.
• Performed a thematic analysis of interview and artifact data
• Provided recommendations for the ISS program regarding its resilience traits, based on our assessment of current practices, including recommendation to improve work processes.

Our presentation will reflect on the application of the RAG to study a complex, high risk work setting. We will also share our experience with introducing team members to RE in general, as

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well as RAG in particular. For example, more than once we heard the question “Are these the "official" or sanctioned principles of RE?” This begs the question of how novice practitioners can be introduced to and undertake RE study without a background in the RE literature. We will conclude with a review of how well RAG served the team, what the team needed to use it well, and provide observations on the evolution of RE field study based on our experience.
Prevalence of resilient skills in general aviation crews.

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General Aviation (GA) is a catchall term for all aircraft operations in the United States (U.S.) that are not categorized as commercial operations or military flight. The International Civil Aviation Organization (ICAO) defines GA operations as "as all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire"[1]. In the U.S. in 2014, GA aircraft comprised approximately 97% of the aviation fleet. Recent estimates by the Federal Aviation Administration (FAA) showed that the GA fatal accident rate has remained relatively unchanged between 2010 and 2015, with 1566 fatal accidents accounting for 2650 fatalities during this time[2].

Traditionally, the literature base for this domain has focussed on identifying resilient skills and strategies employed by crews in commercial aviation operations. However, in this paper, we seek to supplement several research efforts that have been directed towards better understanding of the causes of GA accidents. Understanding the behaviour of pilots/crew plays a critical role in potentially better understanding of the causes for both fatal and non-fatal GA accidents. Specifically, in this paper we seek two answers to the following questions: (1) How many fixed-wing GA accidents involved "surprise" or "unexpected events"?; (2) Did the pilots/crew in these accidents demonstrate resilient skills?

To answer the first question, we analyze historical accident data from the National Transportation Safety Board (NTSB) database. We analyze fixed-wing GA accidents that occurred in the US between 1982 and 2016. We identify accident reports that suggest that pilots encountered surprise/unexpected events during aircraft operation. We argue that analyzing non-fatal GA accidents (approximately 86% of GA accidents in the U.S.) could provide additional insight into the skills demonstrated by pilots. For the second question, we carry out an in-depth analysis of factual accident reports using the resilience indicators presented by Wachs et al.[3], Dekker and Lundstrom[4], and Grøtan et al.[5], to determine if pilots demonstrated sign of resilient behaviour.

We propose that eventually the value of this research will be evidence that certain resilient skills are in fact helpful in potentially mitigating undesirable outcomes. Especially for those events that could be labelled as unexpected. Thus, once this is understood with supporting evidence, training organizations will finally have empirical support and thus a better grasp on skills that could be taught during all levels of airman certification. The focus of this effort will be that if more pilots possess these skills once trained, then these abilities acquired by all airmen

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may help to finally decrease the stagnant GA accident rate in the U.S.

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Abnormal and emergency situations in aviation: Improving the QRH to support resilience.

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Commercial airlines are known for using highly reliable technology and highly-standardized operations which reduce uncertainty, variability and risks. The systems resulted from these approaches are effective to handle well-defined problems[1] for both normal and abnormal operations. For the latter is expected that: pilots identify the problem; choose, read and understand the contents of the Quick Reference Handbooks (QRH) checklist, execute the steps; and evaluate the results[2]. The rationale behind traditional QRH is that anomalies and emergencies can be addressed by using one checklist for each situation[3].

However, what if pilots face situations that cannot be solved following the prescribed sequence or not covered by the selected checklist in the QRH? Our previous study[4] with pilots from a major commercial airline has shown that the successful management of ill-defined emergencies and anomalies lies on the strategies deployed by the cockpit based on the interactions between a range of “resources for activity (RfA)”, which include but are not limited to the QRH. Since not all circumstances are covered by the QRH, the cockpit interweaves strategies supported by fragments from different RfA in order to deal with the problem while trying to concurrently manage the flight.

Hence, this study suggests improvements in the QRH design, so as it can interact more effectively with other RfA, and thus support the cockpit to manage both well and ill-defined anomalies. In particular, we propose to transform the paper-based QRH in an electronic tablet-based information system (which allows for dynamic properties) with the following functionalities:

- The system must be ready to be used when needed and it must include feedforward mechanisms (e.g. predicting what might go wrong based on past maintenance reports).

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• The QRH should concurrently aid the cockpit to make sense of the nature of the failure, to diagnose the probable cause(s) of disturbances and to act therapeutically or diagnostically.

• For time critical emergencies, the QRH should provide ready-to-be-used checklists and elect, suggest and provide guidance for the nearest suitable airport(s).

• Whenever the failure compromises the aircraft performance, the QRH should display landing performance calculator.

• It should be possible to remotely modify and manage the QRH, thus reducing the time required to update.

• Passive and active feedback from users and recent events should allow continuous improvement of the QRH. In this case, "machine-learning technologies" should be considered.


**Keywords:** procedures, anomaly management, abnormal, emergency, quick reference handbook, QRH, aviation
Training Resilience
Recruitment, selection, and training of new workers based on resilience skills: A study with grid electricians.

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From the resilience engineering (RE) perspective, the unit of analysis for studying resilience skills (RS) should be the joint cognitive system (JCS) formed by the interactions between the individual professional and their social and material environment. Therefore, data collection for describing RS should account for the context in which they are deployed.

The recruitment, selection, and training (RST) of new workers is an important part of this context. In this paper, we discuss the role played by the RST in the use of RS by front-line workers who perform emergency maintenance activities in an electricity distribution company.

The field study involved three main steps: (i) characterization of the requirements posed by the company for recruiting, selecting, and training new workers; (ii) identification of RS demanded by electricians and control room operators; and (iii) crosschecking the data collected in step (i) with the data of step (ii), which allowed evaluating if RS were accounted in the RST of new workers.

Sources of data involved: participant observations; documents that described the RST; twelve interviews through the Critical Decision Method; data regarding the performance of workers who participated in the RST, including 450 applicants for the electrician job and 80 for the position of control room operator. Interviews and notes from observation diaries were subjected to a content analysis, in which RSs and the work constraints which triggered their use were identified.

