Engineering Design Theory:

Applying the Success of the Modern World to Campaign Creation

A Monograph
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Abstract

ENGINEERING DESIGN THEORY: APPLYING THE SUCCESS OF THE MODERN WORLD TO CAMPAIGN CREATION by MAJOR Xander L. Bullock, US Army, 77 pages.

This monograph directly addresses design, and incorporates elements of Engineering Design Theory to the codified, social act of campaign creation using art, science, and craft. The monograph gives a definition of design and discusses the appropriate language for design. Furthermore, design is expressed as the evolution of military craft, and a blending of military art and military science. Therefore, the monograph is staunchly pro-design, and presents the incorporation of design thinking at the operational and strategic levels as a moral imperative. The argument that MDMP or JOPP are appropriate for the creation of strategy is rejected herein, and design is presented as the next manifestation of campaign creation. Engineering Design, as a theory of social creation, recommends a cultural shift away from single authorship or commander centric leadership. Engineering philosophy, which examines social creation, bounded rationality (stochasticity), competitive creation, risk and safety, intentionality, and methodology, is directly analogous to the needs of military campaign philosophy. The engineering methodology of proceeding through the cognitive phases of divergence, transformation, and convergence is explicated in a way that should inform military thinking. Finally, there is an introduction to appropriate design team size, the design charrette, and design methods (some of which are included in Appendix I).

The monograph makes several recommendations. First, the Army should align its definition of design with industry and academics. Second, the Army should clearly explain the strengths and weaknesses of traditional methodologies (MDMP, JOPP, SOD) and explicate the necessary move to design. Third, the Army should understand craft, and examine its culture and commander-centric leanings, and explain why the increasingly social and political demands of strategy in an interconnected world suggest a need for the social creation of campaign designs. Only by incorporating design thinking will the Army continue to find success in the increasingly complex world context.

This monograph recommends that the SAMS should teach engineering philosophy and theory in order to balance their syllabus. SAMS should teach a variety of campaign creation methodologies, so the informed practitioner can utilize the methodology that is appropriate for his/her current situation. SAMS should educate students on the methods, the “how” of design before this critical concept will become operable. Finally, this monograph recommends examination of Design Research Institute literature and periodicals to understand design.

Design is the next evolution of the military craft, and the inclusion of design thinking into the military will enable intelligent campaign creation. By specifically engaging Engineering Design Theory, the military will harness a design philosophy, which is well developed, clear, highly exportable, and historically extremely effective.

TABLE OF CONTENTS

Introduction 1
What is Design? 4
Definition of Design 5
The Design Community of Practice – A History 9
Design Language 16
The Import of Design for the Army 19
Military ~~Arts and Sciences~~ Design 20
Design as the cognitive evolution beyond craft 21
Design as opposed to MDMP for Campaigns and Strategy 25
Design as a Cultural Shift 29
Incorporation of Engineering Design Philosophy. 31
Social Creation vs. Singular Authorship 32
Bounded Rationality 36
Tied to Competitive Creation 39
Risk and Safety 42
Intentional vs. Unintentional design. 44
Methodology in Design 46
An Engineering Methodology 49
Divergence 50
Transformation 54
Convergence 57
Multiple Methodologies and Design Strategy 60
The "How" of Design. 66
Design Team Size 67
Design Charrettes 68
Design Methods 71
Conclusion 72
Areas for Further Study 72
Design Education 72
Design Thinking 73
Significance 73
Application 75
Recommendations 77

APPENDIX I – DESIGN TACTICS 79
"Design Tactics" 79
Discourse 79
Brainstorming 79
Problematizing 80
Draft Method 80
Networking Method 81
Alexander's Function Model 82
Affordance Theory 83
Broadbent Method 83
Parallel and Collaborative Planning 84

Narratives 85
Framing 85
Assemblages 86
Mechanism Design Theory 87
Engineering Creativity Techniques 87
Traditional Creativity Techniques 88
Method 635 89
Delphi Method 89
Synectics 90
The Gallery Method 90
Solution First Methods 91
Systems Engineering/Systems Testing 91
Traditional Design Method 92
Data Reduction 93
Other Convergent Methods 94
Design Traps. 94
APPENDIX II – Issue History of Design 97
APPENDIX III – An Example Design Syllabus 103
BIBLIOGRAPHY 106

Introduction

"When I read another book or article or listen to a conference paper about the design process I can usually tell whether the author is actually a designer or not." – Brian Lawson[1]

It is a humorous paradox that, in general, those who design for a living do not write for a living, and the theorists who write about design commonly do not design professionally. Design in the military is becoming a buzzword encompassing learning theory, systems theory, architectural philosophy, post-modernism, and several other influences. The military adaptation of design theory is currently incomplete, and focuses too heavily on post-modern philosophy and architectural design theory in a manner that confuses the meaning of design. In direct contrast to the military manifestation of design, industry and the academic community have a clear definition of design, which is a well-developed and rigorous intellectual field. [2] Design, as the world knows it, is a manner of thinking and acting which has direct application to the military craft and which will aid in operational and strategic campaign creation. In order to make design operable, the Army should harness existing design theory and specifically Engineering Design Theory. Design is the practice of those who create, and is not based on Eastern philosophy or post-positivism. The philosophies of design range from art design, fashion design, social design, architectural design, artifact design, to program design and others. Of the existing design philosophies, engineering design philosophy is the most analogous to military design, enabling advancement of the U.S. Army's understanding of design. Incorporation of design culture into the Army will harness corporate creativity and result in a creative, strategic Army verses an analytical tactically focused Army. An understanding of design theory allows the educated and judicious use of design methodologies, which

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[1] Bryan Lawson. *How Designers Think; The Design Process Demystified* (Oxford: Architecture Press, Elsevier, 2006), 303. Bryan Lawson is an influential author on design, and his work *How Designers Think* has been a highly regarded running description of design since its first publication in 1978.

[2] Nigel Cross, "Forty Years of Design Research", article in *Design Research Quarterly* 1:2, Dec 2006. See Appendix I1. If the reader is unfamiliar with the history of design, please proceed first to this Appendix, as Nigel Cross' explanation is thorough and succinct. Nigel Cross is currently the President of the Design Research Institute in London, and is a leading international figure in the world of design research.

empower the military designer enough to incorporate a flexible design strategy. Incorporation of engineering design also allows access to literature on the methods of design, which facilitates the use of design as an operable concept. For all these reasons, the School of Advanced Military Studies (SAMS) should incorporate an education of Engineering Design philosophy, methodology, and methods into its curriculum and allow this field to inform the creation of military design doctrine.

Complexity is not a new phenomenon by any definition, and neither is design. Engineering Design Theory will significantly influence the United States Army's current philosophy of campaign design. This monograph recommends that military campaign designers embrace Engineering Design Theory as a philosophical base to explicate how to operationalize design. This is a distinct departure from the Art of Design's current reliance on architectural design philosophy and post-structuralist problem-solving theories.[3] Engineering design methodology emerged in the 1980's as a systematic branch of design research. Because it is well-developed and focuses on systems theory, complexity, and competitive creative design – this particular branch of design theory has direct application to military art and science. In order to make current military campaign design operable, the Army should incorporate a foundation in an established philosophy of design, the acceptance of a design methodology, and the understanding and use of design methods. There are nearly exact philosophical and physical correlations between an engineering design team and a group of military campaign designers. As clearly explained by Brigadier General (ret) Wass de Czege, and others, design will aid the Army in addressing the complex campaigns of the coming century.[4] However, design is not new, and has its own history and several nuanced

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[3] The "Art of Design" is the phrase used by the School of Advanced Military Studies to describe their methodology and philosophical history with design. The methodology of the Art of Design is to proceed through an Operational Environment Space, to a Problem Space, to a Solution Space. Their philosophical history is rooted in Systemic Operational Design, Architectural philosophy, eastern and post-modern philosophy, and informed heavily by Soviet Operational Art and, of course, the current context of the US Military.

[4] In his article "Systemic Operational Design: Learning and Adapting in Complex Missions", BG (ret) Huba Wass de Czege neatly summarized the flow of design into doctrine. He states "Over recent years the fruits of this inquiry have infiltrated parts of Joint Publication (JP) 3-0 and 5-0; into the new Field Manual (FM) 3-24, Counterinsurgency (Chapter 4); and into FM 3-0, Operations (Chapter 6). In early 2008, the Army's Training and

philosophical disciplines. Before the Army operationalizes design, it should incorporate the theoretical traditions of design, as this will clarify which design disciplines will aid in campaign design. Acting as a natural bridge between art and science, the philosophical history of engineering design is of greatest utility in developing military campaign design and ensuring it becomes a useful operational construct. It is ironic that the recommendation of this monograph brings military philosophy back to the roots of U.S. Army officer education from the 19th century.[5]

Processes and concepts from current engineering design theory have direct utility in military campaign design. Increasing understanding of design allows a cognitive movement from a philosophy and morphology (a loose view of structure and form) to a methodology (a method combined with a philosophical base and school of thought) to the simple methods of design.[6] This progression is analogous to Peter Senge's levels of learning disciplines.[7] Senge argues that a discipline proceeds from a practice

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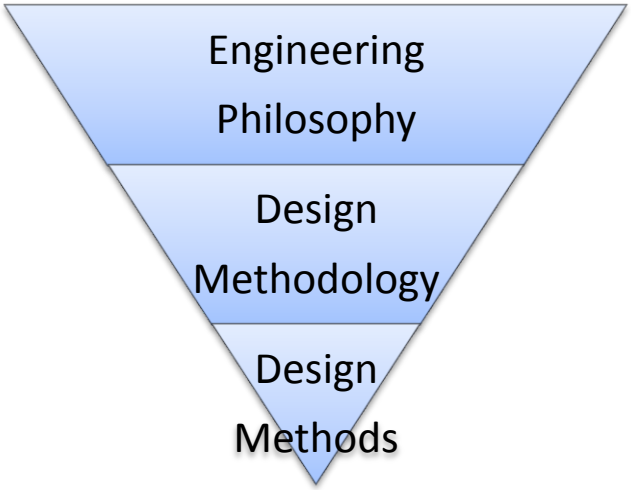
Doctrine Command published a guide entitled Commanders Appreciation and Campaign Design, and in late 2007 the Army War College expanded emphasis on design into its Campaign Planning Handbook".[4] BG Wass de Czege goes on to state that these are only the initial attempts at integrating a "new intellectual culture" with older knowledge. This monograph seeks to illuminate some of the older knowledge of design.

[5] The United States Military Academy, established in 1802, exclusively trained officers in the philosophy and discipline of engineering design for the past 200 years. Until the date of the publication of this monograph, academy trained officers must receive at least a minor in engineering design. The irony is that in this modern stage of the U.S. military's cognitive development, they rediscover "design" as central to military thinking in both command and staffs. In truth, engineering design has been with the U.S. Army officer corps since very near its inception.

[6] Morris Asimow, a professor of engineering and philosophy at the University of California, in Los Angeles, was the initial author to discuss morphology in engineering design. His methodology was connected directly to his creation of engineering philosophy. His morphology then, was simple, he stated "design morphology proceeds from the abstract to the concrete." He then gave an early (1950's) rendition of complexity and socio-economic systems which would make such a process very difficult, and defined the "operational discipline" of engineering as that of design. It is fascinating to read Asimow's connection between socio-ecological systems and engineering philosophy, written in the 1950's. This connection shows that an understanding of complexity and emergence predates some of the more recent evolutions of complexity and chaos theories. Asimow, *Introduction to Design*, 5.

[7] Peter Senge. *The Fifth Discipline: The Art and Practice of The Learning Organization.* New York: Doubleday, 1990. 373-376. Peter Senge coined the phrase Learning Organization and is an influential theorist in management. His model of an organization is comprised of practices, principles, and essences. By changing the practices of a company, you can alter the principles, and eventually the intangible essence. This monograph addresses the process in reverse, discussing philosophy in length to attempt to alter methodology and finally to hint at methods.

(what one does), to a principle (guiding ideas) to an essence (a state of being of those with a high level of mastery).[8] This monograph uses the same framework, presented in the inverse, and translated into the engineering taxonomy. Therefore, this monograph starts with engineering philosophy, then proceeds to the methodologies, and finally discusses the methods of design.



What is Design?

Before discussing design further, it is important to develop a common understanding of what design is, and what it is not. The concept of design is vague because there are many theories of design, which stem from various fields of design, all of which should inform the discussion.[9] In order to consider the adaptation of design theory, the Army must understand the meaning of design and clarify the accompanying language.

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[8]Ibid, 374.

[9] Lawson illustrates the problem when he demonstrates both engineers' and fashion designers' design which execute design and are commonly understood to be technical or imaginative respectively. He states succinctly "Actually both these descriptions are to some extent caricatures since good engineering requires considerable imagination and can be unpredictable in its outcome, and good fashion is unlikely to be achieved without considerable technical knowledge. Many forms of design then, deal with both precise and vague ideas, call for systematic and chaotic thinking, need both imaginative thought and mechanical calculation." Lawson, *How Designers Think*, 2.

Definition of Design

In order to discuss design, the reader must be clear as to the essence of the concept under examination. Design is when a group creates in a codified manner using the balanced elements of art, craft, and science. Reiterated, when a group of people come together to create something new, constrained by the rationalism of science, liberated by the creativity of art, and informed with the craft of the past, and creating in a manner which is recordable and codify-able, they are designing. Therefore, this monograph presents design as dialectic. The deterministic and procedurally bound science of planning is the thesis; the Post-Structuralist and creatively critical philosophy of art and architecture is the anti-thesis. The synthesis is campaign design, engineering design, or – stated simply – design.

It is useful to examine the design definitions of previous theorists, in order to come to an informed understanding of this set of concepts. Christopher Jones is one of the earliest and most influential authors in design theory, and his definition is the most empowering to the designer. He defines design as: "To initiate change in man-made things."[10] Another influential design theorist, Brian Lawson echoes this broad mantle for designers when he states "The very essence of (a designers) job is to create the future, or at least some features of it."[11] Lawson alternately describes design as "a contribution to knowledge" in the positivist tradition and posits the postmodern antithesis that design is "the identification of a problem".[12] Gerhard Pahl and Wolfgang Bietz, two of the paramount authors and creators of engineering design, define design as an activity that "affects almost all areas of human life, uses the laws and insights of science, builds upon special experience, and provides the prerequisites for the physical realization of solution ideas".[13] Perhaps this last component is what is so attractive to military

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[10] Christopher Jones quoted in Lawson, *How Designers Think*, 33.

[11] Ibid, 112.

[12] Ibid, 118.

[13] Gerhard Pahl and Wolfgang Bietz, *Engineering Design*, (Springer-Verlag Berlin Heidelberg New York. 1996), 1.

theorists developing the Art of Design. One of the fathers of design, Herbert Simon also broadly defines design as "changing existing situations into preferred ones".[14] Less well known outside of engineering circles, Dr. James B. Reswick's definition of design is useful to any author; he stated design is "A creative activity – it involves bringing into being something new and useful that has not existed previously."[15] Morris Asimow was one of the first Americans to embrace Engineering Design Theory, and was an early and influential engineering philosopher. His definition illustrates an obvious kinship to the military context when he states that design is "decision making, in the face of uncertainty, with high penalties for error."[16] This is particularly germane to how the Army educates and trains its officers to lead and command organizations. Design thinking is essential for effective battle command and is additive in that design informs our existing planning and leadership theory. It is the common spirit of creation and of initiating change that will define design with a little "d" in this monograph.

For the purposes of this essay, "Design" refers to the embryonic campaign creation methodology the United States Army is honing to plan campaigns that manage complex problems, commonly called the "Art of Design". The School of Advanced Military Studies (SAMS) defines design as "an approach to critical and creative thinking that enables a commander to create understanding about a unique situation and on that basis, to visualize and describe how to generate change."[17] Post-modern philosophy, complexity theory, Eastern philosophy and relatively recent developments in planning theory form the

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[14] Herbert Simon, quoted in Vermaas, *Philosophy and Design: From Engineering to Architecture*, 1.

[15] J.B. Reswick, *"Prospectus for an Engineering Design Center"*, (Cleveland, OH: Case Institute of Technology), 1965. Quoted in Christopher Jones, *Design Methods*, 4. Dr. J.B. Reswick is widely considered one of the first American pioneers in design theory.

[16] Christopher Jones, *Design Methods*, 3.

[17] FMI 5-2, *Design*, HQDA, 20 Feb 2009. 4. The schools earlier definition of design fleshes out this reduced definition. As of Feb 8, 2009 – the definition of design in the schools Design 101 brief stated that the Art of Design was "the theory and practice of iterative learning and adaptive action that develops and employs critical and creative thinking, enabling leaders to apply the necessary logic to manage complex ambiguous problems within limits of tolerance." PowerPoint Brief by COL Johnson, Design 101, Feb 2009.

foundation of the current Army concept of design.[18] Designers of this creatively critical paradigm have a different definition that relies on an understanding of potential and ontology. A recent SAMS graduate, MAJ Ed Hayward wrote a dense summary of design philosophy. His definition is accurate, but is not accessible to those with little formal training in the traditions of philosophy. He stated, "The process of design is about the recognition of difference; internal difference as essential identity, a consequence of flux rather than circumstantial difference, a predicate of identity". Hayward's influential monograph on the philosophy of design captured and recorded the way SAMS initially viewed design. His philosophy dissected the nature of knowledge and information, and he thoroughly explored a descriptive philosophy of design in a compelling manner. Hayward stated, "The designer should view his purpose as a translator." He also places heavy reliance on understanding identity and emergence, and states "the designer is able to see an emerging path, rather than the chaotic jumble that represents chaos, and is now capable of designing strategy".[19] Using these definitions, Design can be seen as a way of thinking, a state of mind, and a philosophical paradigm.

Reviewing the philosophical underpinnings of Design, as it exists currently in the School of Advanced Military Studies (SAMS), is a descriptive exercise, and there are approximately six monographs in recent years that complete the task admirably.[20] More interesting, is a discussion of what the philosophical underpinnings of Design should be, and what direction SAMS should pursue as it advances this vital field. Philosophers of artifact creation, or engineering, such as Herbert Simon at

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[18] Milan Vego, *A Case Against Systemic Operational Design*. (Joint Forces Quarterly, Issue 53,2nd quarter 2009) 69.

[19] Major Edward P. W. Hayward. *"Planning Beyond Tactics: Towards a Military Application of the Philosophy of Design in the Formulation of Strategy."* (SAMS AMSP monograph, AY 2007-2008.). MAJ Hayward's comments on the process of design are on pg 7, the discussion of the designer as a translator is on page 15. The final quote about design as a way of thinking is on page 48.

