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# Employing a Model Based Conceptual Design Approach to Design for Resilience

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**Abstract**. During the development of a conceptual system, it is common to address the capability gaps or create additional capabilities in the system concept. The Model Based Conceptual Design (MBCD) approach can be helpful to identify, catalogue, trace, and develop these capabilities, particularly as they cross different domains. This paper explores the use of MBCD to insert and improve resilience within an existing MBCD schema. An approach is offered to evaluate how resilience may be viewed and analyzed by using an MBCD approach.

## Introduction

*Resilience* became one of the leading concepts for 2020. Whether it was the disastrous Australian bushfires at the beginning of 2020 or the global COVID-19 pandemic that remains with us today, the need for society and systems to be more resilient in the future is evident.

The word resilience is derived from the Latin verb 'resilire', which means to 'recoil'. When you think of this in terms of a spring, recoiling is to return to its original form. For another definition, we can look to Merriam-Webster's online dictionary (www.merriam-webster.com). It provides two definitions of resilience that are broadly similar, except that they diverge through the perspectives of the physical and functional aspects of systems:

- **Physical**: the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress.
- **Function**: an ability to recover from or adjust easily to misfortune or change.

INCOSE's definition, captured in the SEBOK (www.sebokwiki.org/wiki/Resilience (glossary)), defines resilience as:

*Ability to maintain capability in the face of adversity.*

Broadly, we can think of *resilience* as the need for a system of interest to continue to perform (function) in a resilient manner, i.e. being able to maintain capability in the face of adversity. Resilience is, therefore, the ability of a system to firstly be robust and resist the misfortune, or shock, and then secondly recover from the shock-induced change in performance and hopefully re-attain the original performance or better.

Resilience, as identified from the events of 2020, is a concept for Systems of Systems (SoS); a focus on the resilience of a SoS to maintain capability in the face of adversity. Resilience emerges at the mission level (Bodeau et al., 2014), so should be firstly considered at the operational level when developing or acquiring a new system. Secondly, it should be considered at the Test and Evaluation (T&E) of the system when the emergence of resilience should be tested for and validated.

Research on Model Based Conceptual Design (MBCD) (Flanigan and Robinson, 2019 and 2020) demonstrated the need to incorporate the T&E domain and consider how to adjust the proposed T&E in the Concept Phase to support successful system development. The model-based framework they proposed demonstrated the operational level information and, though MBCD, extended the traceability to T&E information so that the T&E domain can be adjusted to better validate the system under test.

The research outlined in this paper seeks to demonstrate adequacy of the MBCD approach, and its extension into the T&E, to demonstrate how resilience can be designed for by firstly considering resilience in the Concept Phase, and secondly ensure that the T&E is adequately identified to validate the defined resilience measures.

## Context

Highlighted by Bodeau et al. (2014), resilience is a concept at the mission level. At the mission level, the military define the system-of-systems as a larger system that delivers a capability, as a “combined effect of multiple inputs” (Australian DoD, 2006). We consider a SoS to be a collection of constituent systems that the USA DoD Defense Acquisition Guidebook (Defense Acquisition University, 2010) recognizes four types SoS, summarized below:

- **Directed SoS**: The directed SoS engineered and managed to fulfil a specific purpose. The constituent systems can operate independently, but their normal operational mode is subordinated to the central managed purpose.

- **Acknowledged SoS**: The acknowledged SoS has recognized objectives and a designated manager, with the constituent systems retaining their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the system.

- **Collaborative SoS**: The constituent systems interact voluntarily to fulfill agreed upon central purposes. The central players collectively decide how to provide or deny service by providing some means of enforcing and maintaining standards.

- **Virtual SoS**: There is no central management authority or agreed upon purpose for the SoS. Large-scale behavior emerges, relying upon relatively invisible mechanisms to maintain it.