With respect to results of step (i), the company demanded a number of technical and educational background requirements, psychological tests, medical examinations and physical tests. For the electrician job, applicants who had been approved in the initial psychological and medical tests (i.e. 215 out of the initial 450 applicants) attended a 360 hour training course, at the end of which they could be eventually hired or not.

As to findings related to step (ii), 11 categories of RS and 10 categories of work constrains were identified. These RS were checked against the requirements of the psychological tests used.
by the company over the RST process, both for the electricians and for the control room operators (step iii). This comparison indicated that all of the 11 RS were at least partially covered by the psychological tests, even though these had greater emphasis on personality traits, reasoning and memory. Also, results indicated that, provided some RS had not been considered over the RST process, this would imply the creation of some of the identified work constraints in the future.

In fact, the company’s training coordinator acted so as the RS and work constraints identified in this study were accounted by instructors during the electrician’s training course. This made the practical training sessions more likely to demand the use of RS. As a result of these changes, 10% of the 215 applicants were considered as inapt during this late stage of the RST process. This is contrast with the 1% failure rate that was previously common in the company.

**Keywords:** Resilience skills, training, electricians, recruitment and selection
Serious games: An efficient tool for the learning about city resilience.

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The relevance of resilience has increased significantly over the last years as both natural and man-made disasters have augmented. Moreover, as cities continue to grow, there is a need of building cities resilience, not only in a theoretical but also in a more practical way. There are several studies that define resilience policies and actions in order to achieve higher resilience levels1. However, none of these studies explain the inter-relations existing between the policies and the way they must be implemented.

In parallel, the use of serious games (SG) for didactical objectives has also been a significant topic lately. Due to the appearance of new technology, the way humans communicate, learn and teach have changed. Moreover, by having new technological tools, learner’s profile changes and demands a more interactive way of learning 2. In light of this situation, tools such as SG are commonly used. While some experts define SG as a non-usable and ineffective tool, others claim SG environment can promote learning and motivation, providing features that prompt learners actively process the learning content3.

Taking both realities into account, the aim of this research is to develop a successful serious game with the objective of training cities to be more resilient. Through the SG decision makers and crisis managers will be taught which way is the most effective to achieve resilience and will understand the inter-relationships existing among the policies.

The serious game is based on a maturity model that defines the path cities need to follow in order to improve their resilience level. The maturity model is structured in five maturity stages achieved by cities in a systematic and incremental way through the stakeholders’ involvement. Each maturity stage is defined by different policies stakeholders need to implement to progress. Furthermore, all the presented policies are inter-related and therefore, depending on the order in which policies are applied, the efficiency of the implemented policies will vary and thus, different results will be achieved.

Furthermore, the structure of the game is divided in two main parts; a system dynamic (SD) model and the interface. On the one hand, a user friendly interface is created as an intermediary between the user and the SD model. The input data will be introduced through the user interface and the results of the simulation will be represented in a more visual and understandable

*Speaker
way. On the other hand, a system dynamic model is developed where the simulation is carried out based on the input introduced by the users. The SD model contains the structure of the model taking into account all the inter-relations and the temporal order of the policies and it simulates the evolution of the resilience level over time.

Developing successful serious games to train pedagogically cities being more resilient is of utmost importance and incipient in the field of crisis management. This research goes a step further developing tools that will support the learning of the cities in the resilience building process.

**Keywords:** Critical infrastructures, inter, dependencies, system dynamic, simulation
Simulation games for developing complex systems thinking skills and strengthening adaptive capacity.

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Resilient infrastructure requires people that are capable of thinking in complex systems ways. Since actionable resilience depends upon the processes of sensing, anticipating, adapting, and continuous learning, the adaptive capacity of individual decision makers relies upon their understanding of the complexity. Existing academic and training programs provide inadequate focus on developing the complex systems thinking skill which are necessary for infrastructure managers to address the US infrastructure crisis.

We learned from the Kolb Learning Cycle that there are four stages required for transformative learning: abstraction, experimentation, experience, and reflection. Experiential learning, which requires real-world context, is lacking in current educational platforms because it would be impractical or impossible to stage infrastructure crisis conditions. We cannot stage a week-long power-outage to provide training opportunities to engineers and infrastructure managers. Even within the real-world systems, some infrastructure failures occur over hundred year periods. This means that multiple generations of decision makers never experience the task of managing the infrastructure system during the failure conditions. We propose the use of simulation games for teaching complex systems thinking skills. Because simulation games can imitate the conditions of short and long-term infrastructure failures, decision makers can experience the complete lifecycle of infrastructure management.

We developed a series of infrastructure simulation games which teach four components of complex systems thinking skills: (i) interdependencies, (ii) feedback loops, (iii) nonlinearity, and (iv) stochasticity. The first game is The LA Water Game, which teaches the feedback loop between the LA water distribution system quality, public opinions, and funding. Students play the generational role of the LA Water Manager and are tasked with managing the LA water distribution system without being fired. This task is difficult because the complex system behaves in nonlinear ways and players’ decision fall subject to stochastic pipe break events. Power-Water Game, teaches interdependencies between the power and water systems by illustrating how the power and water systems are effected by climate changes. The third game is the Water Sustainability Climate Game, which teaches how vulnerabilities in the power and water systems are interdependent and demonstrates how strategic investments can be made to mitigate the consequences of climate driven vulnerabilities. To establish the validity of the simulation game method for teaching complex systems thinking skills, it is import to assess and substantiate what students

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learn during the games. We propose a concept mapping activity to assess students’ understanding of complex systems pre and post game play. Students interviewed will be conducted to complement the concept mapping assessment.

The LA Water Game has been piloted in ten group work-shops with more than 100 individuals. First, we observed that students’ prior experiences and disciplinary training impacted the students’ performance. Second, The LA Water Game revealed to students the generational inheritance of infrastructure problems. Lastly, after playing The LA Water Game participants demonstrated new understanding of infrastructure systems and acquired appreciation for complex systems thinking skills. The simulation game provides a context rich with potential for complex systems thinking skill development, as well as engaged learning through all four stages of the Kolb Learning Cycle.
Using simulation games to assess the resilience of critical infrastructures in the payment system.