[20] *The Nature of War and Campaign Design* by MAJ Peterson (AY94), *Building a Campaign* by LTC Heredia (AY95),), *Systemic Operational Design* monograph by Kettie Davison (AY05), *Systemic Operational Design* monograph by a team headed by LTC Sorellis (AY05), *Planning Beyond Tactics* monograph by MAJ Hayward (AY08), *Foundational Concepts* monograph by MAJ Robertson (AY08).

Massachusetts Institute of Technology (MIT) and Brian Lawson at the University of Sheffield, are developing new theories on design that are not tied to post-structuralist traditions. This is important for the military, as post-structuralist philosophy has an unapproachable vocabulary, and a palpable friction with military planning culture. Methodology is important, as military staffs must structure their thoughts and actions to create workable plans. The study of design heuristics and methodology is advancing rapidly, and authors such as Pahl and Bietz demonstrate clearly "to begin solving a problem, humans need a certain amount of factual knowledge, or epistemics. They also need a "heuristic structure" of human thought."[21] Unfortunately, there is reluctance among post-structuralist designers to incorporate a design philosophy tainted by the industry of engineering. This monograph recommends that the Army adopt the philosophy of engineering design and Engineering Design Theory as the underpinnings of military design.

Because there are so many theories about design and the execution of design, as Lawson says, "we begin to get the picture that the design process is essentially experimental." There are as many theories of design as there are operative designers, and their methods and influences are trendy and constantly shifting based on developing theory.[22] This is also the current situation with military campaign design; there are as many methods currently as there are chiefs of staff, and doctrine thus far has not produced a comprehensive methodology.[23] Before the Army can make design operable, much less

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[21] Pahl and Bietz, *Engineering Design*, 49.

[22] This is characteristic of craft, without a socially accepted methodology, each artisan has his own techniques and solutions.

[23] Stephen Banach, "The Art of Design: A Design Methodology*", Military Review*, March-April 2009). Colonel Banach writes in his article, "Another obstacle is that a methodology for design has not been described in any detail. Wass de Czege rightly declares that there is no formulaic way of presenting design. But a philosophy of design by itself is too broad to function as a guideline for action. What is needed lies between the rigid precision of a technique and the abstract wisdom of a philosophy. Peter Checkland notes that "while a technique tells you 'how' and a philosophy tells you 'what,' a methodology will contain elements of both 'what' and 'how.'", 106. This monograph engages design at the level of philosophy, and then follows through to address methodology and methods.

doctrinal, the organization must be clear on the philosophy, methodology, and methods that comprise design.

Before integrating design into military philosophy or methodology, military theorists should study the issue history and contemporary theory of design. This should not be confused with post-positivism, eastern philosophy, or Soviet war-making theory. A study of the history and theory of design will illustrate the differences, show why design remains a vital philosophical model for military application, and demonstrate how to make design operable.

The Design Community of Practice – A History

As seriously as the military is considering integrating design into doctrine as part of creating campaigns, it is confusing to note the lack of formal design study. Design as a field has its own history, its own professional institutions, and is a very thorough and well-developed body of theory. A study of design history will help inform the language and use of design in the military context.

The history of creation started with early craft, which is the important cognitive predecessor of design. As the demands on artisans grew, craftsmen began to work in groups and record their work for exportability and training purposes. Design followed craft in order to allow creation by a social body, and to record and apply a methodology of creativity. Therein, design entered an early positivist and modern phase in the mid-eighteenth century. Design as an independent field of study emerged in the 1960's out of a series of important lectures within the informal community of engineers and architects. This renaissance of the 1960's truly forged design theory and formally acknowledged complexity as implicit in design. From this renaissance forward, the intellectual center for design theory was the Design Research Society in the United Kingdom and the Design Methods Group in the United States. These two bodies are constantly discoursing on design, and the Design Research Society publishes two regular periodicals where professionals examine every facet of design theory and practice.

To start at the beginning, upon creation, humankind immediately found the need for "things". This need was met by people who made it their life's work to create innovative and effective artifacts,

called craftsmen. Therefore, successful creation preceded design by millennia, just as successful military operations preceded either Design or Operational Art. Occupying the intellectual space between art and science, craft seeks to create in an unselfconscious and deliberate manner.[24] Craftsmen historically perfected their creations over generations, without drawings, using a system of trial and error.[25] Their knowledge was passed through oral tradition and apprenticeships, and the secrets of the craft were not recorded, or taught, and generally were secretly guarded.[26] As the requirement for innovation on a broader scale increased, positivism quickly eclipsed craftwork and one by one, bodies of craftsmen concluded that their mystical craft was recordable, exportable, and trainable.[27] This unmarked transition was the inception of design. Western militaries, punished by the brilliance of Napoleon, made a similar transition at the beginning of the 19th century. Arguably, the early 1800's were the emergence of military positivism as militaries struggled to utilize staffs, to problem solve in groups, and to record and export their craft.[28]

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[24] As Christopher Alexander noted on the first historic phase of design, "the unselfconscious craft-based approach to design must inevitably give way to the self-conscious professionalized process when a society is subjected to a sudden and rapid change which is culturally irreversible." Lawson, *How Designers Think*, 24.

[25] Lawson gives the most commonly referenced example of design as craftwork. Early in his work *How Designers Think,* he gives an overview of George Sturt's book *The Wheelwright Shop*. Christopher Jones references the same concept – both authors noting that successful creation preceded design (and complexity theory) by millennium. By making minor corrections to the horse-drawn carts through the centuries, the people of Sturt's book gradually improved the cart in ways that were unconscious to any one wheelwright. What is now called emergence was central to traditional design, called craftwork historically. The development of pitching the axles down and forward slightly, of dishing the wheel so that it was concave, and of rounding the hub all emerged in England in the 18th century.

[26] One of the most extreme cases of modern craftwork resided in the Royal British Navy of the 1800's. As late as the mid 1800's, British naval vessels were made by guilds, which secretly guarded and rarely recorded the method or layout of ship construction. In stark contrast to the continental 74 gun Ships Of the Line, which were mass-produced during the Napoleonic wars from designs, the British navy relied on a body of experienced craftsmen to essentially hand-make their warships.

[27] While the reliance on oral tradition and lack of effective record seems ludicrous, the reader should consider the significant cognitive resistance in the military community to recording or training leadership.

[28] Louis A. Dimarco, "The U.S. Army General Staff: Where is it in the Twenty-First Century?" *Small Wars Journal* (published on www.smallwarsjournal.com, Small Wars Journal LLC, 2009.) 2.

A student at SAMS once remarked that contemporary Operational Art "is neither art nor science, it is a craft."[29] This is very true, the creation of contemporary campaign visions in the US Army Headquarters or Combatant Commands (which rarely employ the Military Decision Making Process (MDMP) or the Joint Operation Planning Process (JOPP) to create their strategies) is very similar to craft. Arguing against military design is equivalent to arguing for the use of MDMP (disguised as JOPP) as a methodology at every level, to include strategic and operational. The dysfunction of JOPP for the creation of strategy has driven senior leaders to derive innovative solutions in the form of military craft. Design, in all fields and now in the military, is the natural and professionalized extension of craft. Craft has severe limitations – it is not replicable, is not historically recorded except in its creations, exists in the mind of the craftsman, and relies on heuristic learning.[30] And so it was for warfare before Napoleon – and before the application of the scientific method and rational study. Warfare was a craft, part art, part knowledge, with no real record of the reasons or form of warfare other than the record of the engagements themselves. Military design is therefore the natural evolution of the art of command.

In the 1800's, craft evolved alongside other emerging positivist philosophies. As artisans began to work in ever-larger groups to fill an exponentially increasing need, their rapidly modernizing world and the incredible Industrial Revolution forced them to work in teams, record, and codify their processes for exportability. This modern stage of creation was reductionist, optimistic, and often misguided – all of which became summarized as positivism. The Industrial Revolution grew out of positivism, and

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[29] Major Glenn Henke – class discussion of 9 Feb. The discussion in this Evolution of the Operational Art class focused on definition of Operational Art.

[30] Christopher Jones delineates the limitations of craft and why mankind moved to design. His deductions about craft, and its strengths and weaknesses, are: "1. Craftsmen do not, and often cannot, draw their works and neither can they give adequate reasons for the decisions they take (refer to the "professional judgment. 2. The form of a craft product is modified by countless failures and success in a process of trial and error over many centuries. This slow and costly sequential searching for the "invisible lines" of a good design can, in the end, produce an astonishingly well-balanced results and a close fit to the needs of the user. 3. The cumulative store of the essential information generated by craft evolution is, firstly, the form of the product itself, which is not changed except to correct errors or to meet new demands. 4. The two classes of data . . . the shape of the product and the reasons for the shape, are not recorded in a symbolic medium and therefore cannot be investigated and altered without makeshift experiments with the product itself." Jones, *Design Methods*, 19.

positivism fed off the success of the Industrial Revolution. In this manner, those who created also changed society forever. One of the early positivist philosophers, Rene Descartes, described the reduction of complex problems into apparently more simple problems, which the creator could then solve through cause and effect rationality.[31] The result of this social analysis was an explosion of creations, both crafted and designed, in the 19th century. Many of these creations had harmful effects and were eventually disregarded, such as the coal-burning furnace for factories, but many, such as the railroad – endured as compliments to the ingenuity of their creators. The philosophies and accomplishments of the positivist era were not entirely misguided. Even modern design, despite an acknowledgement of complexity, ultimately rests on a cause and effect based philosophical model, as does any predictive endeavor. The contributions and progressive philosophies of the 19th century changed the world forever, and gifted humanity with the ability to create socially in an exportable manner through design.

The modern and positivistic design philosophies dominated design conventions in the first half of the 20th Century, through to the 1960's. In Germany in the 1920's, the famous engineer Ferdinand Redtenbacher identified the need to determine strength, stiffness, and wear of components in his "Prinzipien der Mechanik und des Maschinenbaus" which pioneered modern design based on mechanistic requirements. In the 1920's, another famous engineer named Andre Erkens incorporated the principles identified by Redtenbacher into the first known systematic design approach.[32] Throughout the middle of the 20th century, design processes became more mechanical, focused on function and optimization, and

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[31] Kettie Davison, a SAMS graduate and author on military design, neatly summarized the history of modernism and convergent thinking when she wrote: "The principle of analytical reduction that characterizes the Western intellectual tradition came from Rene Descartes. Descartes described analysis as the process of identifying the simple natures in complex phenomena, and analytical reduction as the process of dividing each problem into as many parts as might be possible and necessary in order to best solve it. Reductive analysis is the most successful explanatory technique ever used in science." Davison, *Systemic Operational Design*, 11.

[32] Pahl and Bietz, *Engineering Design*, 12. Ferdinand Redtenbacher is considered by the engineering community to be the father of mechanical engineering, a field which had some impact on the rest of humanity. Andre Erkins is known for positing the first analysis of design methodology in his book *Beitrage zur Konstruktionserziehung in* 1928.

generally less creative. By the 1950's, design was in its infant state, and was emerging as a deterministic philosophy, involving rigid methods and procedures for achieving optimal function.

The 1960's were a transformational period for design, from the modern to the more complex. The first 'Conference on Design Methods' was held in London in 1962 and focused on acknowledging complexity.[33] This conference, in conjunction with others in the 1960's, was seen to launch design as a field of its own, and design methodology as a topic for further research. Furthermore, design theory in the 1960's became increasingly philosophical and identified the indeterminate nature of designing anything that interacted with humans. Thus, design theory began with a great deal of the humility not usually recognized in other academic fields.

Skeptics of engineering design will posit that engineering design is mechanistic, predictable, and as the Commanders Appreciation and Campaign-Design (CAC-D) pamphlet on design states, "assume that there exists an optimal solution and that we can find this solution by applying the established rules and techniques of our profession."[34] However, even a beginning student of engineering design, attending a 100 level course on design theory, knows this is entirely wrong. It is central to engineering design and philosophy that the technical models will always be incorrect, and that there is no optimal solution to a design problem. To illustrate an engineer's view of design, consider one of the early engineering design theorists, Thomas T. Woodson, who wrote in his 1966 book *Engineering Design*:

> "The 'true' solution to any problem, taking into account all the conceivable relevant factors and related effects, is understandably quite impossible. First, no one can know all the relevant factors, or predict all the possible effects. Second, many influences are only slightly relevant and can be neglected. Only by extended experimentation, can an engineer come to understand this relevancy and correctly choose which of these marginal influences to neglect. It is a truism that all the detailed macroscopic and microscopic phenomena of the natural world bring a staggering, overwhelming complexity into even the simplest problem."[35]

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[33] Nigel Cross, "Forty Years of Design Research", (*Design Research Quarterly*, 112, Dec 2006), 3.

[34] TRADOC PAM 525-5-500, *Commanders Appreciation and Campaign Design*, 14.

[35] Woodson, *Introduction to Engineering Design*, 128.

However, engineers recognized that they must create, despite complexity. The engineering philosopher Bucciarelli stated neatly: "We begin by noting that within all design contexts there are uncertainties. Some of these may be identified explicitly, given probabilistic expression and thereby brought within an object world for instrumental assessment."[36] With the emergence of design theory, design became controversial, and design theorists in the 1960's and 1970's ranged from highly systematic to ardently artistic.[37] At the center of this contest was the debate about certainty of knowledge and creation.[38] Engineering design theory emerged out of this dichotomy in the 1980's, initially in Germany and later in the United States and England. Some of the more influential authors were Christopher Jones (1978), Vladimir Hubka (1982), Gerhard Pahl and Wolfgang Bietz (1984), Michael French (1985), and Nigel Cross (1989).[39] Engineering design theory embraced the indeterminate and artistic design theory of the 1970's, and built on the systematic and systems approaches of the 1960's. This included a deliberate discussion of complexity, stemming from the 1970's until the present.[40] In the canopy of design theory,

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[36] Louis Bucciarelli, *Engineering Philosophy*, 24.

[37] The most famous illustration of this dichotomy is between Herbert Simon, who stated in 1969 that design was to be "a body of intellectually tough, analytic, partly formalizable, party empirical, teachable doctrine about the design process", and Christopher Alexander who stated "There is so little in what is called design methods that has anything useful to say about how to design . . . that I never even read the literature anymore". Cross, 4.

[38] Hansen's publication of his *Science of Design* in 1974 showed that uncertainty must be incorporated into a design system. Pahl and Bietz, who are some of the more deterministic engineering theorists, began to identify engineering problems with complexity and uncertainty, as opposed to tasks, which require mechanical solutions. Beyond microscopic and macroscopic physical uncertainty, the move from modern design to systematic design occurred because of the realization that "engineers are forced to consider how the material products they create interact with human agents." This is further complicated by the knowledge that in socio-technical systems, the users redesign parts of the system from within in unforeseen ways. Vermaas' example of the redesign of the French Minitel phone by users applies directly to military design. (Vermaas, 11) This is an extension Jones' man-machine design method, useful for cases in which an object is design to interface with a human. This is called socio-technical design. In socio-technical designs, the artifact is designed to interact with all of society, instead of an individual human. If, in campaign design, the users are the subordinate units and soldiers, than a reasonable military designer must expect (as does a open-source software designer) that his creation will affect his user, and the user will recreate his creation. All of these developments mandate that engineering move from modern reductionist design to incorporate the ability to deal with complexity. Pahl and Bietz, 13 + 47.

[39] Nigel Cross, "Forty Years of Design Research", 4.

[40] Brian Lawson was one of the first design theorists to discuss complexity in design in the late 1970's. Lawson has a unique view of complexity, and creates three methods for dealing with an uncertain future. Acknowledging the complex interface between humans and the designed world, Lawson proposes designers only

engineering design theory stands out as a well-balanced and central field that is useful, pragmatic, and well-developed.

Language is central to philosophy and understanding. Hence, the community of architects and engineers serve to fill out design vocabulary with accuracy and long-standing professional culture. When examining a new field, it is appropriate for the military to refer to the appropriate academic and professional experts. The Design Research Institute publishes two design periodicals that reflect the ongoing development of design thought and therefore design language. As an example, when Major Hayward "seeks to examine the theory behind the systemic design approach through the explanation form, function, and logic", he uses the traditional design approach of connecting form to function, and binding both with logic.[41] The problem is that he gives the same definition for both form and function. This reflects an incomplete understanding of traditional design vocabulary. Further, it contrasts with a recent article from design theorist R A. Meier, who indicated that the inclusion of affordances should influence the form-function-logic model. The Affordance Model, first introduced by psychologist Donald Norman in his book, *The Design of Everyday Things*, examines the Artifact-User interface, and the Artifact-Artifact interface to explicate the de-linking of form to intended function.[42] The Affordance

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options are to procrastinate, make a non-committal design, or create a throw away design. In this realist model – procrastination is clear – one may wait until the future is more determined. A non-committal design is creating something that is generic, bland, flexible but without determined specialization. A non-committal force design is one that would stress high intensity conflict, low intensity conflict, stability and security operations all within the same force. Bernard Tschumi offers two alternate solutions within the non-committal dilemma.. He states that given complex and uncertain future, a designer can create either an exemplary design that will affect its system and create its own value, or a counter design "as a way of countering the unpredictable mass of mainstream society." The only other option is to determine a throw away design – that is, to design for specific use knowing that shortly that use will become obsolete. Within this construct, he admits that commonly solutions can sometimes create future problems – thereby reinforcing the seemingly nonsensical procrastination and research model. Bernard Tschumi, *Architecture and Disjunction*, 13. Bryan Lawson, *How Designers Think*, 114.

[41] Major Edward Hayward, "*Planning Beyond Tactics*", 2.

[42] R A Maier, "*Rethinking Design Theory*", 3. Affordances are a complicated subject which will require explication below. Essentially, the affordance model allows for an artifact to complete unintended functions, both in interaction with other users and with other artifacts. This clarifies complexity in the form-function model – as humans may interact with any intended function, or use an artifact for a host of unforeseen functions. This understanding is a key component of engineering philosophy, and will be revisited below. Affordances are only

addition to function and logic, illustrates clearly that "simple" engineering design of artifacts becomes complex as soon as the artifact is placed in the hands of humans. This is one simple example that illustrates why the U.S. Army (if it adopts design) should stay informed of developments in this relevant and directly analogous field, and capitalize on the clear and established language of design.

The consequence of not studying current design theory will be the creation of an incomplete and confused vocabulary, and will thus negate the ability to glean useful pragmatic developments. Recommending the addition of design to military operations and philosophy will only be possible given commonality of language.