For both the Directed and Acknowledged SoS, and to some extent the Collaborative SoS, they can collectively identify the operational needs that enable them to maintain capability in the face of adversity. A resilient SoS needs to "*anticipate, withstand, recover from, and evolve to improve capabilities in the face of, adverse conditions*" (Bodeau & Graubart, 2011). The goals of a resilient SoS are to *anticipate* the imminent adverse condition, then *withstand* that adverse condition, and then *recover* from the adverse condition induced change in performance and the hopefully *evolve* the original performance or better. In some contexts, resilience can be considered opposite of brittleness. If there is no robustness to *withstand* the adverse condition and the effects promulgate through the system unabated, then the system will fail. There will be no opportunity to *recover*. If there is robustness and the systems can *withstand* the adverse condition, but no *recovery*, then the effects of the shock will still promulgate through the system unabated, albeit at a slower rate, and the system will again fail. In both cases, the system is brittle, with catastrophic failure resulting from the adverse conditions. The designer of the system must design for resilience and avoid brittleness in the system.

To engineer a system that contributes to the resilience of the SoS, the designer must consider the principles that guides the designer through the conceptual design of the systems of interest. From the literature, Jackson and Ferris (2013) outline 14 principles of resilience, with their independencies, that can provide this guidance. Their paper summarizes "…the purpose of each principle, its limitations, vulnerabilities, and conflicts with other principles" and considers four broad categories for resilience principles. For robustness, and the ability to withstand the adverse condition, Jackson and Ferris consider Capacity and Tolerance. They consider Capacity as the ability of the systems to survive, whereas Tolerance is its ability to degrade gracefully. For recovery, they consider Flexibility in systems design as it allows for the systems to adapt and recover from the adverse condition. Finally, Cohesion is considered across the whole resilience concept as the ability of the system to perform as a whole and be resilient to the adverse condition.

Aligned to the four broad categories for resilience are the 14 principles themselves. They identify principles[1] from functional redundancy through to human-in-the-loop, all of which provide the guidance that can inform the conceptual design of a system in the context of the mission (and SoS) the system is contributing to. In exploring the adequacy of the MBCD approach, these principles will be investigated in the application of the schema. Additionally, when considering alternative solutions to delivering resilience in a SoS, a quick-look assessment will be made against the resilience design principles.

The US Department of Defence (DoD) utilizes an Analysis of Alternatives (AoA) approach that is "…an analytical comparison of the operational effectiveness, suitability, risk, and life cycle cost of alternatives under consideration to satisfy validated capability needs." (Office of Aerospace Studies, 2017). For the concept of resilience with its potentially large solution space, particularly

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[1] Rather than describing the principles in detail in this paper, we recommend readers remind themselves of these principles by reading Jackson and Ferris (2013).

in the context of a SoS, the AoA approach provides a framework that can be employed to keep a capability focus to derive the system of systems resilience needs.

## Approach

To investigate the adequacy of the MBCD approach to design for resilience a three-step approach is taken and described in this paper:

1. Assess the suitability of the MBCD Schema against the frameworks published that describe the concept of resilience.
2. Establish the Analysis of Alternatives framework to test the MBCD approach with the example of bushfire resilience.
3. Conduct a thought-experiment to demonstrate the viability of the application of the MBCD Schema for resilience.

### *Test Case: Bushfires*

The Australian Royal Commission into National Natural Disaster Arrangements recently presented its report to the Australian Parliament (COA, 2020). This report focused on recommendations that would lead to a nation "…capable of building our resilience, and better addressing future preparation for, response to, and recovery from, natural disasters." Recommendations from the report cover all aspects of resilience. This includes enhancing Australia's ability to *anticipate* bushfires through "multi-agency national-level exercises", *withstand* through "interoperable communications for fire and emergency services", and *recover* through "establishing a standing resilience and recovery entity". Finally, the Australian Royal Commission itself is an example of a guidance process that *evolves* to improve Australia's national bushfire response capabilities.

The examples of bushfires from around the world, including the Australian bushfires of 2019/20, provide a resource-rich case study in which to test the adequacy of an MBCD approach to design for resilience through a thought-experiment.

## Suitability of the MBCD Schema for Resilience

As we evaluate the previous MBCD schema developed (Flanigan and Robinson, 2019) to show the relationships between the system domain, operational domain, and test domain, the primary motivation was to explore how different parts of each domain can interact and influence other domains. However, this was designed primarily with the system development in mind, and tracing to how system functionality and performance will represent operational activities and metrics, resulting in a well-informed operational need. In this paper, we will explore resilience as a concept at the mission level – and seek to understand how a capability need of increased system resilience will result in the derivation of additional operational activities and metrics, in addition to influencing the test and system domains. We examine each domain in detail with a notional example of bushfire resilience to determine if the MBCD schema retains its validity. Figure 1 provides an overview of the interactions between the three domains.