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Infrastructures for fuel, food and payment systems become increasingly entangled[1] in dependencies on each other and a large variety of support systems as well as other systems that provide services crucial for the function of the overall system. When a disturbance occurs, the resilience of these infrastructures depends more and more on the ability to produce collaborative responses from individuals with diverse backgrounds that may not be familiar with side impacts in totally different areas. Resilient behavior through collective action patterns of involved stakeholders allows for dealing successfully with disruptions in these critical infrastructures.

Given the variety of interpretations of resilience[2], resilience is hard to operationalize into measurable indicators[3]. Lundberg and Johansson3 have therefore proposed the Systemic Resilience (SyRes) model as a way to describe process, functions and strategies on a conceptual level in an effort to synthesize different perspectives in the field of resilience research. Weick and Sutcliffe[4] describe resilient behavior as anticipation through ”reluctance to simplify” and ”action in order to think more clearly”. It may seem contradictory that Weick and Sutcliffe argue for sensitivity to operations and reluctance to simplify (i.e. an interest in details and scrutinize the situation at hand) while encouraging simultaneous blunt and immediate action without thorough analysis. The way out is that the deep knowledge about the system should have been acquired earlier (long before the disruption) so that in case of disruptions quick and blunt action is possible based on deep understanding of the system’s dynamics.

This paper presents initial findings from a project aiming to develop a gaming simulation (a combination of role playing games and computer simulation) that can be used to better understand the complex dynamics in the payment, food, fuel and finance system. The purpose of developing the gaming environment is to train decision-makers in handling crisis situations in a multi-organisational context. Gaming simulation[5] aims at representing reality and enabling an individual actor or a group of actors to experience the dynamics of the simulated system. The SyRes model will be used to guide the simulation approach so that all core functions of a resilient system, as well as coping strategies, will be addressed in the gaming sessions.


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Poster
Boxing and dancing - The challenges of enforcement in global shipping

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The author propose to present his paper entitled "Boxing and dancing - The challenges of enforcement in global shipping". Read the paper to have a precise idea of the thematic broached.
Redefining and Measuring Resilience in Emergency Management Systems

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Emergency management system (EMS) provides a crucial barrier for the protection of socio-ecological infrastructure from man-made disasters and natural threats. To meet diverse demands from hazardous events, resilience engineering is considered as an effective approach to enhance the performance of EMS. While conceptual and qualitative descriptions of resilience are abundant, ideas of operationalizing resilience are scarce. In this regard, this poster presents an attempt to redefine resilience in the EMS and propose a framework of measuring resilience by abstracting the EMS as a joint cognitive system.
Some implications of bone’s biological features for systemic resilience

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To understand resilience in large, deliberately constructed systems it may be useful to examine it in smaller, naturally occurring ones. The development, maintenance, and repair of bone is one such system. At both the micro- and macro-scales, bone dynamics demonstrate the functions, costs, and limits of resilience. Development of the skeleton is carefully orchestrated and maintenance and repair continue throughout life. Bone is a storehouse of the organism’s calcium - the most important inorganic elements. The turnover of bone is tied to calcium homeostasis. Far from being a static, inanimate, mechanical frame, bone is a richly innervated, highly perfused, and has a subtly complicated structure.

The organism is constantly resorbing and replacing bone along lines of stress. This optimizes the mechanical strength while limiting weight and preserving scarce minerals elements. In combination with the body plan this results in regular skeletal features including emergent architecture for specific bones. Overt damage (e.g fracture) produces cascading repair mechanisms that involve several different pathways that can take years to resolve. Influences on bone resorption and creation are integrated locally and globally.

Bone system resilience is both limited and susceptible to failure. Bone disorders arising from molecular defects, various cancers, and faults in signaling associated with abnormal organ function can lead to disorganization, disruption, or depletion of bone. Studying the array of disorders provides insight into the mechanisms of resilience and the patterns may suggest general properties of resilience.

Some features related to resilience include:

- The presence of both programmed and emergent features
- Having continuous, directed replenishment rather than periodic or episodic renovation
- Localized signaling that can garner and make use of resources for damage control
- The ability to sacrifice lower level goals (e.g. mechanical strength) for higher level ones (e.g. maintenance of serum calcium levels)
- Susceptibility to disruption by loss of internal regulation (e.g. the effects of parathyroid adenoma)

The existence of a naturally occurring resilient system and the detailed physiological, and now,
molecular biological models of that system provides avenues for more general study of resilience. The poster and proceedings paper will sketch the nature of bone resilience and suggest connections to resilience engineering work at other scales.

**Keywords:** systems biology, bone, calcium homeostasis, remodeling, goal hierarchy
Project RESOLUTE - enhancing resilience in urban transport systems

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Increasing Europe’s resilience to crises and disasters is a topic of highest political concern in the EU and its Member States and Associated Countries. Regarding the specific case of transport systems, it can be said that those have developed a prominent safety and business critical nature, in view of which current management practices have shown evidence of important limitations in terms of resilience management. Furthermore, enhancing resilience in transport systems is considered imperative for two main reasons: such systems provide critical support to every socio-economic activity and are currently themselves one of the most important economic sectors and secondly, the paths that convey people, goods and information, are the same through which risks are propagated.

RESOLUTE is based on the vision of achieving higher sustainability of operations in European UTS. The project recognises foremost the ongoing profound transformation of urban environments in view of ecological, human and overall safety and security needs, as well as the growing importance of mobility within every human activity. Sustainability is rapidly becoming an imperative need across all economic and social domains. Among many things, this requires overall heightened operational efficiency, mainly by optimising the allocation and utilisation of available resources (organisational technical and human), whilst striving to continuously minimise any source of waste, namely incidents, accidents and other operational failures.

Within this context, RESOLUTE considers resilience as a useful management paradigm, within which adaptability capacities are considered paramount. Rather than targeting continuous economic and financial growth of businesses and market shares, organisations must generate the ability to continuously adjust to ever-changing operational environments.

