Agile Response Capability – Protocols and guidance

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Future Sky Safety is a Joint Research Programme (JRP) on Safety, initiated by EREA, the association of European Research Establishments in Aeronautics. The Programme contains two streams of activities: 1) coordination of the safety research programmes of the EREA institutes and 2) collaborative research projects on European safety priorities.

This deliverable is produced by the Project P5: Resolving the Organisational Accident. This report presents the Agile Response Capability (ARC) guidance material and methodology, consisting of the Agile Response Capability Method for EXercise planning (ARC-MEX) and the Agile Response Capability Crisis Operations and Plan Enhancement (ARC-COPE).

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Acronyms

Acronym	Definition
AAR	After-Action Review
A/C	Aircraft
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ANSP	Air Navigation Service Provider
ARC	Agile Response Capability
ARC-COPE	ARC Crisis Operations and Plan Enhancement
ARC-MEX	ARC Method for EXercise Planning
ATM	Air Traffic Management
ATS	Air Transport System
C2	Command and Control
C-LEAD	Crisis Leader Efficacy in Assessing and Deciding scale
CREAM	Cognitive Reliability and Error Analysis Method
EACCC	European Aviation Crisis Coordination Cell
EBAT	Event Based Approach to Training
FRAM	Functional Resonance Analysis Method
HAZOP	Hazard and Operability Study
ICAO	International Civil Aviation Organization
LMX	Leader-Member-Exchange
SRIA	Strategic Research and Innovation Agenda

EXECUTIVE SUMMARY

Problem Area

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 volcanic ash. The immediate response to volcanic ash was uncoordinated and even chaotic. Volcanic ash was a natural event, but the possibility of "man-made" events such as accidents as well as intentional coordinated events must increasingly be taken into account. How would the European aviation transport system respond to a major European nuclear accident or a 9/11-style coordinated attack in several European capitals?

What is needed in such situations is not only rapid coordination, but an agile response, fast and effective. This requires a new approach for aviation. Agility refers to the ability to cope with dynamics and complexity in a flexible manner by adjusting and/or adapting performance and/or the organization of work to better fit changing demands, both pro-actively as a way of preventing unwanted events and re-actively as a way of coping with unwanted events. NATO SAS-085 developed a conceptual framework showing how organisations (in particular command and control/crisis management organisations) may develop and display agility. The current work aims to apply agility to safety management in organisations within the ATS, based on the NATO work combined with related advances in Resilience Engineering.

The resulting approach is to provide ATS organisations with an Agile Response Capability (ARC). This is done through organising exercises for the roles that need to provide agile response during crises or otherwise challenging situations. Designing scenarios that challenge exercise participants and their organisation(s) in their agility to an appropriate degree so that intended learning outcomes can be achieved, is the central issue that the work reported here aims to address. This includes enabling organisations to identify challenges and articulate why these are challenging, generating scenario elements and "what-if" courses of action, and identifying assessment points along which to assess the organisations responses.

Description of Work

A number of workshops, meetings, exercise observations, and analyses have been performed to develop the ARC methodology. These activities included studies into actual past or future events, and studies into exercises and exercise scenarios. Furthermore, these activities included studies that focussed on the before, during, and/or after phases of event/scenario/crisis management in either exercises or actual events. The outcomes presented in this document are thus the result of an activity using a number of study techniques and analyses to iteratively generate the proposed approach. In that sense, the various parts of the approach have been tested in various empirical endeavours, and subsequently improved

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iteratively. The approach builds on the principles of command and control agility research, resilience engineering research, and the Event Based Approach to Training (EBAT).

Results & Conclusions

This report presents the ARC guidance material describing the ARC approach to aid Air Traffic System stakeholders to increase their Agile Response Capability. The ARC approach consists mainly of the *Agile Response Capability Method for EXercise planning (ARC-MEX).* The ARC approach is also applied to actual operations (planning prospectively and analysing retrospectively) as the *Agile Response Capability Crisis Operations and Plan Enhancement (ARC-COPE).* Both approaches have been iteratively developed and, through exposure to different scenarios and stakeholders, have been found applicable.

Applicability

ARC generally aims to provide the exercising organisation(s) with a means for reflection and argumentation about what was difficult in past crises or expected ones, and incorporating this knowledge into focused exercises. Currently, selecting challenges is often done implicitly or by expert judgment of experienced members of the crisis team, while ARC stimulates the explicit and methodical articulation of these challenges, thus channelling expert judgment and imagination in a structured way. It also allows the organisation(s) to build up a repository of challenges observed or expected, that may be reused to vary exercise contents throughout an exercise series, or to vary the difficulties that participants face around the same theme across different teams trained across exercises. In this way, the organisation(s) can keep track of the contents and results of their exercises, plan for the efficient use of the (often, substantial) resources that are spent on training and exercising, ultimately increasing preparedness. In this way, organisations can focus their exercises on learning objectives in particular contexts. This in turn facilitates a reasoned, explainable and strategic build-up of preparedness throughout and across organisations through training programmes. At the same time, the analytical method behind exercise scenarios (ARC-MEX) can inform the way organisations learn from actual challenging events and crises that occasionally happen during their everyday operational activities, as well as further enhance their ability to construct and test their preparedness plans (ARC-COPE).

Since the objectives of ARC-MEX and ARC-COPE are different, both methods are directed at different target user audiences. ARC-MEX aims to aid staff responsible for the planning, design, observation, analysis, and/or reporting of (series of) exercises. ARC-COPE is aimed at staff responsible for developing preparedness or crisis plans and/or analysing and reporting on past incidents or crises. The Agile Response Capability methodology and ARC-MEX and ARC-COPE have a number of links to various management processes and plans that are typically implemented by Air Traffic System stakeholders in a variety of ways. This means that the generic guidance of the ARC approach (including ARC-MEX and ARC-COPE) that is presented here may be implemented in connection to various existing functions, processes and roles depending on how the aviation organisation is structured and on the specific event or scenario.

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1 INTRODUCTION

1.1. The Programme

Future Sky Safety[1] is an EU-funded transport research programme in the field of European aviation safety, with an estimated initial budget of about € 30 million, which brings together 33 European partners to develop new tools and new approaches to aeronautics safety, initially over a four-year period starting in January 2015.

Future Sky Safety contributes to the EC Work Programme Topic MG.1.4-2014 Coordinated research and innovation actions, targeting the highest levels of safety for European aviation in Call/Area Mobility for Growth – Aviation of Horizon 2020 Societal Challenge Smart, Green and Integrated Transport. Future Sky Safety addresses the Safety challenges of the Advisory Council for Aviation Research and Innovation in Europe (ACARE) Strategic Research and Innovation Agenda (SRIA).

Future Sky Safety, established under coordination of EREA, is built on European safety priorities around four main themes, each consisting of a small set of Projects:

- Theme 1 (New solutions for today's accidents) aims for breakthrough research with the purpose of enabling a direct, specific, significant risk reduction in the medium term.
- Theme 2 (Strengthening the capability to manage risk) conducts research on processes and technologies to enable the aviation system actors to achieve near-total control over the safety risk in the air transport system.
- Theme 3 (Building ultra-resilient systems and operators) conducts research on the improvement of Systems and the Human Operator with the specific aim to improve safety performance under unanticipated circumstances.
- Theme 4 (Building ultra-resilient vehicles) aims at reducing the effect of external hazards on the aerial vehicle integrity, as well as improving the safety of the cabin environment.

1.2. Project context

The objective of Project P5 "Resolving the organisational accident" is to reduce the likelihood of organisational accidents in aviation via development and implementation of a Safety Performance System. P5 answers to Future Sky Safety Theme 3, which aims at strengthening the resilience to deal with current and new risks of the humans and the organisations operating the air transport system. P5 focuses specifically on organisational aspects of safety.

The Air Transport System (ATS) is a system-of-systems, wherein each subsystem (airport, airline, air navigation service provider, etc.) is complex and inter-connected, operating as an open, global 24/7 macro-system that is also in a state of constant evolution. By definition, systems-of-systems are not easy to analyse, nor is their behaviour easy to predict. Resolving the organisational accident in such a domain

[1] See https://www.futuresky-safety.eu/ accessed 15JAN2016.

therefore cannot be achieved by a single 'silver bullet' solution. To resolve the organisational accident, all of the key safety components need to be activated and coordinated across the entire ATS: executive safety intelligence at the top and middle management layers of the organisation, as well as the political layer above; safety culture throughout the organisation; safety mindfulness at the operational layer; and an agile response capability to ensure robust response to crises with varying time dynamics. These solutions must be bound together into an agile organisational safety system that is more in the hands of the operational division running an organisation's business. In this way, safety will emerge in day-to-day operations, every single day, 24/7 – as a Safety Performance System. Safety will not be something separate, but will be inextricably bound with other business imperatives.

We need to understand how organisations can work together to detect and respond to crises, with various time dynamics, from major system events or 'surprises' (which can never be fully designed out) towards risks and crises that change at a slower pace with longer-term dynamics. This includes how such events are detected and communicated, and how distributed parts of the aviation system can respond to resolve them. This will create an Agile Response Capability for the entire ATS.

1.3. Research objectives

The objective of this work is to outline a concept for developing training/exercise scenarios that aim to increase the ability to initiate and sustain an agile response by crisis responders in the Air Transport System.

1.4. Approach

This work utilizes a combined approach where concepts from agility and resilience research are used to inform scenario analysis and development based on the principles of the Event Based Approach to Training (EBAT). By structuring the development of scenarios in this way, workshops with stakeholders can outline training scenarios that challenge participants in training sessions in such a way that they have to reflect upon aspects that increase their ability to respond to crisis in an agile way.

The outcomes of this document are the result of an activity where interviews, workshops, and exercise and actual crisis analyses have been performed to iteratively generate the proposed approach. In that sense, the various parts of the approach that is described have been tested in various empirical endeavours, and subsequently improved iteratively.

1.5. Structure of the document

Chapter 2 introduces the background of the Agile Response Capacity (ARC) approach. Chapter 3 describes the general ARC approach. Chapter 4 describes the guidance for the proposed Agile Response Capability Method for EXercise planning and analysis (ARC-MEX) and Chapter 5 the associated method of Agile Response Capability Crisis and Operations and Plan Enhancement (ARC-COPE). Chapter 6 treats other considerations related to the ARC approach.

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2 ARC BACKGROUND

This chapter briefly outlines the theoretical background that has inspired the development of the Agile Response Capability (ARC) guidance, and the studies that comprised the methodology of ARC development. The ARC scenario development and analysis concept is structured according to the basic principles outlined in the Event Based Approach to Training (EBAT) which suggests that scenarios should be organised around independent triggering events that challenge exercise participants in specific ways. In line with this, development of team training with the purpose of improving adaptability and agile behaviour may benefit by inclusion of theoretical concepts from C2 agility theory, including the C2 approach space, the endeavour space, and the agility maturity ladder in the scenario development process. The ARC scenario development and analysis concept is methodologically enhanced with analytical concepts inspired by safety analysis methods such as HAZOP and CREAM/FRAM.

This chapter provides a short background for the three main theoretical components that the ARC-MEX takes as inspirational sources, i.e. event-based training (EBAT), command and control agility theory, and analytical methods such as HAZOP and CREAM/FRAM.

2.1. Event-based training and adaptability

The event-based training and assessment technique (EBAT) is a methodological approach to designing and performing simulation-based exercises. Events are directly linked to training and learning objectives are implemented in training scenarios (Fowlkes, Dwyer, Oser, & Salas, 1998). This provides insurance that the exercise actually includes the necessary elements of training on identified skills or competencies, which also facilitates relevant observation, data collection, analysis, and feedback (Dwyer, Oser, Salas, & Fowlkes, 1999). The objectives of EBAT are to ensure that (Oser, Cannon-Bowers, Dwyer, & Salas 1997, in Oser, Gualtieri, & Salas, 1999):

- Training opportunities are structured by use of appropriate methods, strategies, and tools.
- Learning objectives, exercise design, critical tasks, performance measurement and feedback are tightly linked.
- Training results in improved team performance.

EBAT was originally developed for assessment of military team training in complex scenarios, but its use has been extended to supporting simulator training in other domains, as resident medical training (Rosen et al., 2010) and training of Unmanned Arial System (UAS) operators (Dietz, Keebler, Lyons, Salas, & Ramesh, 2013).

In addition, even though EBAT was created to support simulator-based exercises, it can also be used to structure more traditional training, and especially concerning assessments of the training (Salas, Burke, Wilson-Donnely, & Fowlkes, 2004). Thus, its methodological approach can also provide structure to more basic types of training exercises, as for example tabletop exercises. The only requirement is that the exercise presents some type of event or scenario to the participants. Another important aspect is to

identify the training needs of the concerned organisation/organisations. These depend on several aspects and can range from involving only key personnel such as high-level decision-makers to comprehensive approaches involving more or less all personnel that would have to be involved in a crisis response operation. In terms of training, this suggests a range of scenarios such as low-fidelity scenarios with a relatively low level of detail, which can generally be used for tabletop training exercises, to high-fidelity scenarios that are needed to create the necessary dynamics and realism in full scale training exercises.

The ARC training approach takes inspiration from EBAT but goes beyond it in the sense that it provides a method and analytical support during the various stages of training. Gaining experience from exercises and training the ability to be adaptive and respond to a range of partly unexpected circumstances (see also Woltjer, Trnka, Lundberg, & Johansson, 2006) is the central idea in the ARC training approach. The ARC approach aims to provide guidance to the following important steps in the development of effective team training on adaptability:

- Decide the purpose of the training.
- Generate scenarios in cooperation with stakeholders with domain knowledge.
- Ascertain that generated scenarios provoke adaptability and agile responses.
- Decide the type of exercise.
- Develop methods for data collection and analysis that are subtle enough to capture adaptive responses.
- Develop methods for provision of feedback, e.g. on changes, or possibilities of improvement, on adaptive behaviour.

2.2. Command and control agility theory

The C2 approach space is a conceptual model used to describe different approaches to C2/crisis management. A core idea in C2 agility theory is that no single approach to C2/crisis management is suitable for coping with all problems/challenges that can potentially be encountered. Instead, organisations or collectives of organisations must recognize that different challenges must be addressed in different ways. A way of understanding different problems is to describe them in terms of a problem space, a rich description of the most challenging aspects of an organisation's activities. The agility maturity ladder is a concept describing to what extent different entities are trained and equipped to work jointly in coping with a crisis situation. This section further elaborates on these concepts.

Research on agility and C2 (Command and Control) agility has primarily been conducted in the military domain, although some exceptions can be found in domains such as business management, complexity theory and organisational theory (Dyer & Schafer, 1998; Holsapple & Li, 2008; Spaans, Spoelstra, Douze, Pieneman, & Grisogono, 2009). Research on agility and resilience in cybernetic terms may be said to investigate how a system (e.g. an individual, team, or organisation in the ATS) retains requisite variety in the face of (potentially) adverse events, for example by changing the organisational structure or organisational processes, in order to retain acceptable values for essential variables. Agility as a concept was developed from the point of view of command and control, which is characterised by time pressure,

uncertainty, and risk, in the face of complexity. Typical dynamics in the ATS are changing weather, new regulatory laws, the economy, and human and technological variations in performance, often occurring in unpredictable combinatorial and emergent ways (see Hollnagel, 2004).

The primary focus is on agility and C2 agility as defined by and in connection to the NATO STO[2] SAS[3] task-groups (NATO SAS-065, 2010; NATO SAS-085, 2014) whereas other definitions and uses of the term exist. In the non-military context, *organisational agility* (Johansson & Pearce, 2014; Dyer & Schafer, 1998) has been used to describe how business organisations adapt to changes in the market. From this point of view a dualistic relationship exists between *agency*, the ability to respond to changes with flexibility and acuity, and *structure*, the process constraints and functions that organise work in terms of coordination and cooperation. The organisation thus must provide the necessary structure for work while giving the members of the organisation the freedom to be creative and take advantage of opportunities as they appear (Johansson & Pearce, 2014; Dyer & Schafer, 1998). Holsapple & Li (2008) propose a similar view of organisational agility by pointing out that the organisation must be able to recognise opportunities and challenges (both internal and external to the organisation) and respond using resources in a timely, flexible, relevant and affordable manner. Alberts & Hayes (2007) build upon work performed within the NATO research group SAS-065 (2010) and explains the need for agility based on the limitations in the dominant form of command and control as a hierarchical approach focusing on control of internal processes.

Agility can in part be achieved by being command and control agile, meaning that the actual systems and organisation is rearranged in order to better fit the current or foreseeable future situations. The most important conceptual tool developed in the NATO STO SAS work is the *command and control approach space* (see Figure 1), a three-axis model presenting an organisation's[4] approach to C2 (C2 approach) in terms of "information dissemination" (who gets to know what?), "allocation of decision rights" (who has the mandate to take action) and the "interactions" (who is interacting with who?) (NATO SAS-065, 2010). Hierarchical, formal bureaucratic organisations with limited capability to disseminate information will position themselves on the "lower" end of the dimensions while more networked, distributed organisations with a high degree of allocation of decision rights will position themselves further out on the axes. The positioning of different approaches should not be interpreted as one being "better" than another. Instead, the appropriateness of a C2 approach can only be evaluated in the light of the situation and problem in which it is applied. For some situations/problems a formal bureaucracy may be a good choice, while other situations demand other approaches to command and control/crisis management.

[2] Science and Technology Organisation.

[3] System Analysis and Studies.

[4] Or *entity*, using the language of the SAS-groups.

