A Model-Based Approach to Capability in Fire and Emergency Services

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ABSTRACT

In 2013, the Department of Fire and Emergency Services (DFES) of the Government of Western Australia initiated the development of a capability framework to facilitate rigour in the definition, description and documentation of elements and characteristics necessary for service delivery. A 'capability'-based approach, similar to that now commonly used in defence and related industries, and model-based techniques from systems engineering have been applied into this new area.

This paper summarises the process that has been undertaken to develop this framework, including the previous work this concept has drawn from and a description of the content and structure of the framework developed. Examples of the processes implemented and demonstrative example outputs produced directly from developed capability models are shown. Perceived benefits from using this approach to support high-level decision making are discussed, as are lessons learned from undertaking this initial implementation project.

INTRODUCTION

Taking a 'capability' approach to the management, acquisition and organisation of resources has become an accepted concept in defence departments around the world. As with defence, fire and emergency service providers have a wide range of well-defined responsibilities, and a set of interrelated resources that are designed and implemented to meet them. Recognition of this similarity allows these agencies to appropriate and apply some of the same techniques for managing defence service delivery, with the aim of realising many of the same benefits that defence has experienced.

The Department of Fire and Emergency Services (DFES) of the Government of Western Australia is responsible for coordinating emergency services for a range of natural disasters and emergency incidents across Australia's largest state. It is the hazard management agency for nine categories of emergency, including bushfire, flood, cyclone, earthquake and tsunami. This hazard management role requires DFES to coordinate response between all agencies involved in the combat and support of emergency events. DFES is additionally responsible for a number of roles in other emergencies, such as air search and rescue, land search and road transport emergencies (DFES 2013).

With this large, multi-role organisation, acquisition, management and organisation of the Department's capabilities are large and complex tasks. In "New Beginnings 2024" (DFES 2012), DFES described the concept behind development of a capability framework to tackle these issues:

> *"A major focus for DFES in 2012/13 is to design a capability model that addresses risk and vulnerability at the local level, whilst acknowledging the need to optimise our available resources. Maximising the potential for resource sharing and interagency cooperation is fundamental to achieving the best outcomes for the community."*

In 2013, DFES initiated the development of a capability framework to address this, with the aim of improving rigour in the definition, description and documentation of elements and characteristics necessary for the Department's service delivery. The scope of works achieved in the initial implementation of this capability framework was to:

1. Identify existing context to clarify and define DFES mission, drivers and capabilities.
2. Design a capability management framework for the DFES environment.

3. Operational modelling of aspects of the 'as-is' capability of DFES.
4. Provide an implementation and communications plan that outlines the desired end state, how this is to be achieved and how to communicate this to the wide range of stakeholders involved.

Future work, described later in this paper, will concentrate on developing 'to-be' capabilities in addition to the 'as-is' capability analysis, and applying these approaches to major development projects.

CAPABILITY AND SYSTEMS ENGINEERING

Henshaw *et al.* (2011) describe the varying uses of the terms 'capability' and 'capability engineering' across industry and government. These are described through related yet distinct worldviews. In each of these worldviews, the word 'capability' is used in a varying context, resulting in a different understanding of the scope and activities involved in 'capability engineering'. Each of these capability worldviews can be considered appropriate depending on the context in which capability engineering activities are to be taken place, and the desired outcomes of any analysis and engineering processes.

The worldview of capability used to design and deliver a capability framework to DFES is that described by Henshaw *et al.* (2011) as W7 – Enterprise Planning:

> *"**Managing the interdependencies between capabilities:** Described by a system in which: Strategists (supported by all Components of Capability owners) develop, maintain and ensure implementation of an integrated plan in order to manage the interdependencies between all Components of Capability changes, across all capabilities and all business service delivery, in order to support strategy, finance and Components of Capability owners."*

This recognises that many capabilities may be built from common components of capability, all managed by various owners within the broader organisation. The same paper concludes that capability engineering is the "overarching approach that links value, purpose and solution of a systems problem" (Henshaw *et al.* 2011). It is broader in scope than product systems engineering, and provides a holistic perspective to the systems engineering activities. While the scope and context problems are different in capability engineering, the processes used for capability engineering are largely the same as traditional systems engineering.

Within DFES, the broadest capability is seen as the ability to deliver effective fire and emergency services. For the DFES to perform its mandated activities effectively, it requires a range of elements to be present simultaneously. Capability derives from the synchronised effect of these elements and their integration to deliver services in the operational environment. Under the new capability framework, capability is the foundation of the department's service delivery.

