THE SYSTEM OVERLAP MATRIX – A METHOD AND TOOL FOR THE SYSTEMATIC IDENTIFICATION OF COMMONALITY OPPORTUNITIES IN COMPLEX TECHNICAL SYSTEMS

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1   INTRODUCTION

The use of common elements across systems or products that are part of the same program or portfolio has generally been identified as a way to increase affordability and decrease risk of the development and operation of the portfolio [1, 2, 3]. Given the potentially high impact, it is desirable to identify opportunities for commonality and assess associated benefits and draw-backs as early as possible in the design of the portfolio (maximum design freedom). The work presented here is therefore focused on the early stages of system design, often called system architecting or conceptual design.

2   EXISTING METHODS FOR IDENTIFYING COMMONALITY

In the most general sense, commonality is defined as the "possession of shared features and attributes across different systems" [4]; these could include: specific functions, the system architecture, specific operational characteristics, specific technologies, and specific design parameters of the system. A number of methods for the systematic identification of commonality opportunities would have been proposed; they can be broadly grouped into two sets:

- Function-based methods [1, 4, 5]: opportunities for commonality are identified based on similarities in the function structures of the associated systems. Conceptual design solutions are then created by assigning common functions to common modules.
- Methods based on similarities in engineering model parameters: these include optimization-based platform analysis approaches such as described in [2, 8], as well as DSM-based approaches [7]

Methods based on function structures do not take into account similarities or differences in architectural concepts, technology choices, or operational requirements, and are therefore not sufficiently detailed to identify commonality for complex systems. Methods based on engineering models can be very effective at identifying commonality opportunities for complex systems; the required detailed models are, however, usually based on a specific concept and are therefore not available during conceptual design. This indicates the need for new methods for the systematic identification of commonality opportunities in complex systems during the architecting phase; the System Overlap Matrix is proposed as one such method.

3   THE SYSTEM OVERLAP MATRIX

The SOM method is part of an integrated framework for architecting and commonality analysis of portfolios of complex systems shown in Figure 1 [9]. As the SOM is used during the identification of commonality options, its inputs are a set of interesting architectures / concepts for each of the systems in the portfolio, which have been identified in the analysis of individual system architectures. Output is a set of technically feasible commonality opportunities between systems for evaluation with regard to benefits and penalties of commonality (see Figure 1).

The SOM itself captures 3 key system characteristics: functionality (i.e. functional requirements), operational building blocks (i.e. operational requirements), and technology choices associated with the functions. Figure 2 shows an example SOM for a spacecraft (excerpt); the functions and associated technology choices are arrayed vertically to the left, essentially forming a vertically oriented

Morphological Matrix [5]. Operational building blocks with their environmental subcategories are arrayed along the top. As the number of functions and associated technology choices does not necessarily equal the number of operational building blocks, the SOM is generally rectangular. A SOM constructed like this can capture different concepts for one system in the portfolio. In order to be useful for commonality identification between concepts for different systems in the portfolio, the matrix has to be able to capture concepts of all systems in the portfolio. To that end, the union of the functions, technology choices, and operational building blocks from all systems in the portfolios is used. Concepts are marked in the SOM using "1" if a particular function / operations combination is required, and "0" otherwise. Figure 3 shows the result of overlaying SOMs for concepts of two different systems in the same portfolio; the overlay is accomplished by adding the entries in the matrices for the individual systems. By successively overlaying matrices for pairs of system concepts, an analysis of commonality opportunities can be carried out in an automated fashion.

The SOM can only provide insight into commonality opportunities related to requirements (functional and operational) and technology choices associated with functionality; in order to identify opportunities for architectural and design commonality, information about the internal connectivity of the systems in question is required. We propose the use of component-component DSMs coupled to the SOM via component-functionality and component-operations matrices (see Figure 4) [11]. Similarity in the number of components, component connectivity, as well as functionality and operations assigned to components is a strong indication of opportunities for architectural and design commonality between systems.

4   CONCLUSION

A new method has been developed using a matrix which captures the union of all functions, associated technologies, and operational building blocks for all systems in a system portfolio. All interesting concepts identified for the systems in the portfolio can be mapped out in the matrix. The matrix can be used in an automated fashion to identify opportunities for commonality in functionality, associated technologies, and operations between concepts for different systems in the portfolio. When coupled with a component-component DSM to allow for the assessment of system-internal connectivity, it can further provide a tool for identification of opportunities for architectural and design commonality.