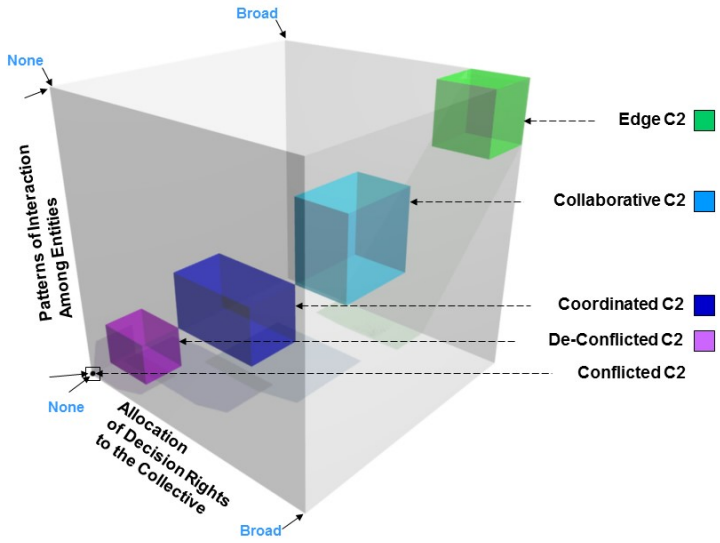

Figure 1. The C2 approach space depicting the archetypical approaches to C2 (NATO SAS-085, 2014).

The NATO SAS-065 (2010) report suggests five archetypical approaches to command and control that can be found along the diagonal going from the lower left corner of the cube towards the upper right corner on the opposite side of the space. The following archetypical C2 approaches are described (NATO SAS-065, 2010):

- *Conflicted C2* represents a lack of coordination of action between the involved entities. Each entity acts on its own accord and does not consider or respect the act of other entities. No information sharing exists between entities and no entity has decision authority over another entity. Surprise, duplication of work, poor resource management, and even potential risk (especially in the military context where friendly fire incidents may occur) is common.
- *De-conflicted C2* is signified by basic coordination, such as dividing an area of operations into different sectors that the entities are restricted to, or by functional division of work. Decision rights are usually centralised and information is only disseminated on a need-to-know basis. Continuous coordination does not take place, making the approach inflexible and unable to adapt to sudden changes.
- *Coordinated C2* represents an approach where the involved entities actively coordinate their efforts. Planning may still be centralised and the internal organisation of the entities may be hierarchical, but some degree of joint planning and resources management exist. At least, the involved entities must seek mutual support for their actions. This demands a certain degree of information sharing to make sure that the involved entities are aware of each other's actions. Technical systems must not necessarily be interoperable between entities as long as the commanding nodes of each entity can exchange information with other command nodes.
- *Collaborative C2* demands active collaboration between the entities involved and also a collaborative planning and goal formulation. A common intent, a single shared plan, must exist within the collective of entities. Such an approach demands interoperable systems on several

levels so that local coordination can take place between parts of different entities. Entities employing a Collaborative C2 approach accept symbiotic relationships and are interdependent. Very frequent interactions, indeed approaching continuous interactions between/among identified individuals/organisations, involving richer and more extensive interchange of information.

- *Edge C2* is an envisioned approach to C2 that is based on highly networked interactions where all entities share a common intent and the allocation of decision rights are established in its broadest sense. Work is coordinated by self-synchronisation. The patterns of interaction are dynamic and reflect the confluence of mission and circumstances. The resulting distribution of information is emergent as a function of the emergent decision-related and interaction-related behaviours.

The term *command and control maturity* (NATO SAS-085, 2014) refers to the ability of the organisation/organisations to function at different positions in the C2 approach space. It should be observed that there is a difference between C2 *maturity* and *C2 manoeuvre agility*. C2 maturity only tells what parts of the C2 approach space an organisation/entity can occupy. Having C2 manoeuvre agility means that the entity also has the ability to recognize when it should perform such a movement and do so. To be C2 agile is thus a function of what parts of the C2 approach space that an organisation/entity or a collective of such potentially can occupy (the C2 maturity) and the ability to position itself appropriately in relation to the endeavour space (the C2 manoeuvre agility). It should also be noted that the need for being C2 agile can emerge as a consequence of the composition of a crisis response organisation (the collective, using the terminology of the SAS-groups). Lack of technical interoperability or technical failure may even degrade an operation to de-conflicted, or even conflicted C2, at least if the participating entities are located far from each other in terms of physical distance. Having organisational agility is thus not a guarantee for agility in collectives of organisations.

2.3. Safety analysis methods

The analysis methods of ARC take some inspiration from several safety analysis methods, both traditional as well as recently developed. The hazard and operability study (HAZOP) originated in the 1960s in the chemical industry as a method for analysing a physical and functional design of a chemical plant for hazards. The method applies guidewords (e.g., more, less, early, late, before, after, reverse, not) to the various nodes that represent a design of a system to identify whether alternative outcomes of the performance parameters (e.g., flow, pressure, temperature, time) of the nodes reveals hazards that need to be managed. HAZOP has been standardized as British Standard BS: IEC61882:2002.

The Cognitive Reliability and Error Analysis Method (CREAM; Hollnagel, 1998) was developed as a response to first-generation HRA techniques. CREAM describes a number of failure modes, which were further developed into the variability modes of the Functional Resonance Analysis Method (FRAM): Hollnagel (2004) defines ten modes along which variability of functions can occur: timing, duration, distance/length, speed, direction, force/power/pressure, magnitude, object, sequence, and quantity and volume. These variability modes are used in FRAM, which may be used to analyse the way socio-technical functions can vary in their performance over time (Hollnagel, 2004, 2012), both retrospectively to

understand past events (Herrera & Woltjer, 2010; Hollnagel, Pruchnicki, Woltjer, & Etcher, 2008; Woltjer & Hollnagel, 2007), and prospectively to analyse risks of future systems (Lundblad, Speziali, Woltjer, & Lundberg, 2008; Woltjer & Hollnagel, 2008).

2.4. Methodology and studies for developing ARC

A number of workshops, meetings, exercise observations, and analyses have been performed to establish the ARC methodology. These may be divided into studies into actual past or future events, and studies into exercises and exercise scenarios. Furthermore, these studies may be divided into studies that focus on the before, during, and/or after phases of event/scenario/crisis management in either exercises or actual events. Thus, a 3-by-2 matrix may be formed, which is shown in Figure 2, specifying the studies that have informed the development of ARC. A number of the examples that are presented as part of the guidance in this guidance are taken or adapted from these studies.

The project was dependent on the cooperation of both operational partners as part of Future Sky Safety WP5.4 team and outside the Future Sky Safety Consortium to provide their expertise on daily operations and crisis management and feedback on the ARC concept and method. Practical issues of access to practitioners and organisations made it difficult to access crisis exercises and planning processes, so that some of the research work had to be informed and tested with exercises already planned or analyses of exercises and events performed after-the-fact. Moreover, exercise planning and execution typically have several months to several years-long timescales, which are difficult to match with a research project. This meant that the full cycle of studying exercises before-during-after was not feasible to implement for all studies, and a more fragmented pragmatic approach needed to be used. This however opened up for exposure of the ARC approach to a wider scope of scenarios and stakeholders than would have been possible with studying fewer stakeholders throughout all the steps of the exercise cycle, which may have led to the ARC approach currently being better-informed by a wide range of cases, types of stakeholders, and informants.

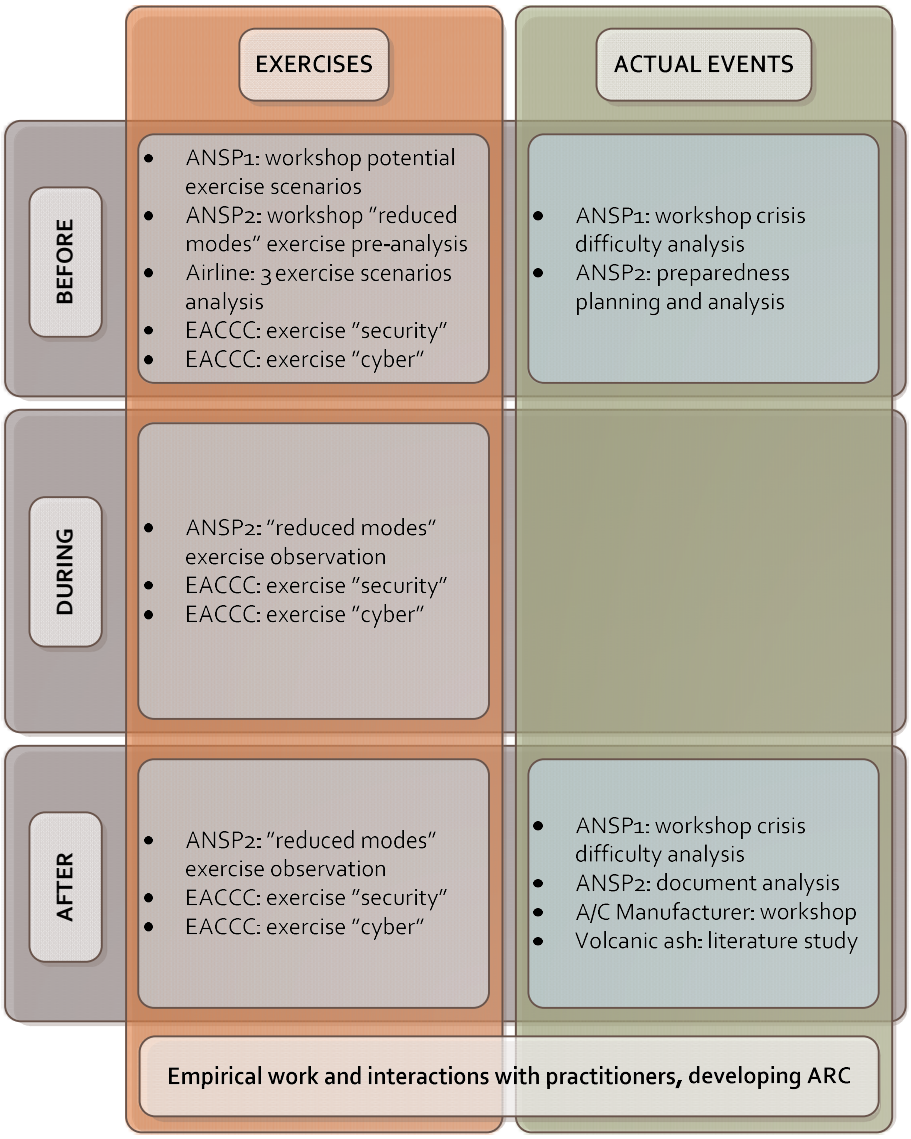

Figure 2 Studies that have informed the development of ARC.

3 THE ARC APPROACH

This chapter describes a scenario development process that aims to inform the design of exercises and training for improving the ability of organisations to respond to crises in an agile way. The first section provides a discussion of the need for organisational agility. The second section describes the agile response capability (ARC) approach, introducing the ARC Method for EXercise Planning (ARC-MEX) and the ARC Crisis Operations and Plan Enhancement (ARC-COPE). The ARC methodology used in both ARC-MEX and ARC-COPE is described in the third section. ARC-MEX is described in more detail in Chapter 4, ARC-COPE in Chapter 5.

3.1. The need for Agile Response Capability (ARC)

The Air Transport System (ATS) is a system-of-systems, wherein each subsystem (airport, airline, air navigation service provider, etc.) is complex and inter-connected, operating as an open, global 24/7 macro-system that is also in a state of constant evolution and change. By definition, systems-of-systems are not easy to analyse, nor is their behaviour easy to predict. Resolving the organisational accident in such a domain therefore cannot be achieved by a single 'silver bullet' solution. *Organisational agility* has been used to describe how business organisations adapt to change.

To achieve organisational agility, the organisation must provide the necessary structure for work while giving the members of the organisation the freedom to be creative and take advantage of opportunities as they appear. In addition, the organisation must be able to recognise opportunities and challenges (both internal and external to the organisation) and respond using resources in a timely, flexible, relevant, and affordable manner. Further, all organisations involved in the ATS must be prepared to collaborate and share resources and information with each other to resolve disturbances. Typically, crisis teams of various organisations, consisting of personnel from top to middle and line management and various operational and staff experts, need to exercise these skills to manage or cope with a crisis in an agile way (illustrated in Figure 3). The scope of ARC is thus agile crisis team cooperation within and between Air Transport System organisations to cope with a crisis.

> *The agile response capability (ARC) of actors in the air transport system can be described in terms of their ability to anticipate/detect events, control them and bounce back after they have happened. Doing so involves adapting their own organisation and resource use, learning, and self-monitoring as well as the ability to coordinate activities with other actors.*
>
> *The guidelines presented in this text are intended as support tools for creating scenarios to be used in training and exercises aimed at improving agile response capability.*

Agility can thus be seen as the ability to create direction and control in situations characterised by complexity, time pressure, uncertainty, and risk. Scenarios used for training and exercises must therefore reflect this complexity and need for collaboration in order to prepare the stake-holders in the ATS to

detect, communicate and respond to such events, thereby providing an improved organisational and inter-organisational capacity for resolving complex, unexpected disruptions (conceptually illustrated in Figure 3). Typically, this involves multiple organisations' crisis teams with representatives from all layers of the organisation, who need to interact to jointly respond in an agile way.

The *agile response capability* (ARC) of an entity or a collective of entities in the ATS can be described in terms of their ability to anticipate/detect events, manage them and bounce back after they have happened. Being agile involves adapting their own organisation and resources, learning and self-monitoring as well as the ability to coordinate own activities with other actors. In terms simplified for the purposes of the ARC approach, the activities that the various stakeholders can use to manage or adapt to the crisis (the solution space) must regularly be adjusted to meet (anticipate and respond to) the way that an event or crisis evolves (the problem space), as illustrated in Figure 4. For situations lasting over longer time periods, joint planning capability may also be necessary. As the complexity of large disturbances in the ATS often require interaction between several actors, interoperability in terms of technical solutions, processes and regulation becomes increasingly important when striving for improving agile response capability.

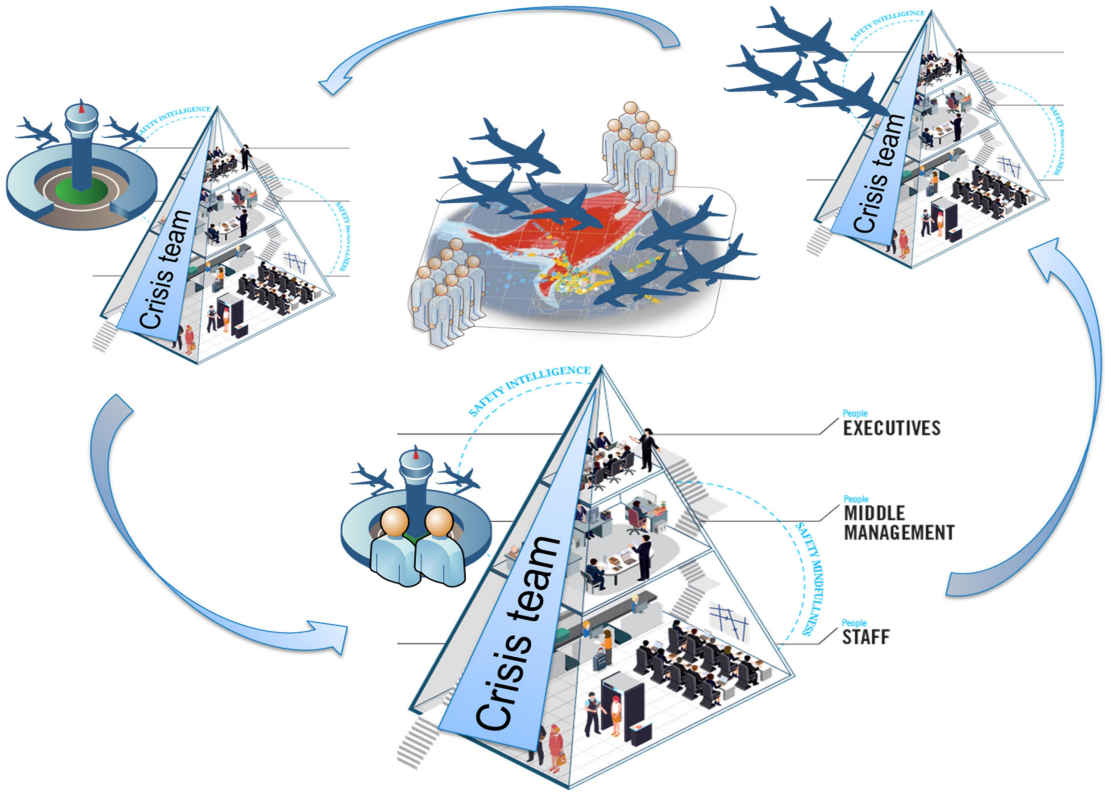

Figure 3. Overall conceptual scope of ARC: Agile crisis team cooperation within and between air transport system organisations to cope with a crisis.

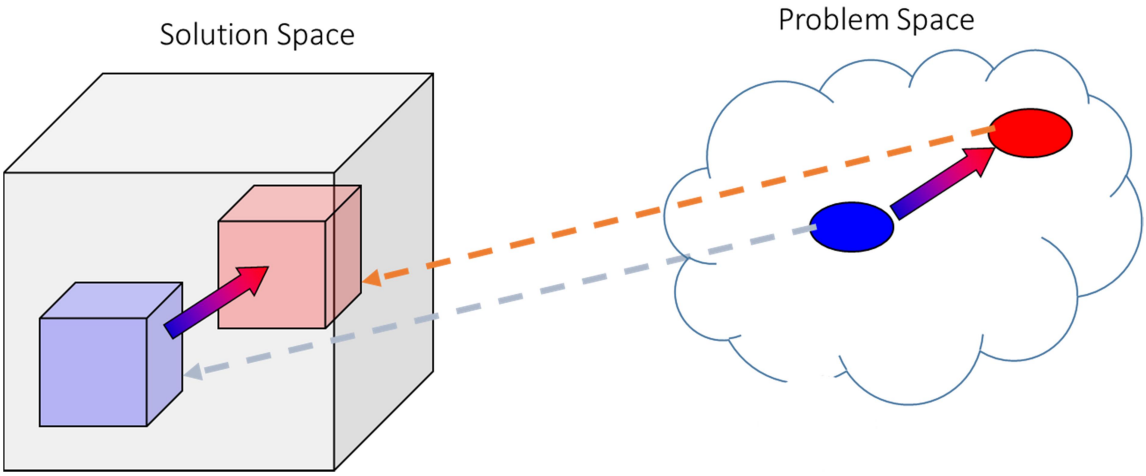

Figure 4. Simplified representation of the need for agility: If the Problem changes, the Solution to the Problem must likely also change, to manage or cope with the changing Problem.