A capability is:

- designed to satisfy the Department's mandated operational and administrative requirements;
- applied through the activities of the Department;
- innovated and developed through projects; and
- sustained through maintenance and logistics activities.

Mollett (2010) describes the "capability challenge", where competing demands and expectations in an increasingly complex environment require a new approach in response. Solving capability problems effectively requires collaborative working relationships between all stakeholders. This becomes increasingly difficult with multiple organisations involved in the delivery of elements of capability, and with various systems contributing to multiple capabilities. Effective capability decision making is enabled by the availability of accurate, coherent and timely data, presented and structured appropriately. It is the goal of the capability framework to provide such information in order to support decision-making activities.

Using the Capability Framework, DFES has shifted the management of capability from an asset-based to an effects-based approach. The effects-based approach facilitates understanding of the impact and significance of changes in systems, people, processes and structure. It allows DFES to clearly relate their legislative requirements and other drivers (such as declared government strategies) to achieve outcomes and thus substantiate capability investment decisions. The projected benefits of this approach include a firm basis for future capability planning, including facilities requirements, fleet simplification and other efficiency measures.

THE DFES CAPABILITY FRAMEWORK

The Capability Framework developed for DFES provides a comprehensive model of system architecture so that all views of a capability are interrelated and consistent.

Prior to the introduction of a Capability Framework, DFES had a system designed to meet local risks and needs with required equipment. The skills and competencies of its people (both volunteer and career) have been enhanced by the deep experience and knowledge of many dedicated emergency services personnel, as well as delivery of effective task-oriented training programs. A significant portion of the tasks performed within the Department are well documented through established procedures and operating standards. In addition, the department has in place a program of producing high-level strategic plans on each of these capability areas linking to the department's main strategic vision.

The need for a Capability Framework was identified to fit between these areas, by linking the high-level strategies to the implementation and acquisition of each element involved in capability. The implemented framework also links each capability with the higher mandated need for the capability, for example in legislation, government regulations and state emergency plans, providing the basis for traceability and therefore impact of decisions from the lowest-level choice to the mandate for each capability.

The Capability Framework produced consists of:

- **A Tool:** The elements making up DFES capabilities and their relationships can be stored and accessed through models stored in a relational database, providing a persistent knowledge base from the capability model. This was developed in Vitech's CORE®, a model-based systems engineering environment. A series of customised Microsoft Excel, Microsoft Word and HTML outputs of the tool can be produced for communication within and outside the organisation.
- **Structure:** A Reference Model of the Capability Framework addresses the underlying structure of the models developed in the tool, how the inputs and outputs of the model are related, and how Capability is modelled within the tool using this framework.
- **Processes:** A set of standard processes were defined for capability management and development, which identify how information is captured and used within the Capability Framework.
- **Glossary:** Defining a Department-wide set of capability management and development terms, and definitions of common fire and emergency services terms used.

A feature of the framework, and the framework tool, is the ability to produce standard and customised reports or views of the modelled data.

Once described, the capability elements can be more thoroughly considered during planning, development, execution and review of the service delivery models developed to deliver those capabilities. The Department's strategic approach to the management of these elements can be readily described, and managed, through detailed strategic plans. Once developed, such plans allow the effective and strategic synchronisation of the Department's evolving service delivery models. A mature Capability Framework also provides an effective reference point for impact analysis when internal and external pressures to modify services or resource allocations develop.

The Capability Framework enables full traceability from high level capability needs driven by statute requirements such as governing legislation, cascading down to the basic, solution-independent capability needs and through to functional and performance requirements of systems required to meet those needs.

The resulting capability elements can be broken down in various ways (Henshaw *et al.* 2011). These have included:

- Australian Department of Defence Fundamental Inputs to Capability (FIC – Command and Management, Organisation, Major Systems, Personnel, Supplies, Support, Facilities, Collective Training)
- UK Ministry of Defence Lines of Development (TEPIDOIL - Training, Equipment, Personnel, Information, Doctrine (and concepts), Organisation, Infrastructure, Logistics).
- US Department of Defense (DOTMLPF – Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities).
- Rail Components of Capability (People, Organization, Safety, Operations, Maintenance, Logistics and supply, Rolling stock, Infrastructure).