RESOLUTE is answering those needs, by proposing to conduct a systematic review and assessment of the state of the art of the resilience assessment and management concepts, as a basis for the deployment of an European Resilience Management Guide (ERMG), taking into account that resilience is not about the performance of individual system elements but rather the emerging behaviour associated to intra and inter system interactions. The final goal of RESOLUTE is to adapt and adopt the identified concepts and methods from the defined guidelines for their operationalization and evaluation when addressing Critical Infrastructure (CI) of the Urban Transport System (UTS), through the implementation of the RESOLUTE Collaborative Resilience Assessment and Management Support System (CRAMSS), that adopts a highly synergic approach towards the definition of a resilience model for the next-generation

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of collaborative emergency services and decision making process.
Beneficial interruptions in the emergency department

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Introduction: Work system interruptions in the emergency department (ED) threaten patient safety, since interruptions disrupt clinicians’ cognitive processes and increase their cognitive demands, thus increasing the risk for committing errors. Identifying the positive uses of interruptions in the ED though demonstrates the system’s ability to succeed under both expected and unexpected conditions. Therefore, the present study prospectively examined the characteristics of interruptions in the ED with respect to current protocols and whether the interruption was considered appropriate.

Method: Interruptions of attending physicians were prospectively collected in the ED at one academic institution. Convenience sampling was used to select the location (i.e., wing) in the ED observed. Data included the description of the interruptions, the clinical role of the interrupter, and location of the interruption. Following the data collection, the interruptions were categorized thematically. Institutional procedures were also reviewed to determine whether or not relevant protocol existed and whether the interruption was appropriate. Interruptions were considered appropriate when its purpose was pertinent to the patient’s continuing care and necessary for the physician to be updated.

Results: Across 16 hours of observation, 22 interruptions of the attending physician occurred. Six interruptions occurred in the pediatric wing and the remaining interruptions occurred in the main adult wing. Eight of the identified interruptions (8/22, 36.4%) were considered appropriate. Nurses and residents interrupted ED physicians regarding patient updates (3/8, 37.5%), ordering patient tests (2/8, 25%) the lack of beds for admitting (3/8, 37.5%). Only three of the interruptions had a relevant protocol that was followed (ordering patient tests and one patient status update).

Discussion: Interruptions can have both positive and negative effects, yet researchers typically focus on the negative aspects in order to examine ways to minimize interruptions and decrease the risk of error. More than one third of the interruptions were considered appropriate, indicating there is value to certain interruptions. Furthermore, the presence of interruption reveals there is system flexibility to make performance adjustments as necessary. The results suggest that appropriate interruptions assist the clinical team function in the ED by providing updates on patients and discussing care plans. The characteristics of the appropriate interruptions also

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indicate a lack of protocol for admitting patients when resources are limited. Future work will involve including clinicians in the process of identifying and understanding appropriate interruptions to facilitate resilience education in the ED setting. Additional work will investigate the ‘negative’ interruptions in order to evaluate the tasks and events that did go right.

**Keywords:** interruptions, emergency department, safety II
Staff members’ chats in a refresh room as a way of knowledge sharing for maintaining the resilience of socio-technical systems

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For maintaining resilience of every socio-technical system, it is believed necessary to learn not only from unsafe events but also from normal operation[1]. To develop a safety information system figured by J. Reason[2] is an usual methodology for enhancing learning from unsafe events. However, it is often difficult to enhance learning from normal operation by this methodology caused on its nature of a safety information system. The most critical problem is that this system should be depending on information reported by staffs, while it would be difficult for them to find out information should be reported from their daily normal operation or figure out the information to a "report" (usually as a written paper) on their own.

By the way, in a refresh room, many staffs usually chat lively about various topics, some of which are related to their jobs. Such a chat can include information to be learnt, like know-how to mitigate a threat, a new idea to improve their performance as well as their experience of a previous incident or error, of course. Further, Chatting is believed an effective media to enhance learning from them because 1) they can use non-verbal language, onomatopoeia or various rhetoric like metaphor, to more lively and correctly express their intended information, 2) they can modify their expression to get intended information shared correctly with watching reactions of a companion, and 3) they can more clarify their own knowledge as they have a communication as a situated interaction, even if they wouldn’t have had so clear image of the knowledge in them before chatting. Therefore, authors expect that enhancing lively chats can lead sharing some information which is difficult to be shared by Reason’s safety management systems.

Standing on this background, authors conducted a survey to examine the relationship between chats in a refresh room and knowledge sharing about safety in a Japanese hospital. As a result, it was suggested that not only a frequency to participate in chats in a refresh room but also a frequency of their chat about their job (especially positive experience in jobs) would positively affect how much knowledge related to safety would be shared. Furthermore, authors attempted to develop a new method to enhance chats related to positive job experience applying Information Communication Technology and theories of cognitive psychology. As long as the laboratory

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experiments, the result showed that authors’ method was effective to enhance a chat with a specific topic that authors intended to enhance.

The limitation and future work is discussed in a full paper and presentation.

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**Keywords:** knowledge sharing, informal communication, chats in a refresh room, learning
Exploring efficacy of adaptive safety practice for social sustainability in construction supply chain management.

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The adaptive age of safety[i] is argued as transcending traditional safety practice through providing a different lens from which to consider organisational practices. The orientation towards acceptance of adaptive capabilities refocuses the view of workers as a source of innovation and a solution to safety performance[ii]. Centred on the ‘messy’ reality of work with variable demands, resources and trade-offs[iii]; questionable faith in prescribed systems, and understanding of the rational acts of workers, the blurred lines between facilitating productivity and safety make it a strategically attractive prospect for organisations in justifying the business case for safety management and reducing bureaucracy.

In contrast to other industries who are applying these theories, the Construction Sector relies on temporary, dynamic and multi-stakeholder networks within a supply chain setting. Planning and delivery exist temporally and logistically remote to one another[iv]. Approaches to addressing adaptive safety require mechanisms for anticipating, monitoring, responding and learning about and from challenges in an effective manner that requires engagement and commitment underpinned by a just culture and safety leadership across the supply chain[v]. In this highly fragmented, transient sector, this can prove difficult.