The ability of a collective of actors to jointly cope with a complex situation may be described according to ARC maturity levels (see Figure 5). These maturity levels are to be seen as preconditions for agile capability rather than predictors of agile capability. On the first, most basic level, the actors in a collective experiencing challenging events have no prepared means for interacting and very limited or no means for communicating. Such a collective of stakeholders is likely to spend a significant amount of resources on coordinating their actions in situations that are confusing and time pressured. At the next level, the concerned actors have resolved basic problems and have established some means for assuring communication as well as some prepared methods for collaboration. Occasional joint exercises may occur, suggesting that some understanding of roles and responsibilities may exist. Some technical systems may be shared or use the same standards. The third level is characterized by prepared channels and ways of collaborating. Joint exercises are common and well-established methods and procedures for collaboration are in place. Technical systems are largely shared or even depending on each other. The fourth, final level, represents a collective of organisations that almost live in complete symbiosis, where collaboration occurs on an everyday basis, and is an integrated part of operations. Technical systems for exchanging data and communication are in place and crisis response exercises occur on a regular basis.

Figure 5. ARC maturity ladder.

The ARC maturity ladder presented in Figure 5 relates to concepts developed in military research on command and control agility. These concept propose that actual systems and organisation must have the ability to be rearranged or altered in order to better fit the current or foreseeable future situations.

> *What are we doing – is it working?*
>
> *What should we be doing*?
>
> *What prevents us from going where we want to go*?

Agile response capability is thus a function of how quickly and accurately an organisation (or a collective of organisations) can re-arrange their internal and external structures and procedures to manage better the situation or problem that is to be handled. It should also be noted that the need for being C2 agile can emerge as a consequence of the composition of organisations partaking in a crisis response operation. As suggested by the maturity ladder presented in Figure 5, lacking technical interoperability between the involved organisations, or technical failure, may even degrade an operation so that the preconditions for coping with the situation at hand is severely hampered, at least if the participating entities are located far from each other in terms of physical distance. Individual agility is thus not a guarantee for collective agility. All organisations that potentially could be involved in an event must be taking into account when training is needed for improved agile response capability.

In order to achieve agile response capability, a number of questions must be answered by the involved organisations: *What are we doing – is it working? What should we be doing?* and *What prevents us from going where we want to go?* Using the concept of the C2 agility (as described above), these questions can be re-phrased to:

Is the C2 approach working? Is the C2 approach enabling both the operational approach as a whole and its individual lines of effort? This can be assessed by bottom-up reporting of information flows, collaborations, and if decisions and actions can be performed in a timely manner.

What has changed or could change in the operational environment that will/could impact the C2 approach? It is not possible to present a comprehensive list of what could change as each mission and

Future Sky Safety has received funding from the EU's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 640597.

operational environment are likely to be different, but examples could be changes to the mission itself, changes to the organisation (within the collective or in other organisations that have significant impact on the operation), changes in the number of involved organisations/actors, changes in the actual operational environment (such as a major change in weather or changes in public opinion or political ambitions), or communication disruptions (technical failures, security issues, etc.).

What indicators would illuminate change in the operational environment and how can they be monitored? How can such indicators be implemented? What kind of intelligence must be gathered and from what sources? Who is responsible for monitoring those information sources?

What are the most important changes to address first? The C2 approach could be altered along the dimensions of the C2 approach space, but different changes comes at different costs, and may also be more or less feasible depending on the situation and the current composition of the collective. Urgency and risk must be compared.

How will the most important changes impact organisation and interoperability with other organisations? What is the most appropriate way to organise the collective responding to the crisis? What adjustments are required to achieve this?

As can be seen, there are some basic obstacles that need to be overcome in order to be able to adopt more sophisticated approaches to C2, both in terms of training as well as in terms of procedures and equipment. As often in safety and crisis management, these demands are usually not called for in everyday operations. The need emerges as the situation changes from everyday operations to crisis response operations. The type of crisis will also create different demands on the capability to respond in an agile way.

3.2. Overview of the ARC approach

The Future Sky Safety WP5.4 Agile Response Capability work develops agility concepts into guidance for air transport system stakeholders in order to improve their agility in the face of crises and other challenging situations.

A way to increase the agile response capability within or between organisations is, as pointed out by the ARC maturity ladder, not only to invest in compatible ICT or create principles for collaboration, but also to perform regular, joint, exercises. Such exercises must however challenge the participating organisations in such a way that they actually have to produce agile responses. To assure this, this work proposes an approach to scenario development called the *Agile Response Capability Method for EXercise planning (ARC-MEX)* as described in Chapter 4. The ARC methodology (described in Section 3.3) is the analytical method that underlies ARC-MEX. It is possible to utilize the ARC approach and the ARC methodology for applications other than scenario or exercise design. The related and conceptually similar activities of preparedness planning and analysis of actual events, crises, and incidents may thus also benefit from the ARC approach, although in a different form: the *Agile Response Capability Crisis Operations and Plan*

Enhancement (ARC-COPE), as described in Chapter 5. The main focus of this work and the main product of application described in this report (Chapter 4) is however *exercise planning and management*, by means of ARC-MEX.

The ARC approach may thus be applied to *actual* past or future events and scenarios, and *simulated* events and scenarios in exercises. Furthermore, ARC may be applied to the *before, during, and/or after* phases of event/scenario/crisis management in either exercises or actual events. Thus, a 3-by-2 matrix may be formed, outlining the ARC approach, and the foci of ARC-MEX and ARC-COPE, as shown in Figure 6.

In the *before* phase of *exercises*, the ARC approach generally and the ARC method more specifically aim to support the team responsible for setting up and planning the exercise to generate scenarios that challenge the agility of the exercise participants and organisations, thus setting the stage for "raising the game" for the participants. Concretely, applying the ARC method to the exercise scenario generates the events or injects that are to be played, including various what-if situations, described in the exercise playbook. *During* the exercise, the ARC-generated playbook enables the exercise white cell (the personnel playing simulated roles and events that the exercise participants to be trained interact with) to "control the heat" of the exercise by choosing appropriately challenging injects from the playbook, as well as what data to collect to monitor the exercise and inform debriefing and after-action review. After the exercise, the data collected during and immediately after the exercise, based on the ARC-based playbook, is analysed to inform debriefing and after-action review, and offline analysis, as part of the work to derive lessons learned from the exercise.

Similarly, as a preparation for actual events, i.e. the *before* phase, the ARC methodology can be applied to preparedness plan analysis as part of the ARC-COPE method, which aims to enhance preparedness through supporting the requisite imagination[5] that is necessary to develop a preparedness plan that covers many of the aspects of the variability that is expected to be met during actual events. These preparedness plans aim to improve the aviation stakeholders' response *during* the actual event, possibly informing which events should be monitored to recognize the onset of the event triggering the response plan, as well as circumstances to monitor during the event that trigger parts of the response plan and its termination. After the event, the ARC methodology may be used to analyse the actual course of events, and variations of what happened in what-if scenarios, in order to determine lessons to be learned for future events or exercises.

Since the objectives of ARC-MEX and ARC-COPE are different, both methods are directed at different target user audiences. ARC-MEX aims to aid staff responsible for the planning, design, observation, analysis, and/or reporting of (series of) exercises. ARC-COPE is aimed at staff responsible for developing preparedness or crisis plans and/or analysing and reporting on past incidents or crises. (Section 6.1 explains that due to a high variety in organisational terminology used throughout the Air Transport

[5] See Adamski & Westrum, 2003.

System, the organisational "home" of these processes and tasks may differ greatly depending on the organisation, and ARC may be applicable to different roles in each organisation in a different way).

ARC generally aims to provide the exercising organisation(s) with a means for reflection and argumentation about what was difficult in the past crises or expected ones, and incorporating this knowledge into focused exercises. Currently, selecting challenges is often done implicitly or by expert judgment of experienced members of the crisis team, while ARC stimulates the explicit and methodical articulation of these challenges, thus channelling expert judgment and imagination in a structured way. It also allows the organisation(s) to build up a repository of challenges observed or expected, that may be reused to vary exercise contents throughout an exercise series, or to vary the difficulties that participants face around the same theme across different teams trained across exercises. In this way, the organisation(s) can keep track of the contents and results of their exercises, to plan for the efficient use of the (often, substantial) resources that are spent on training and exercising, increasing preparedness. In this way, organisations can focus their exercises on learning objectives in particular contexts. This in turn facilitates a reasoned, explainable and strategic build-up of preparedness throughout and across organisations through training programmes. At the same time, the analytical method to reasoning about exercise scenarios can inform the way organisations learn from actual challenging events and crises that occasionally happen during their everyday operational activities, as well as further enhance their ability to construct and test their preparedness plans.

ARC-MEX is described in more detail in Chapter 4, ARC-COPE in Chapter 5. The methodology as part of the ARC approach that is applied in the various phases of analysis of ARC-MEX and ARC-COPE is described in the following section.

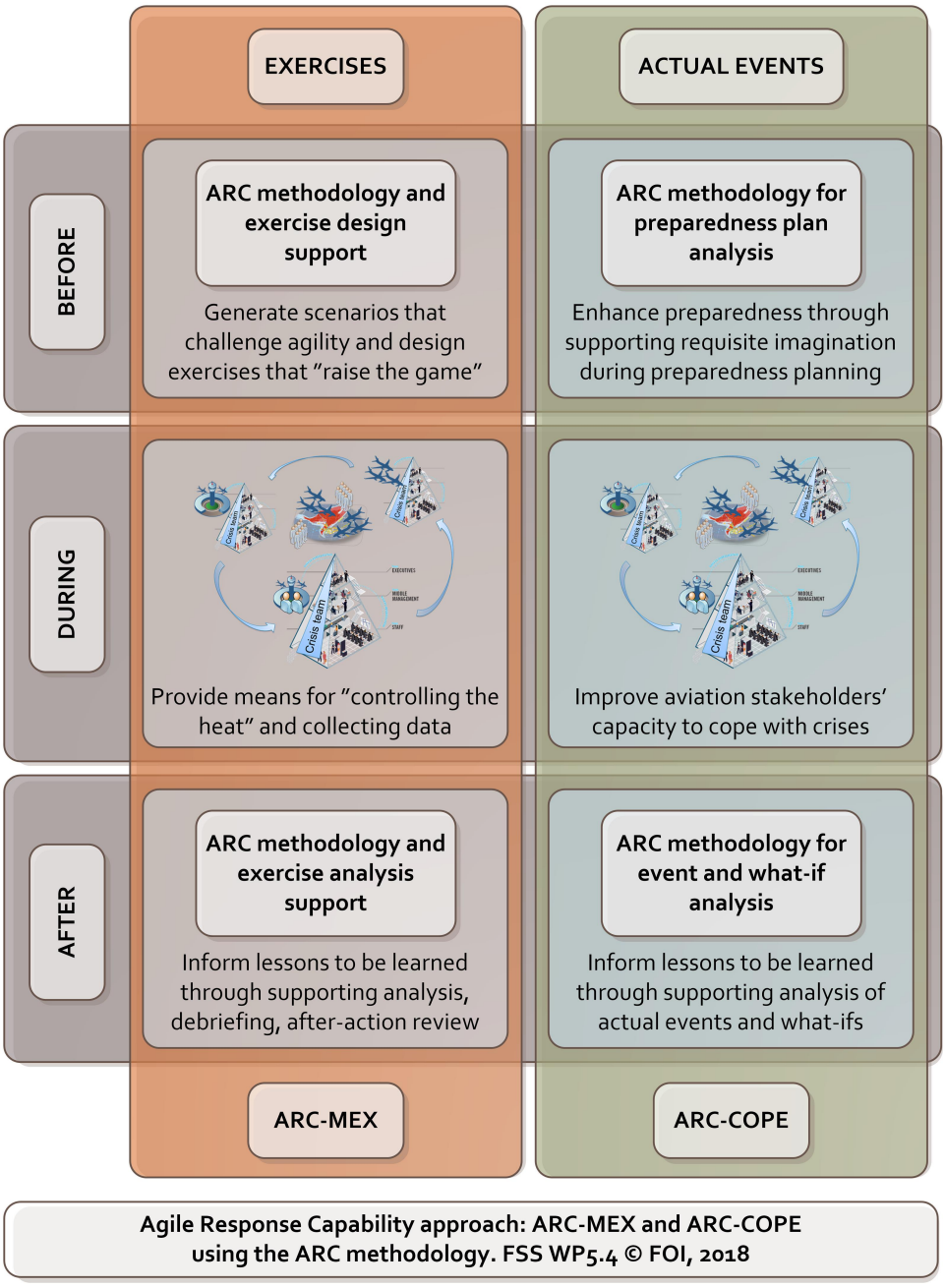

Figure 6 The ARC approach to supporting exercises (ARC-MEX) and preparedness planning and learning from actual events (ARC-COPE) using the ARC analysis method.

3.3. The ARC methodology

The central analytical tool as part of the ARC approach that is applied in the various phases of analysis of ARC-MEX and ARC-COPE is the ARC methodology, inspired by safety-analytical methods such as HAZOP

and CREAM/FRAM. It consists of a combination of *Parameters*, *Guidewords*, and *Active verbs*, as explained in this Section.

The aim of ARC is to provide support to the imaginative as well as analytical process of running exercises and preparing for and learning from actual events. This means that *ARC can be applied flexibly where appropriate (not necessarily in an exhaustive manner)*, particularly to the processes that a (set of) organization(s) experience as difficult, e.g. because it is difficult to generate appropriately challenging scenarios, generate what-ifs, provide input to brainstorming or analysis sessions, evaluate events and exercises, etc. The ARC methodology thus does allow the structured investigation of various permutations of events and circumstances, but may also be used selectively when analytical resources are not available or some aspects are already decided by other means. The application of ARC should therefore be preceded by an analysis or reflection of the organisation in terms of which processes are related to the ARC approach and which aspects of existing processes are challenging and why.

3.3.1. Parameters

The ARC methodology uses a set of parameters to describe both the problem space and the agile response space. These parameters can be used as an analytical tool to increase the resolution of the scenario description and provide a methodological support to the analysis of both triggering events and stakeholder actions. The following parameters are currently defined[6]:

- State: This typically describes the state of the crisis, or the state of the crisis organisation. Examples are that the organisation is formally in “crisis mode” (such as the Network Manager’s EACCC has defined) or any other alert state that a team, organisation, or set of organisations may have defined. Thus the state tells something about how serious the situation is and how the organisation is doing.
- Information: This parameter describes information aspects about the information that is known or not known, or needs to be known, in order to take action on the crisis. This can mean any information that in the context of the crisis is relevant, which may be information that is collected or monitored on a regular basis (e.g. an airline’s information about their flights, aircraft, passengers, and cargo), as well as information not commonly available (e.g. ash particle density during the first volcanic ash crisis).
- Resources: This parameter is about what the organisations meeting the crisis have to work with in terms of materiel, personnel, time, money, etc. that are applied, used or consumed for the resolving of the crisis. It thus concerns questions like what the crisis teams have to work with, what they need, and how to get it.

[6] Note that during the course of the development of the ARC methodology, these parameters seem to be adequate, sufficient, and necessary to describe the situations and actions that were described in the exercises and events that were studied. However, future analyses may surface the need to revise this list of parameters.

- Goals: This parameter describes in which direction the organisations want the crisis to develop, what are desired and undesired states. For example, these could be: to reduce flight delays below an acceptable number of delay minutes, saving lives, restarting traffic as usual, etc.
- Organisation/Collaboration: This parameter describes inter-organisational and collaborative aspects, as well as information exchange between organisations, teams, and roles. Thus, issues such as who needs to communicate with whom, how actors work together, how responsibilities and mandates are arranged, and which information is exchanged.
- Competence: This parameter describes the competence of personnel that is available and/or needed. For example, volcanic ash experts of various kinds were necessary to understand the potential impact of volcanic ash on air traffic, an expertise which was not readily available to all actors that needed to make decisions to cope with the first volcanic ash crisis.

3.3.2. Guidewords

Some guidewords[7] that can be used to express variations or variability of the parameters described in 3.3.1 are the following:

- Magnitude: How much/serious? (e.g. the organisation's crisis state, the magnitude of closed-off airspace, the capacity set for an airspace sector or airport)
- Timing: When? What is "the right time", what is early/late? (e.g. the timing of a decision)
- Availability: Is it available? (e.g. availability of information, resources, or competence)
- Uncertainty: Is it certain? (e.g. uncertainty of information, unclarity of crisis state)
- Duration: How long has it lasted, or is it going to last? (e.g. duration of technical failure, duration of crisis state)
- Rate of Change: How can the situation change and how fast does it change? (e.g. how does the crisis state change, how fast do actors act, how does the weather change, how does a nuclear spill cloud travel?)
- Object: What object does the parameter apply to? (e.g. which organisation is affected, which countries are affected, etc.)

These guidewords are interpreted somewhat differently depending on the parameter they are associated with. These relations are described in further detail in Section 3.3.3. It should be noted that not all guidewords are applicable to every parameter, depending on the type of scenario and triggering events in question.

[7] Note that during the course of the development of the ARC methodology, these guidewords in combination with the parameters seem to be adequate, sufficient, and necessary to describe the situations and actions that were described in the exercises and events that were studied. However, future analyses may surface the need to revise this list of guidewords.

