Development of integrated principles and framework to address future-proofing and resilience in the design of engineered-systems.

1 Background

The Capability Systems Centre (CSC) is exploring the possibility of collaboration with researchers with expertise to address the future-proofing and resilience issues in the design of engineered systems. We are particularly interested in the development of integrated principles and framework for future-proofing and resilience which allow for a system designer to systematically deal with two very important aspects of the long-life system. CSC calls for EOIs from interested researchers with the suitable background and expertise to tackle the following work package.

2 Work package overview

A major research direction in the CSC is to address system design issues under uncertainty which are associated with the long-life systems such as Defence systems. CSC is interested in exploring the system design methods which lead to a future-proofed and resilient system which enable systems to remain in service for long time as well as able to handle future emerging threats as a system goes through various capability lifecycle phases. Towards this goal, the purpose of this work package is to:

a) explore the future-proofing and resilience literature to establish why these two attributes of the system are used interchangeably despite differences in their basic taxonomy, definition and application; and
b) develop integrated principles for system design to address the future-proofing and resilience attributes in the design simultaneously.

2.1 Scope

Resilience and future-proofing are relatively new as formal concepts and there are some questions yet to be answered. In the literature the terms future-proofing and resilience are used interchangeably despite the fact that there are some fundamental but subtle differences (Hollangel et. al. 2006, Masood et. al. 2016, Rich 2016). From the system engineering point of view it is necessary for system designers as well as other stakeholders to know and understand the system needs and trade-offs. The exploration of this difference is also useful to make informed decisions at the higher level as to whether a system needs to be resilient or future-proof or both. Furthermore, an efficient system design must not contain any more solution than required and must be cost effective. Therefore it is useful to know the taxonomy of different designs with subtle differences and classification of their principles so that appropriate principles are applied without repetition.

2.2 Focus

Principles and frameworks for resilience and future-proofing have appeared in the literature (Jackson et. al. 2013, Madni et. al. 2009, Rehman et al. 2016, 2017, 2018, Rich 2016) which aim to provide designers with a systematic approach to achieve the required attributes in the system. The framework for future-proofing and principles are mostly applied to the build environment and architecture preservation, see e.g. Rich 2016. Similar to the future-proofing, resilience framework and principles are mostly applied to the design of engineered system see e.g. Jackson et. al. 2013. However in both literature these two attributes are used interchangeably despite some of the fundamental differences between them. For example, resilience attribute implies elasticity property i.e. system survives and recover to its natural shape (original equilibrium position) after system encounter any internal and external threat. The resilience in the system resist any threat to the system (which leads the system

away from its equilibrium position) and tries to bring the system to its natural position. Whereas the main theme of future-proofing is to defer/deter obsolescence thereby ensuring that a system lasts longer. Future-proofing tends to bring the system at different equilibrium position by reducing capability gap permanently and allows for a system to evolve with time. Therefore, future-proofing a system is almost impossible if the system has (resilience) elasticity property. Beyond any doubt, if a system needs to live longer (i.e. defer obsolescence) these two system's attributes must be incorporated in the system design.

In this study, we aim to address future-proofing and resilience attributes with contradictory properties in the system design by addressing the following questions:

1. Drawing on existing literature on future-proofing and resilience, why are they used interchangeably in the literature?
2. What are the basic taxonomy, attributes and principles which either required to change or develop to address this difference/contradiction?
3. How can we use a theoretical as well as a case study approach to develop integrated principles or methods to achieve future-proofing and resilience in an engineered system?

2.3 Milestones and Deliverables

Milestone #	Milestone description	Date
1	Initial workshop to establish working arrangements, further define the problem and to clarify any questions or issues.	Within two weeks of commencement of agreement, Location: TBD
2	Literature review and analysis of resilience and future-proofing in system design. The analysis should result in explicitly categorizing the taxonomy and principles of these two system attributes by identifying: (a) their various definitions (b) available frameworks, and (c) principles used to address the system design, in various engineering field and literature. The exploration must also specifically brings out the gaps and limitations in the literature, and any expected future research direction.	
3	A proposed plan or outline of the theoretical method which can be developed to achieve integrated design method.	
4	Selection of case studies to be performed to further augment the research theme based on the theoretical approach. This could be similar to the work presented in Jackson et. al. 2013.	
Deliverable 1: Joint paper with CSC staff covering Milestones 1-4 to be submitted to relevant conference or a journal (TBD)		
5	Development of integrated principles and framework for "design of a resilient future-proof engineered system" and performance analysis of the design methodology by applying to the selected case studies as identified in milestone 4.	
Deliverable: Joint paper with CSC staff covering Milestones 1-5 to be submitted to relevant journal (TBD)		

3 References

E. Hollnagel, D.D. Woods, and N. Leveson, (Eds.), Resilience engineering: concepts and precepts, *Aldershot, UK*: Ashgate, 2006.

Madni, A. M., Jackson, S., Towards a conceptual framework for resilience engineering, *IEEE Systems Journal*, vol. 3(2), pp 181-191, July 2009.

Masood, T., McFarlane, D. C., Parlikad, A. K., Dora, J., Ellis, A., & Schooling, J. M., Towards the future-proofing of UK infrastructure, *Infrastructure Asset Management*, vol 3, 28-41.

Jackson, S., Ferris, T. L. J., Resilience principles for engineered systems, *System Engineering*, July 2013.

Rehman, O. U. and Ryan, M., A framework for life–cycle cost analysis for futureproof systems. In *Proc. 26th Annual INCOSE International Symposium*, 2016.

Rehman, O. U. and Ryan, M., Future-proofing process. In *Proc. 27th Annual INCOSE International Symposium*, 2017.

Rehman, O. U. and Ryan, M., A framework for design for sustainable future-proofing. *Jounral of Cleaner Production*, vol. 170, pp 715-726, 2018.

Rich, B. D., Future-Proofing: Seeking resilience in the historic built environment, *Master's thesis, University of Washington*, 2016.

Resilience engineering: concepts and precepts, *Aldershot, UK*: Ashgate, 2006.

4 Requirements

Please provide

- A brief CV describing your research background.
- A focused statement of your suitability for undertaking the work detailed above.
- A detailed description outlining how you would undertake the research described above.
- A brief project plan attaching dates and an outline budget to the milestones outlined above.

5 Submissions

Submissions must be lodged via email, as a PDF file, to: capabilitysystems@adfa.edu.au.

Inquiries may be directed to: Associate Professor Mike Ryan, Director, Capability Systems Centre, capabilitysystems@adfa.edu.au.