In DFES, the following breakdown was used, with the combined motivation of taking good practice and ensuring that it integrates smoothly with the extant strategic planning structure in the organisation, with each of the Capability Element types directly relating to specific strategic plan documents produced by the department:

- the department's **Assets**;
- **People** (including their individual skills and competencies);
- established organisational **Knowledge**;
- **Information and Communication Technologies**; and
- overarching **Governance and Accountability**.

The traceable structure of this model has been defined in detail, and is based on the initial high-level concept shown in Figure 1 below, based loosely on the DoDAF model (Department of Defense 2009).

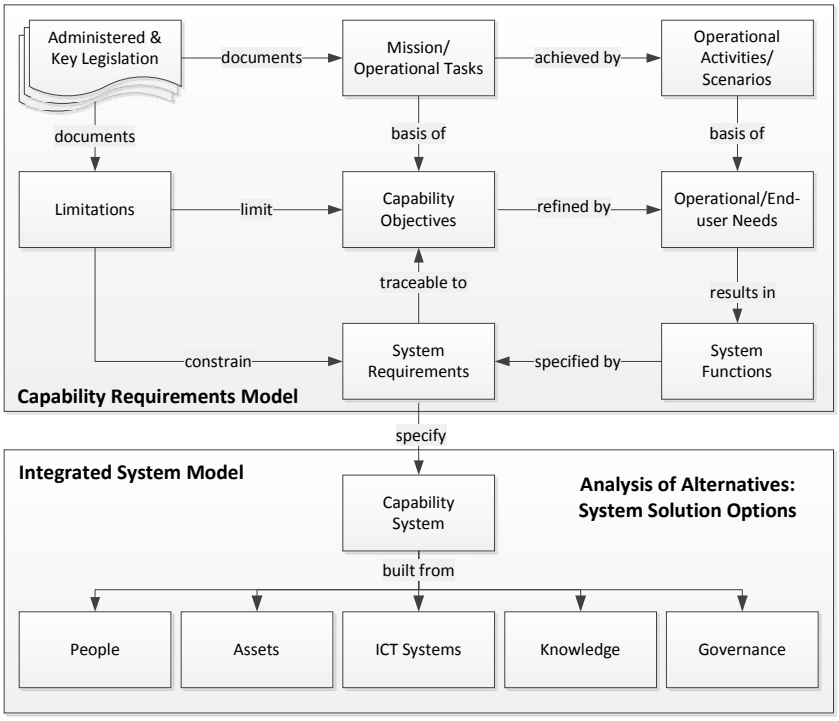

Figure 1. Capability Framework model concept.

Viewpoints address the concerns of defined stakeholder classes and describe various views on the data model to address those concerns. Each of these viewpoints describes a particular set of objects and attributes in the model, and contains a set of views on the data. The viewpoints provided in the Framework are:

- The **Capability Viewpoint** addresses high-level descriptions of the Capability of the organisation. The views and forms within the capability viewpoint manage the full portfolio of capabilities, the link to guiding legislation, regulations and strategies, and the organisation elements that are responsible for each capability.
- The **Operational Viewpoint** includes a set of scenarios designed to describe the use of the complete capability of the organisation, which are decomposed into activities that result in solution-independent operational/end-user needs of the capability.
- The **Integrated Systems Viewpoint** links the operational needs to solutions formed by a set of capability elements. These capability elements are defined further by their functionality in an integrated system model, and linked together by a physical view of the interfaces between them.
- The **Acquisition Projects Viewpoint** specifies requirements based on the capability elements and functions in the Integrated Systems Viewpoint, and maps them to projects used to acquire them. This viewpoint has links to external project management systems.

The structure overall provides an integrated model of these various perspectives in a similar way as described by Schmidt and Macdonald (2003).

In addition to the structure of the capability model, a process has been developed for its use. It details the processes used in capability management and capability development. The highest-level process flowchart is shown in **Error! Reference source not found.**, with the stages of:

- **Determine and Characterise Capability** – Determine, describe and characterise the capabilities that are necessary to meet the organisation's responsibilities.
- **Determine Solution-Independent Needs** – Using scenario analysis, determine the missions, operations, roles and interactions that form each capability, and derive the solution-independent needs of that capability. These needs include desired outcomes from the analysed activities and metrics for determining operational effectiveness.
- **Model Existing Capability Elements and Identify Capability Gaps** – Map the existing capability elements, and identify any gaps in the capability needs that need to be met.
- **Design Required Capability Elements** – Design future capabilities based on the unmet operational needs, and derive the requirements of these elements contributing to the capability.
- **Determine Development of Acquisition Projects** – Link the requirements of these future capability elements through to the projects involved in their development or acquisition.

