Research Statement: Applied Design Innovation

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The emerging complexity of the world requires repeatable low-cost innovation strategies. My research builds on scientific principles to achieve this through research of design, systems, and DIY culture via industrial collaboration trials as well as controlled laboratory studies. These studies invoked mixed research methods, including qualitative ethnographic and quantitative testing, I developed new methods in several topics including concept ideation, prototyping, and rapid fabrication. My work is informed by the broad spectrum of design, process, simulation, and applied practice research areas. This enabled me to map the state-of-the-art and synthesize several new methodologies.

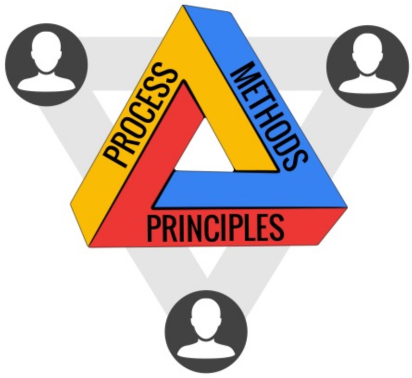

Figure 1: Illustration of the inter-relationship between process, methods, principles and human factors in design innovation

System Engineering (Discover)	Requirements Engineering (Define)	System Configuration (Develop)	Validation & Acceptance (Deliver)
SRR Programmatic CONOPS	PDR Benchmarking Trade-study RFI	CDR RFQ Unit Test Simulation	TRR/ORR Integration Verification test
Design Prototypes		Engineering Prototypes	

Figure 2: Integration of prototyping to inform design early in the process – example drawn against ECSS-40 standard for space system development. Innovation phases shown in parenthesis. It is critical to involve testing early – yet often overlooked.

Prototyping is one of the most critical and yet often overlooked aspects of the design process. When I began studying this topic, many papers were limited to the assessment of a single case study or the primitive alpha-beta distinction of prototypes. There was little in the way of an integrated science of prototyping. This is because traditional design processes typically assume that the key application point for prototypes comes well after establishing the design concept and requirements. Prototyping was historically seen as a precursor to manufacturing. However, the use of physical artefacts to inform design planning at a concept level is equally critical, yet underexplored, relative to sketching or CAD modeling in design. A core thrust of my research to date is cataloguing the state-of-the-art in tools methods and technologies for prototypes. I evaluated correlations between factors such as iterative testing versus parallel testing, and their impact on performance outcome versus techniques such as scaling and subsystem isolation that reduce overall cost. I explored this research thrust through high-level theoretical study; work in design education, and in industrial design engineering practice.

Research in Theory of Design Prototyping

In collaboration with the US Air Force Research Labs, I categorized and evaluated strategic approaches in prototyping. While a number of publications had been produced in this field, there was relatively little in terms of integrated strategic approaches to prototyping. Firstly, in my work, I identified the major strategy variables. These are strategies of implementation in prototyping that were seen in product service and system development. These were described in a sufficiently abstract way as to be broadly applicable across fields. Next, I pushed this field of research further by quantifying correlations between the various strategies and their impact on cost and performance. Finally, I verified that when this approach was introduced to designers it was possible to improve the overall design performance outcome (B. Camburn et al., 2015; B. Camburn et al., 2017; Bradley Adam Camburn et al., 2017; Bradley A Camburn et al., 2017; Bradley Adam Camburn, Jensen, Crawford, Otto, & Wood, 2015; Dunlap et al., 2014; Hamon et al., 2014).

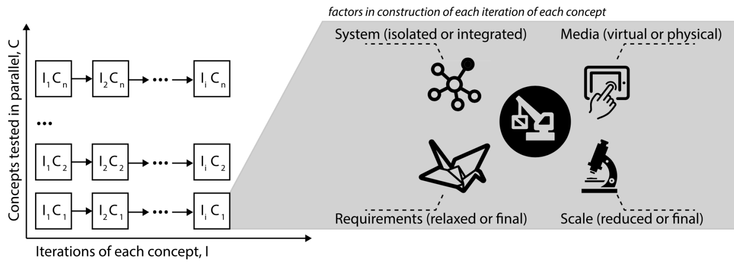

Figure 3: Fundamental design theory, mapping of the design prototyping variables space