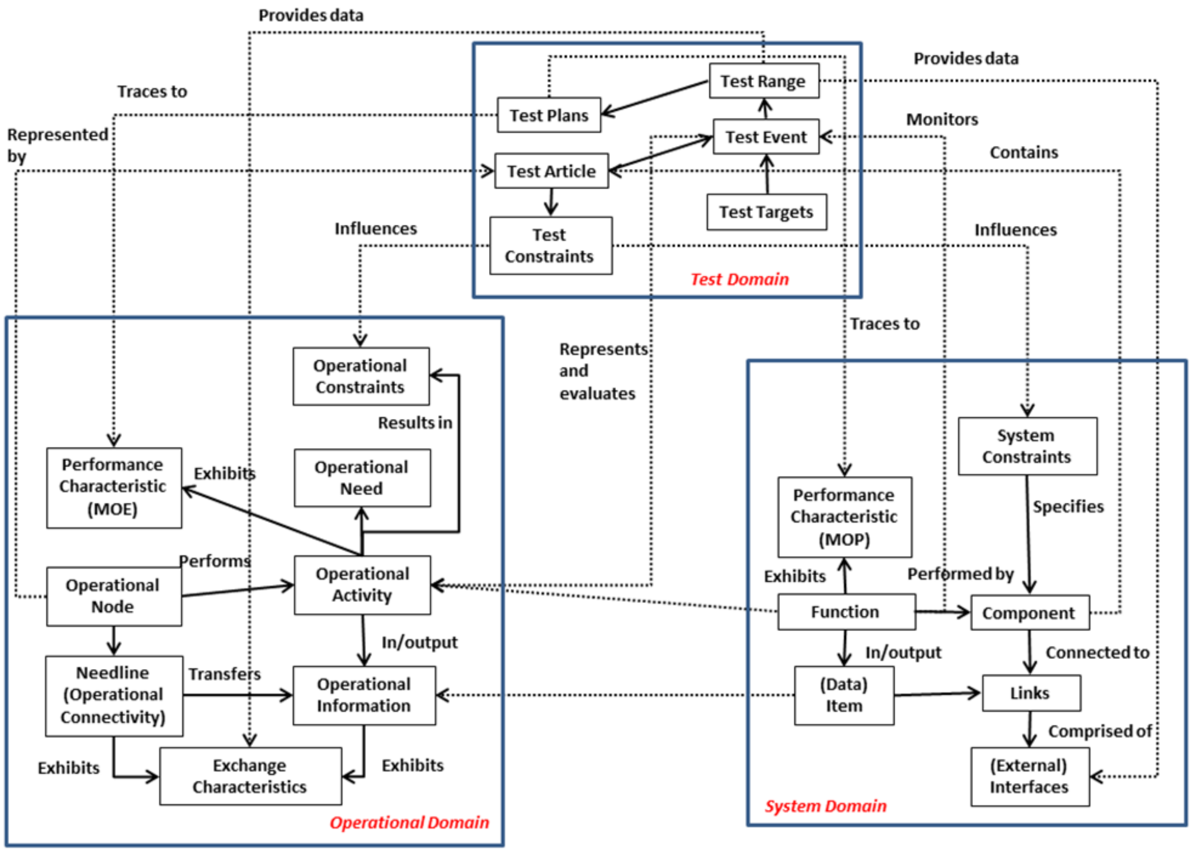


Figure 1. Overview of MBCD Domain Interactions

## *Operational Domain*

We start in the operational domain, as the operational need is derived from historical data and current events that motivate such a need for bushfire resilience. From September 2019 – March 2020, the world watched as Australia endured a period of unusually intense bushfire in many parts of the country. Thus, we are motivated to introduce new operational needs that promote additional resilience for systems against fires. In this context, the SoS of an Australian neighborhood, needs to be resilient to bushfires.

