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Breakdowns in coordinated decision making at and above the incident management team level: An analysis of three large scale Australian wildfires

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ABSTRACT

Emergency situations are by their nature difficult to manage and success in such situations is often highly dependent on effective team coordination. Breakdowns in team coordination can lead to significant disruption to an operational response. Breakdowns in coordination were explored in three large-scale bushfires in Australia: the Kilmore East fire, the Wangary fire, and the Canberra Firestorm. Data from these fires were analysed using a top-down and bottom-up qualitative analysis technique. Forty-four breakdowns in coordinated decision making were identified, which yielded 83 disconnects grouped into three main categories: operational, informational and evaluative. Disconnects were specific instances where differences in understanding existed between team members. The reasons why disconnects occurred were largely consistent across the three sets of data. In some cases multiple disconnects occurred in a temporal manner, which suggested some evidence of disconnects creating states that were conducive to the occurrence of further disconnects. In terms of resolution, evaluative disconnects were nearly always resolved however operational and informational disconnects were rarely resolved effectively. The exploratory data analysis and discussion presented here represents the first systematic research to provide information about the reasons why breakdowns occur in emergency management and presents an account of how team processes can act to disrupt coordination and the operational response.

1. Introduction

Wildfires[1] are both becoming more common and are increasing in complexity and duration due to factors such as climate change, increased carbon emissions and deforestation (Liu et al., 2010). Wildfires are also doing more damage in terms of mass casualties and infrastructure/economic damage (Chen et al., 2008). Increasingly wildfires require coordination between multiple agencies to provide effective response and recovery (cf. Owen et al., 2013). At the same time financial constraints from government, declining volunteer numbers, an aging workforce and workforce restructuring are presenting agencies with significant challenges (cf. Canton-Thompson et al., 2008). One consequence of this growing number of challenges in complex emergency situations is the likely increase in the frequency of degraded operational situations, breakdowns within and between teams and the occurrence of errors. This research considers three large-scale Australian wildfires and how differences in shared understanding between teams can effect co-ordination by interfering with situational assessment, planning, and plan execution.

1.1. Incident management

In Australia, large-scale wildfires are typically managed at three organisational levels: Local, Regional and State. The local level consists of personnel (many of whom are volunteers) who are at

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[1] In this paper we use the term 'wildfire' which is considered to be synonymous with the Australian term 'bushfire'.

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the frontline of emergency response and are responsible for direct management of the fire. Regional and State level personnel (who are typically paid staff) provide strategic support and oversight, as well as managing inter-agency coordination. Regional and state levels of coordination have been referred to as the 'many second coordination cycle' during incident management to reflect the larger time window for operations (Chen et al., 2008). This is distinct from the 'mini second coordination cycle', which refers to the local onsite response coordination and has a smaller time window for operations (Chen et al., 2008).

Wildfires are typically managed using an Incident Command System (ICS), or one of its variants (Bigley and Roberts, 2001). In Australia, the Australasian Inter Service Incident Management System (AIIMS) provides an ICS framework to be used by emergency services for incidents of all sizes and it 'provides the basis for an expanded response as an incident grows in size and complexity' (AFAC, 2011, p. ii) (As shown in Fig. 1.). AIIMS is structured around four functions of: Planning, public information, operations, and logistics. Each of these functions can be further sub-divided (see Fig. 1). In a small wildfire an incident controller will carry out all these functions. In a larger wildfire some or all of these functions will be delegated to others, with the incident controller in overall charge of coordinating the response.

Managing natural events (such as a wildfire) is arguably more challenging than managing a technical system (such as a power plant) because of the uncertainty, unpredictability, time criticality and involvement of multiple stakeholders in managing natural events (Owen and Hayes, 2014). According to Owen and Hayes (2014) when managing a natural event, emergency services personnel are required to operate in uncertain and sometimes degraded conditions, making time-critical decisions using information that may be incomplete, inconsistent, or ambiguous.

Managing a natural event is also different from managing a technical system in that emergency events are often unpredictable and don't 'play by the rules' (Weick and Sutcliffe, 2007). Many other safety-critical domains are largely proceduralized, where safety is attained through adherence to well-established doctrine and protocols together with reflection on the way those procedures are functioning (Owen and Hayes, 2014). While these processes are important in the emergency services sector there is also a reasonable degree of flexibility in decision making required to deal with the unpredictable nature of the events (Elliott and MacPherson, 2010; Owen et al., 2013).

Emergency incidents are also characterised by condensed timelines, which means that people need to pay particular attention to the management of stress, fatigue and information-overload (Owen and Hayes, 2014). Finally, there are frequently multiple stakeholders involved in the operational response who may have differing objectives that need to be reconciled. Stakeholders in the management process may be from different emergency management agencies, but may also include people who are injured, traumatised or distressed by events (e.g., community members, Owen and Hayes, 2014).

In Australia, emergency incidents (such as wildfires) are separated into three distinct levels depending on their severity (AFAC, 2011). A Level 1 incident can be resolved at the local level using the available resources on-hand. Level 2 incidents are more complex in nature due to increasing size, need for resources or community risk and can last from a few hours to several days. Level 3 incidents require divisions to be established to effectively manage sections of the incident and support from numerous external agencies. In Level 3 and some Level 2 incidents, Incident Controllers are supported by Regional and State Coordination Centers that provide strategic coordination and additional resources. We are particularly interested in Level 3 incidents in this paper where Regional and State levels of coordination are required and there is a large amount of complexity.