Design Language

Theorists of design philosophy utilize what they term to be "precise" language to describe their activities. The purpose of language is simply to communicate. In that vein, language warrants careful consideration. One would no more write of the military application of design in the flowery (and purposefully imprecise) language of architectural philosophy than one would compose a letter to a friend in Mexico in Arabic. Post-Modern philosophy charges that language belongs to the reader to interpret and that each reader will take away their own message, their own feeling, and their own impression. For this reason, postmodern language is specifically vague, lofty, and unattainable. In contrast, both operational and engineering languages are basic, easily understood by the practitioner, but no less precise. The word 'epistemology' serves as a useful example. Discussing epistemology in a post-modern essay allows elevation of the readers thought by the use of a lofty word for "the study of knowledge". Epistemology has a rich and well-developed history. The benefit of using "epistemology" is a sense of creative liberty, to understand epistemology as the reader wishes and to inform the reader's mind with all the philosophical development that comes with reading multiple books and articles on epistemology. Such a

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included here to illustrate the danger of exploring design language without an understanding of the issue history of design theory or a contemporary understanding of design language development in current periodicals.

mental exercise of divergent thinking is essential for education and for forcing creative thought patterns. Even in planning and creation, invoking the liberty of the mind of the reader can be vital. However, what is commonly lost in the use of lofty language is precision in communications and thus a common base of understanding across the operating force.[43]

It is important to critically analyze and de-bunk some of the language borrowed directly from architectural philosophy, which may confuse this discussion. For the purpose of this monograph, and in order to promulgate design theory in a useful manner, several obscure terms require clarification. Epistemology is the study of knowledge.[44] Taxonomy is the practice and science of classification, or assigning words to concepts.[45] Ontology is the study of being, and the knowledge of being, especially related to entities that are admitted into a language system.[46] Meta-cognition is analyzing thought from a higher plane.[47] Plateau thought is unbounded, and striated thought is bounded, or directional.[48] A tree is a hierarchical growth, whereas a rhizome is flat and unbounded. Orchids are flowers, and assemblages are

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[43] An influential author concerning engineering philosophy, Louis Bucciarelli gives an imminently accurate picture of language in design when he states: "Different participants with different responsibilities, competencies, and interests, speak different languages when working, for the most part alone, in their respective domains. For this to ring true, we ought to construe language in the broadest terms – to include the sketch, the prototype, the charts even a computer algorithm as elements employed in the productive exchange among participants. But individual effort within some disciplinary matrix does not suffice: Designing is a social process; it requires exchange and negotiation as well as intense work within object worlds." Commonality of language in this vein is not restricted to composition, but to drafts, doctrinal maps, PowerPoint slides, etc. Just as every equation in an engineering paper is an artifact of language, so is every paragraph of an OPORD. The more social and multi-disciplinary the endeavor, the more common and clear language is mandatory. Bucciarelli, *Engineering Philosophy*, 21.

[44] Webster's Third New International Dictionary, 8th ed, s.v. "Epistemology." Definitions in this section are drawn from the unabridged dictionary that stands near the School of Advanced Military Studies computers, on the second floor of the library in Eisenhower hall. This unabridged dictionary is a 1976 edition, purchased in 1982 and given its own stand by the SAMS research carrels, and is offered as common linguistic grounding for generations of SAMS graduates.

[45] Ibid, s.v. "Taxonomy."

[46] Ibid, s.v. "Ontology."

[47] Ibid, s.v. "Meta."

[48] Gilles Delueze and Guattari, Felix. *A Thousand Plateaus; Capitalism and Schizophrenia. (*Minneapolis: University of Minnesota Press, 1987).

simply a bipolar grouping of things that have a mutually beneficial relationship.[49] Stochastic is a dialectic term – regarding that which lies between unpredictable and predictable.[50] Heuristics are a trial and error process for learning, or anything that provides aid or direction to solving a problem without solid justification.[51] It would be easier to say "trial and error" but having a structured process is an important component, and germane to this discussion.

Morphology is the scientific study of form and structure to draw a methodology from a philosophy by requiring a function.[52] This differs slightly from methodology, which refers to both the procedural and the philosophical underpinnings and the rules involved in an activity, which are likewise tied to function. This again differs from a method, which is simply the procedural activity without the paradigm of rules and philosophy. A frame is a mental boundary around all a set of ideas, artifacts, or things affecting a design. Therefore, a problem frame is a mental boundary around all things affecting or affected by a problem. A theory is a postulation of what exists that must be either provable or disprovable.[53] Neither problematize or problemitization are words in common use, but in some literature refer to putting into words the difference between that which exists, and what the designer desires.[54]

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[49] Manuel DeLanda. *A New Philosophy of Society; Assemblage Theory and Social Complexity*. (London: Continuum, 2006).

[50] Felix Klein, *Mathmatische Annalen*, (Berlin, Ge: Verlag Von Julius Springer, 1934). Stochastic was originally a term used in probability and statistics, and has become associated with problem solving which is only partly cause and effect driven. The most common use relates to medicine, and to engineering within design curriculums.

[51] Webster's Third New International Dictionary, 8th ed. s.v. "Hueristic."

[52] In the late 1960's, Tom Markus and Tom Maver mapped the design process and coined the term "design morphology".[52] Their process applied to architectural design specifically, and to all design obliquely. Their (and the industry's) first morphology moved from analysis, to synthesis, to appraisal and finally decision. Analysis is the ordering and structuring of the problem, and synthesis is "an attempt to move forward and create a response to the problem – the generation of solutions. Appraisal involves the critical evaluation of suggested solutions against the objectives identified in the analysis phase." Lawson 37.

[53] Webster's Third New International Dictionary, 8th ed, s.v. "Theory."

[54] Major Edward Hayward, "*Planning Beyond Tactics*", 12.

Therefore, it is accurate to state that the above is a practitioner's epistemological view of the taxonomy of architectural ontology on design. However, using those words would seriously, gormlessly, and intentionally obfuscate the practical reader's understanding. It is far more useful and direct to say that the aforementioned list of definitions will serve as references for the remainder of this monograph.

After developing at least a feel for the definition of design, and clarifying some of the more unapproachable language, the Army can make an argument for incorporation of design into doctrine. Founding the definition in design theory gives design some credibility, and adaptation of traditional design language (instead of the language of philosophy) renders design accessible. Given these two innovations, the Army may then successfully argue that design will significantly advance the development of battle command, decision-making, and strategic and operational campaign creation.

The Import of Design for the Army

"Those who protest that time and rigor invested in design is wasted effort do not understand that 'doing the right thing' is more important than 'doing things right' on the way to 'worse' or 'irrelevant' rather than 'better' outcomes." – Huba Wass de Czege[55]

Design is a mode of thinking, acting and decision making which has direct application to the military craft, which will aid in operational and strategic campaign creation. In order to invest in design, the Army must determine why it wants to shift its campaign creation processes, what initiated the change, and why now?

The creation of military campaign plans in a complex world is extremely difficult, which makes the profession of arms what historian Leonard Holder calls "the most difficult profession."[56] The

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[55] Wass de Czege, "Systemic Operational Design: Learning and Adapting in Complex Missions", 7.

[56] Holder and Murray, "Prospects for Military Education," *Joint Forces Quarterly*, 81. LTG Leonard D. Holder Jr. (ret) was a previous commandant of the US Army Command and General Staff college and a regular contributor to Joint Forces Quarterly.

indeterminate nature of designing for social systems, within an ever more complex environment induces art and subjectivity to the military profession.[57] The essence of military art is a lethal competition of applied creativity. The more asymmetric the situation, the more creativity is required. Stated again, warfare, especially asymmetric warfare, is a contest of the creative application of national power, and the stakes are the operator's life and the lives of the soldiers involved. To make things more difficult, this creativity and application must occur in a high stress environment, executed by a coalition of willing participants.[58] While complexity is not new, the increasingly interconnected nature of the global system increases interaction among agents, which increases the entropy of the system.[59]

Military ~~Arts and Sciences~~ Design

Military Arts and Sciences are the application of military theory to practice. There is no body of philosophy better suited for this transition, either cognitively or socially, than engineering philosophy. A giant in design theory, Christopher Jones argues convincingly of the need for integration of design into operations. He sharply criticizes the rift between designers focused on divergent creativity, and creators focused on causal procedures that ignore complexity. He stated:

> "The results of this mutual unawareness of the underlying skills of other professions are twofold: the designers do not realize that they must learn to distinguish what they *believe* to be true from what can be *proved* true, while scientists, mathematicians and other experts may fail to realize that what they perceive as a well-defined problem can be

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[57] Writing on the Interwar years, Murray and Millet write "The process of innovation within military institutions and cultures, which involves numerous actors, complex technologies, the uncertainties of conflict and human relations, forms a part of this world and is no more open to reductionist solutions than any other aspects of human affairs." Murray, Millett, *Military Innovation in the Interwar Period*, 303.

[58] Kettie Davison highlights some of the unfortunate difficulties when she states, "a systematic rational approach runs counter to how human beings make decisions in a natural setting. Time pressure, unclear goals and dynamic conditions characterize natural settings." Kettie Davison – "Systemic Operational Design – Gaining and Maintaining the Cognitive Initiative", SAMS Monograph AY 2005-2006, 11.

[59] Entropy is an engineering expression for the measure of chaos of the system. Entropy is never zero, and it is never one – meaning that somewhere between order and complete chaos is a measure of the unpredictability of the system. This understanding that reality lies between determinate knowledge and indeterminate chaos is central to engineering philosophy.

invalidated by the new situations that are constantly taking form in the mind's eye of a skilled designer."[60]

This illustrates the essential departure between the modern and post-modern philosophies of creation, and why it is vital for any military design theory to bridge this gap. Jones further notes that the critical difference between art, science, math, and design is the concept of timing. He indicates that artists and scientists work in the present, while the designer must forge into the future. [61] This heroic mentality posits that the divide between art, science, and design is the willingness to attempt to create the future. Accepting this paradigm suggests that the military should change the term Military Arts and Sciences to Military Design. Historically, the United States uniformly educated its military officers as design engineers, and taught them in the philosophical traditions and culture of design and creation. The uniquely applicable analogy between design and military operations, discovered by BG (ret) Shimon Naveh in recent decades, is therefore not a new philosophical joining. Instead, it is a recent manifestation of a much older understanding that craft, problem solving theory, design theory, engineering theory, and military application are inextricably interrelated.

Design as the cognitive evolution beyond craft

Before adopting design, the Army must be clear as to why. The design renaissance of the late 1970's and early 1980's produced a series of valuable works on design, which identified difficult and relevant questions about the transition from craft to design. An early design theorist, Christopher Jones analyzed the shift to design in industry in a way that is very relevant for the military. Consider the import of Christopher Jones' argument for military campaign designers:

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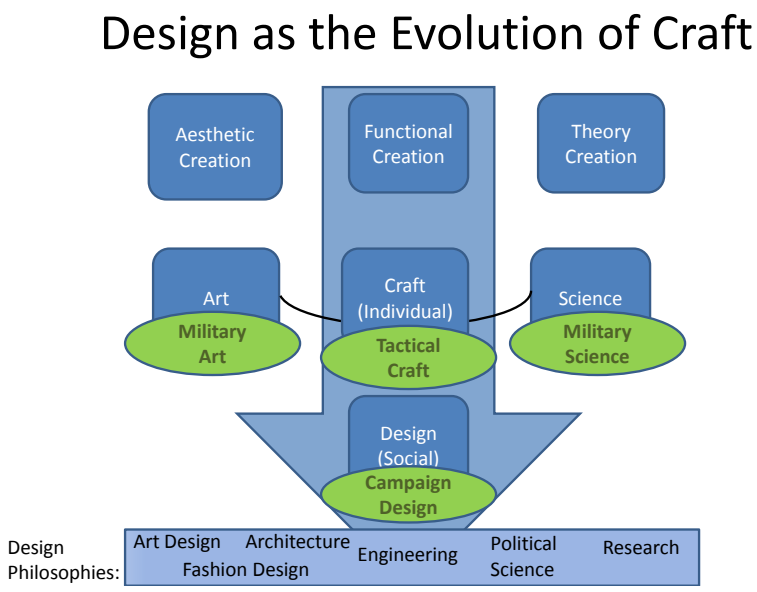
[60] Jones states "Both artists and scientists operate on the physical world as it exists in the present (whether it is real or symbolic), while mathematicians operate on abstract relationships that are independent of historical time. Designers, on the other hand, are forever bound to treat as real that which exists in the imagined future and have to specify ways in which the foreseen thing can be made to exist." Jones, *How Designers Think*, xii.

[61] Ibid, 10.

> "1. How did traditional designers cope with complexity? 2. In what ways are modern design problems more complicated than traditional ones? 3. What are the interpersonal obstacles to solving modern design problems? 4. Why are the new kinds of complexity outside the scope of the traditional design process?"[62]

Before the Army adopts the nearly perfect analogous design process for creating campaigns, as an institution the Army *must* answer Jones' challenge. How did traditional campaigns cope with complexity? How are modern campaigns more complicated than traditional? What are the interpersonal obstacles to creating modern campaigns? Finally, and most importantly, what indicates that the new kinds of complexity are outside the scope of the traditional campaign planning process? If traditional processes can deal with contemporary demands, then the military should maintain traditional processes (MDMP and JOPP) as its exclusive campaign planning artifacts. However, if Jones argument is convincing, the increasingly interrelated context of the late 20th century already required new methods that super-ceded traditional planning and design practice. The design community of the last century answered Jones' challenge with the emergence of engineering design theory in the early 1980's.



[62] Jones, *Design Methods*, 27. Before any effort to change the mental model of the U.S. Army, the critical mind should question why the change initiated. Is a side-effect of the war on terror a disruption of the military cognitive process? What exactly about campaign planning of the 1990's was broken?

Traditional designers coped with complexity using a variety of methods. The first was to rely on their experience and imagination. This mirrors the Army culture of commander-centric warfare. The second was to deliberately work to overcome individual mental rigidity and develop personal insight. By applying single conceptions of the whole successively, designers were able to cope with complex circumstances. By identifying a tentative solution both as an exploratory act, the designer could challenge his selected model against the situation and the design itself.[63] This is analogous to the feedback mechanism of unit reports in the Army, to which the commander iteratively applies experience and imagination to overcome challenges and complexity. While dealing with complexity alone is a successful method, it is dated and not generally advisable when the stakes are mortal. The United States Army is one of the most successful, and one of the most commander-centric, Armies in the world. However, to broaden access to creative thinking and imagination, overcome mental rigidity and develop group insight, the Army must learn to utilize group learning and thinking, through a fluid and creative open process.[64] In industry, that process is design.

Next, the Army needs to address the ways in which modern design problems are more complicated than traditional ones explicitly. In fact, current problems are neither more complicated nor complex than previous ones, but the awareness of the complexity changes the moral charge of the designer.[65] This is concurrent with the understanding that past design solutions are the seeds of current social challenges, such as the automobile (in technology) or the partitioning of Africa (in strategic terms). While design problems are not different in character from past problems, the increasing

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[63] Jones, 28-30.

[64] Louis A. Dimarco, "The U.S. Army General Staff: Where is it in the Twenty-First Century?" *Small Wars Journal* (published on www.smallwarsjournal.com, Small Wars Journal LLC, 2009.) 7. DiMarco's excellent article explores command and staff centric operational art in a way that explicates the strengths and weakness of each. This is relevant to the design theorist, who must constantly balance single-authorship verses social design.

[65] Jones, *Design Methods*, 32.

interconnectedness of the world induces more complexity.[66] Therefore, complexity has not changed but is increasing, but the awareness of complexity creates a moral responsibility to design more holistically and socially.[67]

There is an increase of stakeholders who have a vested interest in and are connected to modern designs, which increases both the complexity and the need for social design mechanisms to overcome interpersonal barriers. Christopher Jones posits that the old joke of 'designing by committee' is not only feasible, but is a requirement of future design. All successful future designs will be 'by committee', with the list of connected stakeholders including sponsors, the design team, suppliers, planners, distributors and subordinate teams, purchasers, users, operators, and society at large.[68] The inclusion of social and economic indeterminism and multivariate stakeholders in design logic has nearly obliterated the ability to willingly converge on a social design crafted by a single author. These traditional but now amplified complexities increasingly illustrate the need for new methods in design, which in the 1980's spawned engineering design methodology.

The Army must answer Jones' challenge before adopting design as a means to change the Army's leadership and command culture, which in turn will enhance campaign creation. Military designers are more aware than ever that their campaigns have a complex effect on broad social systems upon which they act, and within which they interact. The awareness of the impact of their designs creates a moral responsibility to move beyond the intuition and experience of one commander, to include the learning and experience of the corporate organizational intellect applied to the creation and execution of a design.

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[66] External complexities (technology transfer, interconnected side effects, required compatibility, human overlap, and systems transformation), and internal complexities (requirement to be right the first time, information from outside sources, difficult decision sequences with new information) of design are nearly timeless. However, the rate of interaction is unarguably increasing, which moves increases the entropy of a design toward one (or increases the complexity).

[67] Jones, *Design Methods*, 42.

[68] Jones, *Design Methods*, 37-41. Jones presents the old joke that "A Camel is a horse designed by committee", and uses this to drive forward his point that group learning and group creation will be the necessities of the future.

Reiterated, now that the military is aware that current campaigns can sew the seeds for future problems, there is a moral responsibility to design as effectively as possible and as thoroughly, which demands moving beyond craft and beyond single authorship techniques. While the world is no more complex than it was 200 years ago, the increasing interconnectivity of the world and systems in the world increases the number and influence of stakeholders in design, as well as the range of impact of the design itself. In this context, if the Army answers Jones' challenge on the acceptance of design honestly it will conclude that design is a moral imperative. Further, the Army will discover that its sponsors demand inclusion of well-informed design processes as a precursor to action or campaign creation.