3.3.3. Parameters x Guidewords

A fundamental idea in ARC-MEX is to create scenarios around one or several triggering events that challenge the participants in an exercise in such a way that they are encouraged to develop their agile response capability. Each event should ideally be described according to the parameters presented in

> *Parameters, guidewords, and active verbs are used to identify and refine triggering events in an effort to assure that the exercise participants engage in agile response during the exercise.*

Section 3.3.1. An event is thus described as one or several states that have information, resources, and goals associated with it. In addition to this, the event takes place in an organisational context that can be used to further challenge the participants. Lastly, the parameter "competence" describes the need for, and availability of, expertise to cope with the event at hand. In some cases, such as the first volcanic ash cloud, the ATS had to be supported by a number of experts to even understand in what way the ash cloud could impact air traffic and predict where and for how long the disturbance would remain.

As pointed out, the guidewords found in 3.3.2 can be used to refine the description of the state in an effort to further tune the triggering events to be used in the scenario. These guidewords are applicable to each state as illustrated in Table 1 although they refer to different things depending on the kind of state they are connected to. For example, the parameter *State* can be described in terms of its *magnitude* which states if the state has been described as for example high or low alert state of the crisis, which crisis mode the organisation is in or whether the crisis team is activated. *Timing* can illustrate if the state has been set late, early or prematurely. *Availability* points to the questions of whether a state description exists at all. *Uncertainty* concerns the ambiguity that often follows crisis events – what has actually happened or is happening? Are there several alternative truths that the crisis responders must consider to determine the state of the crisis? This can be used to increase the complexity of a scenario. *Duration* describes the temporal aspect of the state – is it an event that leads to the organisation being in a crisis state for a long time, or is the crisis team deactivated after a quick response? *Rate of change* illustrates the dynamics of the state or event. Does it involve sudden change? Is it static in its nature? These guidewords may also be combined: In combination with increasing magnitude, a quick rate of change indicates a quick escalation of the crisis. *Object* is used to describe what the state concerns, i.e. the geographical place or the individuals that are affected by the crisis event, such as an ANSP, a part of the European airspace, a conglomerate of airlines, etc. These guidewords can support the process of "regulating the heat" of an exercise, and being explicit about what aspects make the situation at hand challenging to deal with.

In a similar fashion, "Information", "Resources", "Goals", "Organisation" and "Competence" can be described in terms of magnitude, timing, availability, uncertainty, duration, rate of change, and object. Table 1 suggests examples to use the guidewords, but it should be noted that not all guidewords apply to all parameters in all cases. Depending on the type of triggering event, only some may apply or be useful. Note that these combinations of parameters and guidewords can be used to describe the problem and

solution space that are central to the ARC approach. Green text refers to that the text describes the solution space, red text refers to the problem space, and orange text may refer to either or both problem and solution space.

Table 1. Examples illustrating the relation between parameters and guidewords, and the relation to problem space (red), solution space (green), or possibly both (orange).

Parameter	MAGNITUDE	TIMING	AVAILABILITY	UNCERTAINTY	DURATION	RATE OF CHANGE	OBJECT
State	situation classified as high/low severity, crisis mode (not) activated	late decision /understanding of state, premature state assessment	no decision made, no understanding of state classification	several states valid at one time, unclear whether to activate crisis mode	duration of situation with high severity, duration of crisis mode activation	rapid, dynamic, slow, static state changes	the object that is in a certain state, e.g. EACCC, airline crisis team, ANSP, a part of the European airspace, a conglomerate of airlines
Information	too much information, too little information	delayed information, waiting for information, early warning	missing information	different or inaccurate information	validity of information: seconds, minutes, hours, days	immediate feed-back, delayed feedback	the object that the information refers to: e.g. airspace (worldwide, Europe, national, local, …), airport, aircraft, aircraft fleet, aircraft type, airline, technical system, passengers
Resources	too much resources, too little resources	resources available late, waiting for resources, resources available early	(no) resources available	different resource, exchangeable resource, wrong resource	resources only available during a certain time period	resources can be allocated and deployed quickly, resources become available slowly	types of resources, interchangeability of resources
Goals	many goals, need to prioritize /satisfice /sacrifice, goal-fixation, optimizing inappropriately	goal formulated late, waiting for goal, goal formulated early on	no goal articulated	multiple goals, conflicting goals	goals valid for a certain duration	rapid goal formulation, slow goal formulation	what objects/units are affected by the goals, and are goals shared across these? e.g. crisis team, several ANSPs, several airlines, airline and airport company and ANSP (stack) around hub/base airport
Organisation/ Collaboration/ Exchange	overspecified collaboration, unnecessarily complicated collaboration /exchange, degree of informal exchanges between organisations	organisation of collaboration is determined at late stage, waiting for new organisation to be put in place, organisation of collaboration determined early on	no established organisation, no collaboration /exchange	unclear which organisational structure is applicable, unclear mandate, several actors with conflicting mandates	organisation permanently available, organisation will only last for limited time	time taken to establish new organisation, activation time of organisatio	which organisations and relations between them? what are formal and informal information channels used?
Competence	many experts available, few experts available	expertise available at late stage, waiting for experts, expertise available early on	(no) competence/ expertise available	different expertise /competence available than needed, competing opinions between experts, inconclusive	experts only available for parts of the event	time taken to identify/get access to expert, expert is permanently or irregularly available	competence/expertise about which specific subjects?

Future Sky Safety has received funding from the EU's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 640597.

3.3.4. Parameters x Active verbs

The ARC analysis processes may, in addition to the parameters and guidewords, be supported by using active verbs. Such active verbs are, just like the guidewords, associated with the parameters and may either be used as a complement to, or instead of, the guidewords. The active verbs can be seen as a way to reason about the possible solutions or ways to cope with an event, and thus refer mostly to the solution space of the situation, i.e. *in what way teams or organisations can act in order to change the state of the parameters*. Table 2 presents example active verbs and how they can be used in connection to the different parameters.

Table 2. Illustration of how active verbs may be used in connection to the parameters.

Parameter	Active verbs
State	**assess, define, revise, upgrade, downgrade, communicate, predict, anticipate, activate, declare, establish**
Information	**collect, monitor, define, assess, share, dismiss, restrict, deny, receive, transmit, broadcast, delay, confirm, request, analyse**
Resources	**assess, receive, maintain, deploy, mobilize, dismiss, share, activate, switch, request**
Goals	**define, set, revise, remind, prioritize, communicate, share, agree, reduce, downgrade, re-establish, maintain**
Organisation/ Collaboration/ Exchange	**define, maintain, activate, revise, share, communicate, agree, remind, update, brief, publish**
Competence	**recruit, maintain, consult, mobilize, request, dismiss, engage**

These are examples, as the context of the specific crisis determines which active verbs span the solution space, or possible activities that are available to be undertaken. Thus, the active verbs are not a principled list of activities, instead they are intended to start discussions on which actions that could be taken to chart both the problem space describing the crisis and the various ways of responding to the changing problem space. However, future analyses should therefore not be restricted to the use of these active verbs per se, but instead chart the most useful actions (and thereby verbs).

The active verbs related to the parameter “state” are for example “assess” in the sense of trying to understand what the current state is, “define” as in setting a state for a situation like when deciding whether a situation is to be considered a crisis or not, “revise” as when a state is re-considered in the light of new information, “upgrade” or “downgrade” when a state is considered as more or less severe after a revision, and so forth. The parameter “Information” can likewise be described in relation to a number of activities such as “collect”, “monitor”, “define” etc. depending on the type of triggering event and state in question.

As in the case with guidewords described above, all active verbs will not apply to all situations, but are intended to provide guidance during the brainstorming sessions in steps 1 & 2 of the ARC-MEX (see Section 4.1.1).

3.3.5. Parameters x Guidewords x Active verbs

The combination of parameters, guidewords, and active verbs, which may be used in analyses as they are, as well as be combined into questions and discussion points for brainstorming and analysis meetings, thus form the analytical ARC methododology, which can be applied in various ways in both ARC-MEX for exercises and ARC-COPE for actual events. ARC methodology may graphically be summarized as in Figure 7.

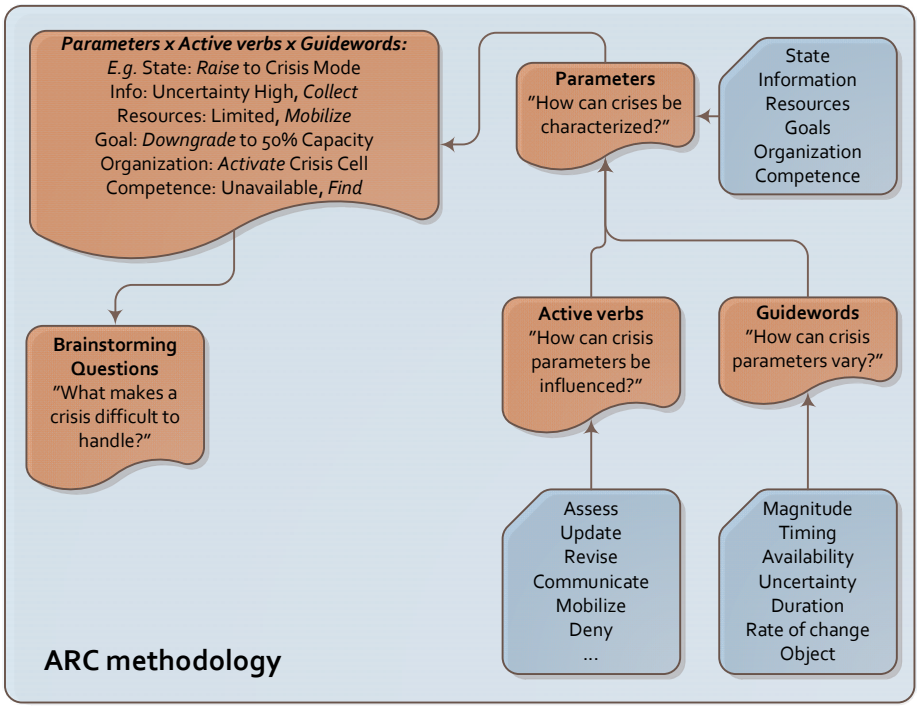

Figure 7. Summarizing and exemplifying visualization of ARC methodology.

4 THE ARC APPROACH TO EXERCISES: ARC-MEX

To ascertain that developed scenarios are relevant and provide effective training, stakeholders with domain knowledge must be included in the scenario development process. ARC-MEX uses three steps to

The Agile Response Capability Method for Exercise Planning (ARC-MEX) aims to create scenarios that support event-based training for ATS-wide agile crisis response.

explore the dimensions of how an event or crisis can evolve (the problem space) and which dimensions make up the activities that the various stakeholders can use to manage or adapt to the crisis (the solution space).

Before the exercise, ARC-MEX aims to support the team responsible for setting up and planning the exercise to generate scenarios that challenge the agility of the exercise participants and organisations. *During* the exercise, the ARC-generated playbook enables the exercise white cell to "control the heat" of the exercise by choosing appropriately challenging injects from the playbook, as well as what data to collect to monitor the exercise and inform debriefing and after-action review. After the exercise, the data collected, based on the ARC-based playbook, is analysed using ARC methodology to inform debriefing and after-action review, and analysis towards lessons to be learned.

Scenarios should have the capacity to expand the domain knowledge of the trainees, and include both recognition and assessment of prototypical situations and application of domain knowledge in novel situations. In order to create such scenarios they suggest a number of factors that should be considered, for example: number of learning objective addressed in the scenario; how to specify or select events that call upon skills of interest; how to ensure that intended events actually occur; and how to accomplish the links between the learning goal, event, performance measure, and the feedback

The Agile Response Capability Method for EXercise planning (ARC-MEX) aims to create scenarios that support event-based training for ATS-wide crisis response. The purpose is to identify scenarios that include events that fundamentally challenge the involved organisation(s) ability to act in a purposeful and coordinated fashion, forcing the participants to reflect upon and work with their ability to formulate goals in the face of uncertainty, coordinate assets, and improve information exchange under pressure.

ARC-MEX differs from traditional exercises in the sense that there is no single "correct" solution. Instead, the purpose of ARC-MEX training must be to have the trainees reflect upon the way they organise themselves and how they conduct work.

Training for agile response capability is challenging as it differs from traditional exercise approaches in the sense that it is difficult or impossible to state what the 'correct' solution to the challenge posed by the

Future Sky Safety has received funding from the EU's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 640597.

training scenario is/should be. Rather, the purpose of such training must be to have the trainees reflect upon the way they organise themselves and how they conduct work. In order to achieve this, "trigger events" must be created that challenge the participants in the training session to start reflecting on, rather than merely reacting to, the events. Scenario design may thus include events that:

- Force participants to collaborate with partners they do not normally work with.
- Create a need for information that is not available from single sources but must be aggregated from different sources and stakeholders.
- Create situations that challenge prioritization so that different organisations must negotiate, compromise, or otherwise focus on global rather than local goals.
- Create situations where the chain of command is ambiguous, encouraging self-synchronization and collaboration.
- Create situations where responsibility for handling the critical event may be unclear, encouraging initiative and assuming responsibility when facing uncertainty.
- Create situations that challenge information management in the involved organisations.
- Create situations which demands an understanding of the collective of organisations involved in the crisis response, in order to respond rapidly and efficiently. Such an understanding can prove crucial in critical situations.

In what way does the ARC-MEX differ from other exercise or scenario generation approaches? On the surface, the conceptual overview does not differ from other organisational learning. The core contribution comes in approach taken and methodology employed during the various steps of the scenario development process (see Figure 8). This module consists of a number of methods to facilitate a focus on agility during scenario development and analysis, such as active verbs, guidewords, brainstorming questions, and parameters. Combined, these methods can be used to assure that the scenario developed will challenge agile capability.

ARC-MEX provides methods that assure scenarios that challenge the agile capability of the organisation or organisations that participate in the exercise. It provides guidance on the analysis of the phases before (planning), during (performing), and after (learning from) the crisis exercise.

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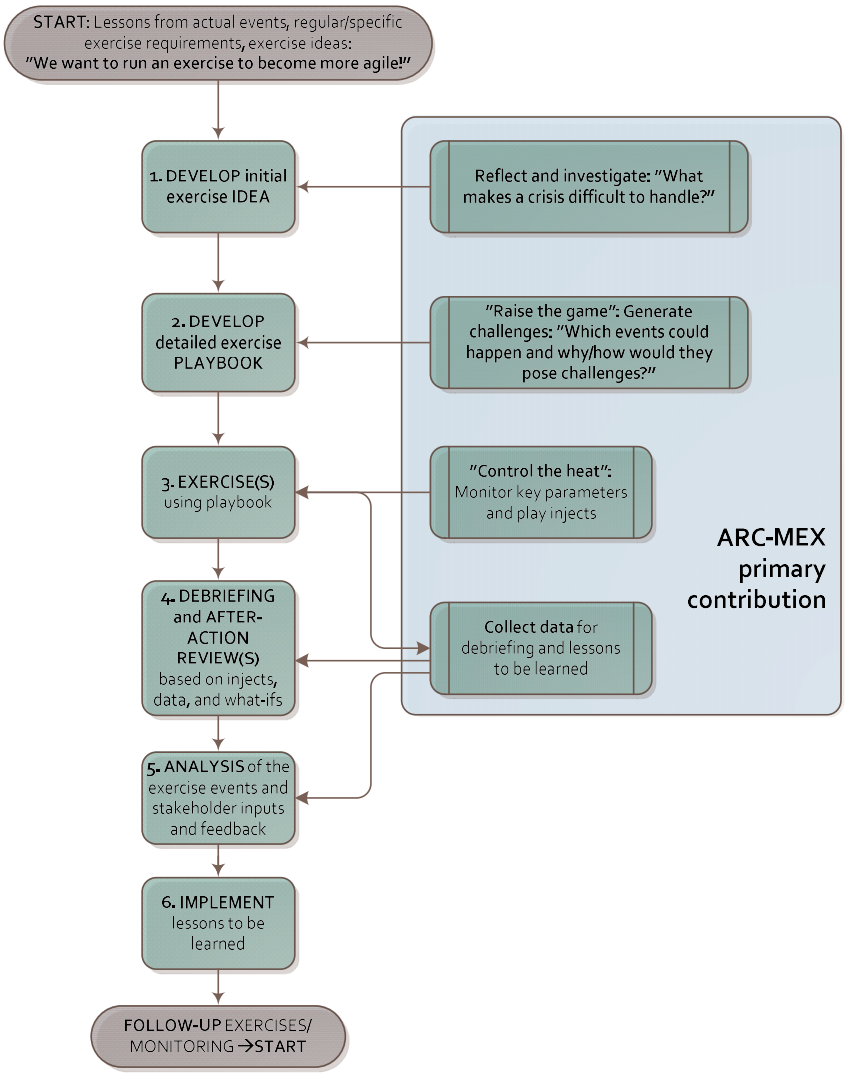

Figure 8. Conceptual overview of the ARC-MEX process.

ARC-MEX consists of six distinct steps, starting with the assumption that an exercise is needed. This assumption can be more or less well-informed depending on the purpose and maturity of the concerned organisation(s) and the incentives at play to having exercises. Thus, the assumed starting point is that the overall purpose is to exercise with the purpose of improving agile response capability: If the exercise has another purpose, such as developing basic skills or strictly exercise specific procedures, a more traditional exercise approach may be used.

Once the decision has been made, the first step consists of focus groups or workshops with stake-holders from the concerned organisation(s) to reflect and investigate which aspects of crises are challenging to the organisation(s) that are about to exercise together. The resulting description is used to clearly define the exercise idea in terms of the "what", "why", and "who" of the exercise.