Recently, there is some evidence in the public domain that companies within UK construction are turning away from ‘zero accident vision’, and the traditional foundation of compliance it embodies, to explore the potential for resilience through adaptive safety. Industry efforts are also evident to transform CDM management. With a strategic organisational change in ethos, employee-centric engagement processes, which include appreciative enquiry, collective insights and evaluation of normal work, are contributing to narrowing the gap between belief and reality in providing a key source of organisational learning for work effectiveness and safety. This is being examined as part of PhD research.

The overall PhD research aims to explore the efficacy of applying adaptive safety theory to construction supply chain management and the alignment of this theory to social sustainability principles at an supply chain level. Following initial theory construction with systematic combining using abductive logic, a small grant from the Supply Chain Sustainability School UK will soon fund a survey of construction industry orientation towards the ‘new view’ of safety. Case studies which differentiate varying procurement models and therefore construction supply chain dynamics will also be carried out. These efforts propose an outcome that shall support the construction sector more widely to evolve safety practice.

*Speaker
This proposal aims to provide details on the methods and initial findings from ongoing work on this project. It is proposed to deliver this outcome with a poster at REA2017.


**Keywords:** adaptive safety, construction, supply chain, culture
Design of a Functional Modeling Based Technique to Support Operators on improvising Counter-Measures for Unexpected Events

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Lessons from the Fukushima disaster indicate that there is an inadequate response capability. Responding, the ability of knowing what to do and being able to do, is one of the key capabilities of resilience engineering. Strict compliance of procedures can indeed make the plant more resilient in responding to the accidents. The unexpected situations, however, are challenging to plan a response, when nothing has been prepared in advance. Operators are required to take advantage of available plant equipment and even their creativity to improvise a counter-measure to mitigate the accidents. In perspective of resilience engineering, it means the need of adapting functioning and matching the conditions to sustain desired goals during the unexpected. We must acknowledge that it is hard for human to handle these complex knowledge-based tasks even they have been well trained. This study therefore focuses on how adapting capability of operators in responding can be strengthened by technology. A computerized operator support system on human-machine interface is designed based on functional modeling of plant knowledge. With the influence propagation rules in a model, a series of operations on components to achieve a safety goal can be identified whether the plant conditions are expected or not. An example that is similar with the accident of Fukushima Daiichi nuclear power plants is used to demonstrate how the technique can generate multiple mitigation alternatives when various safety systems are unavailable and rare responses are prepared.

*Speaker
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Resilient capabilities in single pilot and crewed flight operations

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Pilots are increasingly encountering unexpected events (e.g., loss of control) for which they sometimes do not have procedures or specific checklists to consult. Unfortunately, some of these events deteriorate to aircraft upsets, loss of control, and other undesired aircraft states eventually resulting in both, successful and unsuccessful accidents. When faced with these events, pilots are expected to evaluate the operational circumstances and respond in an appropriate way; whether it is an aircraft malfunction, environmental threat, or other types of threats including combinations. Pilots are expected to be cognitively equipped to handle any possible threat experience. However, as past accidents have shown, both individual pilots and crews do not always perform equally well in all of these situations. Furthermore, research has shown that pilots who appear to be more resilient than others when faced with such events tend to have better outcomes[1].

Here, we present research that helps us better understand what resilient skills or strategies are most effective when faced with unexpected events. By reviewing past accidents and observing in real-time routine simulator proficiency checks, the types of resilient strategies that are deployed to make some accidents more successful than others (e.g., US Airways flight 1549 vs. American Airlines 587), or the determination of check ride pass/fail outcomes. After an extensive literature review across numerous domains, including aviation, we have identified those efforts described there as resilient skills, capabilities, and indicators.

The value of this research for the global community is in the identification of requisite resilient skills for problem solving/decision making when confronted with an unexpected event. We suggest that these skills, of which many are described in the aviation literature, are potentially deployable to other domains. To demonstrate their efficacy, we first extracted from the literature base, these resilient skills as demonstrated and observed across numerous safety-sensitive domains. We then searched for these resilient skills in those accidents that can be described as both successful and unsuccessful. Further, we proceeded to identify these same skills or strategies while observing both successful and unsuccessful check rides. Our goal is to verify if the resilient skills from literature appear in both historical accident reports, and real-time check rides (in flight simulators). From the earlier literature base review, to the accident reports and simulator observations, we envisage being able to decide on the resilient skills or strategies consistent throughout this research, and propose to construct a resilient training course for pilots that can now be tested empirically. To achieve our goal, we will design a simulator-training event where one group of pilots will be trained in these skills, while a second group (which will
serve as our control group) will not receive resilient skills training. We aspire to show that those pilots that received resilient training perform better than those that did not as found in the literature base, accident reports and check-ride events.

Regardless of the safety-sensitive domain, those at the sharp end are challenged beyond capabilities when confronted with situations that are both unexpected and exceed the norms of what could be considered normal failures. These types of events are impossible to train for a priori because of their extreme and unique nature that make them only possible to grasp in concept after they occur. What this research offers in value across domains, not just aviation, is that if these resilient skills are shown to be effective when facing challenging unexpected events that stretch resilient capabilities beyond what could be described as normally trained for expected technical events, then these additional capabilities can now be deployed to help ensure success. Essentially, we will have shown that resilient skills training is effective and positions those at the sharp end with additional skills that can be deployed when facing events that are both unexpected and that exceed the typical technical events for which they are already proficiently trained.

City Resilience: Analysis of strategies world-wide

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Increasing resilience to crises and disasters is a topic of highest political concern worldwide. Cities and communities need methods and tools to prevent and manage the effects of natural hazards such as floods, storms, earthquakes, and tsunamis as well as man-made threats such as accidents and terrorism. A challenge when developing such methods and tools is to go from theory to practice, that is, from theoretical models of resilience to methods for applications and concrete action plans. The 100 Resilient Cities[1] (100RC) initiative, founded by the Rockefeller Foundation, is a global initiative to support and improve resilience at the community-level.