1.2. Team coordination

A large scale emergency response requires a variety of implicit and explicit relationships between actors and technical systems

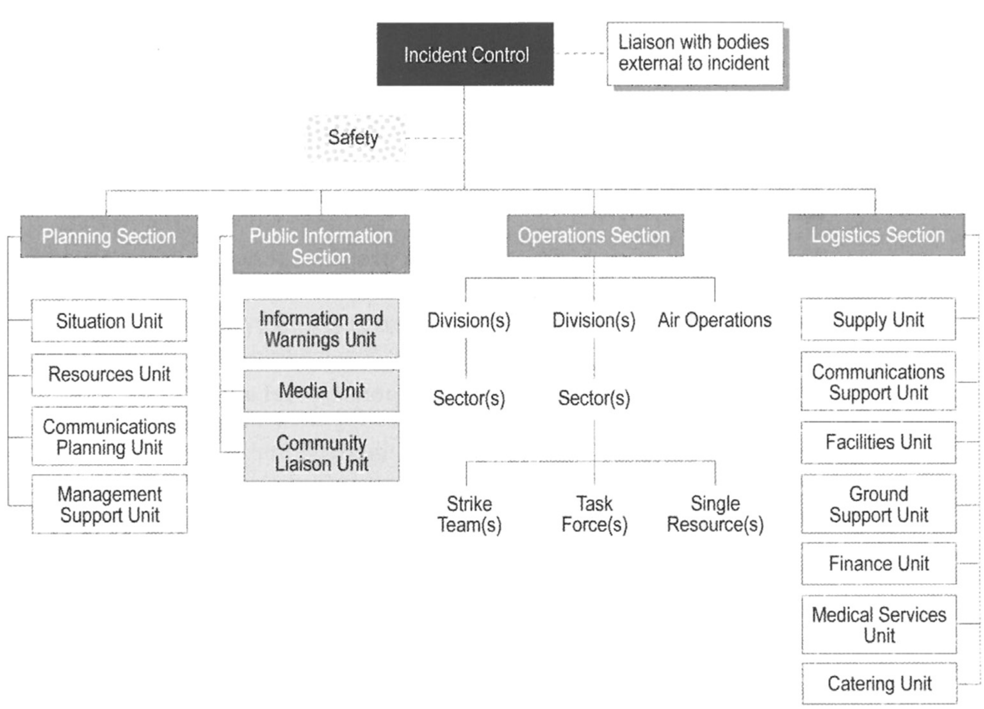

Fig. 1. AIIMS structure (AFAC, 2005).

(Johansson and Hollnagel, 2007). Effective coordination is dependent on individuals and teams of people working together to coordinate their activity through these relationships. Teams may be defined as a group of two or more people who interact dynamically, interdependently and adaptively towards the same goal (Baker and Salas, 1992). In order to coordinate effectively teams need to share information appropriately (Johansson and Holnagel, 2007; McLennan et al., 2006). To do this the team needs to have a certain amount of shared information about the knowledge, beliefs and assumptions of the team (Bigley and Roberts, 2001; Klein et al., 2005). Such information forms the shared mental models of the team and provides a basis for interactions, placing all communication in an appropriate context (Burke et al., 2006).

The development and maintenance of shared mental models allows individuals in the team to interpret information and develop a shared understanding of a situation (or shared situation awareness) with other team members, which is crucial for the development of coordinated plans and actions (Bigley and Roberts, 2001; Salas et al., 2005; Burke et al., 2006; Parush and Ma, 2012). A greater overlap of shared knowledge, beliefs and assumptions has been shown to lead to better task performance and enhanced system flexibility (Marks et al., 2000; Mathieu et al., 2000; Weick and Roberts, 1993), although it is not clear how much overlap of shared knowledge is required for effective team performance (Kozlowski and Klein, 2000). This is an issue that we will not attempt to address here.

While there is often a large degree of overlap between the mental models held by the team (because of familiarity; role expectations; and organizational coordination frameworks, such as AIIMS) it is also likely that subtle yet crucial differences will exist. For example, Bearman et al. (2010) have identified subtle differences in the way pilots and air traffic controllers understood concepts that were expected to be highly shared, such as operational safety. It is also the case that in dynamic situations, the shared team understanding can become degraded and needs to be continuously updated and repaired by team members (Burke et al., 2006; Klein et al., 2005; Johansson and Holnagel, 2007). Inconsistencies in the team's shared understanding set the scene for breakdowns in coordinated team functioning.

1.3. *Team breakdown*

A team breakdown can be defined as a situation, or state, where there is a failure in coordination, cooperation or communication due to a difference in shared meaning that leads to a temporary loss in the ability to function effectively (Bearman et al., 2010; Comfort, 2007; Wilson et al., 2007). These breakdowns can last for a short or long time and remain until the team is able to resume functionality to a typical or near typical standard.

At a more fine grained level a singular instance of disparity between team members is referred to as a *disconnect* (Bearman et al., 2010). A breakdown state may therefore contain several disconnects between individuals or teams. Bearman et al. (2010) have identified three key types of disconnects: operational, informational and evaluative. *Operational disconnects* occur when there is "either a difference between the actions of one party and actions expected by the other party or a mismatch in the plans that each party has about the physical operations of the response." (Bearman et al., 2010; pp178). *Informational disconnects* occur when there is a difference in information that each party possesses and *evaluative disconnects* occur when there is a difference in the evaluation or appraisal of information that is available to both parties (Bearman et al., 2010). Considering breakdowns in terms of disconnects allows for simple identification of recurring events that contribute to both causes and consequences of breakdowns. The focus on disconnects also highlights the different components that must be managed by the team and the potential consequences of not resolving these components, such as reduced team effectiveness. Breakdowns and disconnects are distinct from errors and can be conceptualized as temporary disruptions to team performance.