Each of these stages includes deeper levels of process description that have been built as part of the capability framework.

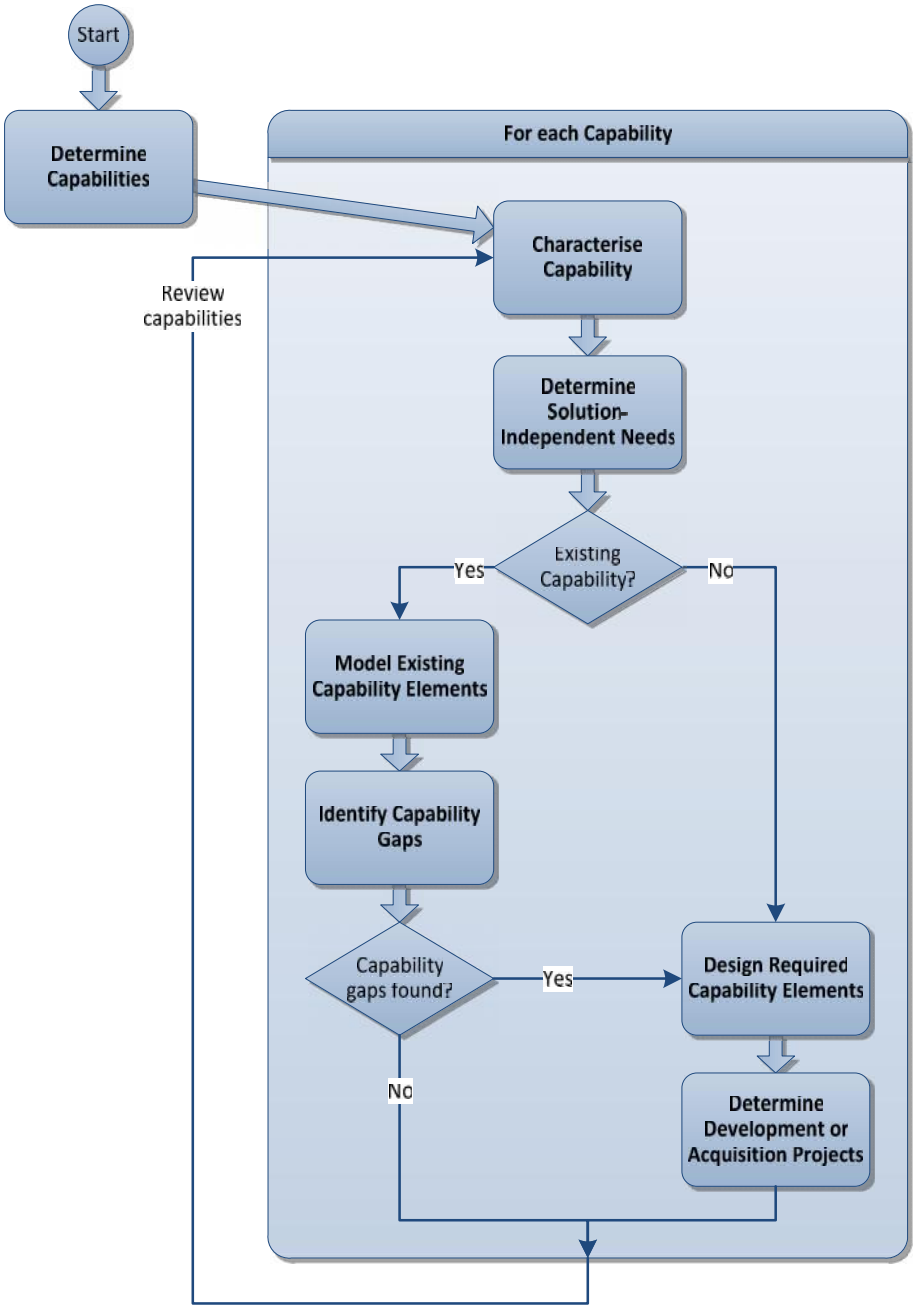

Figure 2. Capability Framework top-level process.