In this paper, we analyze 18 RC100 member cities and their resilience strategies. The aim of the analysis is to identify common challenges and suggested actions to improve city resilience. Also, the analysis aims to highlight differences and commonalities with regards to resilience implementation processes, offering a discussion on the generalisability of the approaches. Furthermore, a set of interviews with city representatives in the Smart Mature Resilience (SMR) project[2] are carried out regarding implementation of 100RC strategies and SMR resilience strategies.

The results of the study indicate that the resilience strategies and concrete actions of the 100RC cities are focused on measures to improve community cohesion and information gathering (monitoring), and resilience-thinking based on graceful management of "disasters" (e.g., being in control of a flood). With regards to cohesion, cities aim to approach internal management silos as well as improving communication with citizens, business and other stakeholders. A common approach to tackle challenges identified by the 100RC cities include creating community plans and expanding present programs or plans. A widely-applied solution is to modify evaluation processes of already existing projects to also include aspects of resilience, with the aim to make it an integral part of policy-making and everyday operations. However, approaches to manage the local challenges vary greatly between cities, and are adapted to local possibilities and constraints such as the cities ecology, geology and history. The latter indicates that resilience guidelines and tools must allow local contextualization. The findings of the study offer insights for (1) the development of support tools to aid the resilience building process in general and, (2) the replication efforts, the standardization potentials and the practical uptake of developing and implementing City Resilience Strategies within the 100RC framework.

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SIGNIFICANCE/TAKEAWAY

Theories of resilience have in the past decade developed models and methods to understand resilience, demonstrating the importance of resilience to cope with complex and dynamic events such as crises and disasters. However, critical questions on how to operationalize resilience are still unanswered and more examples of applying resilience concepts to real-world problems is needed. In this paper we explore the development and content of city action plans (strategies) aimed at increasing city resilience. The paper discusses hand-on practical applications that aim to increase city resilience, offering guidance to (1) development of support tools, and (2) city representatives aiming to set up an action plan for city resilience.

http://www.100resilientcities.org/

http://smr-project.eu/home/home/

**Keywords:** City, Community, Resilience, Strategies, Action plan
A Decision Support Framework for Improving Cross-border Area Resilience to Disasters

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In spring 2017 the research-project INCA (A Decision Support Framework for Improving Cross-border Area Resilience to Disasters) with a French-German consortium will start. Aim of the proposal is to present the context, the aims, the methodology and the results expected of the project.

The aim of the INCA project is to contribute to the understanding and to the enhancing of cross-border area resilience with regard to the risk of disasters by considering two topics in particular: the resilience of medical dependent citizens and the management of volunteers in a cross-border area. Scientific knowledge and decision-makers’ contributions to cross border areas resilience to disasters will be enhanced with an interdisciplinary approach combining conceptual and empirical research, decision support system engineering and a campaign of experiments.

Results of the project will be novel models for the thematic of cross border area resilience and on the perspective of medical dependent citizens and volunteers; an assessment tool; a set of experiments reports on the utility, usability and acceptability of the solution developed and practical experience for resilience to disaster stakeholders.

**Keywords:** Disaster Resilience, Cross border, Black out, décision support system

*Speaker*
Voluntary safety leader at the sharp-end:
From controlled safety to creative safety at an expressway maintenance site

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Background
Now that we have identified the limits of the SAFETY-I or controlled safety model[i] which requires making and following a comprehensive safety manual, our next objective is creative safety, which requires flexible and creative correspondence regarding unexpected situations and efficient requirements on site[ii]. Creative safety also aims for resilience on site. Creative safety is not so straight forward, however, as simply requiring workers at the sharp end of a situation to make decisions flexibly and think creatively, as there may be a wide variation in individual workers’ ability to do so. To accumulate the information, we will need to resolve this difficulty; the authors interviewed site workers, most of whom are employed by an expressway maintenance company. The results indicated a need for specific safety workers who volunteer to pay particular attention to unexpected dangers or dangers caused by efficiency requirements and to cope with these dangers as they unfold. We call these workers the voluntary safety leaders and have written this study with the aim of clarifying their necessary attributes.

Methods
We developed the safety leader index, a 69-items questionnaire based on the developed leadership scales[iii],[iv]. We asked 440 site workers at an expressway maintenance company to complete this questionnaire, once with their safety manager in mind and a second time with their voluntary safety leader, if they had one, in mind. The safety manager is a position assigned by the company; for the voluntary safety leader, we asked workers to think of one of their colleagues who, although not assigned a safety-oriented role by the company, took particular care for workers’ safety. Finally, we asked them to answer 11 questions regarding the workplace safety climate.

Results
We received intact data from 101 out of 440 participants. We received completed questionnaires regarding both safety leaders from 59 participants. We compared the two leader types’ average scores for each item through a T test. On 16 of the 69 items, the voluntary safety leaders received higher scores than the safety managers did. We performed factor analysis on these 16 items for the 101 participants. The results indicated two factors, which we named ”troubleshooting” and ”commitment to colleagues.” We then performed multiple regression analysis

*Speaker
dependent on workplace safety attitude as assessed by means of the final 11 items. Only ”commit-
ment to colleagues” contributed to workplace safety attitude. Therefore, we concluded that
the seven items associated with ”commitment to colleagues” represented the necessary attributes
of a voluntary safety leader. According to these seven items, a voluntary safety leader involved
in work allocation, information delivery, and operational instruction; is able to think for his/her
colleagues in a dangerous situation; and consistently emphasizes safety.

Discussion
Our study identified the necessary attributes of a voluntary safety leader at the sharp end. Being
aware of these attributes, and, in the future, identifying the environmental factors that produce
leaders with these attributes will enable us to develop ways to train such leaders and thus to
realize more resilient organizations.

**Keywords:** leadership, safety, flexibility, creativity, organizational safety
Assessing resilience through investigating adaptive capacity

Anthony Smoker *, 1, Matthieu Branlat † 2, Ivonne Herrera 3, Rogier Woltjer 4, Billy Josefsson 5

While numerous definitions of resilience exist, the field of Resilience Engineering puts the notion of adaptive capacity at the centre of its investigation of work systems. Given the nature of most operational environments, especially in typical high-risk, high-consequence domains, adaptive capacity is understood in the context of complexity, uncertainty and variability. Resilience Engineering is primarily concerned with how work systems adapt to challenging events and surprises; that typically characterise adaptations to compensate for performance variability influences system performance. Exploring adaptive capacity, in unusual events as well as in everyday operations, thereby provides the means to explore resilient performance.