A useful way to understand how breakdowns occur in teams is through a phase model of teamwork. In a phase model the team is theorized to pass through a number of stages or phases in order to solve problems or respond to opportunities (Bales and Strodtbeck, 1951). Phase models are a common way to frame the decision making of experts in naturalistic settings (Lipshitz and Bar-Ilan, 1996; Van Den Heuvel et al., 2012) and have been used by a number of Emergency Service agencies to conceptualise the tactical decision process (cf. South Australian Country Fire Service, 2011).

Generally a phase model of teamwork involves the team identifying problems, building an understanding of the situation, generating possible solutions, evaluating these solutions and choosing a course of action (Lipshitz and Bar-Ilan, 1996). The Adaptive Team Performance model proposed by Burke et al. (2006) is considered to be particularly representative of teamwork phase models (Van Den Heuvel et al., 2012) and has been proposed as a suitable teamwork model for investigating strategic emergency management (Owen et al., 2013). Given our interest in the relationships between individuals in teams we have chosen a phase model of teamwork to frame the analysis rather than a more management inspired model (such as the Emergency Response Coordination Life Cycle proposed by Chen et al., 2008). Fig. 2 presents a modified version of Burke et al.'s model that emphasises the cyclical nature of each phase of teamwork.

Although Burke et al.'s model is concerned with team adaptability the mechanisms of the model provide an explanation of team functioning that is useful in understanding how breakdowns can interrupt the dynamic flow of teamwork by interfering with the formation of shared information and the development and execution of plans.

Burke et al. proposed four main phases within the adaptation framework: situational assessment, plan formulation, plan execution and team learning, each of which has its own emphasis on shared mental models and shared situational assessment. The initial phase focuses on information gathering based on environmental cues that signal a need for change or adaptation. These cues are shared with other members of the team thus allowing others to use different perspectives to aid in the formation of a shared mental representation of the unfolding event. This shared perspective allows individual team members to predict and identify future states and cues regarding the actions of other members.

The situation assessment stage is followed by the plan formulation stage which uses information gathered in the previous stage to shape team strategies. This includes setting goals, attributing tasks and responsibilities, clarifying expectations and sharing task related requirements amongst team members (Stout and Salas, 1993). Sharing a plan allows individuals to align with a mutual goal, thus both shared mental models and team situational assessment are strengthened. Similarly the plan execution stage uses this shared goal to drive member actions towards the shared outcome. This provides benefits in regards to increased ability to monitor performance and assist team members due to a shared understanding of the outcomes. The final phase is team learning, which facilitates the development of a common understanding about lessons learned within the team. It also incorporates past team experience in the development of future strategies.

Burke et al.'s model provides a useful tool that identifies where disconnects can occur but also how they may impact on future phases of team activity. A disconnect that occurs during the situational assessment phase for example, would be highly likely to

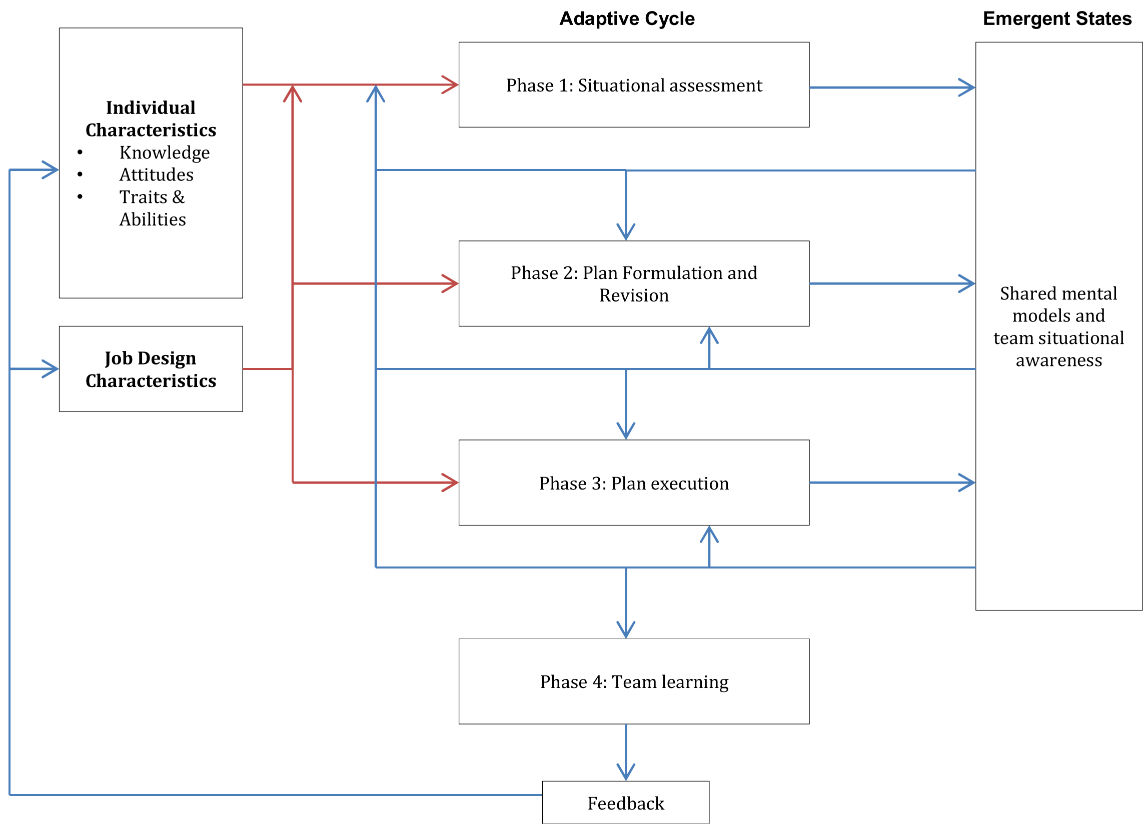

Fig. 2. A modified version of Burke et al.'s (2006) model of teamwork.

negatively impact the subsequent plan formulation, plan execution and team learning phases due to the dynamic cyclical nature of the model. It also shows how important team elements interact and feed back into the framework at various stages to allow for adaptive team performance.