TOOLS AND METHODS – A MODEL-BASED APPROACH

The use of Model-Based Systems Engineering (MBSE) tools to address capability problems is well documented, with Robinson and Graham (2010) providing an outline for the Whole-of-System Analytical Framework (WSAF), on which this approach for the DFES capability framework modelling was based. This was expanded further by Logan *et al.* (2013), with a discussion of the implementation details of the WSAF. Additionally, an approach to model the full integrated organisational capabilities, at a similar level to DFES, was demonstrated in Schmidt and Macdonald (2003). Morris and Sterling (2012) also demonstrated a capability-level analysis using CORE and the WSAF. The implementation of the capability model for DFES in CORE is based on the same principles as these demonstrations.

This tool and a model-based approach to the management and development of capabilities, allows a consistent, yet flexible structure for the underlying Reference Model which defines what information can be gathered and how it is related. The alternative approach for storage of the data would have been either a customised or off-the-shelf database management system. This was considered less desirable in the early stages of development, giving less flexibility and adding much higher cost of changes to the model structure than the flexible systems engineering environment used.

Using standard tools and methods allowed for the leveraging of existing enterprise architecture frameworks such as AUSDAF, DoDAF and TOGAF, such that only minor changes were needed to meet the specific requirements of DFES. These changes involved using a subset of these frameworks, or changing wording to meet their current usage, using a lean approach akin to that described by Turner *et al.* (2013). Similarly to Turner *et al.*, appropriately structured document-based input forms were used as a basis for collecting stakeholder information.

Presenting the capability models in formats common in systems engineering, though relatively easy for the wider stakeholder community to interpret and understand (e.g. functional flows, interface block diagrams) enhances communication of the ideas investigated in the analysis. These views are presented from the underlying data model, which provides consistency between them and any other textual and tabular outputs produced.

LESSONS LEARNED IN THE APPLICATION OF THIS APPROACH

Application of capability engineering in a new area – whether that is in a new country, such as discussed with Korean defense by Kwon and Cook (2010), or in a new industry such as healthcare discussed by Turner et al. (2013) – will result in some lessons learned. These cover both positive lessons from what has gone well and negative lessons highlighting what could be improved in the future. Prior to implementing a capability framework with DFES, the wealth of information in such previous papers provided very useful preparation.

One key lesson stood out during this project – the importance of language. As systems engineers with limited understanding of fire and emergency services, it was important to be aware of different language use within the organisation. In this project, this effort was supported well by a senior manager within the Department, as they had a defence and capability background, and were consequently able to "translate" between people of different backgrounds. This was also supported by the use of a glossary as a key component of the framework, recording definitions for terms from both systems / capability engineering and fire and emergency services.

Additionally, when dealing with language, the early discussion of terms with key stakeholders is important. As mentioned earlier in this paper, there are many related meanings (or worldviews) relating to capability, and it is important to discuss these as early as possible.

DFES CAPABILITY FRAMEWORK EXAMPLE AND FUTURE

As part of the initial implementation of the Capability Framework in DFES, three scenarios were selected as exemplars to build an initial capability model. The selected initial scenarios covered:

- Metropolitan Structural Fire – a fire within an 8-storey apartment block in the Perth CBD;
- Rural-Urban Interface Fire – a fire at the outskirts of the Perth metropolitan area; and

- Command and Control – covering the specific command and control activities taking place in the Rural-Urban Interface fire example.

To demonstrate some of the data used in the DFES capability models, this paper will describe an example using the Rural-Urban Interface (RUI) Fire scenario. This example is of particular interest, as it is an area of increasing threat, as the city encroaches further into previously rural areas. Communities at the RUI are exposed to the threat of fast-moving, intense bushfires moving into densely populated city suburbs. The doctrine for dealing with the threat at the RUI is currently being developed, and required multiple offensive strategies to control intense bushfire as well as specific defensive strategies where numerous assets are threatened simultaneously.

The specifics of the scenario chosen were very similar to events that have occurred in the past. Figure 3 below shows the general scenario situation used in the analysis. Details include:

- The location is on the outskirts of the Perth metropolitan area. Land involved is managed by a mix of government bodies, with a nearby residential development in a cul-de-sac. A railway line runs through the area.
- The day of the incident is a day of *Very High* Fire Danger Rating. In this case (as opposed to Extreme or above) no pre-formed teams are in place to tackle incidents. The day also includes high winds.
- Fire is started at multiple points along one side of the railway line by a faulty braking system on a train carriage. Winds are blowing across the nearby land, including a forestry area, and towards the nearby residential development. Due to the mix of land, a multi-agency response will be required.
- Notification of the incident is initially via a 000 call reporting of smoke in the area.