Design as opposed to MDMP for Campaigns and Strategy

Design is vital to the continuance of the development of Operational Art and Strategy in the United States Army. It is an essential addition to military planning, and a critical advancement in military planning theory. The field of Military Arts and Sciences is awkwardly named for good reason. Historically, the military profession conforms more closely to craft than either art or science.[69] Moving beyond craft has been the challenge for designers in the past two centuries.[70] Furthermore, design is distinct from the doctrinal military decision making process (MDMP) which is an integral addition to the United States Military planning methodology. As BG (ret) Wass de Czege wrote, "the biggest decisions of command are not about how to achieve set goals but what those goals ought to be within a campaign

[69] As noted by Clausewitz, *On War*, 172. The craft analogy is seconded (if Clausewitz needs a second) by Morris Asimow, who defines Design by Evolution – or craft, as the basis of design theory. The military profession contains elements which are more replicable than art, and more context driven than science. The second stage of design history was Design by Innovation, which was followed in the last two centuries by Deliberate Design. See Asimow pgs 2 and 3. Any profession which evolves by examining historical case studies and attempts to innovate to meet a new context without agreed principles remains a craft. When that profession develops standardized methodologies which allow a replicable approach and the inclusion of multiple problem solvers to solve unique and contextual problems, that profession begins to move beyond craft to design.

[70] Christopher Jones – See Craft Paragraph in the History of Design, *Design Methods*, Appendix I.

design."[71] Furthermore, design represents a cultural shift that will enhance battle command, leadership, and military decision-making.

The problems of design are directly analogous to the problems of creating a military campaign. Lawson's constructed maxims on design will illustrate the similarities. To communicate these maxims he defines the characteristics of a design problem and design solutions. A design problem "cannot be comprehensively stated", and requires subjectivity in interpretation. Lawson's explication on design solutions also illustrates the problems with complex military campaign designs. He classifies a design solution as such: "there are an inexhaustible number of solutions" which defy optimization and require holistic responses. Finally, his maxims on the design process also illuminate the characteristics of campaign design. Accordingly, the design process:

> "1. Is endless, 2. There is no infallibly correct process. 3. The process involves finding as well as solving problems, 4. Design inevitably involves subjective value judgment, 5. Design is a prescriptive activity, and 6. Designers work in the context of a need for action." [72]

Lawson's life work studying design reveals truths in design that nearly exactly conform to the problems, solutions, and process of military operational campaign design. In contrast, JOPP has an end state, is by doctrine the infallibly correct process, involves only solving problems, is also prescriptive, and works in the context of a need for a solution. The differences in end state, deterministic optimism, and problem solving verses problem identification are monumental. The enormity of these differences recommends a shift in leadership, philosophy, and command culture in the U.S. Army.

In her monograph on Systemic Operational Design, Kettie Davision clearly illustrates the differences between the Military Decision Making Process (MDMP), Effects Based Operations (EBO)

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[71] Wass de Czege, 5. His article, "Systemic Operational Design: Learning and Adapting in Complex Missions" describes the relationship between planning and design. His proposed model of Design, Plan, Prepare, Execute was developed in conjunction with BG (ret) Shimon Naveh, whose original model was Design, Plan, Act, Learn. In either case, the military need for a precedent to planning is emerging.

[72] Lawson, *How Designers Think*, 121.

and Systemic Operational Design (SOD).[73] She convincingly argues that MDMP is relevant for tactical use, and that EBO and Design are clearly relevant for operational use.[74] The danger is that operations have become a set of grand tactics, and that Army leaders will rarely study or discuss strategy creation and focus their attention below the level of civilian control. Currently the Army lacks critical and creative examination of strategy, and incorporating design into our culture will allow discourse and the creation of effective strategies. MDMP is simply inadequate as a vehicle in the future for either operational, or for strategic planning. Even in the hands of the most experienced operator – the steps of MDMP become more of a hindrance than an amplifier of creative energy and critical thought.

Very experienced artists alter the focus and timing of the steps of MDMP to enable operational and even strategic planning, but when so altered, MDMP becomes not so much a methodology as a philosophical basis for planning. Effects Based Operations also have basic philosophical limitations. While they do emphasize BG Naveh's assertion that Operations are a "cognitive space focused on disruption and systematic interference", they are essentially reductionist in scope, and the philosophy has already been disavowed by General Mattis, commander of Joint Forces Command, in his now famous memorandum.[75] SOD, as developed by Shimon Naveh, is an important theoretical advance, but has roots in systems theory, post-modern philosophy, and post-structuralism. These philosophical models contradict progressive creation and are problematic. The language of SOD is also a problem, as it is unattainable by practitioners and inaccessible to the executors. One might argue that Operations should be planned by the very bright, and that the language of SOD acts as an intellectual colander. However, such

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[73] Kettie Davison, "Systemic Operational Design: Gaining and maintaining the cognitive initiative". SAMS Monograph, AY 05/06.

[74] Ibid, 51

[75] Reference Mattis memorandum. General J. N. Mattis, MEMORANDUM FOR US JOINT FORCES COMMAND, Subject: Assessment of Effects Based Operations. 14 August 2008. 5. Gen Mattis examines the history of Effects Based Operations (EBO) and concludes that the momentum generated by the Millenium Challenge 2002 exercise was overwhelming traditional and tested planning methodologies. His conclusion is that US Joint Forces will no longer use or promulgate EBO as a concept.

an academic argument "smells more of the lamp than the field"[76] and would not pass muster in a Corps headquarters staffed with U.S. Army captains and young majors who are writing plans for dissemination to Divisions, and increasingly, to Brigades.

When Shimon Naveh harnessed the philosophy of architecture to drive advancements in operational art, he adopted the lexicon of design, specifically architectural design. Naveh stated that he used the architectural analogy because the philosophy and cognitive requirements were similar.[77] While design philosophy is a nearly perfect analogy, narrowing the field of study to architecture is counterproductive. Conceptually, design is very broad, and designers of MP3 players, virtual worlds, graphics designers, and computer programmers have many conceptual commonalities reflected in their philosophies, vocabulary, and culture. In many ways, the engineers who designed the I-Phone, or Disney's Imagineers, have more in common with military campaign designers than do architects, because their contexts are complex, they have a daily demand for generating creativity, and they must constantly outsmart their competition.

Design is distinct from MDMP in focus, structure, and intent. Major Hayward indicates this difference clearly and accurately when he states "Design is contrasted with planning, theory with action, smooth with striated and analysis with synthesis."[78] Pahl and Bietz' design approach, and that of many engineering Universities, proceeds from philosophical "conceptual design" to methodological "embodiment design" and finally to detail design, which is analogous to planning.[79] Therefore, Naveh's

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[76] T.E. Lawrence, *Seven Pillars of Wisdom*, 202.

[77] Conversation with BG (ret) Naveh, 20 Dec 2008.

[78] Hayward, "Planning Beyond Tactics", 48.

[79] Pahl and Bietz, *Engineering Design*, this is the organization of their entire book. A good example of a design syllabus comes from McGill University in Canada, whose class on Design Theory and Methodology (ME593) proceeds from Introduction to Conceptual Design, to Embodiment Design and Detail Design. It is interesting to note that McGill includes discussions of the role of knowledge, complexity, representation, entropy, and stochastic understanding in his design class, which centers on engineering design theory. Their recommended reading on the history of design and design schools is excellent. See www.mcgill.ca/cden/courses accessed on 21 March 2009, in Appendix III.

model of design, plan, act, learn is in accord with traditional design problem solving, and design should proceed and be concurrent with MDMP to inform that tactical planning tool with context and understanding. However, design must depart from its current post-structuralist taxonomy to be effective in the larger Army context. It is the irony of the emerging design process that by holding to its rhizomatic and divergent roots, it will lose the ability to adapt to the needs of the Army. This outcome will hamper future operations with a lack of solid campaign planning. The remedy is to inform design theory with its own philosophical history and practice, loosen the grip of SOD and post-structuralist philosophy, and allow a limited morphology to define Design. Only in this manner will Design emerge as a useful approach that is antecedent to MDMP, exportable to the Army, and vital to success in campaigns and operations.

If MDMP and striated thought are the thesis, and post-structuralist philosophy is the anti-thesis, then Campaign Design must be the necessary synthesis. Campaign Design must be stochastic, that is, neither based on the complex unpredictability of systems where one must "act to learn", nor based on scientific methodologies that give a false sense of reality and prescribe action based on a decision cycle. Campaign design must have both a heuristic element, and a predictive element – much like medicine, the practice of law, or engineering.

Design as a Cultural Shift

The recommendation to move away from commander and cognitively-focused Architectural Design Theory toward socially and staff-focused Engineering Design Theory represents a cultural shift for the United States Army. Such a change in the philosophy of design suggests the commander is a servant leader, who manages adaptive learning and receives nearly fraternal creative input from the design team.[80] This is a departure from the vision of the commander as a power leader, or enlightened

[80] Servant leader is a term coined by Robert Greenleaf. Greenleaf, R. K. (2002). *Servant leadership: A journey into the nature of legitimate power and greatness* (25th anniversary ed.). New York: Paulist Press.

savior, which is so pervasive in American leadership culture. In order to harness the creative energy of the organization, a leader intending to utilize Engineering Design Theory must evolve his organization so that a free exchange of ideas and a positive and fraternal command climate enables creative and critical discourse. Such a leader must accept intellectual challenge and critical debate in order to unleash the creative energy of the organization. The cultural shift toward social creativity recommended by Engineering Design Theory is counter to American traditional values, which emphasize individual achievement and promote super-hero characteristics. Instead, Engineering Design Theory proposes harnessing the creative energy of the entire organization to solve complex problems. There were no Michael Jordans in the design team that created the Blackberry. The automobile that the reader will drive home tonight was not invented by a superstar, and is not the manifestation of one person's artistic genius. The design teams that are evolving the modern world work in a state of relative anonymity, with each design incorporating their collective artistry, the science of their profession, and the craft of previous evolutions.

However, the recommendation to make the cultural shift toward social creation does not imply that the commander has a diminished role. In contrast, commanding in a critical and creative environment requires intellectually agile and competent leadership. Design is part of battle command, and properly harnessing the creative energy of the organization intentionally enhances leadership and decision-making. The first step to battle command is to Understand, and FM 3-0 states, "Understanding is the basis of the commanders visualization".[81] However, the only method for gaining understanding in doctrine is battlefield circulation, and reliance on the commander's education, intellect, experience, and perception. Design, especially Engineering Design Theory, offers an increase in methods of gaining understanding. Furthermore, design broadens the knowledge, judgment, and experience base available for intuitive

[81] FM 3-0, *Operations*, (HQDA, Feb 2008), Para 5-16+5-17.

decision-making from sole reliance on the genius of the commander, to harnessing the creative energy and experience of the organization.[82]

Design requires a culture of openly exchanged ideas, intellectual rigor, critical thinking and transparent decision-making. While every unit is different, these are not common qualities in the culture of the United States Army. To incorporate design, leaders must create an organizational climate that allows for critical discourse without fear of repercussion. Such a climate will amplify corporate genius, instead of requiring individual genius to create a new future. Therefore, the requirement for the leader is to lead and harness the generated corporate learning in a productive manner. Inculcating corporate learning through design, over time, will allow generational corporate learning. Such a cultural shift will produce a creative strategic Army verses an analytical tactical Army.

Harnessing an organization using Engineering Design Theory has several prerequisites. First, the designer must understand military arts, sciences, and craft, and design as the natural evolution of that craft. Second, they must understand that design implies a cultural shift away from power leadership and the certain comfort of analytical decision making to cope with complex situations. Willingness or ability to endure such a cultural shift allows for the understanding of Engineering Design Philosophy.

Incorporation of Engineering Design Philosophy.

"Engineering design almost always requires a synthesis of technical, human, and economic factors; and it requires the consideration of social, political, and other factors." Asimow - 1962[83]

In order to make design operable, the Army should draw directly from design theory and specifically engineering design theory. Emerging design theory in the Army focuses on architectural philosophy, and should incorporate engineering design philosophy. Of all the design philosophies,

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[82] Ibid, Para 5-11.

[83] Morris Asimow, *Introduction to Design*, 2.

Engineering Design Theory is the most analogous to military design. Engineering design philosophy is distinct from architectural design philosophy in six major ways, which are all of great importance to military design. First and foremost is the critical understanding of social verse singular authorship, which is analogous to the difference between command and staff centric operations in the military realm. Second is the vital understanding of complexity through bounded rationality (stochastic philosophy). Third is the understanding of the engineer's need to create, to meet functional requirements that are distinct from either art, architectural, or scientific theory. Fourth is the cognitive incorporation and tradition of risk and safety, absent in art and architectural theory. Fifth is the illuminating discussion of the difference between intentional or unintentional design. Finally, because engineering design is done is teams, the acceptance of engineering philosophy allows for the unlocking of methodology. Acceptance of a variable but discernable methodology is the critical final step, because it allows for accessibility and exportability of design theory to a broad audience. This final component makes engineering philosophy more approachable by practitioners, and more in line with the traditional education and causal culture of Army Officers. As a well-developed and approachable field, engineering design theory is inherently operable and exportable, whereas architectural philosophy is intentionally obscure and difficult for most people.

Social Creation vs. Singular Authorship

One of the key differences between architectural philosophy and engineering philosophy is the focus of the former on the author. Architectural philosophy focuses on creativity and indeterminism, and the primacy of a single author. While the average academic can probably name several famous architects, the same academic cannot probably name even a few famous engineers. That is because Engineering Design Theory focuses on the design team, instead of an individual author. This is a strong point for engineer philosophers, who argue that even the prestigious architect must work with his sponsor and client. The work of Louis Bucciarelli, in his book *Engineering Philosophy*, prescribes a multi-disciplinary and socially-focused approach. He states "Design, like language, is a social process" and that rejecting engineering philosophy "is a mistake. It fails to acknowledge that designing is a social process of

negotiation, of iteration, of rectifying missteps, even misconceptions – a process rich in ambiguity and uncertainty."[84]

It is quite common that the architect is considered the author of the building he or she designs, and receives the fame or infamy of the success or failure of that project. Conversely, an engineer works in a design team, given the constraints of the user and the client –and works in relative obscurity with a team of designers all yoked to the same project.[85] This has important ramifications for the difference between engineering and architectural philosophy. It is common for engineers to focus on group methods and dynamics, whereas architectural philosophy focuses on cognitive patterns and conversations between a single designer and another person, artifact, or method involved in the process. This distinction is relevant for military designers, who also work in large teams and in relative obscurity. Prestige and the culture of the hero is only part of the issue; it is the pressure and the orientation on team creativity that is germane.[86] To make this analogy useful, a discussion of "commander centric" vs. "staff centric" design teams to inform the analysis is important. In contemporary design, this balance is the theoretical tension between lone operators and methodological social creators.

Part of understanding design as a social process involves not only the design team and the commander, but also all future implementers of the design. Software engineers and programmers clearly understand the relationship between the implementer, or user, and the design. The critical point is that users will shape, add to, and change designs to meet their needs through the course of a design's life. "Open software design explicitly recognizes the legitimacy of others, downstream to contribute to design,

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[84]Louis L. Bucciarelli, *Engineering Philosophy*, (Published by DUP Satellite, 2003. Original from the University of Michigan). 9.

[85] Vermaas, 4.

[86] In the American context, the cultural norm of individuality and hero worship can work directly against the social creation suggested by Engineering Design Theories, which developed both in Germany and England before the United States. The continual reliance of the United States upon singular actors is sustainable only when those actors are supported by a team of well educated designers. This is the center of Dimarco's argument for an American General Staff. Louis A. Dimarco, "The U.S. Army General Staff: Where is it in the Twenty-First Century?" 2.

calling into question the idea of a 'finished product' as well as challenging traditional norms governing 'ownership'.[87] The analogy to military design is direct, the subordinate units will contribute to the design, implicitly and explicitly, and as a design moves through a military unit it will necessarily be altered, changed, improved, and translated.

There is some evidence to support the designer as a lone-operator is an effective model.[88] Jones calls this the "Designer as a Black Box" or alternatively – the designer as a magician. Central to successful theories of a lone operator is that the moment of insight is never explainable, and can only be linked to experience, judgment, and genius. Holding to those assertions, the lone operator theorist can argue that all design insight is in fact personal insight, and transcends rational analysis. Jones summarizes this reliance on the "magic" of design when he stated, "It is therefore rational to believe that skilled actions are unconsciously controlled and irrational to expect designing to be wholly capable of rational explanation."[89] The results of a sole author design are generally heavily influenced by recent inputs and past experiences, are rapid but more random than group work, rely on a 'leap of insight', and can be directed by controlling the information flow to the author. This understanding of the designer as a single person is pervasive in the traditional military, which relies on the creativity and experience of the commander to guide the organization.

Using a sole author design has its own methodology, methods, and attributes. The methods of brainstorming and synectics are the most influential in advising a sole author designer. If the Army chooses to accept a more commander centric interpretation of design, which is not the recommendation of this paper, then as an organization the Army should study the "Black Box" methodologies of design theory. These methodologies allow a single author to deal with complexity in an adequate manner, and

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[87] Bucciarelli, *Engineering Philosophy*, 4.

[88] Jones, *Design Methods*, 47. This model is supported by Osborn (1963), Gordon (1961), Matchett (1968), and Broadbent (1966).

[89] Jones, *Design Methods*, 46.

the theories involved rely heavily on architectural theory and the cognitive examination implicit within SOD.

The "Black Box" idea contrasts directly with the "Glass Box" method, which presents the designers mind as a transparent system, open to determinate rational explanation for each cognitive step of design.[90] This is a rational explanation of the design process, which with specific steps and various methodologies proposes that design has normal cognitive phases. The Glass Box method allows for the design process to be split into cognitive segments, worked in parallel or series, and for the solution to be assembled by a group working with a methodology. This is a fixed mechanistic view of design, and was commonly expressed in the 1960's as a progression from objectives, to analysis, to evaluation, and then to strategy formulation.[91]

Drawing on the lone-operating designer as a creative magician as the thesis, and the design team as a transparent group of linked computers as the anti-thesis, the design team as a self-organizing organism serves as the synthesis. The development of merging these two design philosophies occurred in the 1980's, and became known as Engineering Design Theory. Jones calls this the strategy control method – in which the team leader loosely controls the creative methodology through requirements for production. This model leads to a very loose heuristic methodology that roughly describes a designer's cognitive pattern beyond magic, but focuses on social interaction and the need to think, learn, and act in groups to solve complex problems.

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[90] Ibid, 48-50.

[91] Understanding design as an exercise in mathematical instrumentation, according to Bucciarelli, "is a mistake. It fails to acknowledge that designing is a social process of negotiation, of interaction, of rectifying mis-steps, even misconceptions – a process rich in ambiguity and uncertainty". The rational examination of social cognition into a formulaic system is the goal of Glass Box design theorists. This is very reminiscent of MDMP. Bucciarelli, *Engineering Philosophy*, 32.