The research presented here investigates the way that coordinated decision making breaks down at the incident management team level and above in three separate large scale fires in Australia (the Kilmore East fire, Victoria, 2009; the Wangary fire, South Australia, 2005; and the Canberra Firestorm, ACT, 2003). Of particular interest is the response of team members to these breakdowns and disconnects and whether the disconnects were resolved.

2. Method

2.1. Design

The study employed a qualitative coding method using a top down, theory driven approach and a bottom-up data driven approach. In a top-down coding scheme the data is coded according to a particular theory or existing coding scheme. In a bottom-up coding scheme the data is sorted into categories that emerge from the data. In this study breakdowns and disconnects were identified and classified according to a previous coding scheme developed by Bearman et al., coding breakdowns into the three previously discussed disconnect categories; informational, operational and evaluative. Reasons why disconnects occurred were allowed to emerge from the data in a bottom-up way. This was done by drawing thematic elements from the data and grouping them into logical configurations based on similarities and core disconnect elements (Braun and Clarke, 2006). This combined qualitative method allows the richness and complexity of the data to be preserved and is an ideal technique for an investigative study such as this.

2.2. Materials

Data for the study came from three sources; the Victorian Bushfires Royal Commission Interim Report (Victorian Bushfires Royal Commission, 2009: http://www.royalcommission.vic.gov.au/Commission-Reports), the Coronial Inquest into the Wangary Bushfires in South Australia (South Australian Coroner's Court, 2005: http://www.safecom.sa.gov.au/site/initiatives_reviews/wangary_bushfires.jsp), and the Canberra firestorm inquiry (ACT Coroner's Court, 2006: http://www.weepa.com.au/_dbase_upl/CanberraReportSmall.pdf).

The Kilmore East fire started on 7th February and was one of a number of bushfires in Victoria on the day that came to be known as Black Saturday. In the Kilmore East fire 119 people died and 1242 homes were destroyed (Victorian Bushfires Royal Commission, 2009). The Victorian Royal Commission produced a thorough investigation into the various elements that contributed to the Kilmore East fire, including communications between the state, region and fireground incident control levels. In particular breakdowns were drawn from Chapter 9 of the interim report which contained a compiled case study of the entire event based on witness statements. This report displayed information in a chronological pattern allowing researchers to understand the direct consequences of actions/inactions.

The Canberra Firestorm occurred between the 8th and 18th of January 2003 and resulted in four deaths and property damage totalling between $600,000,000 and $1,000,000,000 (ACT Coroner's Court, 2006).

The report on the inquiry into the fire conducted by the ACT Coroners Court contained a thorough description of events relating to several key fires (the Bendora fire, the Stockyard Spur fire, the Mount Gingera fire, and the McIntyres Hut fire). Each fire was described in a day-by-day report of events, including specific strategies that would be implemented to combat each fire, the crew involved and their recounts of events, communications between key individuals and critiques of decisions made on the day (critiques were done by both those directly involved and expert witnesses).

The Wangary fire occurred in the Eyre Peninsula of South Australia between 10th and 11th January 2005. It resulted in 9 lives being lost and 93 homes being destroyed (South Australian Coroner's Court, 2005). The report on the coronial inquest into the fires contained a summary of events that included information about the causes of impaired teamwork at the IMT and Regional levels of incident management.

Examples of the data from Kilmore East and the Canberra Firestorm are included in Fig. 3 and Fig. 4 respectively.

2.3. Extraction of breakdown situations

Statements that *prima facie* described potential breakdowns between teams or individuals were identified in each of the three reports. Breakdowns were defined as "a *failure of coordinated decision making that leads to a temporary loss of ability to function effectively*" (Bearman et al., 2010) and could be recognised as instances where distinct differences in information, operational understanding or situational evaluation existed between team members.

For breakdown instances to be included the source text had to include references to at least two teams or individuals, and a clear difference had to exist between those teams or individuals. The IMT, regional and state coordination centers were each classified as teams. For example, a breakdown instance identified in the Wangary fire was as follows:

"During the course of the afternoon the CFS officers and members attending at … Region 6 headquarters were finding it extremely difficult to obtain any relevant information about the fire, its status and its size, bearing in mind the requirement for regular SitReps from a fireground."

The example refers to the Regional Control Center having difficulties obtaining information from the fireground. In the example information should be coming up from the fire ground to the Incident Control Center, which is required to forward that information on to the Regional Control Center. This fulfills the requirement for a breakdown that two or more teams or individuals are involved. The example also describes a scenario where there is a difference in information possessed between the teams, constituting a breakdown based on an informational disconnect.

In some instances multiple breakdowns were imbedded in large bodies of text so to further aid in the identification process it was useful to define a breakdown as containing a single major theme. All of the statements identified in the *Prima Facie* extraction of breakdowns were used in the subsequent analysis.

In total, 44 breakdowns were identified within the secondary sources: 14 breakdowns related to the Wangary fires, ten related to the Kilmore East fires and 20 related to the Canberra Firestorm.

2.4. Analysis

Once the breakdowns had been identified a panel of three academics analysed one quarter of the data in detail. This analysis involved discussing the situation and mapping out the disconnects; including reasons why they occurred, recorded consequences and resolution strategies employed. This process was similar to that adopted by Bearman et al. in their analysis of aviation data. Disagreements were resolved through discussion between the panel members. Following this process the remaining data was analysed by a single coder who used the panel discussions as a coding guide. Disconnects were coded according to the definitions of Bearman et al. (see Section 1.3). A disconnect was considered to be resolved when there was no longer a difference in information, operation or evaluation between team members.