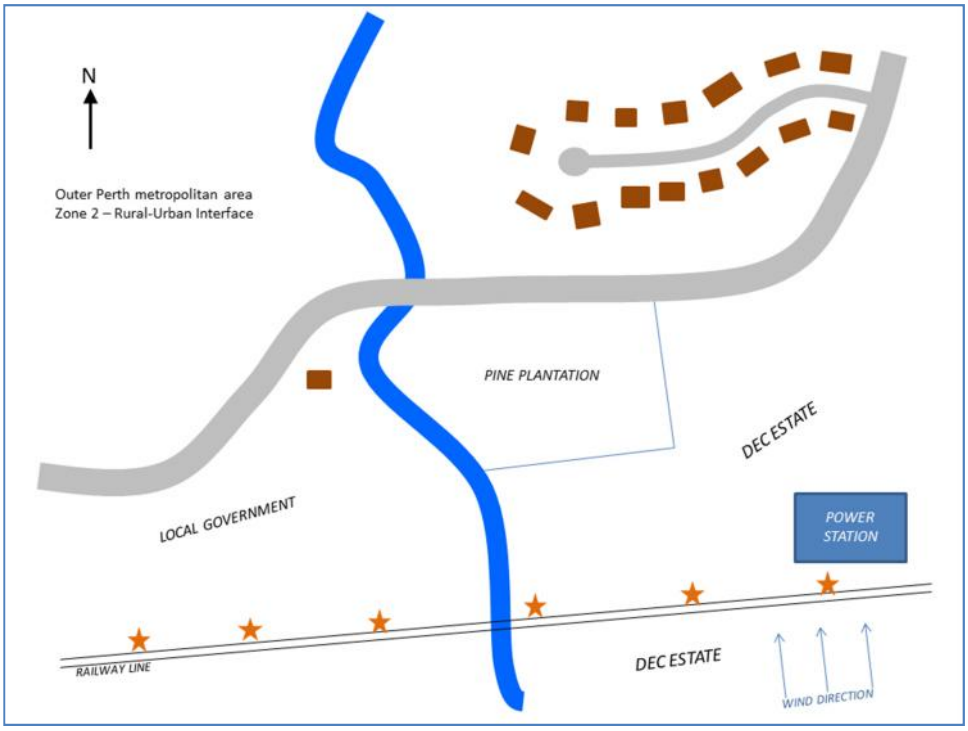

Figure 3. Rural-Urban Interface Fire operational concept graphic.

Having described the scenario to be analysed, existing procedures were consulted to determine the participants' normal actions. These were then workshopped in detail with staff from all of the involved services, until an operational activity model, along with detailed operational information flow, was complete. An example activity flow produced by this workshopping process, showing a small part of the process (incident mobilisation) is shown in Enhanced Functional Flow Block Diagram (EFFBD) form in Figure 4 below.