New designs or concepts of operation transform the work, changing the requirements and capabilities for adaptation, thus changing the nature of resilient performance. In some instances, the sources of resilience that facilitate resilient performance can change. The introduction of new ways of conducting work can lead to the unintended consequences of creating new forms of brittleness in the work system. In other cases, the work system can be juxtaposed to another work system undertaking an adaptation, and experiences a demand upon its own sources of resilience that can induce brittleness. The notion of graceful extensibility has been proposed to capture how a system exhibits resilience by successfully adapting at or beyond its typical boundaries of operation. When new designs or concepts of operation change the sources of resilience and brittleness, they impact graceful extensibility as well.

In one project to operationalise RE, the application of an Resilience Engineering method built on eight principles of resilience to explore work-as done and work as envisaged, encountered a number of methodological issues.

Alternative ways of operationalising RE were considered and a focus on adaptive capacity was deemed to be a more productive way to explore the nature of resilient performance. Woods and Wears (2013) adopts a ‘stress strain’ approach to adaptive capacity. This model, plots the adaptive landscape by representing the base and extra adaptive capacity of a work system.

*Speaker
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The Woods & Wears model was used in one approach to operationalise RE and in particular to explore and identify adaptive shortfalls between current operations and a new system design. In particular can shortfalls in the adaptive landscape be identified and how would this be identified.

Responses to performance variability frequently involve building strategies that draw upon sources of resilience that access a work systems adaptive capacity. Such strategies involve a subtle interplay of managing the system through its sources of resilience. There are consequences and costs associated with these e.g. the costs of coordination and collaboration that will follow as a result of the strategies used. Understanding these provides the knowledge by which to explore a socio-technical systems adaptive capacity and resilient performance.

The paper discusses the theoretical issues around adaptive capacity, graceful extensibility and brittleness the implications for real world application to achieve resilient performance in an Air Traffic Management concept development, and the implications for Resilience Engineering.

**Keywords:** Adaptive Capacity, Adaptive landscape, work systems, adaptations, sources of resilience, work s done
The relationship between lean production and the complexity of socio-technical systems

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1

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The need of companies to increase productive efficiency has been paying attention to the issue of lean production since the 1990s. However, the increasing organizational complexity is evident today, so that production systems are more connected and subject to the unpredictability and dynamism of the external environment. In this sense, recent studies indicate that complexity is responsible for restricting the advance of lean practices. However, these studies are not supported by complexity theory, which is inconsistent, since complexity may also play an important role in sustaining PE. Thus, the research presented in this doctoral thesis aims to characterize and evaluate the impacts of lean production on the complexity of socio-technical systems, using methods aligned with complexity theory. The research strategy was divided into three stages: exploratory research; descriptive; and explanatory. In the first phase, a systematic review of the literature was conducted to show the state of the art in relation to the theme and the existing knowledge gaps. Afterwards, a study in the form of a survey sought to characterize how companies with a higher level of lean principles adoption differ from others in relation to the complexity of their systems. Finally, the explanatory step sought through a case study to model the dynamics involved that support PE in a complex system. At the end of this research, it is expected as an academic contribution to present an in-depth understanding of how PE relates to organizational complexity, as well as to propose guidelines that assist in lean implementation in complex systems, taking into account the distinct nature of these systems.

Keywords: Lean production, Complexity, Complex systems, Socio, technical systems

*Speaker
The gap between Work-as-Imagined and Work-as-Done as an indication for safety.

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Safety is imperative for operations within aviation. Many companies try to measure their level of safety but acknowledge that it is very hard to do in everyday practice. Therefore, new indicators are necessary. This poster explains how the gap between Work-as-Imagined (WaI) and Work-as-Done (WaD) is explored to be a better indicator for safety with the help of agent based modelling. Current safety indicators have severe limitations. There are process and outcome metrics and most safety indicators are based on outcomes with unclear thresholds. Scarce evidence between the relation of process metrics and safety outcomes exists, and therefore the relation is based on credible reasoning. Most of the safety models used in the industry are linear and therefore not representative of current complexity of their operations. The gap between WaI and WaD is a promising indicator according to the literature and practice. Recent literature suggests that the gap between work realities affects safety and the industry already explores the gap. Agent based modelling will be used to create two models, one of WaI and one of WaD which can be compared with the help of a distance vector. Sensitivity analysis will help identify the ‘parameters’ which will influence the process, outcomes and safety the most.

*Speaker
Organisational Interdependencies and Emergency Response

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This study addresses the major challenge of understanding the organizational structure of sociotechnical systems. Organisational behaviour—human decisions, routines, and actions—tremendously affects system safety and capacity to recover from disruptions. However, human interactions within a complex sociotechnical organization are hard to detect and measure, and cannot be described by a linear model. In this study, the organisational structure is examined from a multi-layered perspective. More specifically, the structure is analysed as social networks embedded in the specific sociotechnical context. Thus, to investigate organisational interdependencies, the research focus embraces both formal and informal organisational structure seen as multi-layered networks of actors. This study aims to identify and measure the degree of organisational interdependencies and develops a multilayer model of organisational system to locate fault-prone and fault-tolerant interactions. By identifying vulnerabilities within the structure of organisational interdependencies, this study seeks to provide new insights on the consequences of organisational interdependencies on system resilience. Additionally, the analysis of fault-tolerant areas allows indicating good practices and guidelines for proactive management and anticipation of risk to enhance organisational capacity in coping with disruption and crisis.

Keywords: organisational interdependencies, organisational resilience, crisis, sociotechnical system.

*Speaker
Building an ”adaptive safety culture” in a nuclear construction project – Insights to safety practitioners

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Safety practitioners are in a central role in creating the preconditions and direction for the development of a shared safety culture in high-risk organizations. The work of safety practitioners has been approached from leadership and managerial perspectives. It has been proposed that safety practitioners require both approaches to be successful.