The statements that were used to identify disconnects, reasons why disconnects occurred, consequences and resolutions of disconnects were embedded within the context of the situation and sometimes the links between events did not come out of the section when the breakdown was first identified. It was sometimes only later in the report (typically no more than 3 pages) that a connection between an identified breakdown and the reasons why it occurred, consequences or resolution could be identified. In such cases coding was only made if a direct connection could be drawn between the breakdown and the stated reason why it occurred, consequence or resolution, such as a chronological link or a witness statement that corroborated the evidence. If there was no direct evidence supporting the link it was not coded.

It should be noted that in our coding scheme if both parties have identical but incorrect or incomplete information, it is not a breakdown. This is because both parties share that same 'incorrect' information which is then used to formulate future action plans. While this is undoubtedly an error, there is no actual breakdown (in understanding) between the team members.

> "There is in the evidence some conflict about whether or not it was agreed at the meeting that using the Baldy Range trail as the eastern containment line would be reconsidered the following morning. Mr <A>'s memory was that they were going to try to use the Baldy Range trail as the first option, the fall-back option being Dingo Dell Road. He was definite that at no stage did he convey any opinion that, on the basis of the information he had from Mr <B>, the Baldy Range trail could not be used as a containment line because of the intensity of the fire burning across it." (ACT Coroner's Court, 2006, p148)
>
> "In contrast, Ms C's recollection of the meeting was that the Baldy Range trail was 'just wiped' as a consideration for an eastern containment line. In her evidence, however, she agreed that, although at the meeting she had dismissed the Baldy Range fire trail as a viable eastern containment line, she accepted that, if the fire on Baldy Range could have been controlled, the Baldy Range trail would have become an eastern control containment line." (ACT Coroner's Court, 2006, p148-149).

Fig. 3. Extract from the ACT Coroners Court Inquiry into the Canberra Firestorm.

"The 3:02pm alert message represents an accurate and timely warning concerning the potential of the Kilmore East fire. It was the combined work of the Planning Unit and the Information Unit at the Kangaroo Ground ICC. It demonstrates what could have been achieved by way of information and warning to those who were in the path of the Kilmore East fire. It also demonstrates the time at which information could have been released to the community

However, the draft alert message of 3:02pm was not released. According to Mr <A> it was not released because 'the fire was being controlled by the Kilmore ICC and it was their responsibility to issue information messages be they urgent messages or otherwise'. This message was not released by the Kangaroo Ground ICC because the Kilmore ICC, not the Kangaroo Ground ICC, continued to have control of the fire

Mr <A> stated in evidence that he attempted to contact the Kilmore ICC to pass the information on, without success. He did not know whether the Kilmore ICC was releasing this type of information. Mr <A> was not monitoring the CFA website to see what information was being released but, in any event, he reiterated: 'not being the controlling ICC for that fire at that time, I was not able to issue those information releases regardless

Mr <B> stated that the unauthorised release of fire information may have caused confusion. He understood the draft threat message was forwarded to the Kilmore ICC for approval and release. It is apparent that personnel at the Kangaroo Ground ICC were not aware that the Information Officer for the Kilmore ICC at that time was based at the Seymour RECC, not at Kilmore." [Victorian Bushfires Royal Commission, 2009. P.250]

Fig. 4. Extract from the Victorian Bushfires Royal Commission report into the Kilmore East fire.

Once all the data had been coded an additional coder (who was naïve to the study) was trained in the coding scheme using 25% of the data (drawn from the Canberra firestorm) and then independently coded 18% of the data (drawn from the Kilmore East fire). Intercoder reliability between the independent and original coding was found to be good ($K = .91$).

3. Results

3.1. Types of disconnects

The 44 breakdowns identified in the three reports yielded 84 disconnects. These disconnects were classified into three main types: operational, informational and evaluative (see Table 1). The two sub-types of operational disconnects implicit in Bearman et al.'s definition were made explicit in this coding. Thus, operational disconnects were additionally classified as either: a difference between the actions of one party and the actions expected by another party or a difference in plans about physical operations. The distribution of the various main disconnects is broadly similar to that found by Bearman et al. (2010) who also found that evaluative disconnects were the least frequent type.

3.2. Reasons for disconnects

Some of the reasons why disconnects occurred could be identified and appeared to be similar for each disconnect type across each emergency event. Table 2 summarises the reasons for each type of disconnect identified in this study.

Informational disconnects were by far the most common type and four reasons why they occurred could be identified in the data: information being passed on inaccurately, information not being passed on at all, accurate information being confused or misunderstood, and difficulties sending/receiving information.

Information being passed on inaccurately, or *information not being passed on at all* occurred when one team or person had access to accurate information but did not effectively communicate it to those who required it. Some reasons why this occurred were: use of incorrect terminology, high workload interfering with the transfer of information, communication pathways not being established between teams, and assuming that the information had already been received by the other team.

Information being confused or misunderstood often occurred in our data when a person's personal bias, based on pre-formed opinions and experience, prevented that person from viewing the information objectively. This type of coding was only made when a person explicitly stated that their pre-formed opinions interfered with their understanding of the information.

Difficulties sending/receiving information refers to accurate information being available but difficulties with transferring that information impeding transfer to the people who needed it. Some examples of this were: being unable to upload information to a public database, information not getting approval to be sent by commanding officers, or technical difficulties with equipment.

Table 1
Frequencies of the different types of disconnects.

Disconnect type	Sub-type	Kilmore	Wangary	Firestorm	Total
Informational – Difference in possessed information		14	9	18	41
Operational – Difference in operational understanding	Different actions and expectations	10	9	7	26
Operational – Difference in operational understanding	Different plans about operation	0	5	1	6
Evaluative – Difference in appraisal of information/situation		4	4	3	11

Table 2
Summary of reasons for different disconnects.