Bounded Rationality

Engineering Philosophy incorporates the bounded rationality that must be central to social design and military design. In his book, *Engineering Philosophy*, Louis Bucciarelli clearly illustrates the social connection between engineering design and social or military design. He states that all designed products are subject to:

> "unanticipated interaction among the design contributions of participants from different object worlds. It is this fundamental feature of designing which both makes engineering the challenge that it is and denies the possibility of achieving technical perfection. It also reveals the naiveté of viewing engineering design as the straight forward, rational application of science"[92]

It is the intensely social interaction between the user, sponsor, competition, designers, and several other parties that ensure that the form, function and use of the designed artifact will never be certain.[93] A clear example is the necessary but mundane design of a simple towel rack, which, if installed upside-down, will not hang and will most likely break. The impetus for ensuring that the towel rack is only installed the correct way lies with the engineer – who is humorously unable to create a product that is user-proof. The point is that even the best engineers truly do not know how their product will perform, or be utilized by society.[94] However, the engineer must have a theory that is relatively predictable, because he is bound to create despite the fact that he is dealing with imperfect knowledge and acting in a social system.[95] This balance between knowing and understanding uncertainty is at the center of bounded

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[92] Ibid, pg 28.

[93] Lawson proposes a descriptive model of design problems in his book *How Designers think: Demystifying the design process*, which comprehensively addresses parties and interests involved in design. He defines the key actors as Clients, Users, Designers, and Legislators. These parties generate a series of interacting design constraints, which help define the design and determine if it will be an intentional or unintentional design. Lawson's model translates easily into the military context. The Client is the equivalent of a strategic sponsor – users are the units which will execute the design, practical constraints are the logistics and physical constraints, radical constraints are the campaign designers passion and philosophy of design, the formal constraints are doctrine and institutional knowledge, and the symbolic constraints would be the strategic communications ramifications of the design.

[94] Bucciarelli, *Engineering Philosophy*, 32.

[95] Ibid, 71. Bucciarelli goes on to explain that "engineers in the main, out in the big world, make use of existing theory and methods in the explanation of how their alternative designs will behave in particular settings." This is in sharp contrast to science, and is central to engineering philosophy.

rationality, of the concept of entropy from the second law of thermodynamics, and is the philosophy behind an understanding of stochastic thinking.

An enormous part of understanding the morphology of engineering design is to understand the philosophy of stochastic thinking. In probability theory, stochastic is the antithesis to the deterministic. However, in every stochastic probability there are fixed and known factors based on causal and empirical calculations. Therefore, a stochastic understanding is not indeterminate, but is the synthesis between deterministic and indeterminate.[96] It is a balance between causal theory and chaos theory. Central to the need for stochastic thinking is the admission of bounded rationality in the design of socio-technical systems.

In a recent article on engineering philosophy, theorist Ulrich Krohs discussed social systems design. He states, "Different bodies attempt to design social systems. Among them are governments, political parties, media, and economic enterprises, and at the level of individuals: politicians, journalists, businessmen, and also proponents and followers of theories of Social Systems Design."[97] One might easily add military campaign designers to this list, although they are rarely educated in either social systems design or multi-disciplinary design theory.

A social design is necessarily complex.[98] A social-technical design is stochastic. A great example would be the design of a coal mine or an airport. This is an intentional and deterministic design

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[96] A stochastic view is rooted in Western philosophy, so recently criticized by Francis Julien and others. The root of a stochastic understanding still relies on the Western heroic ability to causally affect the future, within limitations. This is not to be confused with Julien's view of eastern philosophy of harmonizing with an uncontrolled future and harnessing the flow of forces toward a "better" and diverting forces flowing toward a "worse" future. See Francois Julien, *A Treatise on Efficacy: Between Western and Chinese Thinking* (Honolulu: University of Hawaii Press, 2004). The alignment of this recommended morphology with the cultural, linguistic and intellectual heritage of nearly every reader and the western world is deliberate.

[97] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 233.

[98] Richard Buchanan, in his article *Wicked Problems in Design Think*ing, posits that there are four broad areas of design. 1. Symbolic and visual communications or graphic design, 2. The design of material objects, 3. The design of activities or organized services, expressed here socio-technical design, and the design of complex systems or environments, or fully social design. Each of these broad areas has accompanying theory and philosophy.

with a structured human component involved. Unlike social design, such systems are partially predictable and partially complex. As Krohs states, "The structure of a socio-technical system and the functions of its components may come quite *close* to what was intended by those who had designed it"[99] Close, but not exact, is the admission of every engineer of a socio-technical system. There are deterministic components and indeterminist components in every stochastic design that go beyond factors of safety in their inclusion of the human element. Jones demonstrates the complexity of all design when he stated, "The fundamental problem is that designers are obliged to use current information to predict a future state that will not come about unless their predictions are correct."[100] This is compounded in every engineering design with the knowledge that the designers own interaction and their impact on the system cannot be accurately predicted.

A stochastic approach creates inherent flexibility. Lawson illustrates this point by comparing Christopher Alexander's architectural morphology with that of the famous structuralist and design theorist, Herman Hertzberger. In short, Alexander's design methodology consists of breaking the problem down into its constituent parts, and then serving functions and letting form follow. However, Hertzberger "actually advocates a more integrated approach where ambiguity and multiplicity of function are deliberately designed into objects."[101] He shows, for example, in a housing scheme, a simple concrete form outside each dwelling can carry a house number, serve to house a light fitting, act as a stand for milk bottles, offer a place to sit, or even act as a table for an outdoor meal".[102] This understanding of the user interpretation of function, so characteristic in computer engineering, is further articulated by RA Meier's Affordance theory. Engineering language captures this difference between user function and intended function. A designed function is the *function* of an artifact, and the emerging function is the *functionality*

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[99] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 235.

[100] Jones, *Design Methods*, 9.

[101] Hermann Hertzberger, *Looking for the beach under the pavement*. (RIBA Journal 78:1971) 8.

[102] Lawson, *How Designers Think*, 164.

of an artifact.[103] The Army's Joint Security Stations (JSS) in Iraq are a good military example of a design with functionality. A well-placed JSS can serve as an intelligence collection point, meeting point, logistics node, medical evacuation node, and serve a variety of functions that are affordances of the intended function. As engineering design theorist Maarten Frannsen writes, "What an artifact is for generally depends both on what it was designed for and on what it is being used for."[104] This is the admission that use and design are ontologically differentiating. The divorce from precisely determining function is another illustration of the strength of bounded rationality.

What the engineer's understanding of bounded rationality offers is the ability to consider complexity without being blinded into inaction. Full knowledge stands opposite to chaos, and disorder and order are loosely measurable through entropy. It is precise to say loosely measureable, because the concept of noise makes any representation slightly inaccurate. Knowing that chaos can derail any design, and that even order contains the uncertainty of noise and representation, the engineer seeks to act and create. The engineer's mandate to create drives him to a design which is not ignorant or blind to complexity, is taken with conservative humility, and is ultimately an act of faith.

Tied to Competitive Creation

"The scientist carries through his observation and correlation of natural phenomena; the technician relies on his handbook of standardized procedure; but the engineer must create, to satisfy society's need, those things which have never existed before."[105] *– Newman A. Hall – Design Theorist.*

Unique among design research and theory, engineering design seeks to *create* in a competitive environment that is analogous to military design. Unlike art or architecture, the engineer is not creating a one-of a kind masterpiece, which the viewer may admire for its own artistic uniqueness. The engineer is

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[103] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 302.

[104] Ibid, 22.

[105] Quoted in Woodson, *Introduction to Engineering Design*, pg i.

designing to achieve something, which may be achieved by peer designs, or undone by interfering designs. The CAC-D pamphlet is inaccurate and unhelpful when it contrasts engineering and architecture philosophy.[106] The intellectual propaganda that engineering and design are separate fields distracts the military emergence of design from examining the rich and well-developed field of Engineering Design Theory. In contrast, Morris Asimow states, "Design is the essential purpose of engineering. It begins with the recognition of a need and the conception of an idea to meet this need."[107] Engineering design philosophy is clearly design, but differs from that of art design, fashion design, architectural design, or program design. Dr. Thomas Woodson states, "Certainly engineering is more than design, but many believe that design is the essential, unique hallmark of that profession."[108] The CAC-D manual uses the art vs. science dichotomy to define engineers and scientists against artists and architects. However, an early engineering philosopher from the last century, Theodore Von Karman, stated "Scientists discover the world that exists; engineers create the world that never was"[109] The point of clarifying the difference between scientists and engineers is that one is tied to the creation of theory, and the other the creation of reality. This fundamental difference is analogous to the development of academic design theory and the understanding of design in industry.

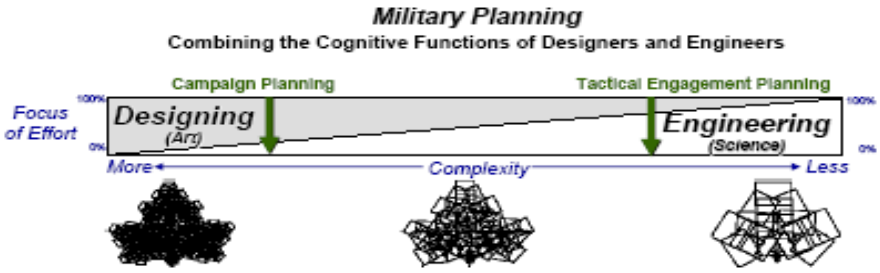

Figure 1 – Diagram from TRADOC 525-5-500 is in direct conflict with numerous design theorists. "Design is the essential purpose of engineering" – Asimow, 1962

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[106] TRADOC Pamphlet 525-5-500, Commander's Appreciation and Campaign Design, V1.0, 28 Jan 2008. 13.

[107] Morris Asimow, *Introduction to Design*, Foreword.

[108] Woodson, *Introduction to Design*, vi.

[109] Bucciarelli, *Engineering Philosophy*, 1.

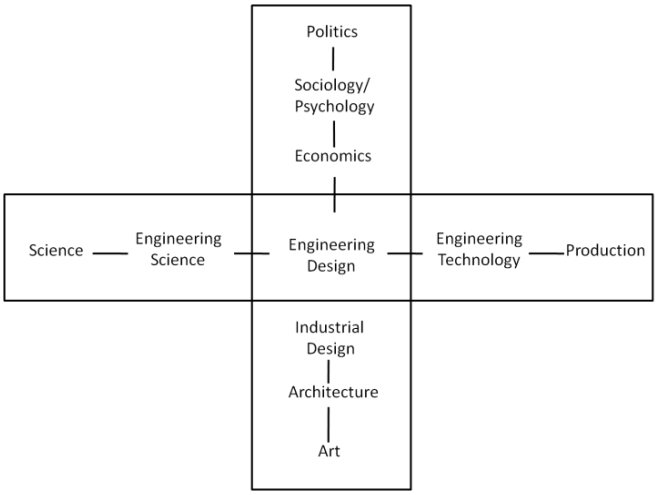

Figure 2- Design as a central discipline – Pahl and Bietz[110]

Military campaign design is one form of design. The field of Military Art and Science is named in a way that brackets the essence of the issue, as campaign planning falls between those two poles. Energetic pursuit of either pole will distract the process, as both divergent and convergent thinking are required to design. Isaac Azimov's addressed the ongoing struggle between creative and mechanistic thinking when he stated:

> "How often people speak of art and science as though they were two entirely different things, with no interconnection. An artist is emotional, they think, and uses only his intuition; he sees all at once and has no need of reason. A scientist is cold, they think, and uses only his reason; he argues carefully step by step, and needs no imagination. That is all wrong. The true artist is quite rational as well as imaginative and knows what he is doing; if he does not, his art suffers. The true scientist is quite imaginative as well as rational, and sometimes leaps to solutions where reason can follow only slowly; if he does not, his science suffers."[111]

Morris Asimow was one of the first to draft an engineering philosophy, in the 1960's, which would become the basis for engineering design theory in the 1980's. Unfortunately, there is hesitancy to put the words "engineering" and "philosophy" together. Culturally, engineering is characterized to represent structured thinking and mechanistic reason, and philosophy to represent free and unbounded

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[110] Pahl and Bietz, *Engineering Design*, 2.

[111] Isaac Asimov, "*The Roving Mind*" (1983) Chapter 25.

thinking. This is unfortunate and incorrect. [112] Engineering and military design are both centrally placed on the spectrum of design and both intertwined with society in a complex manner. So the demand on the engineer and the campaign designer are analogous. To further the analogy, in both engineering and military campaigns, the requirement to get it right the first time is of mortal significance. As Woodson states "one fallen bridge or building, one spacecraft abortion, or one chronic shaft failure in an auto – any of those, regardless of the reasons, has a direct and serious impact."[113] Both engineering and military campaigning must create a change, and do so in a competitive environment that is as unforgiving as it is complex.

Engineering is design, and the theories and philosophies that underlie engineering design are very similar on the spectrum of design philosophies to those of military campaign design. These two fields are neither art nor science, and their social embodiment is as implicit as their need to produce an artifact. Both are tied to the need to create in a high-stakes environment, competitively, and with an understanding of the risks involved.

Risk and Safety

"Thus even innocent-appearing numerical information hides some quicksand of uncertainty, requiring the engineer to use caution and judgment."[114] *- Woodson*

The Factor of Safety is the traditional expression of the stochastic nature of engineering. Factor of safety is a pedantic and decidedly un-academic word, with merely two syllables per noun. However, in the engineering world, the inclusion of a Factor of Safety is a critical philosophical admission that

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[112] Bernhard Reider at the Paris VIII University, in a recent article titled *Beyond Engineering*, stated "the term 'engineering' has come to stand for the technocratic separation between a sphere of technology and a sphere of culture, society and politics; for a mindset that treats the creation of technical artifacts as a detached and orderly process, closer to calculation than creativity. This is a false understanding." Vermaas, *Philosophy and Design: From Engineering to Architecture*, 170.

[113] Thomas T. Woodson, *Introduction to Engineering Design*, 57.

[114] Ibid, 48.

knowledge differs from reality. It is similar to simple redundancy, but different in operation. Factor of Safety is an algorithmic confirmation of an innate understanding of complexity, which is over two centuries old. When an engineer designs a simple, intentional and straightforward project, he uses a factor of safety. An example might be the design of the thickness of asphalt on a road in Kansas. After all the calculations are complete, rigorous soil samples taken, and detail design applied, the function requirement is multiplied by a factor of safety. In everyday engineering practice, this amounts to between 150-200%. The engineer is aware that he is uncertain about the exact composition of the soil, the interaction of the molecular lattice, the compounding Lorenz affect of uncertain stress and strain, and even the weather that will challenge his creation.[115] Essentially, most designing engineers are aware that they will never have perfect knowledge or understanding. They are also aware that affordance theory means his *form*, in the future, may not be used for its currently designed *function*. The designer is aware, at that point, of the difference between the mathematical re-presentation and reality. It goes beyond a philosophical footnote, when a building like the Empire State Building is constructed with nearly a 220% factor of safety, the cost to the sponsor is in the billions. When dealing with mortal situations, the designer must make cautious recommendations to his sponsor, which reflects an understanding of what is known and with enough safety to deal with what is unknown.

Naveh derides this as "simply applying mass to confront complexity", but in a symmetric environment, facing a lethal and complex system, that is exactly what designers from Clausewitz to Svechin recommend.[116] The counterpoint to Naveh's assertion is that stochastic design does not simply apply mass to confront complexity. It is the understanding of stochastic philosophy, and the prediction or

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[115] Lorenz is the author of the oft-quoted "Butterfly Effect" in weather, which applies to any complex and compounding system.

[116] Naveh, Shimon, *In Pursuit of Military Excellence*, 44. Naveh argues that Clausewitz' arguments are a cognitive regression that centers around the principle "of applying it to the increasing aspects of mass". Clausewitz does explicate the use of mass successfully, although not in the central manner that Naveh argues. On War, Book I-Chapter 3 and 5 both deal successfully with the application of mass to meet the enemy. Svechin's argument that "quantity has a quality all its own" is widely known and appears in A.A. Svechin's notes on Strategiia, 1927, in Kadishev, *Voprosy Strategii*, p 220.

emergence of affordance functions, combined with appropriate mass, which allows a good design to overcome both complexity and friction. The understanding of bounded rationality expressed as factors of safety is a concept germane to design, to military operations, and founded in stochastic engineering philosophy.

The understanding of risk and safety greatly informed the philosophy and practice of engineering design in the latter half of the last century. The modern focus on mechanical solutions and determinate optimization of a design became incomplete and at least partially obsolete as a new understanding of complexity informed design. In a recent article on engineering theory, Kiyotaka Naoe expressed the philosophy behind factors of safety when she wrote "since the situations with which risk analysis is concerned are complicated in nature and involve uncertainty to some extent, a complete optimization of technology cannot be expected and rationality of risk analysis must correspond to 'bounded rationality.'"[117] Such "bounded rationality" is at the center of a stochastic understanding and therefore risk, and informs the way engineer designers view the world. A deliberate understanding of risk in design, unfamiliar to other design philosophies, is central to both military design and engineering design theory.

Intentional vs. Unintentional design.

There is a very contemporary debate among design philosophers about the usefulness of understanding design as intentional verses unintentional.[118] Architecture is nearly exclusively intentional due to singular authorship and relatively few constraints or social requirements in design function. Two variables define intentional verses unintentional design. The first is independence, or ability to create an unconstrained vision, and the other is reflexiveness. In intentional design, the designer has a great and

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[117] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 119.

[118] Ibid, 106-108 – Article by Patrick Feng and Andrew Feeberg from 2007.

powerful role to craft his vision and then ensure it is carried through.[119] In unintentional design, the constraints of the other players are so constricting that the design is a foregone conclusion. Reflexiveness refers to the level of self-consciousness of the designer. Craftsmen and early military leaders were the least self-conscious, and academic design theorists and highly self aware staffs being the most self-conscious.[120] Awareness of intentionality of design will help bridge the cognitive space between designing and planning in the military context. Moving design from a commander centric process to a social activity increases the reflexiveness. A good design team leader should understand and be able to fine tune the reflexiveness of a design.

Patrick Feng, a contemporary design theorist, further clarified the difference by defining strong intentionality and weak intentionality.[121] Strong intentionality is the common vision of the designer shaping the world, and advising those above, below, and adjacent with their brilliant design. Weak intentionality is the admission that the designer is severely constrained and that those that affect the design are themselves constrained by economic, political, institutional, social and cultural norms.[122] This development is critical for military designers to understand the context of their creations with reference to their own system's constraints, before examining those of the setting or the enemy. The extreme views are that of the heroic designer on one hand, and the designer subjected to intertwining complexity which means that he cannot change anything on the other. In either paradigm, this discussion in recent engineering philosophy relates directly to the philosophical context of military campaign designers. This is another example where knowledge of contemporary design theory contributes to understanding.