ARC-MEX provides guidance for the exercise cycle before, during, and after the exercise, in six steps:

Before the exercise:

1. *developing the initial exercise idea,*
2. *developing the exercise playbook,*
3. *running the exercise,*
4. *de-briefing and after-action review,*
5. *analysis of the exercise into lessons to be learned, and*
6. *implementation of lessons to be learned.*

ARC-MEX can however be applied flexibly, adjusting the effort in each of the steps to the exercise organisers' needs.

The second step aims to create a "playbook" (see step 3, Figure 8) that can be used as a basis for an exercise, and goes into the detailed specification of the exercise's "how". The contents of the playbook aim to assure that there is an agile response dimension to the exercise. Step 2 aims to further specify challenging events, identify stakeholders, and determine performance measures that can be used for evaluation and after-action review. During step 2, the type of exercise is also decided as the preparations and planning needed differ greatly depending on how the exercise actually is conducted. A table-top exercise with selected members from an organisation is for example less complex and costly than a full-scale live exercise and allows focus on different aspects.

If the exercise idea requires scenarios with a high level of complexity, step 1 and 2 may require iterations, i.e. that the output from an initial focus group is further elaborated in subsequent focus group(s) or workshops until scenarios and events with satisfactory quality have been generated.

This playbook is the basis for conducting the exercise, which is the third step in the ARC-MEX. Performance measures identified in step 2 can also be used to assess the progress of participants during an exercise and thereby allow exercise managers to "control the heat" in the sense that scenario difficulty can be adjusted depending on the progression of an exercise and participant experience. This is a crucial part of assuring training of agile response, as the events presented to the participants in the exercise must challenge the participants to such a degree that they are "forced" to respond in an agile way, i.e. the scenario needs to be sufficiently challenging. In order to have a learning benefit of the exercise the participants need to remain engaged in the exercise, which makes it important not to overwhelm the participants with an inappropriately difficult exercise. Thus, "the heat", the difficulty of the events presented to the participants, may need to be adjusted both upward and downward. The ARC approach provides the means to articulate which events, aspects, and dimensions the exercise organisation staff (often called "white cell") can use to "control the heat": what challenges can be injected and why.

The fourth step consists of debriefing and/or after-action review (AAR). These processes are in place in order to let the participants share their experience and individually and jointly reflect on the course of

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events, and possibly various what-if alternative circumstances or courses of action, in order to formulate lessons to be learned from the exercise. The ARC approach enables a methodological approach to the data presented and questions asked during these sessions (debriefing typically occurring immediately after and AAR occurring immediately or sometime after the completion of the exercise depending on data processing and analysis).

The fifth step concerns analysis of data gathered during the exercise. Step 4 and 5 may occur simultaneously and/or in several iterations, depending on the analysis work required for AAR. The fifth step is concluded when both the events that played out, white cell and participants actions, and their consequences and debriefing and AAR results have been analysed to the extent that the training and exercise objectives are assessed satisfactorily, and lessons to be learned can be generated.

The outcome of this analysis is used in step six to support the implementation of lessons learned. The feedback can also be used as a basis for modifying future exercises.

The remainder of this chapter contains a detailed description of each step of ARC-MEX. A detailed overview diagram of the ARC-MEX can be found in Section 4.7.

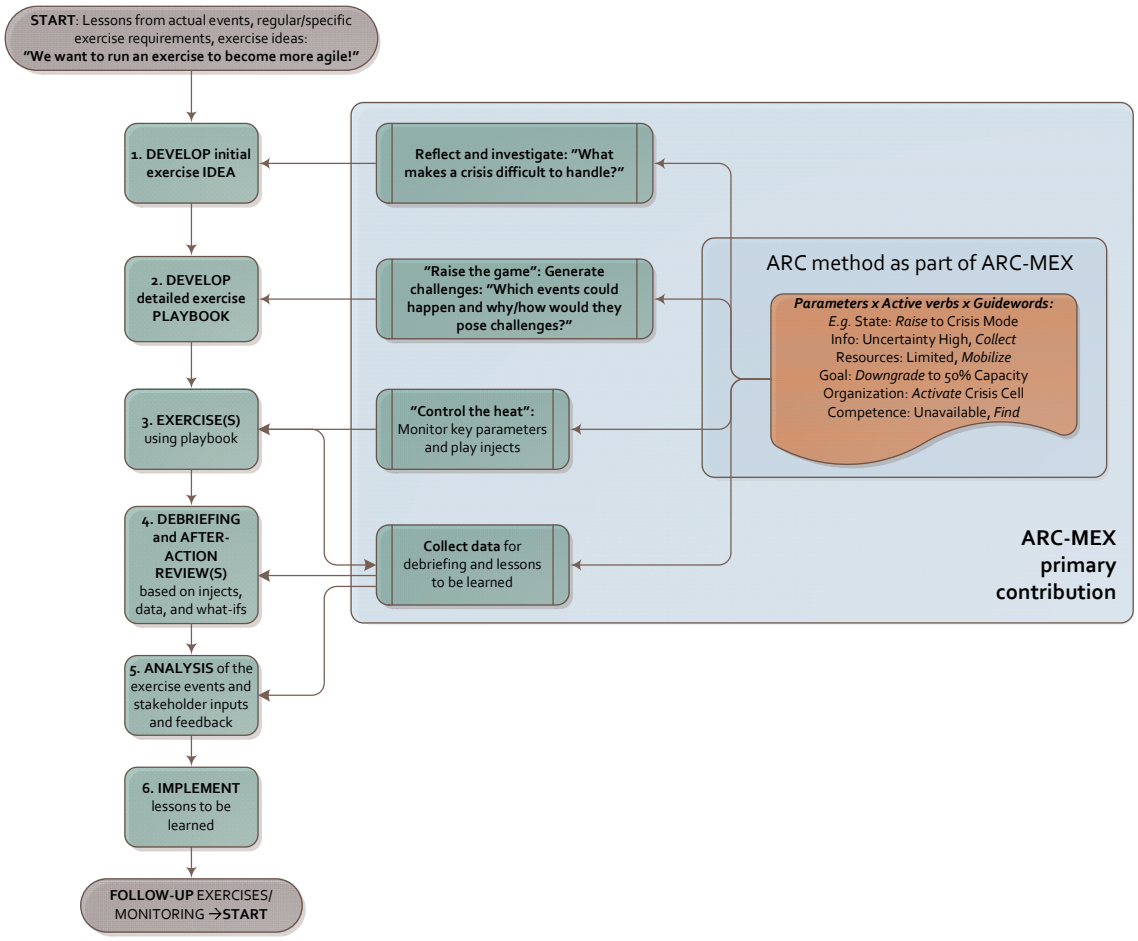

Figure 9 The primary contribution of ARC-MEX to crisis exercise steps and the contribution of ARC methodology to ARC-MEX.

4.1. Step 1 Focus groups and Workshops: Theme, objectives, participants

Figure 10 below shows the details of the first step of the ARC-MEX, the initial scenario design, which is based on focus groups and workshops guided by brainstorming questions. The aim of step 1 is to provide answers to the questions of what the scenario theme is, i.e. roughly what problem space that is to be presented, what the learning objectives should be, and who the participants are. The last question does not only concern the actual participants in the exercise but also comprise simulated participants with whom the actual participants may interact. This output is intended to be used as a basis for the second step in the ARC-MEX, which aims to create the exercise playbook.

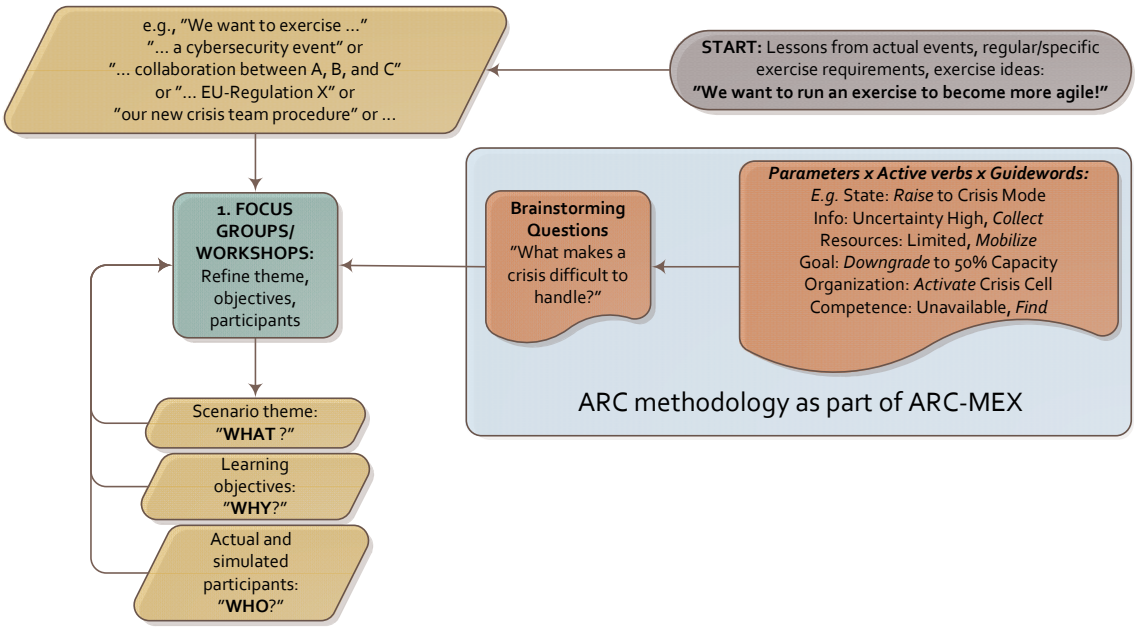

Figure 10. A detailed overview of steps and products of step 1 in the ARC-MEX process.

In terms of methods, step one is a facilitated process that can be conducted as a *focus group*[8] with selected relevant stakeholders. What 'relevant' means in this context depends on the purpose of the training which could range from a few key decision-makers in an individual organisation to larger collectives of organisations working jointly to solve a problem. Ideally, a focus group should consist of 4-8 persons, so it is generally advisable to avoid involving too many persons at this stage, or otherwise hold several parallel focus groups if a larger number of stakeholders is relevant. The primary purpose of the focus group is to identify potential scenarios at a general level, where challenging events can be introduced. In this context 'challenging' refers to challenges in terms of coordination, management, and goal formulation. In the ATS, such challenges could be extreme weather, acts of terrorism, natural phenomena such as the 2010 volcanic ash cloud, or major technical failures at an Area Control Centre or tower. In order to ensure realistic training, events must be transparent and believable to the trainees. Also, events should vary in difficulty and occur at different points of an exercise. To support the generation of events, 27 brainstorming questions (described in detail in Section 4.1.1) have been generated by combining the parameters with active verbs and guidewords (described in Section). The combination of parameters, guidewords, and active verbs into a number of discussion questions thus aims to facilitate the discussion of what makes a crisis difficult and why, and for which actors, (see Figure 7 below) the granularity of the detail in the triggering events and circumstances to be developed in the scenario development process, and their expected or potential consequences.

> *The first step of the ARC-MEX consists of a focus group with 4-8 stakeholders. The purpose is to identify scenario themes, learning objectives, and what participants that should participate in the exercise. The "what" of the scenario should include events that have the potential to challenge coordination, management, and goal formulation of the organisations and actors involved in an exercise. Such "trigger events" can be utilized to challenge standard operating procedures and initiate reflection and action on behalf of the participants in the exercise.* The expected output of focus group(s) performed in step 1 are a set of rough descriptions of potential scenarios and suggestions for triggering events to be included in these scenarios.

The second purpose of the focus group is to explore the potential problem and solution space, i.e. which problems that the participants will be faced with. As the focus of ARC-MEX is to improve agile response capability, the problem space may involve aspects such as managing newly designed constellations of crisis management organisations and roles, including functions and interactions within and between organisations. Developing the problem and solution space provides information on *how and why the identified scenario(s) is/are challenging*. The elicitation of this information can be facilitated by triggering discussion by asking questions like "describe the challenge that gave rise to a need for changing the way you normally manage your organisation/organisations" or "What would have been the consequences of a

[8] See e.g. Bloor et al. (2001) for a detailed description of the focus group method.

failure to manage and coordinate your actions with other organisations/actors?" In the case of creating scenarios for individual organisations, this can be applied to entities within the organisation, but will also help in highlighting dependencies outside the organisation that the participants in the focus group may not have thought of initially.

The expected output of focus group(s) performed in step 1 are a set of rough descriptions of potential scenarios and suggestions for triggering events to be included in these scenarios. These can be designed in different ways depending on the purpose of the exercise, such as short narratives, presentation slides, or flow-charts that describe the proposed composition of events. The brainstorming questions (see 4.1.1) are to be utilized to support the focus group discussions in order to describe the problem and solution spaces and forms a basis that can be used to identify triggering events. Parameters, guidewords, and active verbs as described below are in step 1 thus mainly intended as support for the brainstorming sessions during the focus groups. These are used again in step 2 of ARC-MEX to refine the output from step 1, in facilitated workshops and analyses that are based on the output of step 1.

4.1.1. Brainstorming questions - ARC problem and solution space charting

The ARC-MEX approach intends to facilitate the development of scenarios and triggering events that enable organisations to increase the crisis management capacity of the organisations through exercises. Thus, events that are in some way challenging to the organisation's agile response capability are in focus. The ARC approach therefore focuses on the description or imagination of an event:

- That would challenge the crisis management capacity of an organisation or collective of organisations.
- That would demand information exchange with actors/entities that the organisation/organisations would not normally exchange information with.
- Where the allocation of decision rights within or between organisations could hamper the individual or collective ability handle the event, so that decision rights or information flows would need to be adjusted, or responsibilities clarified (where it is unclear or ambiguous who (what actor/organisation) is responsible for coping with certain aspects).

Brainstorming questions are utilized to identify aspects of a scenario that challenge the way crisis response is organised, how the participants in the exercise exchange information with each other, and the way "operations as normal" are carried out. This is done by challenging different organisational abilities as well as historical assumptions that exist in the crisis response system.

4.1.1.1. Problem space - description of crisis

While the scenario and the events are to be created during the focus group in step 1, the brainstorming questions provide guidance so that the problem space of the scenario can be described in sufficient detail

to identify triggering events that can be used for challenging agile response capability. Although the brainstorming questions do not provide an answer to *what* the scenario should be, they provide hints to what *aspects* such a scenario and events should highlight. Thus, a selection of these brainstorming questions that seem most relevant to the aims of the envisioned exercise may be used to get more clarity into the what, why, and who of the exercise.

The following questions aim to aid in the description of the crisis, for the whole scenario:

1. What "data/variables" are monitored to detect if there is a crisis?

   Motivation: This provides information concerning what the involved actors find essential to assess in order to understand when a crisis is about to happen or to detect that it has happened.
2. What defines a crisis in terms of these "variables", and for whom?

   Motivation: This information reflects the actors' models of what a crisis consists of and what threats it involves. It also provides insights in what the actors normally do NOT consider to be important enough to monitor. The latter can be utilized to create new challenges and insights for the participants in the exercise.
3. What aspects are difficult to capture into "data"?

   Motivation: Monitoring is typically directed towards variables that are easily captured from sensors or statistics, such as radar, delays, and number of aircraft in a sector, etc. However, respondents are often aware of other factors that can contribute to accidents or crisis that are not continuously monitored or not assessed at all. This information contributes to the intuitive, non-formalised, model of crisis that participants may have and can be used to identify scenarios that circle around aspects that usually are not part of exercises.

The following questions can be applied to describe challenges to crisis management, during an event or when walking through a suggested scenario in order to increase the level of detail in the scenario:

4. What are the current and expected effects of the scenario on own and other resources and assets (people, functions, material, etc.)?

   Motivation: When developing a scenario, the focus group participants reason about possible effects on their own work, or the intended exercise participants or organisations. This will also provide information on their view of the causal relations between events and consequences. Apart from physical consequences such as damage, the focus group participants may also mention effects in terms of financial or reputational harm, suggesting that the questions also can provide guidance on which variables are found essential in the description of the various impacts a crisis can have.
5. What "category of crisis" or "alert state" is the organisation in? What about other relevant organisations' alert states?

   Motivation: This question relates to the previous question in the sense that it reflects what core values the focus group participants find to be challenged. Note that many

events can be interpreted as a crisis from different points of view. Physical damage may be a crisis in terms of loss of lives, financial damage, and loss of reputation. One single event can thus initiate a number of different categories of crisis that occur at different points in time. Further, the same event may initiate different types of crisis for different actors, calling for different responses. Organisation A may suffer physical damage, while organisation B suffer financial damage.

6. From whom is data and other input available and necessary? Are communication/information channels in place?

   Motivation: This question reflects the degree to which an organisation or collective of organisations have prepared to cope with this type of crisis or their agility in terms of the capacity to create such access to data or other input so that decision makers have access to it in a timely manner. It will also reflect the involved actors' model of what information that is needed to cope with the situation. This can be used to both to increase awareness of deficiencies in existing communication/information structures, but it can also be utilized as a way to create challenges in a scenario by hampering or denying communication in existing structures.

7. What are the uncertainties and unknowns about the situation?

   Motivation: This question probes the uncertainty facing a decision-maker in the situation described in the scenario. It may contribute with important information about events that can be used to "inject" events relating to the need of resilience or agility in a scenario. Lack of expertise, and how to get access to it, can for example be important aspects of a scenario.

8. What "data/variables" are monitored? What is the frequency of updating information?

   Motivation: This provides information concerning which information the involved actors find essential to monitor and assess in order to understand the development of the crisis as it progresses over time. Access to, or lack of, such data can for example be used as a triggering event in scenario.

9. How long are the events going on expected to last?

   Motivation: This question probes the temporal aspects of the scenario. Will the scenario demand the initiation or establishment of a more permanent crisis response organisation or not? If so, does establishing such an organisation demand a change in the approach to crisis management, as described in the solution space?