Disconnect	Reason
Informational	Information being passed on inaccurately
Informational	Information not being passed on at all
Informational	Accurate information being confused or misunderstood
Informational	Difficulties sending/receiving information
Evaluative	Wanting to go against procedure
Evaluative	Disagreement about how operations should be carried out
Operational (Difference in actions and expected actions)	Assumptions that work will be carried out
Operational (Difference in actions and expected actions)	Confusion over ambiguous responsibilities
Operational (Difference in actions and expected actions)	Going against set procedure
Operational (Difference in plans)	Disagreement in the interpretation of fire information
Operational (Difference in plans)	Plans not being carried out to one groups satisfaction

Evaluative disconnects generally represented an actual disagreement between two teams or persons. Two reasons for evaluative disconnects could be identified in the data: wanting to go against set procedures and disagreement about how operations should be carried out. An example of *wanting to go against set procedure* is where one team who were dissatisfied with the current operation were prevented from changing tactics by a superior officer. *Disagreements about how operations should be carried out given that two or more people had access to the same information* was linked to situations where there were multiple people who thought they were fulfilling the same role (in the Wangary data) but also occurred in instances where people of similar rank could argue their points of view.

Operational disconnects of the sub-type: Differences between the actions of one party and the actions expected by another party occurred for three main reasons: assuming work would be carried out once delegated (where a task was given but never followed up); confusion over ambiguous responsibilities (which were not followed up); and going against set procedures. *Assumptions that work would be carried out* occurred when the expectations of one team were not met by another team (or teams) after directions had been given. *Ambiguous responsibility* was another reason for operational disconnects and occurred when there was confusion between teams about what their actual role was or what job was required of them. In some cases there were procedural ‘grey areas’ where it was unclear which person had the authority or responsibility to make decisions. There was one example (in the Kilmore East fire) of teams *going against set procedures* (an operational disconnect) without informing other teams of their intent (an informational disconnect) resulting in confusion in these other teams. In this case the procedures were disregarded because of the team's increasing frustration about lack of information (another informational disconnect) in an increasingly complex scenario.

The other sub-type of operational disconnect: A difference in plans, was mostly observed in the Wangary data with one example coming from the Firestorm data. There were two main reasons why these disconnects occurred: A disagreement in the interpretation of the fire information and plans not being carried out to one group's satisfaction. The reasons for operational disconnects related to *disagreement in the interpretation of information* were all evaluative disconnects. These disconnects subsequently resulted in a significant disruption in operations, with the development of conflicting or asynchronous operational plans. *Plans not being carried out to one group's satisfaction* occurred when the actions of one party were deemed to be so unsatisfactory that it caused plans to be altered by a higher ranking officer. This occurred when directions were given, usually by a coordinator or incident controller, but those receiving the orders carried out the task in an unsatisfactory way.

3.3. Multiple disconnects

It can be seen in the previous discussion that sometimes disconnects preceded other disconnects. This was a common observation in the breakdown situations. This section presents two examples of breakdowns where multiple disconnects occurred in a temporal sequence.

3.3.1. Containment line confusion in the Canberra Firestorm

The first example of multiple disconnects occurring in a temporal fashion is drawn from the Canberra Firestorm data. This example shows three disconnects which have an apparent flow-on effect. The text of the breakdown is presented in Fig. 3. The following discussion outlines the disconnects that occurred, the location of the disruption according to the teamwork model and the consequences of these disconnects (summarised in Table 3).

In the situation presented in Fig. 3, there is an initial informational disconnect based on a difference in understanding the information. This is apparent from the two descriptions provided by the involved parties. This difference in information disrupted the shared situation awareness of the two parties. The two parties involved then formed conflicting evaluations of the situation, that is, whether Baldy Range Trail can be used as a containment line, which further disrupted the joint team's shared situation awareness. Subsequently, the two parties developed conflicting plans so that on the following morning after the meeting, one team expected to find a containment line being built while the other was at a completely different location. This meant the containment line was placed at Dingo Dell Road instead of Baldy Range Trail. Thus, it can be seen that there are three disconnects that occur in a temporal sequence that appear to have a flow-on effect from each other.

Table 3
The classification, reason, consequences and implication for teamwork of each disconnect in Fig. 3.

	Informational disconnect	Evaluative disconnect	Operational disconnect
Disconnects	Difference in understanding presented information	Difference in evaluation of the containment strategies	Difference in operational containment strategies between two teams
Reason	Important information about operations is not distributed/understood	Disagreement about how operations should be carried out.	Disagreements about the interpretation of fire information
Location in the model of teamwork	Disruption to shared situation awareness	Disruption to shared situation awareness	Disruption to shared planning and plan execution
Consequence	Different understanding of the situation by the 2 agencies.	Difference in opinion left unresolved. Different containment plans are made.	Eastern containment line moved back substantially further to far side of park.

3.3.2. Communication problems in the Kilmore East fire

The second example is from the Kilmore East fire where there were communication difficulties between the Kangaroo Ground Incident Control Center (ICC) and the Kilmore ICC. The text of the breakdown is presented in Fig. 4. The following discussion outlines the disconnects that occurred, the location of the disruption according to the teamwork model and the consequences of these disconnects (summarised in Table 4).

This example contains two breakdowns. The first is located within the last paragraph of the text presented in Fig. 4; the Kangaroo Ground ICC was unaware that the information officer for the Kilmore ICC was located at the Regional Emergency Control Center (RECC). This is an informational disconnect between the two ICCs, and also between the Seymour RECC and the Kangaroo Ground ICC. This informational disconnect disrupts the shared situation awareness between the two teams. Subsequently, an operational disconnect occurs between the Kangaroo Ground ICC and the RECC relating to where to send information for the information officer. The operational disconnect encapsulates a disruption in shared plan formulation and plan execution. The two disconnects in this situation can be described as a single breakdown event because there is a single theme, that is, the location of the information officer at Seymour.