For the purpose of this paper and the bushfire test case, we will define the "system" as any residential home, which can be singular or multiple systems, such as a housing development. The operational need can be refined by different operational constraints, which may describe environmental conditions, or the structure of the housing development, housing density, amount of landscaping and open area between houses, etc. which may influence the home resilience against bushfires.

The operational needs may also generate additional operational activities that may assist the homeowner from saving their home from fires such as employing fire suppression systems, placing buffers (man-made or natural) between the home and potential fire areas, or employing robust fire suppression assistance, such as additional fire trucks and firefighting capabilities. These activities will influence the performance characteristics in terms of how much damage can be sustained to a single house (or neighborhood), time involved from alerting to actions, etc.

In summary, we believe that resilience can be addressed within the operational domain of the MBCD Schema.

### *System Domain*

As alluded to in the operational domain, several solution sets that comprise systems that provide additional resilience to bushfires could be considered, and should be considered in the context of the design principles defined by Jackson and Ferris (2013). An example of a layered defense design principle would be an automated sprinkler system for the home that could alert to fires in close proximity to the house and activation of a water mist or fire retardant, which are components that perform the functions that implement the operational activities. System constraints could be a limited water or retardant capacity to provide protection, thereby influencing the amount of resilience. Other applications in the system domain could be less material, while still adhering to the layered design principle, such as increasing the amount of open space or clearing dead brush that could hasten the fire spread throughout the community; the functions more oriented towards the clearing, with a measure of how much is cleared and the resilience improvement. We may see a similar reversal of flow of influence throughout the system domain as in the operational domain, to consider the different solutions, and consider that resilience can be adequately addressed within the system domain of the MBCD Schema.

### *Test Domain*

In the test domain, depicted in Figure 1, the flow of influence is likely to remain similar to the original schema. We can see the test articles will still be influenced by the operational nodes (represented by) and system components (contains), and then continue to influence the test constraints, test events, test range, etc. This is to be expected, as the test domain is reacting to the changes in the operational and system domains in order to provide a realistic test environment and elements to evaluate the system concepts and operational needs. Where it differs is the consideration of resilience – part of the challenge is how to measure “what is resilient?” and “how much resilience do I need?” as a few example questions. The test environment may need to be refined in order to provide additional threat challenges beyond the original system or operational requirement. However, for the purposes of this paper the Test Domain of the MBCD schema can consider resilience in its definition.

## Analysis of Alternatives for Resilience Space

As discussed, we will consider three separate concepts that may enhance resilience to bushfires for the homeowner. The first concept is to augment the capabilities of fire and emergency services – this may increase the number of vehicles available to the community, or increase the number of fire stations to reduce the distance and time needed to arrive on scene to combat the fires. Other capabilities could employ additional hose capacity to increase the intensity of response once arrived. This both improves both the robustness of the buildings to fire, and aids recovery by ensuring the community can safely return to the bushfire region earlier. The second concept is to provide the home with a self-contained fire suppression capability in which to sense the fires and then deploy the fire retardant agent around the home to prevent the spread of fire and increase robustness. The variability could include a different number of deployment agents, capacity of agent, and range of deployment. A SoS approach may also emerge with the second option: if multiple adjacent homes employ this method and have an overlapping area of protection, this could potentially enhance the amount and duration of protection to the community, dependent on the fire suppression effectiveness. The third concept is to clear area surrounding the homes as well as nearby the community, preventing the spread of fire and enhancing robustness. The variability could include the amount of area that is cleared, obviously influencing the landscaping and style of the community.

Within the AoA handbook, one of the objectives is to explore the potential solution space for the desired capability and conduct analysis to determine if the alternatives to address the mission objectives.

These three notional concepts will then be evaluated using the modified schema to determine if we can acquire sufficient insight into resilience requirements as well as system and testing domain considerations. Stakeholder input and concurrence in these areas are key to ensuring all interested parties have a common view of the concept space. Table 1 summarizes the alternative space and the characteristics that could assess each of the concepts.