10. What is the potential for events to escalate in scale or severity?

    Motivation: This question investigates the consequences of not handling an event in a timely manner. Certain events hold the potential for escalating beyond control and must thus be prioritized before more static events. Events with the potential to escalate are also candidates for being "injected" into exercises in order to see if the participants have enough foresight or anticipating capacity to understand that they need to be dealt with rapidly.

11. Which stakeholders could become affected by the crisis?

    Motivation: Many crises in the Air Traffic System entail a multitude of stakeholders due to overall system complexity, and so identifying which stakeholders would benefit from interactions is not a trivial task, as well as the set of relevant stakeholders' likely changes over time as the crisis, and thus the scenario, unfolds. Scenarios involving a collaborative crisis management by a multitude of actors or organisations will most likely demand a high degree of ARC maturity (see Figure 5) and may be exercise goals in their own right.

12. What does "return to normal operations" mean for this crisis?

    Motivation: This question addresses the problem of understanding what kind of performance level that can be expected or acceptable by an organisation or a collective of organisations, and when (various levels of) crisis modes can be called off.

13. What are potential long-term effects that might need to be countered?

    Motivation: This question relates to the long-term effects that may need to be countered early on, issues that can be anticipated and mitigated or monitored for in addition to the short-term "here and now" problems of crisis management that are attended. Including such aspect in the scenario is a way to challenge the ability of the participants in an exercise to create a feed-forward or proactive aspect throughout the response.

14. When is the situation considered "under control"?

    Motivation: What are the operational criteria for being "in control"? What core values need to be protected or kept functional? Observe that "being in control" does not equal to "return to normal operations", but rather assuring that the crisis no longer escalates in an uncontrollable fashion. Depending on the purpose and type of scenario, this could be a stop criteria for the exercise.

4.1.1.2. Solution space - description of organisation and processes

This section can be used to better understand the point of departure and pre-conditions of the exercise. Note that "organisation" may refer to single organisations or a collective of organisations depending on the type of scenario and purpose of the exercise. The following questions may be addressed initially for the whole scenario:

15. What is the history of the current organisation?

    Motivation: This will create an understanding of the rationale of the organisation and potentially explain why some values are considered as core values while others are not. Hereditary organisational issues may also explain why certain crisis response solutions are in place and why certain interactions that have been established longer work like they do.

16. What pre-defined and exercised organisational structures for exchanging information and data exist?

Motivation: This question reflects the preparedness of the involved organisation/organisations in terms of their maturity to cope with crisis scenarios. This relates to the ARC maturity ladder described in Figure 5.

The following questions can be applied to describe challenges to crisis management and response, when walking through a scenario:

17. What information needs to be gathered before taking action?
    Motivation: This question provides important input to what information that may, or may not, be given to participants in an exercise in order to shape the unfolding of the scenario in a desired manner.
18. What information requires immediate action?
    Motivation: This question provides important input to what information that may, or may not, be given to participants in an exercise in order to shape the unfolding of the scenario in a desired manner. Such information may be a suitable candidate for a triggering event.
19. Are goals, roles, responsibilities, and accountabilities clearly defined within and between organisations?
    Motivation: This question will provided information about the ARC maturity within and between organisations. This can be an important identifier of training needs and hence scenario design.
20. Which aspects of the problem are a challenge to the current procedure for handling a crisis?
    Motivation: This question probes for weaknesses in the current organisation in relation to the crisis event described. Such weaknesses can be addressed in the scenario or included in plans for future improvements of the ARC.
21. What is the role of media and how should they be addressed?
    Motivation: The organised media and social media often play an important role in the spreading of useful or harmful information and possibly also the coordination or hindrance of the crisis response. Addressing media appropriately is considered important by many organisations for resolving the crisis but also to maintain a positive company image in challenging times. Such aspects may be included in the scenario depending on the purpose of and type of exercise. Media and/or social media injects may constitute a crisis event/scenario in themselves.
22. What expertise is necessary to be adequately informed about the crisis? Where is it available?
    Motivation: In the complex ATS system disturbances may originate from a large variety of sources, and subject matter experts on the sources of disturbance to inform decision making may not be available in-house and even difficult to find externally. If expert knowledge is scarce, it may hinder taking action because of lack of understanding of the essential variables of the crisis.
23. What restrictions may limit information exchange (e.g. for security, legal, commercial reasons)?

Motivation: This question will highlight constraints that can affect the capability to cooperate among the involved participants in an exercise, but also the possibilities of obtaining information during a crisis scenario.

24. Are analysis and decision support tools available and do they provide support? What are their benefits and limitations?

    Motivation: This question will reflect both the support for decision-makers as well as the investments made by the concerned organisation(s) in order to prepare for and support crisis management. This will directly influence the response capability of the organisation(s), given that involved personnel have adequate training in handling the tools/equipment. For certain types of exercises, the utilization of analysis or decision support tools may be a central aspect, suggesting that the scenario design must assure that there is an actual need for such tools in order to cope with the scenarios. Likewise, denying access to, or the malfunction of, such tools may be used as triggering events.

25. What are the main tasks that need to be performed and in what way are they interdependent (preconditions, timing, etc.)?

    Motivation: This question aims to create an understanding for the process(es) involved in coping with the events in the scenario. It will also reflect the respondents understanding of both the situation at hand and the own and other involved organisations' ability to handle the situation.

26. What resources are available? Can they be re-allocated?

    Motivation: This question reflects the flexibility and adaptability of the involved organisations and their resources. This can also be the focus of future exercises if resources are found limited as resource allocation and re-allocation is a central theme in ARC. Further, the coordination of resources may in itself be used as an exercise theme.

27. What are the margins and redundancies in the system (e.g. unused but deployable resources) that can be used to adjust to the situation?

    Motivation: This question relates to the question above and adds information by looking into what resources that are available that can be used to compensate for temporary or long-term losses or additional need for resources. Performance at the boundaries of resource availability is more brittle and thus margins are essential to monitor. This also reflects the involved organisations' investment in crisis management capability.

4.2. Step 2 Workshops: Detailed Scenario

Step 2 consists of three interrelated parts. These parts are explained in this section. The main purpose of step 2 is to generate triggering events in the scenario that will force organisations/actors that are exposed to the scenario to reflect upon and act on these events. Triggering events should include properties that challenge participants' standard way of operating and interacting, and thus trigger behaviour or responses

necessary to respond to cope with these challenges. The outcome of step 2 is an exercise playbook that can be used as a basis for the planned exercise. Finally, different exercise types are discussed.

The second step of ARC-MEX aims to refine the output from step one so that it has enough resolution to be useful as input to an exercise playbook. This is done through facilitated workshops that aim to define the triggering events by asking what-if questions, determine stakeholder actions, and determine performance measures that can be used to assess how well exercise participants cope with the scenario and events included in an exercise.

As described in step 1 of the ARC-MEX and in section 4.1, scenario challenges that can be used as triggering events may include changes to the organisation (which may be initiated by events outside the own organisation), changes in the number of involved actors, introduction of new actors, or even changes in the operational environment, as for example in the case of the volcanic ash cloud. In a dynamic exercise the participants must be permitted to make their own decisions, which may set of a chain of event and thus affect the scenario progress in unexpected ways. Therefore, to ascertain that relevant training objectives are fulfilled, exercise management is necessary to ensure that the right type of events are presented in a controlled way. This is achieved by arranging one or more workshops (depending on the type and size of the scenario) where the sub-steps 2.1 to 2.3 are performed. Participants in such workshops should preferably be representatives of the involved stakeholder organisations, exercise managers and/or subject matter experts. The amount of participants in the workshops may differ depending on how many organisations and crisis response functions that are involved, the concerned domain, and the complexity of the proposed scenario. The sub-steps of step 2 are illustrated in Figure 11 and described in detail in the remainder of this section.

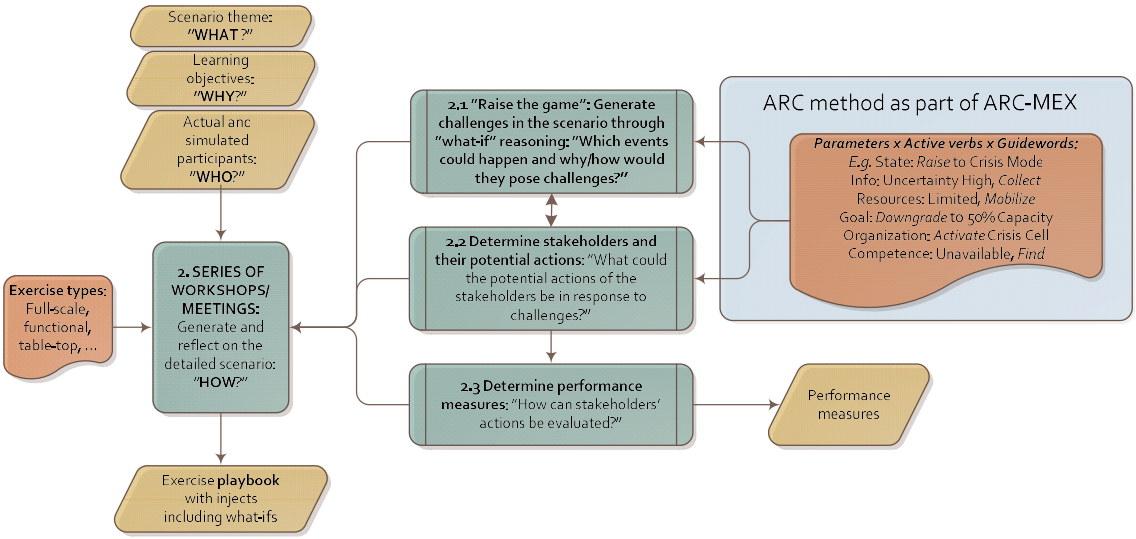

Figure 11 Step 2 of ARC-MEX and its sub-steps and contribution of ARC methodology.

4.2.1. Part 2.1 "Raise the game": Generate challenges

During a workshop session, challenges that raise the game and assure that agile response capability is exercised should be identified. Following the EBAT approach, each training objective should be connected to one or more triggering events that need to be created. Step 1 of the ARC-MEX generates a number of potential elements to be used for this purpose. Part 2.1 concerns the application of the parameters, guidewords, and active verbs to these triggering events in order to generate "What-if" statements that can be associated to the triggering events. This step is no longer a brainstorming session but should instead be seen as a more structured process that preferably should be facilitated. The facilitator will present the scenario(s) outlined in step 1 of the ARC-MEX and then walk the workshop participants through the parameters, guidewords, and active verbs which then can be used to create suitable input for the exercise playbook.

4.2.2. Part 2.2 Determine stakeholders and anticipate actions

Step 2.2 is a workshop, or a continuation of the workshop in step 2.1, with the purpose of identifying the organisations/actors that would be involved in the scenario and the dependencies that exist between them in terms of information exchange and mandate and authority. This workshop can be manned by the same individuals that took part in step one, but other individuals with expertise or other knowledge needed to complete step two may have to be involved as well. Step 2.2 works out the details as envisioned in step 1, which may require iteration between the steps if new information or ideas arise. Again, the brainstorming questions as well as the parameters, guidewords and active verbs presented above are intended to be used to explore the problem and solution space also in step 2, now in more detail.

By the end of step 2.1 and 2.2, which may need to be applied iteratively, it should be clear what the scenario looks like and which actors potentially are involved in such a scenario, as well as the basic dependencies that exist between them in terms of information exchange and decision rights, as well as how these address scenario challenges relating the problem space to the solution space.

Once the organisations/actors potentially involved have been identified, the task of *describing the Command and Control (C2) linkages* between the organisations/actors should be conducted. A C2 linkage consists of a description of what information that should be exchanged between different entities in a collective and what entity that is responsible for establishing the link during the scenario. These are the crucial dependencies that exist between the participants involved in the activity and can be described in terms of procedures, technical pre-conditions for communication such as ICT, inter-organisational agreements, etc., according to the following questions:

- Who is responsible for establishing the linkage?
- How can the linkage be described (e.g. its physical appearance; this description may or may not be of a formal nature.)
- When is the linkage necessary?
- What types of information are expected to be exchanged? While it is not possible to predict in advance all the data that will be needed, enabling discovery is key. More specifically:
  - What do we need from the entity?
  - What will the entity need from us?
- What restrictions, if any, may limit the exchange of information (e.g. access to classified information)?
- How will this information be provided to the new entity?
- Which entity has authority to make key decisions based upon new information?
- What are the means and frequency (how often) for reporting the status of this linkage (e.g. command communications/assessment update)?

When step one and two are conducted, possibly iteratively, it should be clear what the scenario looks like and what actors that potentially are involved in such a scenario, as well as the basic dependencies that exist between them in terms of information exchange. This does not mean that all actors that have been identified necessarily must be involved in the actual exercise events. This information is needed for realism as the exercise managers must be prepared to simulate actors that are not actually involved in the training sessions. Further, understanding the dependencies that exist between actors in a scenario can be useful in order to "regulate the heat" by introducing limitations or disturbances in the capability to exchange information between key actors. Scenarios must be designed where cues and features underlying a problem are not obvious to the participants in order to reflect realistic decision making situations, which are usually characterized by ill-structured situations. Manipulating information exchange or creating uncertainties in terms of responsibilities is one way of achieving this.

4.2.3. Part 2.3 Identifying assessment points and measures

In line with the EBAT approach each triggering event should be connected to performance measures which should be designed and introduced to collect relevant task performance. By associating several performance measures from several triggering events to each learning objective, training profiles of the participants' progress can be created.

Step 2.3 of the ARC-MEX should be conducted jointly by stakeholders and researchers/training personnel. The step aims to create an assessment plan for the scenario. Primarily, this comprises elicitation of information about important skills and abilities that reflect the participants' performance in different parts the scenario. This is vital for the possibility to identify and implement relevant measures of performance.

> *After step 2.3 is completed the following should be achieved:*
>
> *(1) identification of relevant behaviours to observe and which measures of performance should be implemented and recorded, (2) an understanding of how collected data should be analysed, and (3) the design of the data and information to be used in the after-action review, by presentation of relevant feedback from analysed data.*

Monitoring and responding to trigger events is by definition important skills in crisis response. Therefore to identify measures related to these skills, parameters, guidewords and active verbs associated with each triggering event can be used to explore in what way the collective's ability to monitor and respond to the events in the scenario would be challenged, thus informing the exercise organisers about potential assessment points during the course of the scenario, both in terms of points in time and what functions/parts of the collective that should be assessed.

Assessment points should ideally be decision-points, related to responses to triggering events in the scenarios, i.e. situations where key information is available or situations where decisions need to be made in order to prevent unwanted outcomes of the scenario. In scenarios involving several organisations/actors, the assessment points can also be situations where information should be exchanged between organisations/actors in order to enable coordinated action. In short, the assessment points should highlight critical points in the scenario development.

In addition, step 2.3 should not only consider direct measures of performance, but also indirect measures as understanding, effort, and actions taken that influence performance. This can, for example, be measures of sense-making, task load, team communication, and results from social network analysis. If such measures are collected continuously during the scenario, or at least in connection to presentation of trigger events, they can provide valuable information regarding how well the participating team members understand the scenario and how difficult they find it during the different phases, and what kind of communication patterns that develop during the course of the scenario. Also, in training of command and control it may sometimes be difficult to implement relevant direct measures of performance. In that case these types of indirect measures of performance may provide important indicators of performance.

An important item for step 2.3 is also to collect task specific information about the work that the participants will perform to cope with the scenarios. This information is required for three reasons. (1) For identification relevant behaviours to observe and what measures of performance that should be

implemented and recorded. (2) To create understanding of how collected data should be analysed. (3) To design after-action review, by presentation of relevant feedback from analysed data.

4.2.4. Exercise types

A functional exercise (Perry, 2004) is a common specific type of exercise that presents considerable complexity to the participants in testing planning and training. Functional exercises select one or a few functions as a focus, may involve one or more crisis management agencies, and are usually conducted in real-time, by operational personnel with appropriate equipment, in the field and under realistic conditions (Perry, 2004). This includes a detailed preparation and implementation of a simulated course of events, as inputs and reactions to the participants' actions. Realism and validity of functional exercises are important issues in their design. Thus, functional exercises aim to represent the few functions chosen to be included in the design, the participants that would normally perform these functions, and an environment similar to the environments that participants perform these functions in. Timing and pacing and task load aspects can be investigated as the simulated scenario progresses in real-time. A table-top exercise can be seen as scaled-down walk-throughs of action intentions based on an emergency narrative, but does not simulate all roles or interactions and interdependencies and typically does not run in real-time as one can jump or freeze in time depending on the focus of the exercise and specific scenario characteristics. Depending on the table-top exercise details, certain parts may require very high realism whereas others can be simulated on a more abstract level. On the other extreme, a full-scale exercise implements all functions and simulates physical processes in the actual operational and management context. Realism and validity are of high importance in full-scale exercises. These exercise types may be combined for realism and validity of different functions based on the purpose of the exercise.

The issues of realism and validity are thus important exercise design factors and relate to the purpose of the exercise and the educational (learning) goals. Feinstein & Cannon (2002) discuss validity as the relationship between simulation development and educational processes. According to their model, internal validity relates representational and educational validity in that participants cannot insightfully engage in a simulation if it does not behave sufficiently like a phenomenon from the real world that they can recognize or understand. External validity relates to whether (1) the simulation represents real world phenomena (external representational validity) and (2) the simulation has the desired learning effect (external educational validity).

4.2.5. Exercise playbook

The exercise scenario injects may be generated using the methodology, and documented accordingly in an ARC-MEX-based playbook. Key aspects of the playbook are thus the WHY, WHAT, WHO, and WHY of the exercise, as discussed before, adding the WHEN with time-stamped expected injects and what-ifs. The challenges, in terms of difficulties of parameters, active verbs, and guidewords, may be represented explicitly in the playbook, and integrated in the playbook format that the organisation is already using.