What happens next is the formation of a second breakdown concerning the drafted threat message. It begins with an evaluative disconnect within the Kangaroo Ground ICC (not shown in the text in Fig. 4). There is a difference between the evaluation of the current situation between the planning unit/information unit and the Incident Controller, one group believes a message should be sent out while the Incident Controller uses authority and organisational procedure to make an informed decision to not break standard operation. This evaluative disconnect leads to a temporary disruption to shared situation awareness until it is resolved by the Incident Controller. In the end the message is not sent. A further disconnect occurs between the two ICCs in the form of an operational disconnect. The Kangaroo Ground ICC believes that the Kilmore ICC will send the message because the fire is in their jurisdiction but this doesn't happen until much later in the day. The operational disconnect disrupts shared plan formulation and execution. This breakdown resulted in a lack of timely information being sent to the community. This lack of information sharing with members of the community can be considered to be an informational disconnect. While in a strict sense fire agencies and members of the community do not really form teams, they do interact to make coordinated decisions. Fire agencies and members of the community need to possess some level of shared situation awareness so that the plans that community members develop and carry-out are consistent with what the fire services are expecting, based on their understanding of the fire conditions.

It should be noted that this examination of multiple disconnects in the two examples does not necessarily imply linear causality of one disconnect uniquely causing another disconnect to occur. Instead this suggests that once a disconnect occurs it *may contribute* to the formation of other disconnects over time. Indeed subsequent disconnects could develop due to numerous other environmental, organisational and personal variables interacting or not with an existing disconnect. In other words a relationship has been observed between disconnects in some breakdowns and this can in some cases reasonably be assumed to contribute to the second breakdown, but this should not be taken to imply that one disconnect uniquely causes another disconnect.

3.4. Resolution of disconnects

Across the three fires there was a distinct lack of resolution of operational and informational disconnects. Three out of 41 informational disconnects were resolved and five of the 32 operational disconnects were resolved. In contrast, ten out of eleven evaluative disconnects were resolved. All of the evaluative disconnects were resolved by the commanding officer making a judgement about the available facts and giving their opinion to subordinates. Thus, where disagreements occurred the commanding officer overrode the disagreements using their position of authority. Similarly, the five operational disconnects were resolved by someone making a decision about the competing plans. The three informational disconnects were resolved when someone actively sought out the information that they were missing.

4. Discussion

The results of this study show that breakdowns and disconnects are occurring within and between teams formed at and above the IMT to coordinate large-scale wildfires. These disconnects impair team functioning leading to teams not possessing important information, developing conflicting plans and not acting in a timely way.

The reasons why each type of disconnect occurred could be grouped into a number of categories that were generally consistent across the three fires examined in the study. This suggests that these categories will be useful in considering reasons for breakdowns in future large-scale emergencies. While pinpointing the exact causes of disconnects is difficult given the high number of internal and external factors impacting on the situation and the subjectivity of the people involved these categories are useful in identifying a number of practical issues that emergency service agencies should examine in more detail.

In particular, agencies should ensure that the responsibilities of each role are clearly specified and that procedures exist to

Table 4
The classification, reason, consequences and implication for teamwork of each disconnect in Fig. 4.

	Informational disconnect 1	Operational disconnect 1	Evaluative disconnect 1	Operational disconnect 2	Informational disconnect 2
Disconnect	Differences in information about the location of the information officer	Differences in the plans about where information should be sent.	Difference in opinion about whether to send out information	Differences in the plans about information dissemination	Difference in information about the status of the fire between fire agencies and the community
Reason	Important information about operations not shared/distributed	Procedures or responsibilities unclear/ambiguous	Wanting to go against procedure (unable to contact other teams)	Assuming work will be carried out	Important information about operations not shared/distributed
Location in model of teamwork	Disruption to shared situation awareness	Disruption to shared planning and plan execution	Disruption to shared situation awareness	Disruption to shared planning and plan execution	Disruption to shared situation awareness
Consequence	Kangaroo ground ICC did not know where to send information	Confusion about whether information is being disseminated	Resources used to resolve a disagreement	Kangaroo ground ICC do not send message in a timely manner	Community do not possess important information about the fire

communicate any changes in responsibilities during an emergency response. Agencies should also work to identify and resolve procedural ‘grey areas.’ At an individual level, it was apparent that sometimes tasks were given but there was no follow up or feedback from the person to whom the task was given. This is one example of a more general issue, which is assuming that other people are doing something without checking that this is the case. It is important to facilitate adequate communication to ensure that other people are doing what you think they are doing. More generally, it is important to ensure that the correct terminology is always used, that proper communication pathways are established between teams, and that approval processes for the release of information are as streamlined as possible.

In terms of resolution, the analysis showed that informational and operational disconnects were often left unresolved compared to evaluative disconnects. Incidents in other domains have shown a higher resolution of operational and informational disconnects. Across two studies Bearman et al. found that operational and informational disconnects were resolved significantly more than evaluative disconnects. In fact, Bearman et al. (Study 1) found a high resolution rate for operational disconnects. This may be a product of the different domains examined by Bearman et al. to the fire-fighting domain examined here. Aviation and space operations are well structured in that one group provides instructions to the other, who may then carry them out or not. In wildfire, at the IMT level and above, operations are arguably more complex, in that there are often many different routes to achieve the same goal and instructions and feedback loops relate more to strategic rather than tactical considerations. In addition it can be argued that, when working with personnel who are volunteers the levels of training may not be as uniform as they are in other safety critical domains. It is also less clear that information has not been provided or that a plan is not shared by others in teams above the IMT, and hence these types of disconnects are more difficult to resolve. In contrast, evaluative disconnects are easier to resolve because in wildfire operations there is a clear authority structure. In aviation and space operations the authority for the operation is generally shared between the pilot/controller and the commander/head flight controller. Further research that examines differences in the characteristics of different domains is required to investigate this unexpected finding in more detail.