Table 1: Alternative Concept Space

| Concept | Area covered | Responsiveness | Time to set up | Effective time of coverage | Extinguisher effectiveness |
|---|---|---|---|---|---|
| Augmented fire and rescue services | Mobile to cover multiple homes as needed | Longer time to arrive (single to tens of minutes) | Longer time to set up to water system | Dependent on water availability and human exposure to elements | Extinguishing of fire in multiple places dependent on fire spread and intensity |
| Home extinguisher system | Adjacent to home, non-movable | Some time to sense the fire and activate the system (< 1 min) | None | Dependent on extinguisher agent reservoir capacity | Extinguishing of fire limited to area next to home |
| Clearing adjacent brush areas | Adjacent to home, non-movable | Immediate | None | No limit | No active extinguishing of fire; prevents spread |

## *Case Study: Bushfire Resilience*

The three alternatives are evaluated within the modified schema to evaluate the resilience insights that would be needed to satisfy house and neighborhood bushfire resilience. We hypothesize that the schema can provide sufficient traceability to evaluate the needed test environment to provide resilience to combat bushfires.

Utilizing the example criteria from Table 1, we will create an example scenario to evaluate the three alternatives, which may be initiated from a series of fires at randomized locations throughout the neighborhood, as described in Figure 2. For each of the alternatives, we examine what type of testing environment and instrumentation is needed to evaluate the neighborhood fire resilience. Within the figure, there are homes (outlined in green), brush areas, potential fire-starting areas (outlined in red), and firefighting accessible areas (outlined in yellow). Previous analysis (Flanigan and Robinson, 2020) evaluated the utility of a simulation of fire spread given this type of layout.