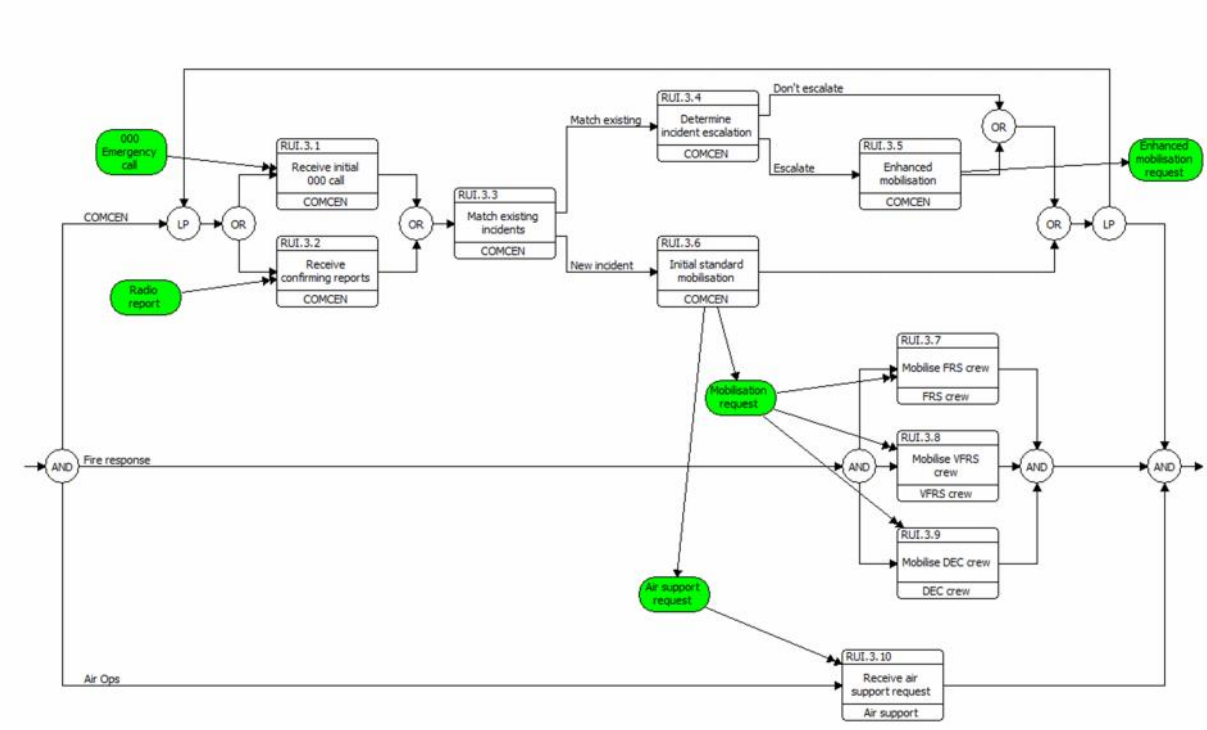

Figure 4. Rural-Urban Interface activity model example – Mobilisation.

After determining the operational activity flows, the same workshop attendees were consulted with some guidance to determine the solution independent end-user (or operational) needs resulting from these activities. A sample of these showing just the names of modelled elements is shown in Table 1 below.

Number	Description	Operational Needs
RUI.3.1	Receive 000 call of smoke coming from multiple points in a paddock. COMCEN interrogates caller to receive sufficient detail.	- Gather sufficient incident details
RUI.3.2	Further reports of fire in the same location are received.	- Receive notifications from other agencies - Gather sufficient incident details
RUI.3.3	COMCEN interrogates caller to gain detail and compare to existing incident. The COMCEN compares incident details from the further reports to confirm that the incident being reported is not a separate incident from the initial calls.	- Ability to match calls to existing incidents

Number	Description	Operational Needs
RUI.3.4	Mobilisation to a bushfire will frequently be greater than the single station standard. If escalation is required, this is determined by the Supervisor COMCEN (SCC)	
RUI.3.5	The Supervisor COMCEN (SCC) is to gauge the appropriate response to a bushfire incident based upon the following: - Information gained through first caller interrogation. - Current or forecast weather/meteorological conditions. - Current or forecast Fire Danger Rating (FDR) for the location involved. In this case, due to the Zone 2 location and after receiving multiple reports of fire in the area, an enhanced mobilisation is initiated.	- Knowledge of inter-agency capabilities - Enhanced response plans
RUI.3.6	A standard mobilisation is initiated as per the mobilisation procedures.	

Table 1. Operational needs derivation example (sample of activities).

The 'capability elements' currently used to provide the existing capability are then determined after detailed systems engineer analysis, along with subject-matter experts. The modelling of this involved determining the capability elements involved, their functionality, and mapping this functionality to the operational needs that they meet (to varying degrees). The capability elements taking part in the Rural-Urban Interface example are shown in Table 2 below.

Element Type	Capability Element
Asset	Breathing Apparatus (BA)
Asset	Gas Detector
Asset	Hoses, branches
Asset	Personal Protective Clothing (PPC)
Asset	Appliance - Country pump
Asset	Appliance - First Response Unit
Asset	Appliance - Medium pump
Asset	Appliance - Rural tanker
Asset	Incident Control Vehicle
Governance & Accountability	Incident Command and Control

Element Type	Capability Element
Governance & Accountability	OH&S
Governance & Accountability	Contracted earthmoving assets
Governance & Accountability	Inter-agency MOUs
ICT	Appliance mobile telephone
ICT	FCAD
ICT	Mobile Data Terminal
ICT	Pager
ICT	Radio system
ICT	Station Data Terminal
Knowledge	Directive - Bushfire
Knowledge	Field Guide - Bushfire
Knowledge	Aerial Suppression Response
Knowledge	Bushfire Response
Knowledge	Crew Safety at Bushfires
Knowledge	Ground Control of Aerial Suppression Platforms
Knowledge	Structural Triage
Knowledge	The Employment of Strike Teams at the RUI
Knowledge	Immediate Street Assessments at the RUI
Knowledge	Structural Defence at the RUI
People	Bush Fire Service (BFS)
People	Career Fire and Rescue Service (FRS)
People	Department of Environment and Conservation (DEC)
People	Volunteer Fire and Rescue Service (VFRS)

Table 2. Rural-Urban Interface Fire Capability Elements example.