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[119] Lawson identifies the same dilemma, and states "The amount of purely expressionistic thinking that may take place is largely a function of the degree to which there is room for designer generated constraints." Lawson, *How Designers Think*, 141.

[120] Bucciarelli, *Engineering Philosophy*, 6, footnote. Bucciarelli illustrates the second variable by drawing a dialectic between the reflexive movements of a pianist or carpenter, and the self-reflective motions of a designer

[121] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 105.

[122]Ibid, 106-108.

Intentionality illuminates another spectrum of variables in problems beyond those of complex or complicated, beyond ill or well structured, and beyond those of designing or planning.

Methodology in Design

"In short: methodology should not be a fixed track to a fixed destination but a conversation about everything that could be made to happen."[123] *– Jones.*

One clear characteristic of engineering design theory is the desire to discuss methodology. This is a reflection of the social nature of engineering design theory, and the focus on the design team instead of the sole author. Because design must produce something other than a new frame of mind, methodologies are important. Nearly every theory of design discussed in this monograph has an element of methodology of proceeding from inception to creation. The appropriateness of a design 'process' is a debate that flows like a pendulum through the recorded discussions of many design theorists. Understanding the methodology of design is commonly a matter of scale. At some level, there is a logical progression of things that must occur during design and a commonality of action and cognition. For example, designers will commonly make some markings, drawings, or record of their progress. Designs will proceed from an inception, to a completion. Adjusting the scale of analysis for design allows the honest analyst to pull out common features in cognition and philosophy. BG Wass de Czege supports the idea of design commonality when he stated, "All people individually reason informally in similar fashion, consciously or not."[124] The extreme follower of this is design theorist Sydney Gregory, who wrote in 1966 "The process of design is the same whether it deals with the design of a new oil refinery, the construction of a cathedral, or the writing of Dante's Divine Comedy."[125]

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[123] Jones, *Design Methods*, 73.

[124] Huba Wass de Czege, "Systemic Operational Design: Learning and Adapting in Complex Missions", 9.

[125] Sydney Gregory, quoted in Lawson, *How Designers Think*, 32.

Whether the design need is open or constrained, the team nature of engineering design requires a mutual understanding of the process and outcomes.[126] Jones explained his early attempt at methodology when he stated that the purpose of his book *Design Methods* "is to explore some first attempts at permitting many brains, rather than one, to grasp, and to explore, the complexities of designing."[127] It is the social nature of design that drives development of a cognitive similarity on how to approach the process. The explication of a methodology is intentionally descriptive, or as Jones states, an attempt to "make explicit what goes on in designer's heads, to externalize design."[128] Lack of a common understanding will naturally force the design team to engage cognitively the process instead of the problem. However, Pahl and Beitz note:

> "Systematic procedures help to render designing comprehensible and also enable the subject to be taught. However, what is learned and recognized about design methodology should not be taken as so many dogmas. Systematic procedures merely try to steer the efforts of designers from unconscious into conscious and more purposeful paths. As a result, when they collaborate with other engineers, designers will not merely be holding their own, but will be able to take the lead."[129]

At times, divergent thinking will engage the process itself in a healthy manner, but strict reliance on an absence of methodology will detract from creative performance.

It is integral to all design philosophy that creation of any methodology is preceded by a great deal of skepticism.[130]However, teaching a design team that there are multiple methods, each with a developed history, is part of enhancing design flexibility.[131] In his book in the 1960's, Woodson includes the chart below to illustrate commonalities of methodologies and "to allow the engineer to make a composite suited

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[126] Ibid, 258.

[127] Jones, *Design Methods*, 10.

[128] Ibid, 46.

[129] Pahl and Bietz, *Engineering Design*, 10.

[130] As Jones states, "one should not expect the invisible but troublesome barriers between professions and between disciplines to be removed by methodology alone." Jones, *Design Methods*, xii.

[131] Lawson states "The writings of practitioners confirm the view that there is not one route through the design process, but many." Lawson, *How Designers Think*, 182.

to his tasks."[132] He adds that any of these outlines are "not a cookbook recipe to be slavishly followed." Such mental agility is admirable and suits experienced practitioners of design.

Engineering Design (Jones)	Design Process (Asimow)	Thought Process (Wallas)	Professional Method (Ver Planck and Teare)	Engineering Method (Traditional)	Scientific Method (GE)	Law (Ballantine)	Management (GE)	MDMP	SOD
Divergence	Analysis	Preparation	Define Problem	Preliminary Analysis	Collect Facts	Reject Irrelevant Material	Plan	Receive Mission	Systems Framing
	Synthesis	Incubation	Plan Treatment	Statement of Question	Develop Hypothesis	Translate	Organize	Mission Analysis	Rival as Rationale
Transformation	Evaluation	Illumination			Design and conduct experiment	Restate	Integrate	COA Dev.	Command as Rational
	Decision		Execute Plan	Solution	Revise Hypothesis		Measure	COA Analysis	Logistics as Rational
	Optimization		Check as a Whole			State Legal Issues		COA Comparison	Operations Framing
Convergence	Revision	Elaboration	Learn and Generalize	Check	Develop Thoeries			COA Approval	Operational Conditions
	Implementation			Interpretation	Prove Theories			Orders Production	Forces and Functions

133

Asimow's design methodology was one of the first in engineering design theory. His methodology proceeds from a study of problem feasibility, to a preliminary design, and then to the more detailed design that later authors would refer to as planning.[134] This early model was only loosely useable, and was modified in the following years when Asimow worked with Woodson to develop the analysis, synthesis, evaluation model that became common in engineering design practice.[135] By the 1980's, Pahl

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[132] Woodson, *Introduction to Engineering Design*, 23-31.

[133] Chart is from Woodson, *Introduction to Engineering Design*, 22.

[134] Asimow, *Introduction to Design*, 19. This early morphology's phases are instructive. The feasibility study was an eight step model to determine whether the organization should pursue design, planning, or no action based on a synthesis of possible solutions. The Preliminary design started with a design concept (no transformative stage) and began to converge based on systems testing method (below) and predictive analysis. This then proceeded into detailed design, which 40 years later would be referred to as planning.

[135] Ibid, 42. Asimow came to understand that a three phase process of Understanding the problem (divergence), identifying some solution concepts (transformation) and then refining to a solution (convergence) was the "process of design". This would be explicated more clearly by Jones in the 1970's.

and Bietz would alter the traditional model to be analysis, abstraction, and synthesis. This methodology relates nearly to the Jones methodology used in this paper – developed around the same time, which is divergence, transformation, and convergence.

The characteristics of an engineering philosophy are imminently useful to the practitioner wishing to conceive of the philosophy of design. These characteristics are best demonstrated through the discussion of one of the methodologies of design. Christopher Jones descriptive design model is one of the most comprehensive, and clearly explicates the different cognitive phases required to prosecute a successful design.

An Engineering Methodology

"To regard thinking as a skill rather than a gift is the first step toward doing something to improve that skill."[136]*- Lawson*

Acceptance of Engineering Philosophy and application of that philosophy to a methodology allows consideration of the engineer's descriptive design methodologies. The most appropriate descriptive methodology is Jones's. An understanding of the theoretical and intellectual background of design can be illustrated using descriptive design methodologies, which educate the military designer enough to incorporate a flexible design strategy.

Colonel Banach, in an address to SAMS Students, stated that the designer must bring to each problem a theoretical toolbox ready to create designs.[137] While this is true, the theories in the toolbox must be creative and directed toward some purpose, not simply descriptive. For example, a theoretical toolbox filled with political science theory and historical evidence will be incomplete for use in the act of

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[136] Edward de Bono, *Practical Thinking*, quoted in Lawson, *How Designers Think*, 1.

[137] COL Banach, address to students, on 5 Dec. Colonel Banach was commenting on a design brief given by the Unified Quest (UQ) seminar from SAMS 08-02, in which the briefer described applying multiple political science theories to the creation of a military design for UQ. Colonel Stephen Banach was the director of SAMS at the time.

prescriptive creation. To fill this need, one should be ready to adapt multiple methodologies, and to understand the academic underpinnings of each methodology. Jones "descriptive skeleton" is useful in order to understand multiple methodologies. This skeleton consists of divergent thinking, transformative thinking, and convergent thinking. BG Wass de Czege mirrors this methodology in his discussion of meta-questioning, creation of strategic logic, and then concept narrowing.[138]

Jones' descriptive methodology explains the cognitive modes that a design team must engage to successfully *create*. These cognitive modes have a rough parallel in the US Army's current Art of Design, as expressed in FMI 5-2. This recent FMI proposes a design methodology which moves from the environmental space, to the problem space, and finally into the solution space.[139] Jones' methodology recommends a cognitive stance for each one of those phases of design which adequately deals with each difficult portion. Using this one widely accepted paradigm allows comparative analysis of other design methodologies.

Divergence

"Reality is itself a combination of determinisms, and freedom consists in overcoming and transcending these determinisms"[140] *– Jaques Ellul*

"There are 100 ways to solve any problem, identify them all before you proceed" – Richard Bullock – 3rd Generation Engineer

The divergent phase dominates the inception of a design. This phase is characterized by meta-questioning, expansion of knowledge and understanding, and the application of post-structuralist philosophy. In this divergent phase, it is important not to limit the expertise referenced to the field that

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[138] Wass de Czege, "Systemic Operational Design: Learning and Adapting in Complex Missions", 10.

[139] FMI 5-2 (draft), *Design*, 20 Feb 2009, 18.

[140] Quoted in Jones, *Design Methods*, 73.

seems most applicable.[141] Divergent thinking is especially useful when the sponsor inappropriately or narrowly defines the given problem. In the military context, this often occurs during contingency planning. Contingency planning in emergencies are often driven to fix immediate problems, when divergent analysis may show deeper requirements. Woodson's discussion in his early work *Engineering Design* demonstrates the use of divergent thinking to military practitioners:

> "Solutions to problems situations come to mind through understanding, not simply by the superficial or fortuitous fitting of a few facts together . . . Such insight or understanding comes from deep penetration and an encompassing of the many aspects and facets of the original situation. Desirable solutions come more from the application of persistence than flash, of care than energy, of wisdom than wit."[142]

Jones defines the divergent phase with a series of characteristics, which are important to note, if not comprehensive.[143]

> "a. The objectives are unstable and tentative
>
> b. The problem boundary is unstable and undefined
>
> c. Evaluation is deferred: nothing is disregarded if it seems to be relevant to the problem however much it may conflict with anything else.
>
> d. The sponsor's brief (directive) is treated as a starting point for investigation and is expected to be revised, or evolved, during divergent search, and possible at later stages as well (but not without the sponsor's agreement).
>
> e. The aim of the designers is to deliberately increase their uncertainty, to rid themselves of preconceived solutions, and to reprogramme their brains with a mass of information that is thought to be relevant.
>
> f. One objective of research carried out at this stage is to test the sensitivity of such important elements as sponsors, users . . . to the consequences of shifting objectives and problem boundaries in many directions and to varying degrees."

It is vital to realize that divergence is not all of design, but simply the necessary first cognitive phase of design. The deliberate increasing of uncertainty is only useful in a certain context, until

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[141] In fact, the inclusion of multiple disciplines and organizations will often aid the divergent phase of design. Lawson notes, "It is interesting that some of the most famous inventions of modern times were made by people who had not been specifically trained to work in the field in which they made their contribution". Lawson, *How Designers Think*, 10.

[142] Woodson, *Introduction to Engineering Design*, 23.

[143] Jones, *Design Methods*, 64.

transformation and then convergence take primacy in the designs cognitive balance. The thesis of divergent design is that "designers may have quite a lot of unlearning to do before they can maintain the detachment, flexibility, and breadth of view that is appropriate *before* design decisions are taken and *before* it is wise to get involved in anything approaching a cut-and-dried solution."[144] However, even in divergence, there must be a structure to the learning, to avoid cost and time overruns. [145] It is the responsibility of the design team leader to structure the divergence and guide the learning in a productive direction. The synthesis of a. the religion of postmodern unlearning and b. a rigid research structure on a schedule is c. a healthy divergent design phase:

> "In short it can be said that the aim of divergent search is to de-structure, the original brief while identifying these features of the design situation that will permit a valuable and feasible degree of change. To search divergently is also to provide, as cheaply and quickly as possible, sufficient new experience to counteract any false assumptions that the design team members, and the sponsors, held at the start."[146]

Woodson informs this discussion with his early work on structuring information gathering as part of conventional design methodology.[147] Because the designer will never have all the information desired, moving through the divergent phase is in many respects a period of simple research. The designers lexicon of information proceeds from facts, to data, to unorganized knowledge, and finally to understanding. Within this construct, the designer's problems with information are: Where can I find it? How can I get it? Can I believe it? How do I interpret it? Is it enough? Each piece of required information

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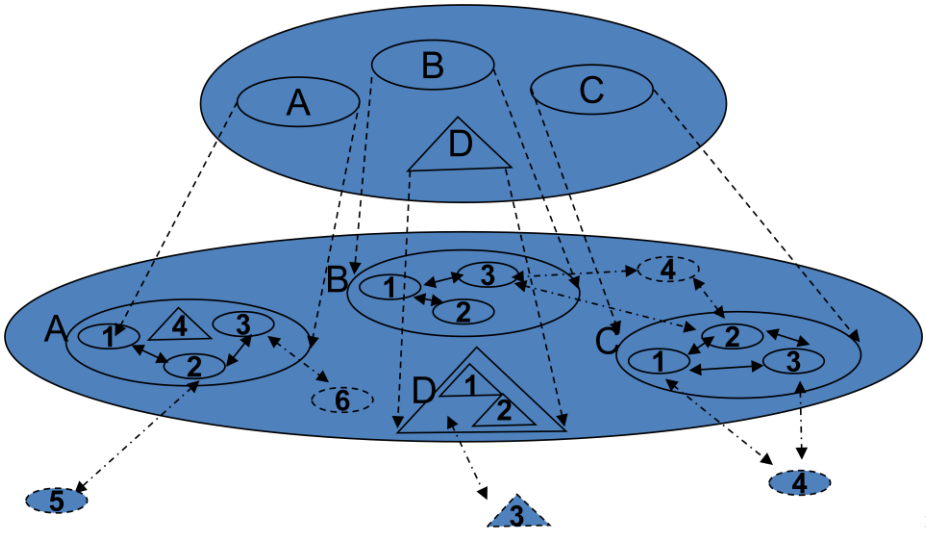
[144] Jones, *Design Methods*, 65.

[145] Jones notes that divergence must be controlled by the design team leader, he states "the costs of this kind of pre-design work (time, man-hours, money) can easily get out of control. It is essential to anchor the work to realistic judgments of the magnitude of the penalties for not collecting information. It is equally necessary to direct a proportion of the search cost to the business of guiding the search rather than carrying it out." Ibid, 65.

[146] Ibid, 66.

[147] Woodson divines four rules for information in design which are appropriate for consideration by the practitioner: 1. A small amount is available at the outset, but it is never complete, much more is necessary, but what to seek is not then known, 2. Time is required to find out what else to search for, and more time is required to find it, 3. Information items offered are frequently conflicting; also much of it is not necessary or useful, and finally 4. Information costs time and money to obtain.[147] The last rule is important, for even military campaign designers should constantly remember that for the unit, design is a cost-benefit exercise that can rarely afford long periods without productive creation. Woodson, *Introduction to Engineering Design*, 41-42.

has the characteristics of availability, accessibility, credibility, meaning, sufficiency.[148] One of the most important decisions for a designer in a time-constrained environment is to decide when enough information is enough. The designer must understand that information has a cost.



[149]

Figure 3 - An Example of Research Divergence, topics expanding to subtopics

Divergence is critical to design – to remembering that there is always more information available and relevant than the design team can consider. This is an admission that the image of reality crafted by the design team constantly requires destruction, more information, and recreation. The product of the divergent phase is an understanding of the system which will interact with the design, and a tentative understanding of the difference between the desired system and the existing system. In short, the product is an understanding of the problem, and tentative feelings about possible solutions.

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[148] Ibid, 41.

[149] This research tree created by MAJ Derek Jones during SAMS AY2009, to aid in his Seminar's study of the operational environment. The diagram depicts initial subjects, A, B, C, and D which when researched led to further subjects 1, 2, 3, 4. The diagram demonstrates visually how design research and function exploration are inherently divergent. As an example, a design team studying South Korea may disaggregate the study into groups examining politics, the military, the people, and the economy. The group studying politics would then find multiple parties to study, requiring further disaggregation.

Transformation

"The artistic approach is relevant when designers have to find their way through a vast number of alternatives while searching for a new and consistent pattern upon which to base their decisions. On these occasions it is necessary to operate at the speed of thought upon a quickly responding medium, or analogue (of reality), that represents the form of the problem." Jones[150]

The transformative stage is perhaps the most perplexing.[151] There are no shortcuts to genius and creative transformation. There are methods that focus on the study of thought to help create a productive transformation. If military design is a demand for competitive creativity, then serious designers should study creative thinking and the education and training of creative thinkers. The transformative phase starts with a mass of divergent information and unspoken concepts of solutions, and then contrasts these with the current problem understanding to determine possible outcomes.

Jones describes the characteristics of the transformation stage, which are rarely controlled but nearly always occur at some point in design:

> "The main objective is to impose upon the results of a divergent search, a pattern that is precise enough to permit convergence to a single design that must eventually be decided upon and fixed in every detail. The chosen pattern must reflect all the realities of the situation . . . deciding what to emphasize and what to overlook."[152]

This may include the definition of problem boundaries and identification of other known realities that may serve as generators for concept development. Design groups will often create sub-groups and sub-tasks if necessary, and the possible creation of specialized language to define sections of the problem, if necessary. The stage of harnessing a massive amount of divergent information and finding a spark of

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[150] Jones, *Design Methods*, 11.

[151] The transformative phase is referred to in traditional design literature as 'synthesis'. Woodson outlines the requirements of this phase preceding illumination. These are: "1. Preparation, the gathering of pertinent information; 2. Concentration, the digestion of all aspects of the problem,3. Incubation, relief or relaxation away from problem for some hours or days, and 4. Illumination: A rush of insight, relief and understanding about a solution." Woodson, *Introduction to Engineering Design*, 48.