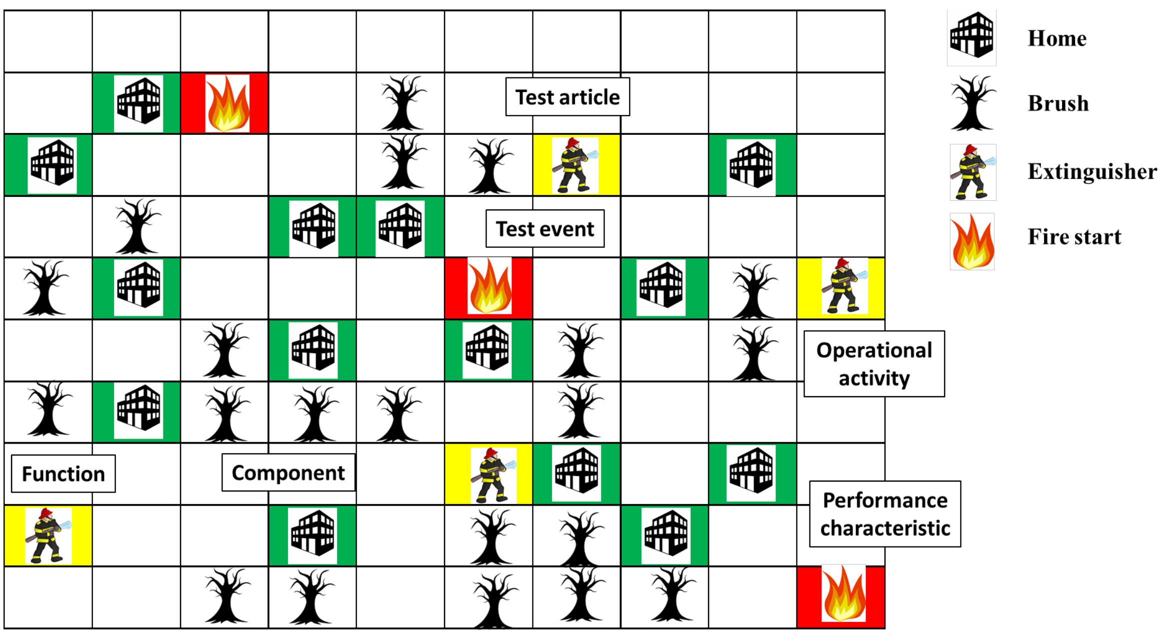


Figure 2. Overview of Neighborhood Layout and locations of fire-starting points

To investigate the concepts of resilience, we developed a simple first-order simulation that explores resilience, both at an individual household and for the entire neighborhood, of a typical neighborhood depicted in Figure 3. At each simulated time step, a random damage criterion calculated for household resilience against fire: if it passes, only minimal damage is accumulated; if it fails, the damage is increased and overall resilience is lowered. A house with lower resilience will be expected to degrade much quicker than houses with greater resilience. The figure on the left (Individual Resilience) shows this trend with the red triangles as a lower resilience, which succumbs to functional destruction of the household at a pre-defined level (in this example is 70% of the cumulative damage, indicated by the horizontal line). The lower resilient house achieves that level quicker than the medium resilience (blue square) and the higher resilience (green circle). We can extend the same approach to a neighborhood bushfire spread to other houses and investigate if using the resilience state of the previous house can be utilized for the current house situation (e.g. if my neighbor's house completely burns to the ground, there is a large likelihood that mine will too), with a look at three similar resilience levels, and how long it takes for the neighborhood to be completely unusable (in this case we set that at 50% of the houses).

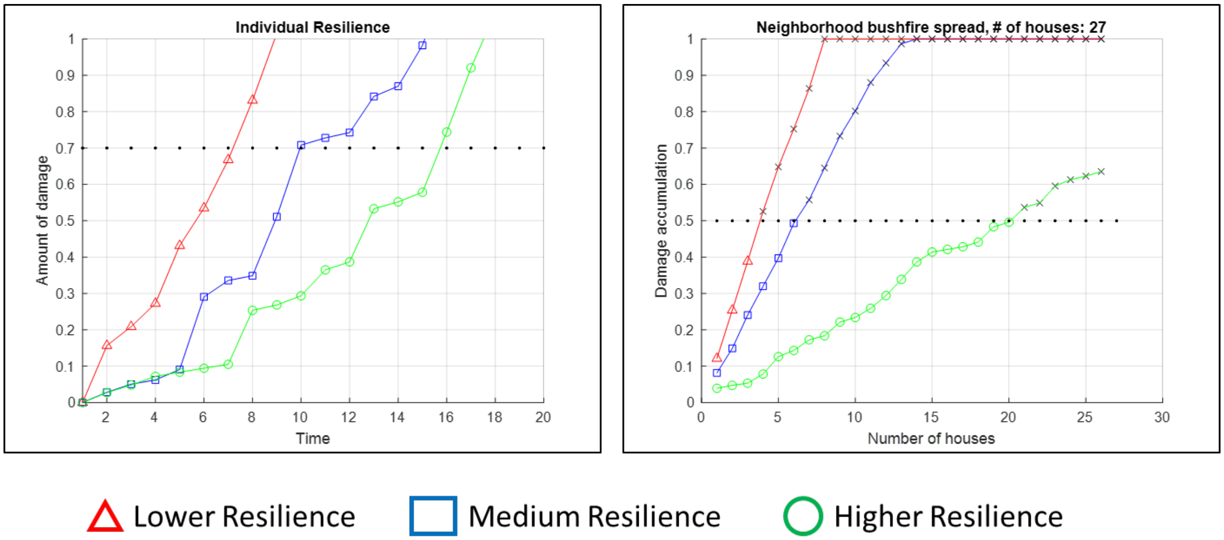


Figure 3. Example Resilience Plots for Individual and Neighborhood Bushfire Resilience

## Demonstrating the MBCD Approach

To ascertain the viability of an MBCD approach, supported by an Analysis of Alternatives, we executed a thought-experiment consider how resilience can be considered. The thought experiment provides a structured approach of intellectual consideration, rather than deliberate real-world experimentation, in order to predict the viability an MBCD approach

### *Alternative 1: Additional Fire and Rescue Capabilities*

Adding the additional vehicles will provide mobile sources of firefighting capability, however, they will arrive on scene at a delayed time prior to the fires starting in the scenario. Note that benefit is gained through additional vehicles, there is an upper limit of how many vehicles are needed before additional vehicles do not provide additional value. The same applies to how quickly the vehicles arrive on scene, which may also affect the number of needed vehicles. Additional analysis may be needed to determine the minimum number of vehicles and/or minimum response time to assist in the resilience.

We may judge the ability of neighborhood resilience as positively influenced by additional fire vehicles responding to the incident and extinguishing the fires, as well as the distance between individual homes that may also influence the number of homes catching fire. There is a vulnerable time point if the vehicles do not arrive in time that the neighborhood will be lost, regardless of how many vehicles arrive. We may identify an additional critical time that the homes and surrounding areas must be resilient to damage before reaching an irreparable point, which may be traced to the individual home resilience.