4.3. Step 3 Run the exercise

Step 3 of the ARC-MEX approach is running the exercise generating exercise data, using the playbook and performance measures generated in step 2.

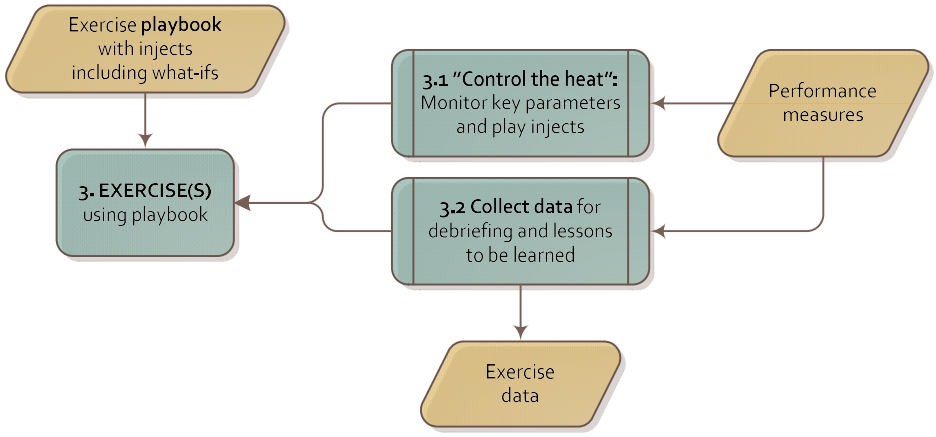

Figure 12 Step 3 of ARC-MEX is running the exercise, using the playbook, generating exercise data, and applying performance measures generated in step 2.

4.3.1. Part 3.1 "Controlling the heat"

Performance measures identified in step 2 can also be used to assess the progress of participants during an exercise and thereby allow exercise managers to "control the heat" in the sense that scenario difficulty can be adjusted depending on the progression of an exercise and participant experience. This is done so that the scenario is kept sufficiently challenging while not overwhelming the participants. Thus, "the heat", the difficulty of the events presented to the participants, may need to be adjusted both upward and downward regularly during the exercise, to be appropriate for the exercise and learning goals. The ARC approach (through various what-if scenarios and potential injects in the playbook) provides the which events, aspects, and dimensions the exercise organisation staff (often called "white cell") can use to modify challenges during the exercise.

4.3.2. Part 3.2 Collecting data

The data collection during the exercise should also be linked to the goals of the exercise, as well as the challenges that were generated during step 1 (what do we expect to be difficult, for whom, and why?) linked to the entries in the playbook generated in step 2. In this way, the organisers of the exercise can follow-up the exercise challenges in a systematic way, and track the challenges and how they were handled, and their potential impact on the course of events during the exercise.

4.4. Step 4 Debriefing and After-Action Review

Feedback is tightly linked to defined training objectives by a clear linkage to performance measures, which in turn are linked to "trigger" events who in turn are linked to learning and training objectives. By this

procedure feedback with very high relevance to the training objectives can be produced (as suggested by the EBAT method). Debriefing directly after, and After-Action Review (AAR) some time after the exercise, may provide this feedback. As the playbook and performance measures that are discussed during these activities have been construed using the ARC-MEX approach, the content of debriefing and AAR can also be informed by ARC.

The purpose of after-action review (AAR) is to elicit participants' views on key events, and to facilitate discussion about adaptations that were successful or not, had consequences as intended or not, or other considerations and thoughts that participants have about actions they took or did not take, as well as imagined similar events and disturbances (what-ifs) that may have to be dealt with in real future events (Downs, Johnson, & Fallesen, 1987; Rankin, Gentner, & Crissey, 1995; Woltjer, Trnka, Lundberg, & Johansson, 2006).

AAR starts with the exercise staff presenting an overview of the planned and unfolding events of the exercise to the participants. Thereafter, the discussion is led by a facilitator who asks questions concerning key events and adaptation. Each issue is given an approximate time slot for review. During this time slot, the participants are first invited to write down their viewpoint to avoid that participants influence each other's answers. Key actors in the exercise subsequently present their individual points of view on the issue, as well as the other participants, after which a discussion is started with a dialogue between key actors and soon thereafter including other participants.

For the review to facilitate agility, the review should both include situations where the team adapted as intended to the disturbances and the unfolding situation, and situations where adaptations had consequences other than expected.

As the After Action Review is a critical tool for reflection it needs to include guiding questions that help the participants in the training session to reflect upon aspects of the training session that challenge their view of how to handle the crisis. The playbook injects that were used, as well as the ones that were not (what-ifs), may be the primary points of the debriefing and after-action review discussion. Furthermore, the ARC method may provide these guiding questions in a structured way.

4.4.1.1. Combining Parameters x Active verbs x Guidewords into Debriefing/AAR Questions

Table 3 below provides examples of how the parameters, guidewords, and active verbs of ARC methodology can be used to generate debriefing questions that can be part of a debriefing, after-action review, by putting them up as discussion points in a joint discussion session, or made part of a questionnaire, or both. As indicated by the colour of the numbering, again, the questions span both the problem space (red), solution space (green), or both (orange). The questions may need to be tailored to the specifics of the exercise, for the participants to rate or discuss the same particular elements that were deliberately designed into the scenario which the debriefing or AAR is meant to provide information about. This could mean for example asking about a specific alert/crisis state (e.g., crisis mode 1), specific information elements (e.g. aircraft delay information, number of passengers on flight), specific resources

(e.g., fuel, fire extinguishing agent, spare aircraft for evacuation), specific goals (e.g. clearing the airspace, evacuating Terminal 1, landing as soon as possible, opening airspace again), or specific expertise (e.g., technicians for system X).

Table 3. Example table illustrating the questions for discussion after the exercise combining parameters and guidewords. Active verbs can be chosen as appropriate to form questions.

Nr	Question	Parameter	Guidewords
1	… it was difficult to **classify what kind of "alert/crisis state"** my organisation was in.	State	not classified, high/low
2	… it was difficult to know **which information I should monitor** to be well-informed about the development of the ongoing crisis situation.	Information	unavailable, too much, too little
3	… of the **uncertainty** in the scenario.	Information	uncertain
4	… **information** that I needed was **unavailable**.	Information	unavailable
5	… it was difficult to estimate how **long the crisis situation would last**.	Time	duration unknown
6	… it could easily **escalate into a much more severe** crisis situation.	State	rate of change, magnitude
7	… I needed **information or resources from other actors** and I didn't know how to contact them.	Information	unavailable, external
9	… it was difficult to know what the **long-term effects** of the crisis would be.	Time	duration leading to uncertainty
10	… it was difficult to know if and when situation would be considered "**under control**".	Goals	assessment difficulty, goal state undefined?
12	… we have **not experienced or exercised** this kind of crisis before.	Competence	unavailable
8	… it was difficult to know what our **goals** were.	Goals	undefined
11	… it required us to **organise our work** (roles, tasks, processes, etc.) in a new way.	Organisation &Collaboration	undefined
13	… it was not clear if we should **act immediately or wait** for the situation to develop before taking action.	Time	availability uncertainty, availability
14	… the actors involved were not **working towards the same goals**.	Goals	undefined, conflicting
15	… **roles and their responsibilities were not clearly defined** within our own organisation.	Organisation &Collaboration	undefined
16	… the **media** was difficult to handle in this scenario.	Informaton	external demand for info
17	… difficulty with getting **access to appropriate expertise**.	Resources /Competence	unavailable, external resource/competence need
18	… of limitations in the **usefulness of the tools** we have available for analysis and decision support.	Information	unsupported
19	… of **complex interdependencies** between tasks of the various roles and actors involved.	Organisation &Collaboration	intractable
20	… the **resources available** were not sufficient.	Resources	insufficient/unavailable
21	… it was difficult to **find and use resources** that we do not normally have available.	Resources	difficult to find/use
22	… we had small **margins or redundancies** and overlaps in available resources.	Resources	redundancies available

4.5. Step 5 Analysis

The fifth step concerns analysis of data gathered during the exercise. Step 4 and 5 may occur simultaneously and/or in several iterations, depending on the analysis work required for AAR. The fifth step is concluded when both the events that played out, white cell and participants actions, and their consequences and debriefing and AAR results have been analysed to the extent that the training and exercise objectives are assessed satisfactorily, and lessons to be learned can be generated.

The findings and lessons learned are indirectly supported by ARC-MEX in that the previous steps use the ARC method to generate challenges, playbook injects, data collected, as well as debriefing and after-action review points. More directly the ARC vocabulary may also be used to perform this analysis and generate findings. For example, findings may be structured along the parameters of state, resources, information, organisation, etc., as these intend to give an overview of both how the problem space evolved throughout the exercise, as well as the solutions that the participants generated. Guidewords and active verbs may be used where appropriate.

4.6. Step 6 Implementing lessons to be learned

The outcome of the analysis in step 5 is used in step 6 to support the implementation of lessons to be learned, which is an assignment of actions to various roles in the participating organisations in the exercise. This process step is not specific for ARC, other than that the previous steps contributing to the lessons to be learned were based on ARC-MEX steps 1-5. The feedback can also be used as an input for future exercises, restarting the ARC-MEX at step 1.

4.7. ARC-MEX Overview

Figure 13 presents a detailed overview of the ARC-MEX.

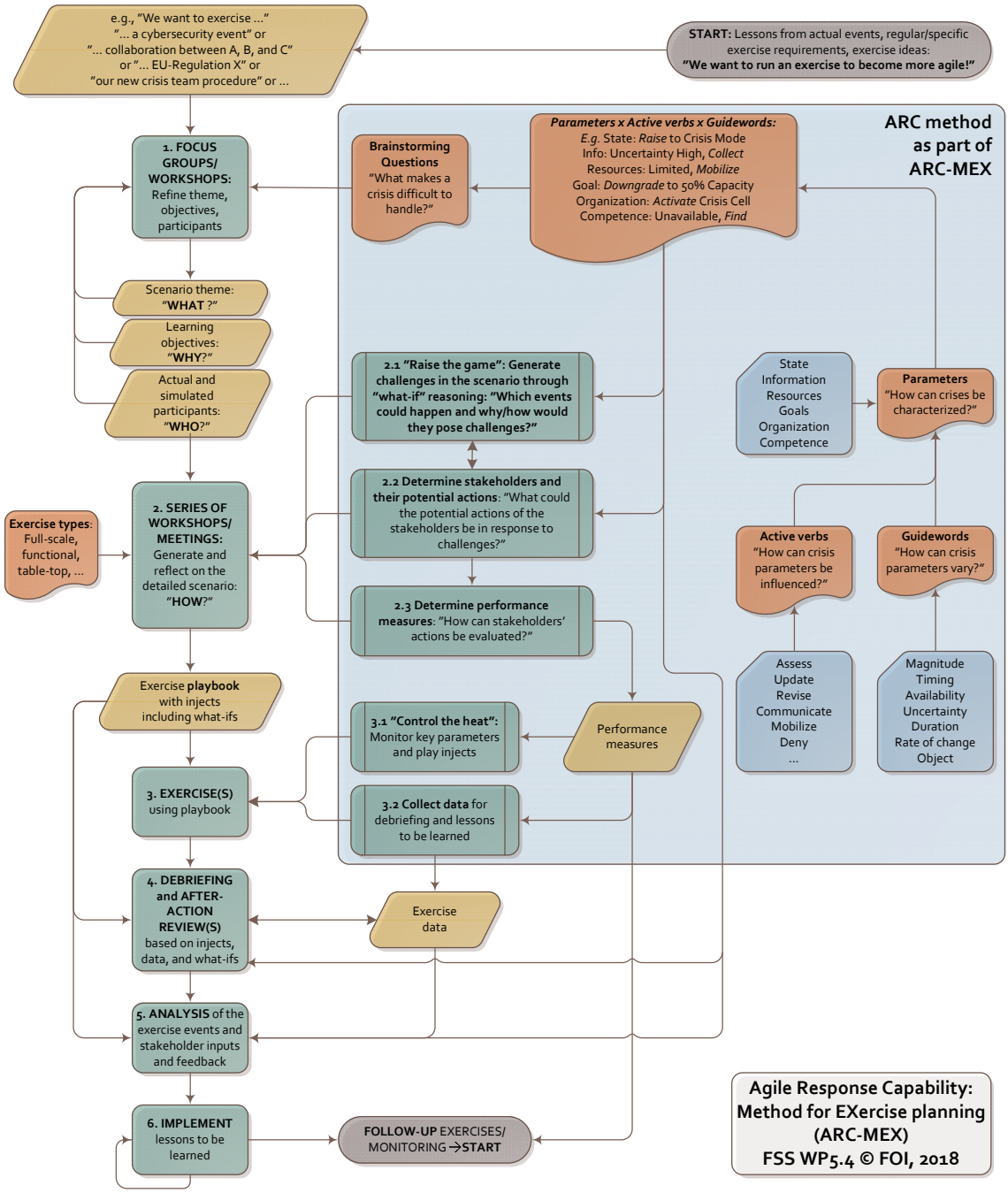

Figure 13 A detailed overview of the ARC-MEX.

5 THE ARC APPROACH TO CRISIS OPERATIONS AND PLAN ENHANCEMENT: ARC-COPE

The method for Agile Response Capability is also applicable to the analysis of preparedness plans and to the analysis of actual crises events. In this format the method is called Agile Response Capability Crisis Operations and Plan Enhancement (ARC-COPE). The various parts of the method have been used during the development of the ARC-MEX exercise planning and evaluation method, in order to analyse and learn from several actual events to inform ARC-MEX method development. ARC-COPE relates to the phases *before* and *after* actual events, as illustrated in Figure 6. ARC-COPE is outlined in Figure 14.

In the *analysis of preparedness plans before* an actual crisis, the ARC method can contribute to the assessment of crisis plans through structured what-if analysis using parameters, active verbs, and guidewords. In the analysis of actual events, the collection of data and their analysis may in a similar way be informed by ARC methodology. The aspects in the fictional or actual course of events and circumstances can thus be understood and analysed for challenges and needs for agility.

The ARC-COPE method was also used as part of the research to establish, develop and test the applicability of the ARC methodology. The ARC-COPE method is in essence a similar process as the steps of ARC-MEX, and since ARC-MEX is the main product of the research reported in this report, this report suffices with an outline of how this analysis could be applied. ARC-COPE using ARC methodology can thus be combined with various preparedness and hazard analysis methods as well as event investigation methods.

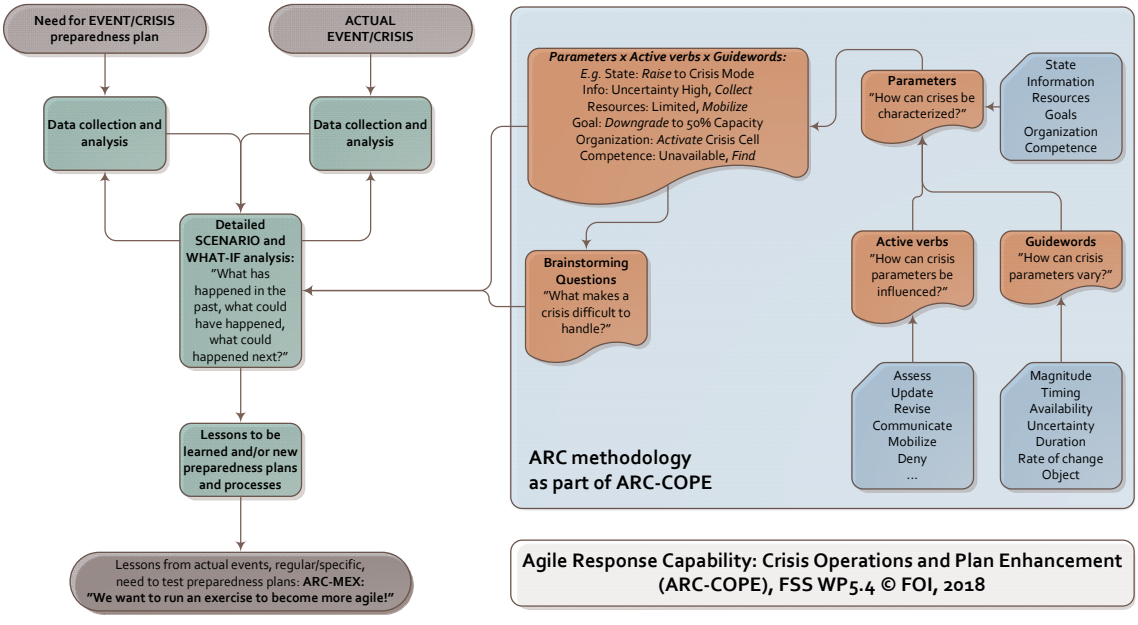

Figure 14 Overview of ARC Crisis Operations and Plan Enhancement: ARC-COPE.

6 EPILOGUE: ARC AND ITS RELATION TO OTHER MANAGEMENT ASPECTS

6.1. ARC and (Safety) Management (Systems)

The Agile Response Capability has a number of potential links to Safety, Security, Contingency, and Business Continuity Management processes and plans that are typically implemented in aviation organisations.

Some of these links to common sections in the plans of aviation organisations are:

- Emergency/Contingency response procedures and plan
- Authorities, responsibilities, and accountabilities
- Identification of hazards and disturbances
- Safety risk control
- Sufficiency of resources
- Safety-related interfaces with external parties
- Variations with respect to procedures and standards
- Management of change

This means that the ARC approach (including ARC-MEX, and ARC-COPE) may be implemented in connection to various existing functions and processes depending on how the aviation organisation is structured, as parts of the processes that ARC connects to may be "owned" by different process owners in different organisations. In addition to this, exercises and event analyses may be run with different exercise themes or different foci at different levels of each organisation, so that the specific roles that use the ARC methodology not only depends on one organisation's terminology but may be applicable to several organisations' levels and roles depending on the specific exercise/event. To keep the guidance general in nature for the Air Traffic System, further suggestions for integration in organisational processes are therefore not given here because of these expected variations across stakeholders.