[152] Jones, *Design Methods*, 67.

transformative brilliance is the most demanding on personal experience and competence. What the designers seek at this time is the Eureka moment.[153] After a period of analysis, incubation of thought is a common method to achieve such an insight. Lawson highlights the use of incubation by quoting a letter from Mozart, "When I am, as it were, completely myself, entirely alone, and of good cheer – say traveling in a carriage, or walking after a good meal, or during the night when I cannot sleep; it is on such occasions that my ideas flow best and most abundantly."[154]

When solutions are not forthcoming, the design team rests in a state of lacking resolution.[155]At this phase, experience and talent are critical to help the group move from the problem space to the solution space[156] through idea generation and transformative thinking. There are hosts of methods that are especially helpful when a design team is stuck in the transformative phase.[157] One such device is the "Generator" which is "used to narrow down the range of possible solutions, and the designer is then able to construct and analyze a scheme."[158] A constraint can commonly transform into a primary generating idea. Designs transformed through a generator are often easily understood and easily communicated. "Good design often seems to have only a very few dominating ideas which structure the scheme and around which the minor considerations are organized."[159] It is important to distinguish a generating idea used to transform a design from a convergent and reduced idea that explains the design. Both may be

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[153] Lawson, *How Designers Think*, 148.

[154] Quouted by Lawson, *How Designers Think*, 148.

[155] Lawson addresses this common cognitive phase when he states, "good designers tend to be at ease with their lack of resolution of their ideas for most of the design process. Designers seem to cope with this lack of resolution in two main ways: by the generation of alternatives and by using "parallel lines of thought" Ibid, 153.

[156] In 1995, Van Bakel invented the solution space based on a triangular morphology. The competing nodes of the triangle were the Program (brief), the concept (strategy), and the site (systems frame). Lawson, relates this to his client generated constraints, designer generated constraints, and external constraints. Whether or not Van Bakel's solution space creates a unique morphology, the understanding of a solution space is a critical addition to design philosophy.

[157] The few that are not social devices, but help internal cognition, will be listed here and the rest are considered "Design Tactics" for use in the methods section (Appendix 1).

[158] Lawson, *How Designers Think*, 46.

[159] Ibid, 189.

necessary. A generator is prescriptive and forward looking while a convergent concept is descriptive and coalesces the work of the design team. Convergent concepts are important, but belong in the next cognitive phase. The Anaconda Plan during the Civil War, and the Rainbow Plans driving the strategic planning of World War II are good examples of generators in the military context, driving campaign design. The design team must be careful not to turn a generator into a "Holy Grail" that becomes important beyond utility based on personal attachment.[160] A well-known example of a "Holy Grail" generator would be the Schlieffen plan of 1906 utilized by Germany in the opening stages of World War I.[161] Common sources of primary generators may be external constraints, guiding principles of the organization or the design, or identified issues crucial to the form of the design.[162] Teams may use multiple generators, or may focus on only one, and generators may be added or dropped as they find utility in molding creativity.

Another cognitive theory, which can be a device for transformation, is the phasing of thought developed by cognitive theorist Henry Poincare. In 1924 he introduced his four phases of thought, which state that after a stage of initial investigation there is a period of cognitive rest, followed by a solution idea stage, solution elaboration, and then verification and development. This important early methodology gives us another device for developing insight. This is reinforced by design theorist George Kneller and his similar five step model of thought. Kneller's steps for generating creativity in the transformative phase are is insight, preparation, incubation, illumination, and verification.[163]

Pahl and Bietz also work to illuminate intuition solutions as the seed of technological and creative development. The connection between military organizations and industrial companies relying on

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[160] Lawson, *How Designers Think*, 189.

[161] The Schlieffen plan was written for a different context, in a different time. However, the entire notion of the concept became a driver for German campaign planning despite its obsolescence. When the situation in Europe changed rapidly in 1914 – the plan remained despite the fact that the changes required major revision.

[162] Lawson, *How Designers Think*, 188.

[163] Ibid, 148.

designers is obvious – there is a demand for creativity. Pahl and Bietz describe the dilemma of requiring creativity on demand, which illustrates the military problem of reliance on the commander:

> "An industrial company should nevertheless beware of exclusive reliance on the intuition of its designers and its designers themselves should not leave everything to chance or rare inspiration. Purely intuitive methods have the following disadvantages: The right idea does not always come at the right time, since it cannot be forced, Current conventions and personal prejudices may inhibit original developments, Because of inadequate information, new technologies or procedures may fail to reach the consciousness of designers."

This highlights the danger of reliance upon genius and a single author. Heavy incorporation of commander-centric operations has the obvious weakness that it provides a single point of failure.

The product of this transformative phase should be a clear understanding of the problem, and an illumination and clear vision of a solution concept, without any details of the complete design. The solution concept, where it is lacking resolution, should contain "as many objectives, problem boundaries, identified variables, recognized constraints, opportunities to be taken, and judgments to be made" as is feasible.[164]

Convergence

"To the extent that designers need to know the present before they can predict the future, they need scientific doubt and the ability to set up and to observe the results of a controlled (or uncontrolled) experiment. But when they deal with the future itself, as opposed to the present, scientific doubt is of no use, and some other ingredient, nearer to religious faith, has to be employed" Jones.[165]

During the divergent and transformative phases, the design team will create many solutions, facts, understandings, and ideas.[166] However, not all of this good information can make it into the representation

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[164] Jones, *Design Methods*, 67.

[165] Ibid, 11.

[166] Pahl and Bietz, *Engineering Design*, 100. Jones also presents his main features of convergence, which comply with the spirit of Pahl and Bietz' reductionist analysis: "Persistence and rigidity of mind and method is a

of the design. Although it is painful, the convergent phase requires selection and evaluation of design information. BG (ret) Wass de Czege explains convergence with relation to current military design. He states:

> "Each of these separate exercises in expanding our relevant knowledge leads to more revision of the cognitive map and narrative of our understanding. Each further outlines and limits the scope and form of the intervention and thus outlines the "operating frame" – the frame of reference that actually shapes our thinking about operations. What remains is to narrow a broad theory of intervention down to the role of the command itself."[167]

Convergence contains two major components, idea or artifact elimination and idea or artifact preference.[168] There are a variety of methods to aid in either of these steps. Options range from a basic decision matrix to the sophisticated application of the commander's experienced opinion. The converging designer may use evaluation criteria, negativity searching, or simply evaluating which design contains the most uncertainty (knowing that they all contain uncertainty).[169] Whichever method the design team selects, they must make difficult decisions on which ideas and information requires representation and communication. They should also decide what they should record for later use, and what they should discard. Identifying whether to address, mitigate, reframe, sideline, or postpone addressing such issues is a leadership requirement during the convergent phase.

On the convergent end of this process, the cognitive boundaries are limited by the zone of tolerance of the situation.[170] The zone of tolerance is always a social construct, but is commonly the impetus of the design. Bucciarelli describes this phenomenon in engineering design when he discusses product failure "failure is a social construct. That is, whether an event is labeled a failure depends upon the beliefs, judgments, and claims of persons concerned with the event – claims which are taken seriously

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virtue: flexibility and vagueness are to be shunned (in process). The main objective is to reduce uncertainty as fast as possible". Jones, *Design Methods*, 11.

[167] Wass de Czege, "Systemic Operational Design: Learning and Adapting in Complex Missions", 11.

[168] Pahl and Bietz, *Engineering Design*, 102.

[169] Negativity searching is deliberately examining each aspect of the design looking for logical fallacies.

[170] Zones of tolerance are discussed by Hayward as the limits of possible solutions which are acceptable to the sponsor. Hayward, "Planning Beyond Tactics", 21.

by those responsible for the design".[171] The same perceived problem boundaries that may have initiated design can help in convergence. To be more clear, information and solutions should be disregarded or maintained based on their relevance to solving the problem in an acceptable manner. Ideas and information that assist in defining the problem or leading to solutions are relevant, and all other information can be filed for later use.

Lawson statement that "Designers express their ideas and work in a very visual and graphical kind of way" holds true for nearly every form of design in every discipline.[172] Rapid, precise creative expression commonly requires a visual depiction. The very requirement to create such a depiction demands convergence of thinking and creativity. One cannot usefully utilize a depiction of all the information derived from the divergent stage of design. Jones argues clearly that one-person drafts a cohesive visual depiction of the design – and that this presents a whole new set of challenges to both information flow and design management.[173] There is a requirement at this convergent stage, to communicate all the information of the design to the draughtsman's, typist, or slide-maker's mind. Alternatively, rejecting this single draughtsman theory, the design team must find a method to review each component design as a committee to ensure their coherence.

One important consideration on transition is the provision of one or many design solutions that will proceed into planning. The question of one or multiple solutions is a classic design debate. In the end, the resolution of this debate is a matter of scale. The use of Broadbent's method (described in Appendix 1) , US doctrinal parallel planning or alternative generation will all result in multiple possible solutions for any one design problem. However, all solutions will answer one cognitive tension. Hypothetically, a fictional design team might come up with four designs for defeating another nation by force of arms. Given the meta-question, "What shall we do about country X?", all the solutions point to a defeat by force

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[171] Bucciarelli, *Engineering Philosophy*, 28.

[172] Lawson, *How Designers Think*, 13.

[173] Jones, *Design Methods*, 22.

of arms. At the scale of national interaction, the team provided one solution, at the scale of military action the team provided four. The difference is not either qualitative or quantitative, but a matter of the scale of the design.

The product of this intentionally reductionist phase should be the input to the detail design, or a planning process. The designer at the design-detail (or design plan) interface works as an information manager. [174] As part of the convergent phase of design, the designer must consider when to halt convergence and detail refinement. Lawson states neatly, "in design, rather like art, one of the skills is knowing when to stop."[175] The halting of creative energy is a critical decision for the leader of the design team, and may be either time or context driven. Of course, creative energy will not stop completely; there must be a shift to create a depiction of the understanding of the design team at that fleeting moment. While it is theoretically accurate to say that design occurs throughout an operation, the designers will eventually need to create a product. This product must re-present the state of the design when creative work halted, and the design moved into the cognitive space of planning. It is implicit that any design product is only one particular snapshot of information and understanding at a particular moment and regarding a particular context. Imagining the future is an important design skill, and the determination that a design is ready to transition to planning merits careful consideration.

Multiple Methodologies and Design Strategy

The methodology of cognitively and deliberately working through divergence, transformation, and convergence is sound. However, this representation of design is only one of many methodologies. This monograph could not hope to catalog the methodologies contrived over the last forty years to handle

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[174] Woodson, *Introduction to Engineering Design*, 37. He states that in the closing phases of design "the engineer earns his salary by organizing, improving and transmitting information."

[175] Lawson, *How Designers Think*, 55.

complex problems and design, but a review of some of the more typical methodologies and especially their military counterparts may be useful. It is important to note that the logic behind providing multiple methodologies is that no one methodology is right for every design team and every context. A methodology is simply a mental model or strategy to proceed through the design. Models can be problematic, but generally allow for reframing complex problems into familiar terms.[176]

There is an aspect of strategy control or methodology control that is central to the design team leader. The design team leader may set out on a rigid design methodology, and hold to that design process through to completion. Alternately, the design team leader may choose to employ what Jones calls strategy switching, which is using a deliberately adaptive methodology or allowing new insights to spontaneously change the design methodology.[177] The balance of control exerted by the team leader will decide the flexibility of the design process. A rigid process may produce a flexible plan, and it is important to divorce planning flexibility from good designs. Good designs may be the result of either flexible or controlled design teams – and good design teams may work in an adaptive or controlled manner. There is no right answer, but the design team leader must decide what works for his context and the needs of his/her sponsor.

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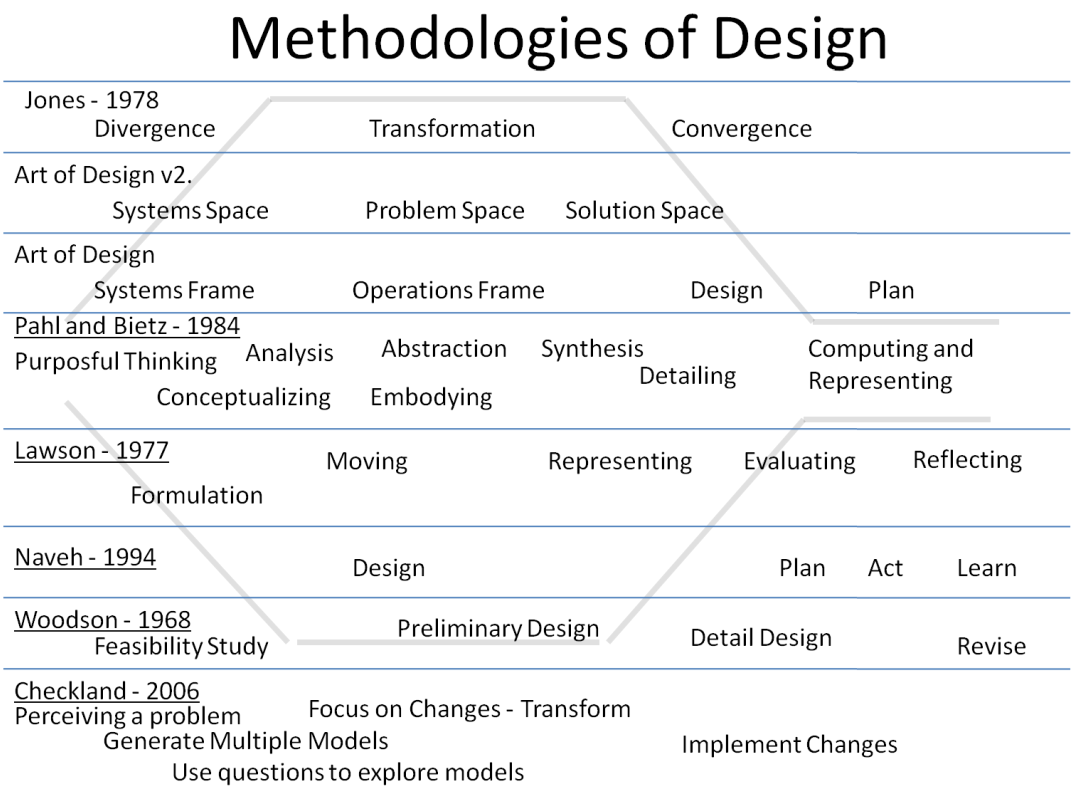
[176] Woodson states "The abstraction of a problem from its specific singular situation into a class or group of problems brings it from a strange field to a familiar one."[176] However, models have their own issues, and Woodson enumerates their deficiencies: "1. They are always wrong – there is always an error. 2. The degree of error depends on your assumptions, 3. Models are not unique, but problems are, 4. Mathematical models are idealizations using constructed logic that do not represent reality exactly." Woodson, *Introduction to Engineering Design*, 143.

[177] Jones, *Design Methods*, 170.



Because there are so many design methodologies, it is useful to categorize them. One simple way to categorize them is into those that are pre-planned and rigid, and those that are adaptive.[178] Furthermore, the mode of divergence is so critical, that the pattern of search is another good categorization. The difference between pre-planned or adaptive strategies is already reflected in our current doctrine, in TRADOC PAM 525-5-500 which delineates the difference between well-structured and wicked problems.[179] However, a critical review of TRADOC 525-5-500 reveals that the actual creation of the design is covered briefly, has only three steps (restate the Cdr's intent, describe the approach, and describe what could initiate reframing), and does not deal appropriately with wicked problems. The point is that while TRADOC 525-5-500 identifies wicked problems, it does not adequately identify an appropriate methodology. While describing in detail the difference between wicked and well-structured

[178] Jones, *Design Methods*, 76.

[179] TRADOC PAM 525-5-500, 9.

problems was an important step forward, the Army needs an understanding of the various wicked and well-structured methodologies.

Pre-planned methodologies may be either linear – as in the case of MDMP, or cyclic and iterative, as with EBO. Design methodologies may also be branching, where the design is split between parallel, collaborative, or alternative stages that reflect the Army's current planning doctrine.[180] Even if the process is rigid, cognitively each stage has some element of iteration. All design problems are iterative, with elements that are both circular and linear.[181] However, it is important to remember, in order to continue in the pre-planned process, it is the designers goal to work toward linearity, not toward endless iterations.

The alternative to a pre-planned methodology is an adaptive methodology. In adaptive methodologies, the design team takes the time at each stage to decide what the next design method or future methodology they should pursue. This is inherently more flexible, as the design team can easily select different methods at each stage and switch between methodologies as the need arises. However, notice that with an adaptive methodology, the design team must take the time at each stage to decide how to proceed. Therein, they are cognitively engaging their own process in a healthy, but very time consuming manner. Furthermore, inexperienced or unskilled designers may create confusion through rapid methodology adaptation. They must be careful not to strain their team or create confusion.

The various current military planning models are probably familiar to the reader. Before proposing or even discussing military methodologies, we need to establish our criteria for evaluation. For the sake of explicitly analyzing each of these methods, we will discuss each in terms of their rigidity, their

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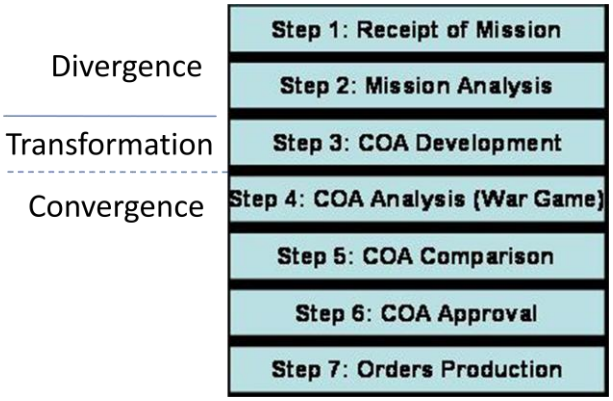
[180] Jones, Design Methods, 76. This is directly related to the planning discussion in Chapter 1 of FM 5-0 which discusses orientation planning, contingency planning, and commitment planning (pg 1-21 to 1-23). The difference is the focus on planning, but the philosophy of design options is inherent in the FM 5-0 argument.

[181] Ibid, 52.

focus on the various cognitive phases of design (divergence, transformation, convergence, etc), and their practical use.

The military decision making process (MDMP) is a comparatively rigid and pre-planned strategy, which focuses heavily on the convergent phase of design cognition. It is probable that Page's cumulative strategy in the early 1960's was the forefather of the military decision making process.[182] While it is possible to use MDMP for campaign design at the operational and strategic levels, the heavy reliance on convergence and the very short transformative phase – attended by just a few officers (usually the Cdr, S-3, and S-2) can hamper the process significantly. This extremely compressed transformation phase is both the strength and weakness of MDMP. While this approach allows for decisiveness, it is reliant on the commander's experience and talent. This reliance is inappropriate for creation of campaigns at the operational and strategic levels. MDMP is useful for well-structured problems, with known critical variables, or those with a great time constraint. Generally, MDMP has many of the advantages and characteristics of the convergent cognitive phase described above, because it does not focus on the divergent or transformative phases.