A common way to frame the decision making of experts in naturalistic settings is to use a phase model (Lipshitz and Bar-Ilan, 1996; Van Den Heuvel et al., 2012). The phase model used in this study (a modified version of Burke et al.’s model of adaptive teamwork) was chosen because it is particularly representative of teamwork phase models (Van Den Heuvel et al., 2012) and has been proposed as a suitable teamwork model for investigating strategic emergency management (Owen et al., 2013). This model appears to be useful in understanding the effects of disconnects. In the Canberra Firestorm example of multiple disconnects (considered in Section 3.3.1) it can be seen that the first disconnect disrupts the team's situation assessment, which appears to contribute to further disruption in team coordination.

The revised version of Burke et al.’s model used here is cyclical, which means that once an unresolved disconnect enters the team's shared situation awareness, it is likely to disrupt team planning and plan execution processes until the disconnects are identified and resolved. More broadly, in terms of teamwork this shows the importance of establishing and maintaining shared meaning between team members (Bearman et al., 2010; Comfort, 2007; Klein et al., 2005). The specification of breakdowns in terms of a model of teamwork allows us to describe some of the processes that occur within teams that identify why the behaviour of individuals in the team makes sense to them at the time (i.e. local rationality, Dekker, 2011) but ultimately leads to degraded team performance.

The exploratory data analysis and discussion presented here represents the first systematic research to provide information about the reasons why breakdowns in coordination occur in emergency management. The importance of this research then lies in promoting an awareness of these issues amongst the emergency management community. At a practical level, the disconnects identified here can form the basis of training exercises where disconnects are embedded in scenarios so that operational personnel can practice how to identify and resolve them. For example, informational disconnects can be presented as missing, confusing or incorrect information. Operational disconnects can be presented as a difference between actual and expected actions, based on standard operating procedures (SOP) and evaluative disconnects can be presented as a difference of opinion of given data (c.f. Grunwald and Bearman, 2014).

The information presented here can be also used to develop aids that personnel can use to help detect and resolve breakdowns before they can negatively impact the operational response. These aids can be designed particularly for use by people who are less experienced or are becoming overwhelmed by a situation to check that they are not engaging in behaviour that would make breakdowns more likely. For example, an aid could be developed that encourages the person to check whether they have followed up on tasks that have been set, checked assumptions about what others are doing and established effective communication lines between teams. By eliminating or mitigating against coordination breakdowns agencies will be better equipped to manage more extreme events by improving the decision making process through more accurate and timely communication practices.

While this research has identified a number of important issues there are a few limitations. The data used in this study can be described as being triple-hermeneutical. This means that the research presented here is based on the researchers interpretation of the interpretation of the investigators of the interpretation of the participants in the event. This approach is fairly common when analysing reports into accidents/incidents and from a pragmatic viewpoint such data is the only information about large-scale fires in the public domain. The reports used in the research have also been used by a number of agencies to improve their understanding of organisational and procedural limitations and vulnerabilities during major fire events.

A further limitation of the research is that the data analysis may have been influenced by hindsight bias and counterfactual thinking. Hindsight bias refers to a few related phenomena, although for the purposes of this discussion it can be defined as the tendency for knowledge about the outcome of an event to lead to that event being seen as more inevitable or foreseeable than it really was (Calvillo, 2013). Hindsight bias could potentially have contributed to the coding of disconnects in that it was only after a problem occurred that it was obvious that information or plans should have been shared. Counterfactual thinking is where the focus is on what people did not do rather than on what they did (Dekker, 2002). Focusing on what people did not do leads to an emphasis on things that were absent rather than on things that were present to provide evidence for disconnects. The issues of hindsight bias and counterfactual thinking are inherent in the data, in our approach to the data and in our use of the phase model of teamwork. However, despite these limitations, this approach has allowed us to provide a useful and accessible way to understand breakdowns. To try to reduce the limitations of hindsight bias and counterfactual reasoning we have attempted to retain as much complexity in the data as possible and have included references to the data that was used in the analysis so that others are able to draw their own conclusions.

While the findings are necessarily qualified by the nature of the data and the framework used, the analysis has allowed us to identify some of the ways that dynamic team processes can contribute to impaired operational performance in real large-scale emergency situations. The rich account presented in the section on multiple disconnects, for example, would not have been possible without this type of data. The data examined in this study does mean however that it is difficult to provide definitive explanations for why certain phenomena occur or the extent to which they may occur in other fires with different outcomes. Such explanations need to be examined further in data obtained from other methods, such as interviews and experiments. These studies form the basis of ongoing research into coordination breakdowns.

5. Conclusion

In conclusion, this article has examined disconnects and breakdowns that occur in teams formed to coordinate large-scale wildfires in Australia. The research in this study begins to unpack the complexity of coordination breakdowns in emergency management. This exploratory research has identified some of the reasons why disconnects and breakdowns occurred and has found resolution rates of operational and informational disconnects are fairly low. In contrast resolution rates of evaluative disconnects are high relative to other domains that have been examined in the literature. A relatively simple straightforward framework has been employed that can facilitate a better understanding of the dynamic nature of teamwork and how it can be disrupted. The exploration of breakdowns in terms of this model of teamwork allows us to provide an account of the way that dynamic team processes can lead to degraded operational performance.

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