FUTURE PLANS

The Capability Framework has been designed to be extensible to include additional processes, interfaces and data capture as needed for its use. The initial area for extension that has been identified is in the verification and validation of the capability models. This is necessary to demonstrate completeness and consistency of the modelled capabilities. Using CORE® as the selected tool for this approach allows for the use of integrated completeness and consistency checks, as well as the use of the simulator for human-readable validation of the scenario and functional models.

Within DFES, further implementation of the framework will be divided into two phases:

- The first stage will continue the implementation of the capability framework descriptions of individual capabilities using the methodologies already developed and include the establishment of an internal Capability Planning Branch and appropriate tools within

Capability Command. During this phase the use of the framework will be further developed for capability management and development activities through business areas with capability planning responsibilities across the Department.

- The second stage will see the business processes and tools mature and the framework expand becoming central to the strategic plans for each of the capability elements.

It is envisioned that this approach could be extended to other emergency services providers, both in Australia and overseas.

USE OF THE FRAMEWORK TO SUPPORT DECISION-MAKING

The structure of the Capability Framework and information within the capability model is aimed to support:

- recording and communicating a sound mandate and basis of requirements for projects;
- capability options analysis;
- development of business cases for capability that are inherently robust;
- development of specifications for tenders, acquisitions and contracts;
- evaluation of tenders, acquisitions and contracts;
- identification of risks relating to capability gaps and inform risk assessment and management;
- informing government of Department capabilities;
- providing internal justification for capability decisions;
- protection of projects and capability requirements from financial or other external pressures; and
- recording lessons learned from capability projects and determine what action is to be taken.

The aim is that, through providing useful information to decision makers, it will ultimately will increase the efficiency of expenditure across the Department as well as assisting with the justification of capability decisions.

CONCLUSION

The DFES Capability Framework is designed to assist DFES to understand, integrate and align its capability elements to achieve most effectively its operational objectives within the Department's limitations. The complete framework, consisting of a capability model implemented in an MBSE tool, using a specifically-designed structure and following a defined process, has been produced. The first iteration of capability modelling using this framework has taken place, and through outputs designed to support decision making, this Capability Framework has addressed the DFES needs to:

- Support the development, change and transition of capabilities through a better understanding of the capabilities;
- Obtain clearly defined, transparent linkages between mandated services being delivered and capability elements that facilitate this delivery;
- Provide defensible support to capability decisions through a requirements traceability;
- Articulate capability to all stakeholders, in DFES and beyond;
- Make clear the implications of capability decisions to decision-makers at all levels of DFES;
- Support business requirements developed through both bottom-up and top-down approaches; and
- Optimise the use of common capability elements.

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BIOGRAPHY

Daniel Spencer is a systems engineer at Aerospace Concepts Pty Ltd. He has over a decade of experience in design and development of systems solutions across a broad range of industries, both in Australia and the United Kingdom. Dan holds a Bachelor of Engineering in Information Technology and Telecommunications from the University of Adelaide. He has been working with Australian Defence clients developing and refining tools and methods for a repeatable and comprehensive MBSE method, while using this approach for real-world capability definition and development projects.

Daniel was the project manager and technical lead for the recent Western Australian Department of Fire and Emergency Services project to design and implement a Capability Framework.

Dr David Harvey is a systems engineer with a particular interest in Model Based Systems Engineering (MBSE). He holds a bachelor degree and a doctorate both in the field of mechatronics. He is currently the Chief Systems Engineer at Aerospace Concepts Pty Ltd. The Aerospace Concepts team has developed an MBSE approach and tailored tool to assist in complex system definition in conjunction with Australian Defence partners. As well as this development, he is also involved in applying the tool and approach to capability definition in major Australian Defence projects such as the Future Submarines project. Recently the company has also extended the focus of this work beyond Defence, starting a similar project with the WA Department of Fire and Emergency Services.