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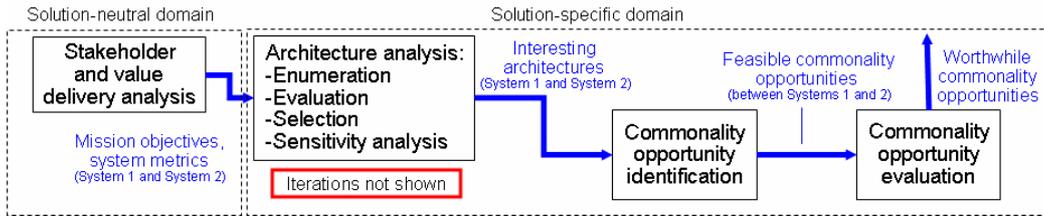Cambridge, MA, 02142, USA
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APPENDIX

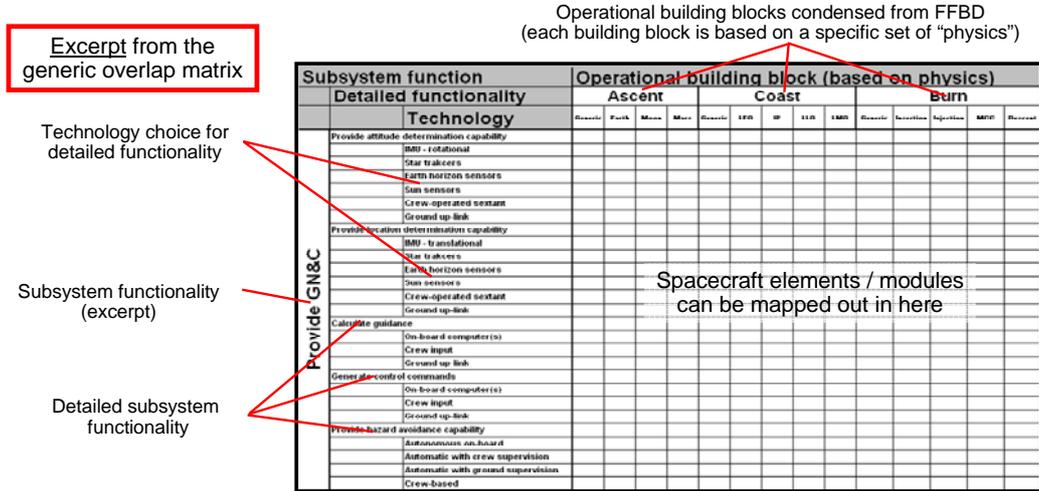*Figure 1: Systems architecting and commonality analysis framework [9] (shown for 2 systems)*

Figure 2: Excerpt from the System Overlap Matrix template for a spacecraft

Subsystem function		Operational building blocks												
Detailed functionality		Ascent				Coast					Burn			
	Technology	Generic	Earth	Moon	Mars	Generic	LEO	IP	LLO	LMO	Generic	Insertion	Injection	MCC	Descent
Provide attitude determination capability		0	1	1	0	0	1	1	2	0	0	2	2	2	1
	IMU - rotational	0	1	1	0	0	1	1	2	0	0	2	2	2	1
	Star trakcers	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Earth horizon sensors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sun sensors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Crew-operated sextant	0	0	0	0	0	1	1	2	0	0	1	1	1	0
	Ground up-link	0	1	0	0	0	1	1	1	0	0	0	0	0	0
Provide location determination capability		0	1	1	0	0	1	1	2	0	0	2	2	2	1
	IMU - translational	0	1	1	0	0	1	1	2	0	0	2	2	2	1
	Star trakcers	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Earth horizon sensors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sun sensors	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Crew-operated sextant	0	0	0	0	0	1	1	2	0	0	1	1	1	0
	Ground up-link	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Calculate guidance		0	1	1	0	0	1	1	1	0	0	2	2	2	1
	On-board computer(s)	0	1	1	0	0	1	1	1	0	0	2	2	2	1
	Crew input	0	0	1	0	0	1	1	1	0	0	2	2	2	1
	Ground up-link	0	1	0	0	0	1	1	1	0	0	0	0	0	0

Figure 3: Overlap of SOM for CEV Crew Module and LSAM ascent stage concepts [10]. Analysis is based on adding the entries from matrices for the individual systems; fields with a 2 indicate overlap. Further overlap: functionality (blue), operations (green), technology (yellow)
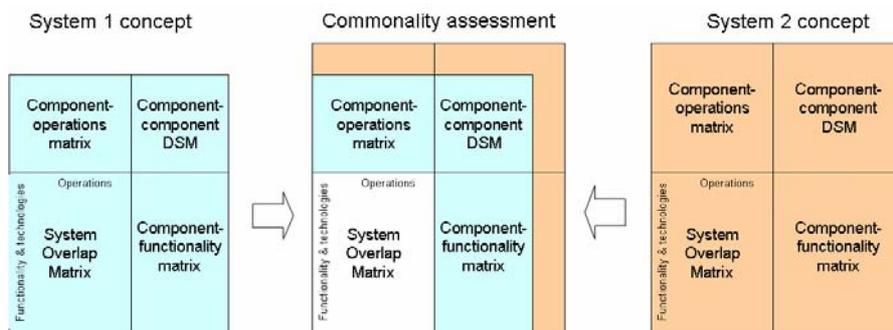

Figure 4: Coupling of SOM to component-component DSM via component-operations / functionality matrices for identification of opportunities for architectural and design commonality