6.2. Crisis leadership – "the right stuff"

The scope and focus of the Agile Response Capability work reported here is on organisational adaptation, adaptive capacity of intra- and inter-organisational crisis response, and organisational agility and resilience. As such, leadership and crisis leadership are not considered to be explicitly within the scope of this project. However, during several discussions with crisis managers and other experts throughout the project, the importance of picking the right individuals for a crisis management task, as well as to lead the crisis management team, were mentioned repeatedly. This is often termed "the right stuff", popularized in the context of test pilots and astronauts in the film with the same name, based on the book by Tom Wolfe. According to the Cambridge English Dictionary "the right stuff" means "the qualities needed to do or be something, especially something that most people would find difficult". Since this phrase or idea was emphasised by several of our informants, this section describes a number of studies, research tools,

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and conceptual frameworks related to personal qualities of leadership in crisis, as an indication of the ongoing research in this area. As crisis leadership is not within the primary scope of this work, this section does not represent an exhaustive overview of the field. It seems, however, that leadership and management generally is a vast research area (too vast to review here), with crisis leadership being an area that is relatively little-researched (Hannah, Campbell, & Matthews, 2010).

Hannah et al. (2010) argue that there is a need for more information about how leadership operates, and what constitutes leadership, in dangerous contexts. For this, they take a multilevel and systems approach to leadership in dangerous contexts. They claim that research on leadership in dangerous contexts must move beyond the individual-level focus towards a multilevel system approach, and point to a number of avenues for future research. They believe that two primary tenets must be kept in mind: (1) Leadership is a complex multilevel dynamic system where a specific leader only is one part, which requires understanding of the causations and contingencies that various parts of the system impose on leadership processes. (2) A "one size fits all" approach that generalizes to all types dangerous contexts is not possible. It should, however, be noted that the focus on "dangerous contexts" here implies a primary focus on military groups that are performing missions with exposure of great risks.

Their multilevel approach follows the three analysis levels generally used in social sciences, with addition of dyad level: micro-level, dyad level, meso-level, and macro-level. Below is, for each level, a short description of factors with relevance for leader style etc. provided (freely abbreviated from Hannah, et al., 2010).

The micro level relates to effects on the individual level. At this level the following factors are discussed:

- *Emotions* – have a critical role for effectiveness.
- *Meaning making* – refers to active leadership to enact sense-giving to help followers make sense of prior events and thus understanding how to engaging more effectively in future events.
- *Cognition and danger* – refers to judgement, which generally deteriorates under pressure.
- *Individual differences and danger* – refers to leaders with appropriate qualities that can positively affect followers' responses to danger.
- *Psychological effects of danger* – refers to how leaders may affect followers' physiological responses to stress.
- *Motivation and danger* refers to the risk of over motivation in dangerous contexts, which may lead to over arousal and reduced effectiveness.

The dyad level relates to effects on a pair-wise level. At this level the following factors are discussed:

- *Leader-member relationship quality* –operationalized as leader-member-exchange (LMX) comprises factors as: levels of trust, liking, loyalty, professional support, contributory behaviours, interpersonal attraction, and bidirectional influence between leaders and followers. Although these factors, are in normal contexts, related to positive leadership effects, some may have different, or non-linear effects in dangerous contexts.
- *Effective leadership style* –is somewhat contradictory, since some researchers favour autocratic or directive forms of leadership, while other favour greater decentralization and participatory leadership.

The meso level relates to effects on the group and social network level. At this level the following factors are discussed:

- *Group/team type* – refers to the leader's potential need to adapt leader style according to type of Group/team.
- *Group processes* – may affect performance, leaders thus need to understand group processes to maintain positive states.
- *Group complexity* – is affected by specialized competencies and that on member cannot grasp all group tasks, which demands that leaders and followers are dynamically interacting over time
- *Social networks* – are needed for leaders to maintain both powerful informal and formal networks through which they can gain information and resources.
- *Group prototypes* – are relevant, since group members are generally more supportive to leaders that match the group prototype, which means that leaders may be more or less effective in different groups.

The macro level relates to effects on organisational and system levels. At this level the following factors are discussed:

- *Organisational adaptability* – can help individuals, groups, and organisations function effectively across varying situations. Assessing how factors as training, education, and experience contribute to organisational adaptability and leadership and organisational effectiveness is needed.
- *Organisational structure and systems and adaptability* – In complex situations there is a tendency to consolidate administrative control, but in situations with high complexity hierarchical systems may break down, which put demands on flexible and adaptable leadership.
- *Professions and professional ethics* – may serve as a core of organisational culture and thus influence leadership processes across organisations. Also, conflicting professional ethics will most likely influence interactions between professions and organisations. However, this area is not well researched.
- *Ethos* – is important, since in many organisations that operate in dangerous contexts have codified ethos in the form of oaths, but in practice ethos most likely also include less tangible dimensions as how it is to be an exemplar member of a group. Even though, ethos is most likely important for organisations that operate in dangerous contexts, there is not much research on this.

Thus, leadership issues may be addressed at a number of different interrelated levels. As stated earlier, a number of studies, research tools, and conceptual frameworks in some of these levels is presented in the remainder of this section, as an indication of the ongoing research in this area (not an exhaustive overview).

Denison, Hooijberg, and Quinn (1995) claim that the importance of the cognitive complexity concept has been widely addressed as necessary for effective leadership (e.g. Weick, 1979), but they argue that this concept may not be sufficient, and that instead behavioural complexity, which connotes action as well as cognition, may be the necessary condition. For that reason they performed an empirical study to investigate the importance of behavioural complexity for effective management. The results showed that

more effective managers exhibit a greater variety of leadership roles and also clearer leadership roles compared to less effective managers. According to the authors, more experienced and effective managers develop more balanced, sophisticated, and complex repertoires that reflect the environment from which they emerged. Further, they claim that because of the complexity and paradox of their environment, such behavioural repertoires must incorporate a host of conflicts, contradictions, inconsistencies, and paradoxes.

Although this study was not performed on managers during crisis management, the results most likely reveal general characteristics of effective management and should, in this respect, also be applicable to leadership of crisis management operations.

The Crisis Leader Efficacy in Assessing and Deciding scale (C-LEAD) has been developed by Hadley, Pittinsky, Sommer, and Shu (2011) in order to assess the efficacy of leaders' capability to assess information and make decisions in the public health and safety crisis domains. It is intended for leaders' self-ratings of agreement and consists of the following nine items (Hadley, et al., 2011, p. 638):

1. I can anticipate the political and interpersonal ramifications of my decisions and actions.
2. I can summarize the key issues involved in a situation to others regardless of how much data I have.
3. I can make decisions and recommendations even when I don't have as much information as I would like.
4. I can assess how the members of the general public are being impacted by my unit's actions or inactions during times of adversity.
5. I can determine which information is critical to relay to other units in advance of them requesting it.
6. I can keep others abreast of my work activities without over-informing or under-informing them.
7. I can make decisions and recommendations even under extreme time pressure.
8. I can estimate the potential deaths and injuries that may occur as the result of my decisions or recommendations at work.
9. I can modify my regular work activities instantly to respond to an urgent need

Hadley et al. (2011) have performed three studies with C-LEAD. According to the authors, the results show that C-LEAD has better predictability of decision making difficulty and confidence compared to general leadership efficiency. They also claim that C-LEAD can predict motivation to lead in a crisis, crisis leader role-taking, and more accurate performance for leaders of crisis management. They thus suggest that C-LEAD can be used to identify the capabilities of leaders in advance of a crisis, and that its predictability of leader role taking can be used in training programs for crisis management to target those most likely to taking the lead.
Unfortunately, Hadley et al. (2011) do not contribute with knowledge on important capabilities for leadership of crisis management, but instead the instrument C-LEAD that may be used to investigate this.

Reiman, Rollenhagen, Pietikäinen, and Heikkilä (2015) take the stance that safety-critical organisations can be perceived as complex adaptive systems, and thus suggest that safety management should be

adaptive, building on several different principles, and having the ability of change to fit the environment and situational factors of the environment (p. 80). They thus suggest that traditional hierarchical views of leadership are less useful in complex adaptive systems that require adaptive leadership. Based on literature on complex adaptive systems, they have developed a framework with four opposing pairs of key principles of complex adaptive systems and also formulated adherent tensions between each pair:

- *(1) Promote safety as a shared guiding principle* vs (2) *Optimize local efficiency.*
  - Tension: (1) values system goals, while (2) values local goals.
- *(3) Facilitate interaction and build connections* vs (4) *Set objectives and prioritize.*
  - Tension: (3) values multiple weak ties, while (4) values few strong ties.
- *(5) Facilitate novelty and diversity* vs (6) *Monitor system activities and boundaries*
  - Tension: (5) values high degrees of variance in the system, whereas (6) values low system variance.
- *(7) Create capability for situational self-organisation vs (8) Create standard operating procedures and define system boundaries*
  - Tension: (7) values flexibility and adaptability, while (8) values repeatability and systematic response.

Reiman et al. (2015) admit that their framework is not completely new, but that the eight principles are based on a more realistic view of organisational behaviour compared to previous work. They claim that they by the introduction of the tensions have tried to provide advice on how to balance between the principles, and also have *attempted to balance the inherent unpredictability of organisational reality and the practical need to work and live with these systems."* (p. 91).

There are two basic types of paradoxes in organisations with relevance for leaders that are either related to the leadership or inherent in the organisation (Waldman & Bowen, 2016). Each of these paradoxes can be divided in two, which leads to four key paradoxes (see Table 4).

Table 4.Four key paradoxes for leadership in organisations (adapted from Waldman & Bowen, 2016)

(1) Paradoxes inherent to leadership	(2) Paradoxes in organisations
(1a) Strong sense of self combined with humility	(2a) Maintaining continuity while simultaneously pursuing change
(1b) Maintaining control while letting go of control	(2b) Pursuing corporate social responsibility for profits while simultaneously maintaining moral purposes

Waldman and Bowen (2016) use the term "paradox-savvy leader" for a leader with the ability to find ways to navigate between these paradoxes, and suggest following approaches to these paradoxes:

- 1a. Exert sense of self and confidence, as well as admitting own incompleteness, while at other times recognise the value of others and thus stressing participation and even delegation.

- 1b. In the short term sense stress maintaining control over decision making, while over the long term stress participation and delegation, and thus searching for ways to letting go of control.
- 2a. Recognize the importance of dealing with the context faced in the present now, but simultaneously try to reserve time for long-term thinking and planning for a changed next for leading in the future.
- 2b. Try to avoid this paradox by not stressing moral values unless they are authentically felt and communicated. Alternatively, start with the moral pole and then work more directly on convincing stakeholders that monetary worth cannot be separated from moral intent.

Pursuing a paradox-savvy leadership has effects for both individual followers and for organisations. If paradox-savvy leaders serve as role models to followers, this may lead to followers that become more proactive, adaptive, and innovative in their own work. At the organisational level, paradox-savvy leadership promote flexible and adaptive decision making, which is characterized by situation understanding and creative handling of changing and uncertain situations. For example, a paradox-savvy leader have the ability to simultaneously deal with the *now* context and simultaneously keep an eye on the *next*, for example the changing environment and the needs of the organisation to promote change (Waldman and Bowen, 2016).

A framework for examining leadership in extreme contexts has been developed by Hannah, Uhl-Bien, Avolio, and Cavarretta (2009) with the aim of supporting leadership in extreme contexts. The framework describes five dimensions of extreme contexts and a number of factors that may influence the ability for adaptive leadership response, irrespective of level of extremity experienced. These dimensions are: Location in time, magnitude of consequences, probability of consequences, physical or psycho-social proximity, and form of threat. The factors include “attenuators” psychological, social, and organisational resources, “intensifiers” time and complexity, and level of extremity.

Hannah et al. (2009) suggest that different forms of leadership may be more or less effective for these five dimensions of extreme contexts.

Regarding *location in time*, the most appropriate form of effective leadership will vary over the stages of preparation, response, and recovery from an extreme event.

When the potential *magnitude and probability of consequences* of a threat increase, organisations need to overcome some of their inertia and resistance to prepare for extreme events, and thus expend resources and efforts for preparatory actions. Therefore, shifts in organisational priorities and more vigilance before events occur can be expected. This also increases the need of capable leaders, which means that followers also may reassess the adequacy of their leaders.

Physical distance has been shown to increase the need of communication in order to maintain sufficient coordination. On the other hand, physical distance may not necessarily lead to less effective leadership. For example, psychological and social relationships built before an event, such as cohesion and trust, may be more important for effective leadership. Regarding *psycho-social distance*, it was previously thought that leaders should maintain an adequate distance from their followers. However, Hannah et al. (2009)

believe that social closeness between leaders and followers leads to higher levels of cohesion and trust which are critical in extreme contexts. High social identification can, for example, reduce team members' stress levels and make them more willing to sacrifice for the leader and the team.

Regarding the *form of threat*, there are mainly three categories of threats: physical, psychological, and material, and different forms of threats most likely requires different forms of leadership responses.

The experienced level of extremeness is directly affected by these five threat dimensions, but is also either attenuated or intensified by a number of factors. Attenuating factors are psychological resources, social resources, and organisational resources. Intensifying factors are time (compression, duration, and frequency) and level complexity. Time compression relates to shortage of time with need of rapid responses.

The framework with the five threat dimensions, level of extremity, and adherent attenuators and intensifiers is intended to provide a general understanding of how to contextualize leadership in extreme contexts and adaptive leader ship responses.

A study by Sommer, Howell, and Hadley (2016) investigated the influence of leadership style on affect (emotions and moods) and its influence on organisational resilience. Two types of leadership styles, transformational and transactional were studied in an organisational crisis in health care.

Transformational leadership refers to four types of behaviours: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Transactional leadership refers to leaders that provide rewards and punishments to their followers and can be further divided in active and passive leadership styles. Active transactional leadership style refers to continuous monitoring of team members' performance to anticipate mistakes before they occur, while transactional passive leadership style refers to correction of problems rather than inspiring new directions.

It was found that transformational leadership was associated with greater levels of positive affect and lower levels of negative affect, which in turn was associated with higher resilience among team members. On the contrary, passive transactional leadership was associated with lower levels of positive affect and higher levels of negative affect, whereas for active leadership there no effects on affect were found. According to the authors, the lack of effects of active transactional leadership is contrary to previous research, where this leadership style has led to negative emotions. They suggest that this may be an artefact of performing the study in a health care setting, where this may be viewed as an appropriate leadership style. Nevertheless, and most important, according to the authors, the results indicate that compared to transactional leadership, transformational leadership styles are more likely to trigger positive emotional states among team members, and thus positively influence resilience building in a crisis.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

This report presents the ARC guidance material describing the ARC approach to aid Air Traffic System stakeholders to increase their Agile Response Capability. The ARC approach consists mainly of the *Agile Response Capability Method for EXercise planning (ARC-MEX).* The ARC approach is also applied to actual operations (planning prospectively and analysing retrospectively) as the *Agile Response Capability Crisis Operations and Plan Enhancement (ARC-COPE).* Both approaches have been iteratively developed and through exposure to different scenarios and stakeholders have been found practicable.

ARC-MEX aims to aid staff responsible for the planning, design, observation, analysis, and/or reporting of (series of) exercises. ARC-COPE is aimed at staff responsible for developing preparedness or crisis plans and/or analysing and reporting on past incidents or crises. The generic guidance presented here is therefore applicable to different organisational levels and roles depending on the specific event or exercise scenario and the specifics of the implementing organisation.

7.2. Recommendations

ARC does not replace experts in their exercise and event analysis roles, but rather enables organisations to allocate expert resources to exercise and event management processes, channelling expert judgment, experience and imagination around potential disturbances, challenges, and crises in their operations into structured and methodological exercise design and event evaluation. ARC provides support to the imaginative as well as analytical process of running exercises and preparing for and learning from actual events. The ARC methodology does allow the structured investigation of various permutations of events and circumstances, but may also be used selectively and in a “light” version when analytical resources are not available or some aspects are already decided by other means. This is why the method consists of various components, from high-level focus group discussion questions, to detailed analytical methods using parameters, active verbs, and guidewords to be applied on specific scenarios, which have been outlined in this report in increasingly detailed steps. This means that *ARC can be applied flexibly where appropriate* depending on where the organization(s) deem that the methodology provides them the most benefit. Practitioner organisations together with their collaborative partners are therefore recommended to apply and evaluate ARC-MEX and ARC-COPE and the various high-level and detailed parts of the ARC methodology in their organisations and processes to experience where most benefit can be gained.

Recommendations for practitioner organisations in the Air Traffic System are to use the ARC guidance presented in this report for:

- reflection and argumentation about what was difficult in past crises or expected ones, and explicitly and methodologically incorporating this knowledge into focused exercises
- building up a repository of challenges observed or expected, that may be reused to vary exercise contents throughout exercise series, across participants and organisations,
- keeping track of the contents and results of their exercises,

- setting up or further enhancing their planning and efficient use of resources spent on focused training and exercising, increasing preparedness through ARC-MEX-based structured, explainable and strategic exercise programme,
- enhancing the way they learn from actual challenging events and crises that occasionally happen during their everyday operational activities, through ARC-COPE-based analysis of past events and preparedness plans.

Recommendations for the aviation safety and crisis research community are to:

- document and analyse the various phases of exercise programmes applying the ARC-MEX approach,
- perform analyses of past events and preparedness plans applying the ARC-COPE approach,
- together with practitioner organisations further develop the use of the ARC approach, and
- report back to the research and practitioner communities on the actual and potential uses and improvements of the methodology.

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