The dynamic project environment creates extra challenges for the creation of strong safety culture. Change is constant due to e.g. growth of personnel at the participating companies, changes in the phase of the project, various unanticipated occurrences, multiple interacting parties and multicultural environment. All this puts increased emphasis on safety practitioners in creating and maintaining the foundations (incl. working practices, cultural values and assumptions) upon which performance in the nuclear project should be based on.

Basing on previous research, Reiman et al. have proposed an adaptive model of safety management which identifies four tensions, each consisting of a conflicting pair of management goals: 1) system goals – local goals 2) repeatability and systematic response - flexibility and adaptability, 3) low system variance – high system variance, and 4) few strong ties – multiple weak ties. We will examine the implications of the model from the perspective of a set of practical safety culture improvement methods. The model suggests that safety practitioners need to be able to recognize and manage the tensions adaptively, depending on the context. It further means they need to use different methods depending on a variety of factors in their organization and its environment.

Our objective is to shed light on how the conflicting management principles can manifest themselves in the concrete activities of safety practitioners, highlight the paradoxical nature of these programmatic methods of changing complex adaptive systems and to provide insight for practitioners on how to manage these issues. Four approaches to safety culture improvement were chosen based on the authors’ previous experience: Safety training, Behaviour modification programs, Safety culture auditing, Facilitation of employee involvement and participation. The first author has conducted research and consultancy work related to these methods, and the second author has first-hand experience in applying these methods as a safety culture manager in a large nuclear power plant construction project.

In this paper we will view safety leadership and management from the perspective of resilience

*Speaker
engineering and complexity thinking and present a novel perspective to the practical development of safety culture in dynamic environments. Our focus will especially be on the role of safety practitioners, who typically hold either an expert or a middle management position. The key question is about adaptation between the inherent properties of different methods (e.g. training), the constrains and possibilities of their utilization (e.g. choice of training approach and topics), the current phase of the organization in terms of work activities, and the current ‘level’ of safety culture (including attitudes towards training).

We will present needed corrections to the model in order to accommodate findings from the application of the model in a nuclear power plant construction project.

**Keywords:** safety culture, safety management, safety leadership, nuclear safety
Developing aviation organisations’ agile response capability

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Aviation is a highly inter-connected system of systems. This means that a problem in one area may not be confined to the local system. Instead it may cause effects in other countries or parts of the Air Transport System (ATS), for example a fire in an airport area may lead to the shutdown of the airport, and if it is a major hub, this can cause disruption over a large part of Europe. Additionally, there is the potential for massive system-wide events such as the volcanic ash crisis. The immediate response to the first volcanic ash crisis was uncoordinated and could even be called chaotic. The possibility of “man-made” accidental events as well as intentional coordinated events must increasingly be taken into account.

The resulting approach of Future Sky Safety WP5.4 (2,3) combining Agility and Resilience Engineering perspectives is to provide aviation organisations with an Agile Response Capability (ARC). This poster aims to present work-in-progress on the development of the ARC approach. Two important aspects to be explored according to agility research are here called the problem space, or the parameters that play an important role in developing and applying an appropriate response, and the solution space, or the parameters that can be varied in the organization of the response in terms of information dissemination, allocation of decision rights and interactions within the response organisation. Guiding questions to explore these spaces are presented.

As an illustration of its applicability the poster applies the essential questions of the ARC approach on a literature survey on the first volcanic ash crisis, which by now is quite well-documented in industry reports and scientific publications. 27 documents and publications were analysed for the literature review. The application of the ARC approach explores the problem space of Eyjafjallajökull ash cloud crisis in 2010, and then explores what the documents analysed reveal on the solution space of how aviation organisations individually and jointly endeavoured to meet the crisis. Implications for how aviation organisations could exercise their agility using ARC guidance are provided.

**Keywords:** agility, resilience, aviation, crisis response, crisis exercises, volcanic ash

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*Speaker
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Simulated exercises in emergency response - A ressource to reconcile WAI and WAD

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In this work we analyze two simulation exercises in emergency response performed as part of a training program for officers of the Fire Department of the State of Rio de Janeiro. The simulations had different formats: tabletop type (June 2015 with 35 officers) and functional exercises (November 2015 with 40 officers). Both have the same script and purpose – verify the management of an operational event (emergency response) by Firefighters officers, while using the Standard Operating Procedures (SOPs) developed by the corporation – but with different features due to their format. The exercises were running from an initial scenario, and new information was inserted to trigger officers’ actions to deal with unfolded escalating situations. Data collection and analysis followed the methodology of cognitive task analysis including direct and non-participative observation, and audio and video recording of the simulation. The material was analyzed by the research team, which sought to understand work as imagined (WAI) and work as done (WAD) during the exercise, as well as aspects of resilience in that context. Validations of the results were performed by Firefighters experts.

Both exercises presented common insights, even with their different simulation format. This fact indicates that the observations of simulations exercises allowed to partially understanding the WAD, contributing to rethink on the WAI and the SOPs design. Our main findings were the dependence of the context for the decision making and the acknowledgment of the insufficiency of the SOPs through these different contexts.

In the first simulation, two moments exemplify this finding: at the beginning of the simulation, a request for police support was made before arrival at the emergency site, and later, the absence of a new request was verified, although it was justified. The first request was made by an officer with knowledge of the region to which they were addressed and who knew from experience that it would be necessary. In the second case, involving an officer that works in a rural area, showed the difference between operating inland, where additional support may take up to two hours to reach, from the ones that operate in urban areas, where the police support can be in place in a relatively short time. These are examples of resilient actions related to the knowledge of each officer that extrapolates the instructions.

In the second exercise we found the difficulty of SOPs in guiding those responsible for actions in a clear way in each scale of an escalating event. This appear when officers fail to realize the situation was escalating to higher level, and thus identify to whom report. Another example concerns the difficulty of following the guidelines of the SOP when the actual situation does not

*Speaker
have adequate information and/or means to do so. Sometimes the officer in command did not have knowledge on the resources available at the site, hindering the situational awareness of all, mainly due to the lack of registration of the previous actions taken and the lack of communication support to aid in the sharing of information.

**Keywords:** emergency response, simulations exercises, wai and wad, firefighters
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