## *Alternative 2: Individual Home Sprinkler Systems*

As these systems are installed in the individual homes, these will have a short time delay before activating their extinguishing agents. As these systems are already installed, these will be immediately available for use when the scenario starts. Note that not every home may have sprinklers installed, so further analysis may be needed to determine how many of these systems could be employed to provide additional resilience for the neighborhood. For the individual resilience, we may evaluate how much protection the individual home can provide, with the extinguisher capacity a critical factor on maintaining the amount of protection. If the fire protection is exhausted, this may cause the fires to spread throughout the neighborhood, to evaluate the neighborhood resilience, where we may look at the critical time point where protection must endure. This will be a critical quantity of individual resilience to watch for in terms of protection duration, for both the individual home and collective neighborhood resilience time.

## *Alternative 3: Clearing of Brush Area between Homes*

As these areas are cleared, this may slow the spread of fire between homes, if the fire continues to spread throughout the neighborhood. This approach may affect the individual resilience if multiple brush areas are adjacent to an individual home, thus hastening the damage potential to the home. For the neighborhood resilience, we may evaluate the quickness of fire spread from home to home, and potentially affect the critical time to save the neighborhood. Note that brush clearing may not be achievable between every home, so additional analysis may be needed to determine how much brush would need to be cleared: perhaps the areas nearest the closely spaced homes could be cleared in order to influence the resilience.

## *Resilience Design Principles*

We perform a quick-look analysis (Table 2) of the 14 principles as applied to the three alternatives to address bushfire resilience within a neighborhood to determine if the alternatives could fully, partially, or not address each of the principles. Through this quick-look analysis the applicably of the MBCD schema to these principles, in the context of bushfire resilience, is considered.

Note that a single alternative will not fully address all resilience principles, but the overlap of multiple alternatives may provide additional resilience.

Table 2: Alternative Concept Space

| Number | Principle | Considered within the MBCD schema | Application to case study | Alternative 1: Additional Fire and Rescue Capabilities | Alternative 2: Individual Home Sprinkler Systems | Alternative 3: Clearing of Brush Area between Homes |
|---|---|---|---|---|---|---|
| 1 | Absorption | Yes, applicable to the *Operational Activity* | Ability to absorb (extinguish) the bushfire | Yes | Yes | No |
| 2 | Physical Redundancy | Yes, applicable to the *Component* | Multiple instances of the | Yes | Yes | No |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | capability | | | |
| 3 | Functional Redundancy | Yes, applicable to the *Function* | Different ways to extinguish the bushfire | Yes | No | No |
| 4 | Layered Defense | Yes, applicable to the *Operational Activity* | Provides more than a single point of failure | Yes | Yes | No |
| 5 | Human in the Loop | Yes, applicable to the *Operational Node* | Provide a human in the system | Yes | No | No |
| 6 | Reduce Complexity | Yes, applicable to the *Operational Node* architecture | Minimize the number of complex components and interfaces | No | Partial | Yes |
| 7 | Reorganization | Yes, applicable to the *Operational Node* architecture | Can change structure in face of a threat | Yes | No | No |
| 8 | Reparability | Yes, applicable to the *Operational Activity* | Can be restored to full operational capability if damaged (during the event) | Partial | No | No |
| 9 | Localized Capacity | Yes, applicable to the *Operational Node* architecture | May enable gradual degradation if one segment is damaged during the event | No | No | Yes |
| 10 | Loose Coupling | Yes, applicable to the *Operational Node* architecture | Limit failures to propagate throughout the system | No | No | Yes |
| 11 | Drift Correction | Yes, applicable to the *Operational Activity* | Measures can be taken if failure is approaching, and can correct (during the event) | Yes | No | No |

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | Neutral State | Yes, applicable to the *Operational Activity* | Humans can delay taking action and survey the situation | Yes | Partial | No |
| 13 | Inter-Node Interaction | Yes, applicable to the *Operational Information/Needline* | Communicates or cooperates with other nodes (neighborhood during the event) | Partial | Partial | Yes |
| 14 | Reduce Hidden Interactions | Yes, applicable to the *Item/Links* | Determine if harmful interactions between alternatives can be reduced (during the event) | Yes | No | No |

## Summary

We have utilized a refined MBCD schema to evaluate the different types of resilience at the individual (system) and group (SoS) level, as well as what types of test structures and analysis that may help to develop resilience requirements for the system of interest. The thought-experiment demonstrated the adequacy of the MBCD approach to design for resilience at the early concept phase. Through the consideration of different alternatives, this may provide insight for decision makers to consider the level of resilience that is desired.