Principles in Design Education for Making

To facilitate the emergence of a new generation of design leaders, another core project of my prototyping research was to evaluate how to identify key principles in low cost, innovative prototyping. There were relatively few to no research publications on this topic. At the same time, it is critical to identify how the actual crafting of physical artefacts has already and can continue to evolve in the 21st century. In order to complete this objective, I designed and led a major study of a prolific online Do-It-Yourself (DIY) database. This database was an ideal source of information as it includes tens of thousands of entries of designs where the creator also discusses how they made the artefacts as well as problems and issues encountered in the process. These DIY practitioners encounter many of the same problems that designers do – the need to create a functional design out of available materials in a limited time with limited resources, and at low quantity but (typically) without the support of industrial fabrication facilities. From this work, I identified the key principles for DIY fabrication (B. Camburn & Wood, 2018). I then tested the effectiveness of these principles to improve prototype quality as well as the team's overall ability to prototype and found a positive correlation with their introduction and improved performance (B. Camburn, Mignone, Arlitt, Venkataraman, & Wood; Bradley a Camburn, Mignone, Arlitt, Venkataraman, & Wood, 2016; Bradley A. Camburn et al., 2015; Otto et al., 2014; Telenko et al., 2016).

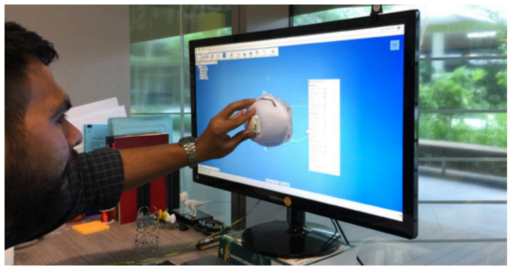

Figure 4: Application of a stencil to reduce design effort, one of the five fabrication principles

Design Prototyping in Practice

In order to validate these strategies of prototyping in the most practical manner, I executed a number of industry and grant based design projects in which these theories and approaches where injected. Not only did this provide funding for my research colleagues but it also provided the unique opportunity to validate the strategy and gain further observations for scientific study. In particular, as I executed a series of large scale industrial projects, I worked to re-formulate an integrated design method approach. The approach integrates business design, systems engineering, design engineering, and design thinking to form an adaptable process model. A key insight of this work was quantifying the variances in design approach across projects as well as integrating several 'schools of thought' for the approach to design in one model. This work was uniquely successful in demonstrating the application of design thinking approaches on complex systems engineering projects. A keystone of this methodology was innovating strategies for prototyping that enable the conceptualization of feasible solutions much earlier in the design process than systems engineers typically thought possible due to the often extremely costly nature of prototyping in industry (Bradley Adam Camburn et al., 2017; Bradley A Camburn et al., 2017; Sng et al., 2017). I applied this approach with several agencies and organizations including NBC Universal, Gilmour Space Technologies, Air Force Research Labs, and the Defense Science and Technology Agency in Singapore, among others.

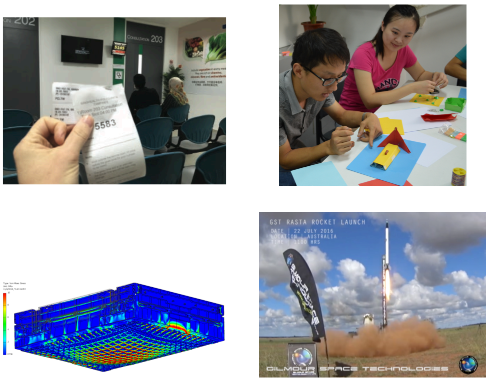

Figure 5: Use of design prototypes across four phases of the design innovation process, (top-left) discover; (top-right) define; (bottom-left) develop; (bottom-right) deliver.

Past Grants, Industry Collaborations, Pending Applications

Multi-Antenna GPS Receiver Design for Launcher Avionics, Australian Research Council, ($ 682,400 AUD) *in review*, 2018
Additive Manufacturing for Composite Aerospace Applications, NAMIC ($ 525,260 SGD), *awarded* 2017
Design Innovation Services for New HR, Finance, and Medical Hub, *NDA*, Sg Gov. Agency, ($ 93,465 SGD), *awarded,* 2017
Design Thinking: Prototyping & User Testing Training Workshop, MOE, ($ 16,200 SGD), *awarded,* 2017
Design Consultation: Design Innovation Course, *NDA*, Sg Gov. Agency ($ 244,733 SGD), *awarded* 2016
Design Consultation Medical Centre Design, *NDA*, Sg Gov. Agency ($ 77,040 SGD), *awarded,* 2016

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