## Next Steps

This paper was based on a thought-experiment to explore the viability of the MBCD approach to inform the determination of resilience in the design of systems of systems. Whilst this provided early indications that the MBCD approach is a viable method, we recognize that there is a need to increase the validity of this research by increasing the fidelity of the experiment through real-world application. Additional analysis could be performed via both descriptive and analytical modelling means to determine the resilient requirements. Tabletop exercises with different stakeholders may help to identify their concerns with the different alternatives and how each could affect the community, and perhaps a form of systems thinking could graphically show the first and second order effects of introducing different solution sets to affect the entire resilience. For further detailed simulation, physical representation of the effects of the fire extinguisher against bushfires at the individual and group level can also serve to quantify the amount of resilience the community would need. Additional experimentation could be applied to different types of SoS to determine how they were able to anticipate, withstand, recover, and improve their resilience.

# References


Australian Government, Department of Defence, Defence Capability Development Manual, 2006.

Bodeau, D., Brtis, J., Graubart, R. and Salwen, J., 2014, August. Resiliency techniques for systems-of-systems extending and applying the Cyber Resiliency Engineering Framework to the space domain. In 2014 7th International Symposium on Resilient Control Systems (ISRCS) (pp. 1-6). IEEE.

Bodeau, D.J. and Graubart, R., 2011. Cyber resiliency engineering framework. MITRE CORP BEDFORD MA BEDFORD United States.

Commonwealth of Australia, Royal Commission into National Natural Disaster Arrangements Report, 28 October 2020, ISBN: 978-1-921091-46-9.

Flanigan, D. and Robinson, K., 2019, July. Exploring the Test and Evaluation Space using Model Based Conceptual Design (MBCD) Techniques. In INCOSE International Symposium (Vol. 29, No. 1, pp. 1072-1083).

Flanigan, D. and Robinson, K., 2020, July. Employing Model Based Conceptual Design to Identify Test Range Resources Required to Validate the Delivered Solution. In INCOSE International Symposium (Vol. 30, No. 1, pp. 65-77).

Force, US Air, 2008. Analysis of alternatives (AoA) handbook. Office of aerospace studies.

Guidebook, Defense Acquisition, 2010. Defense Acquisition University. March, 19, p.2010.

Jackson, S. and Ferris, T.L., 2013. Resilience principles for engineered systems. Systems Engineering, 16(2), pp.152-164.

Merriam Webster online dictionary, <www.merriam-webster.com>, accessed 15 November 2020.

Pyster, A., Olwell, D.H., Hutchison, N., Enck, S., Anthony Jr, J.F. and Henry, D., 2012. Guide to the systems engineering body of knowledge (SEBoK) v. 1.0. 1. Guide to the Systems Engineering Body of Knowledge (SEBoK).

## Biography

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**Kevin Robinson**. Kevin Robinson is the Head of Innovation and Chief Engineer at Shoal Group, with a distinguished career in the field of Guided Weapons in both the UK's Ministry of Defence and Australia's Department of Defence. He has made significant contributions to the development of advanced guided weapons through modelling and analysis, research, and leadership of large cross discipline teams. Throughout his career, Kevin has taken a leadership role in advancing the field of Model-Based Systems Engineering (MBSE) via his publications and contributions to the systems engineering community. He initiated and chaired Australia's first annual MBSE Symposium, formed and chaired INCOSE's Model-Based Conceptual Design Working Group, delivered a keynote address to INCOSE's international symposium in 2016, and has made contributions to INCOSE's Systems Engineering Handbook and related standards. Recently, he has joined INCOSE's Future of Systems Engineering initiative core team.