Systemic Operational Design focuses heavily on the divergent phase of design cognition. Because BG (ret) Naveh linked SOD philosophically to architectural philosophy, both the morphology and the

[182] Jones, *Design Methods*, 149-155. Page developed a 7 step process which focused initially on analysis, and then moved through a rigid process of evaluating different options with established criteria to minimize trial and error learning.

methodology are fluid and commander (author) centric. This evolved into the Art of Design, currently in creation at the School of Advanced Military Studies, which adds some rigidity to the very fluid SOD process. The problem with linking this process to essentially post-modern philosophy is that the divergent phase is overwhelming, and practitioners find themselves "designing into the blue". Pictured below is Shimon Naveh's SOD diagram with Jones' descriptive phases explicated.

The School of Advanced Military Studies currently uses a methodology developed by Dr. Alex Ryan, a complex systems theorist. Their design methodology moves from the environmental space, through a problem space by examining tension between what exists and what is desired, and then to a solution space that produces a campaign directive.[183] The cognitive modes required for this effective and loose methodology reflect Jones' engineering design methodology from the 1980's.[184] If education and application of one single methodology is mandatory, then adoption of one of the more loose

[183] FMI 5-2 (Draft), *Design*, para 3-7, 17.

[184] Ibid, para 3-8, 18.

methodologies is advisable. Therefore, the current "three-space" model proposed by Dr. Ryan and his team is imminently appropriate for adapting design into doctrine.

This monograph will not examine any other methodologies, but highly recommends exploration of existing design methodologies before attempting to *create* using design philosophy. It is vital to the effective use of design that the design team, or at least the team leader, is educated on multiple methodologies. This allows for adaptation should the design teams become stuck in any of the cognitive phases of design. An education in design should discuss the existence of the many well-developed social and cognitive models for creating under-pressure, competitively, and in high stakes environments. These methodologies, supported by their respective philosophical constructs, serve as the tools in COL Banach's tool-bag for design. However, even proper tools require an understanding of application, and now the Army should discuss how to implement design.

The "How" of Design.

An understanding of how to execute design socially will assist in operationalizing the very useful methodologies, morphologies, and philosophy described above. Incorporation of engineering design allows access to literature on the "how" of design, which will also allow practitioners to develop design as an operable concept. An understanding of what must be done in design is as viable in an academic study as the high philosophy of design. Lawson coined the useful phrase, the "tactics of design". If the US Army is to develop teachable and operable design, it must not shy away from learning *methods* from design history and industry. In any design, the design team will probably utilize one philosophy (stochastic, artistic, deterministic, architectural, etc.) and will probably utilize one methodology (MDMP, SOD, adaptive, cyclic, etc). However, in any of those processes, the design team should use a variety of methods that fit the context of their design team. The universally mandated steps in design are the selection and organization of the team, and the structure of interaction with the sponsor or stakeholders. Once these are understood, a healthy appreciation for design methods will empower the design team

leader. Therefore, design team creation, an introduction to design charrettes, and a brief introduction to methods will complete the abbreviated "how" of design for this monograph.

Design Team Size

There is no right size for a design team. There is a great deal of architectural literature that says a one-man design team is efficient and effective. There is some evidence to support the designer, as a lone operator is an effective model.[185] However, many design methods require a small group of four to six.[186] On the other end of the spectrum, several authors believe that more is better.[187] According to the social psychologist A. Paul Hare, writing about small groups in 1962, the design team leader must manage the five characteristics of a design team: the group interaction, the group goals, the group norms, the group direction, and the limits of their activities.[188] The ability of the leader to manage these characteristics and still generate creative designs will set the design team size.

The first critical and unavoidable method of design is determining the work allocation among the design team, or creating the design teams' organizational structure. Organizing the team is highly context dependant, and optimal organization may change day to day or hour to hour, based on which parties are present and the methods employed. Pahl and Bietz recommend several structures, splitting into small teams based on tasks, functionality, design process, etc. Jones describes the possibility of splitting the design team into groups based either on categories of information or sub-functions of the design.[189] The

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[185] Jones, *Design Methods*, 47. This model is supported by Osborn (1963), Gordon (1961), Matchett (1968), and Broadbent (1966). Using a sole author design has its own methodology, methods, and attributes. The results of a sole author design are generally heavily influenced by recent inputs and past experiences, are rapid but more random than group work, rely on a 'leap of insight', and can be directed by controlling the information flow to the author.

[186] Too many sources to list, can be found in Jones, *Design Methods* (1977), Opron (1976), Hare A P (1962) is probably the earliest work. Recent work would be in Stumpf and McDonnell (2002)

[187] Lawson, several places, but note his design model on page 106.

[188] Ibid, 243. Referencing Hare, A.P. (1962). Handbook of Small Group Research. New York. Free Press.

[189] Jones, *Design Methods*, 350.

organizational variety is very broad and requires consideration of personalities, talent, size of project, timeline, etc. Most of the traditional engineering design authors call for a team of four to six people, but this is general and reductionist estimate is based on which design methods the team will apply. For instance, brainstorming theory recommends five to fifteen people.[190] Discussions on the size of the design team quickly become misleading, as the core, team will receive either necessary or unwanted additions from other involved partners.

There are three classes of contributors in design. In traditional design philosophy, there were only two classes of designers, core designers and the proximate designers. The core designers are permanently working on the design, and proximate designers are brought in, especially during divergence, to add to the multi-disciplinary view and help with creativity. In the 1990's, a third category emerged. Patrick Feng identifies the last category of designers as non-designers (clients, stakeholders, and other socially relevant groups)."[191] Non-designers can be as useful in creative methods (discourse, brainstorming, etc.) as either proximate or core designers. The parting shot on team composition comes from Lawson. He stated, "One of the essential difficulties and fascinations of designing is the need to embrace so many different kinds of thought and knowledge."[192]

Design Charrettes

> "Participants in any design project of all but the simplest kind, working in different domains on different features of the system, will have different responsibilities and more often than not, the creations, findings, claims and proposals of one individual will be at variance with those of another. As a results, negotiation and 'trade-offs' are required to bring their efforts into coherence. This, in turn, makes designing a social process."[193]

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[190] As developed by Alex Osborn in 1941.

[191] Vermaas, *Philosophy and Design: From Engineering to Architecture*, 105.

[192] Lawson, *How Designers Think*, 13.

[193] Bucciarelli, *Engineering Philosophy*, 9.

There is no doubt that discourse is an important concept. However, the Army should expand the term "discourse" to insure that it includes all the stakeholders in a design, not just the core design team. Industry uses the term "design charrette", which has its origins in the 19th century scientific emergence of design over craft.[194] Design is an inherently social activity.[195] Complex designs are necessarily multidisciplinary projects. Commonly each designer will have a solution that stems from his or her topical knowledge.[196] The integration of multiple paradigms of knowledge and personal perspectives is a critical component of design, and in industry, this happens in the design charrette. As BG (ret) Wass de Czege notes "Military leaders may value individual creativity, critical thinking, continuous learning, and adaptability in their staffs and subordinate commanders, but individual traits do not necessarily add up to collective abilities needed for the best outcomes."[197]

Design theorist Bill Lennertz authored an excellent article titled "The Charrette as an Agent for Change". Lennertz is an urban planner, but his short article on design charrettes indicates a comprehensive and multi-disciplinary understanding. His nine principles of the charrette process stress the social nature of design, the need to push the group to creation, and the requirement to lead the team from a group of dissociated stakeholders to a chorus of convergent logic.[198] Furthermore, he identifies

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[194] The term "Design Charrette" comes from the Ecole des Beaux Arts in Paris in the 1800's. The students of architecture would work on their drawings as a group, in a moving cart, until the very last moment when the design was submitted to the school for evaluation.

[195] Bucciarelli states that in design, "the quest is to explain how participants in product design and development transform interest, beliefs and intentions into a functioning product", Bucciarelli, *Engineering Philosophy*, 2. Lawson reinforces this sentiment when he states that "One of the essential difficulties and fascinations of designing is the need to embrace so many different kinds of thought and knowledge." Lawson, *How Designers Think*, 13.

[196] Lawson, *How Designers Think*, 54.

[197] Wass de Czege, "Systemic Operational Design: Learning and Adapting in Complex Missions", 2.

[198] Bill Lenertz, *New Urbanism: Comprehensive Report & Best Practices Guide*, 3rd Ed. Ithaca: New Urban Publications), 2003. P 12-2-8. Lennertz' nine principles are 1. Work collaboratively, 2. Design cross functionally, 3. Use design to achieve a shared vision and a holistic solution, 4. Work in detail, 5. Intentionally constrain work schedules, 6. Communicate in short feedback loops, 7. Work for at least four to seven consecutive days, 8. Work as close to the site as possible, and 9. Produce a viable plan.

our three familiar cognitive models and how to move a group of designers from one cognitive mode to the next until a solution is designed.

Managing a design team is undeniably a leadership activity. [199] The design lead must ensure a smooth flow of creative energy and productivity among the design members while mandating forward progress to meet the needs of the client. Lawson notes that "design is often a collective process in which the rapport between group members can be as significant as their ideas".[200] Designers will use equations, theories, spreadsheets, and briefings to achieve perceived expertise and thereby ensure their ideas are included in the solution. The design team leader must manage the five characteristics of a design team: the group interaction, the group goals, the group norms, the group direction, and the limits of their activities.[201] Moreover, leading the design team is only the beginning of the design charrette.

Engineering design philosophy consistently reinforces that design is a team activity. However, this goes beyond the inclusion of multiple designers with different backgrounds and different educational paradigms. In industry, the design team leader invites all the stakeholders to the charrette. Good design will also include the clients, representatives of the users, and all those who have a stake in the design such as parallel organizations. Each element will seek to impose "their own order and express their own feelings through the design."[202] Military design has a great deal in common with industrial designs in this aspect. Consider the design interests involved in building a city airport, or a large skyscraper in a downtown area. Increasingly the client "is actually a collection of parties with distinct interests, owners, users, and those who finance, regulate, or insure the products created." Add to this the complexity of human use and interaction with those artifacts and one can see that similar coalition-building, leadership,

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[199] Lawson noted the changing role of the designer from artist to manager when he states "The issue no longer seemed to be one of protecting the individuality and identity of designers but, rather, had become the problem of exercising what Jones called "collective control" over designers' activities". Lawson, *How Designers Think*, 240.

[200] Ibid, 240.

[201] Ibid, 243. Referencing Hare, A.P. (1962). Handbook of Small Group Research. New York. Free Press.

[202] Ibid, 237.

and complex designing are required in industry as in campaigning. Every case of design benefits from pervasive interaction with the client and as much input from the users as the design team can manage. All of this requires leadership.

Design Methods

"Education is an admirable thing, but it is well to remember from time to time, that nothing really worth knowing can be taught" – Oscar Wilde[203]

In the culture and profession of designers and engineers, there are several books on what Lawson calls "Design Tactics".[204] This monograph does not recommend wholesale adoption of any particular tactic, as each design and each context will differ. However, education on design methods available, and the underlying fundamentals that form the design methodologies, will provide the practitioner with a menu of techniques to apply.[205] The methods listed in Appendix I apply to the divergent, transformative, convergent, or transitional phases of design cognition. The practitioner should understand that design at the method level is dirty, social, political, and never the same twice. It is important to note that, it is rare that a design team would rely on a single method. A good design team must have the knowledge and mental agility to switch between design tactics as required for their context and appropriate for the information available and the experience of the team. Different sub-teams could use different methods for the design of sub-functions, or the design team as a whole may heuristically try several methods until they divine a practical solution. Again, in design, like art, one of the skills is knowing when to stop.

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[203] Quoted in Woodson, *Introduction to Engineering Design*, vi.

[204] Lawson, *How Designers Think*, 200.

[205] This paper differentiates between an individual's internal cognitive methods, and the methods employed in social design. The discussion of the individual's internal method is his cognitive pattern, and is discussed above in the philosophy section of the paper. The remaining discussion in the paper deals with the social methods that emerge out of engineering design theory. Pahl and Bietz note the same difference, in their discussion of either "Black Box" or "Glass Box" descriptive design models.

Conclusion

The use of engineering design theory will allow the Army to make design operable while retaining an element of creativity within a very loose design methodological structure. Design is a critical step that takes military theory beyond either art or science. As such, it is a well-developed field of research, with a rich history and a mature cognitive pattern that deals successfully with both complexity and the demands of creation. Furthermore, Design is a mode of thinking and acting which has direct application to the military craft, which will aid in operational and strategic campaign creation. The Army should avoid turning design into a buzzword that broadly incorporates learning theory, systems theory, architectural philosophy, post-positivism, and other influences. Engineering design theory enables the philosophy of design to proceed to an operational methodology. Furthermore, deliberate education on engineering design theory will unlock a series of useful methods and "design tactics" which design teams may apply when working to create campaign designs. If Design is to find future use complementing MDMP as an exportable planning mechanism, SAMS should align Design with more approachable and analogous engineering philosophy and practices.

Areas for Further Study

Design Education

Due to the stochastic balance between complexity and pragmatism discussed above, teaching design is a considerable dilemma. Teaching causal mechanistic methods will lead the students to adopt a narrow and uncreative mental stance. Teaching divergent post-modern thinking patterns will lead to students who are able to ponder but not create. There exists a considerable body of knowledge in the engineering and architecture schools of the new millennium, which deals with how to teach design to undergraduate and graduate students. The most pragmatic is Lawson's recommendation that experience is

the best teacher. “By making design an everyday activity – it becomes demystified”.[206] The realization that good design team leaders must be multifunctional and interdisciplinary and have a broad understanding further compounds the problem. Students must have a broad understanding of multiple methods and philosophies, as well as an understanding of the emerging mechanical constraints of their design subject. Understanding design as a skill, and not a gift, allows one to make a study of how to train this skill. Such a study should start with Laxton’s model of design learning and explore options in the military for educating officers in design.[207]

Design Thinking

Another possible future essay could delve into the theories for the creation and training of creative thinking. Lawson notes “suffice it to say here that there is enough evidence that we can improve our creativity to warrant careful attention to the educational system through which designers pass”.[208] One good source of this would be the theorist de Bono, who wrote in 1991 on ways to increase creative and directional thought. The majority of theory on creativity in design rests on the initial research of Henry Poincare in the 1920’s. Although postmodern philosophy can help designers explore their thought patterns and intentions, a new review of cognitive psychology may assist in the incorporation of design theory for the US Army. This is especially applicable to those that see design as a mode of thought for the Army to incorporate into leadership doctrine.

Significance

It is important that any military design discussion is multi-disciplinary and not unbalanced by any one philosophical field. Design is becoming a liberal art, and the definition of design is broadening with

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[206] Lawson, 5. He states “We can no longer afford to immerse the student of architecture or product design in a few traditional crafts.”

[207] Ibid, 157. An example of a good design syllabus is attached as Appendix III.

[208] Ibid, 155.

each new theorist to include everything from traditional design to management philosophy. This paper defines design as the codified, social act of creation which applies art, craft, and science. This definition is informed by industry, and is congruent with the Design Research Institute. Aligning the military definition of design with that of the academic world and industry will put a healthy limit on the diverging definitions of design.

An understanding of the issue history of design is important so that one can have an academic common ground and understanding. Design developed out of the inadequacies of craft and the failings of singular artisans to meet the needs of society. As design developed, there were a plethora of social researchers and design theorists who wrote on design theory, social creation, and both methods and methodologies of design. The most applicable of these theories to military use is Engineering Design Theory. However, the comparative conversation cannot even occur unless SAMS endeavors to educate students on historical design philosophies, methodologies, and methods. Teaching the issue history of design at SAMS will allow the discussion to transcend examination of second sources and the postmodern literature of the last 20 years. Further, grounding military design in traditional design theory will make design more approachable to the Army, and more operable for the force. Also, allowing traditional design philosophy, especially engineering design theory, to inform SAMS' conception of design will provide a well-defined and clear language for design. This will not only remove the haughty language of post-structuralism from military campaign creation, but will provide an alternate vocabulary that is accurate, easily taught to those with a four-year degree, and operable for creation.

Design is the evolution of craft, and fills the gap between military arts and military sciences. As the Army moves beyond reliance on genius and experience, as an organization they must learn and create socially. This will mandate examination of methods of recording and communicating designs, methodologies and methods of creating designs, and an informed understanding of the creation theories that form the history of design. The move in industry from inventor, to craftsman and eventually to design team parallels the modern emergence of military staffs. Because the military progression from art to craft to science and then to design matches that of traditional industry, harnessing the writings and theories of

industry will greatly accelerate the Army's learning about group psychology and social creation. This strong position is supported by the lack of operational and strategic campaign creation tools. Neither MDMP (JOPP) nor SOD are adequate to create campaigns above the tactical level. While these methodologies can be used to create campaigns, they are inefficient, and overly commander-centric in a way that will lead to errors. Given the increasingly interconnected nature of the modern world, and the broad impacts of action in that context, the Army should do better than rely on the genius and experience of a single author. The same theories that enabled the development of the modern world, from the railroad to the I-Phone, are applicable to campaign creation. The need to create socially, in a competitive environment, using all the elements of military art, military science, and the craft of command, suggests that the military should use design to create campaigns.

Application

Incorporation of Engineering Design Theory will have a positive impact on how the Army understands design. The fundamentals of engineering philosophy directly address the military conception of design, and incorporating elements of Engineering Design Theory will improve campaign design. Engineering philosophy gives us an understanding of our current tendencies toward single authorship, and of the balance and issues between single authorship and social creation will aid in making the argument to transitioning toward design as a campaign creation artifact. This understanding recommends a cultural shift away from power leadership toward servant leadership, to harness the creative energy of the Army and evolve into a creative, critical, and productive strategic Army. This understanding also includes an honest analysis of intentional verses unintentional campaign designs, which requires an exploration of the existing cultural and normative boundaries to our campaign designers. Furthermore, education on bounded rationality, complexity, entropy, and the stochastic approach will allow the military philosopher to not be blinded by complexity, but understand the need and ability to interact with the uncertainty inherent in social and socio-technical designs. Also, engineering design theory introduces competitive creation techniques and methods, as well as an understanding of using groups to create in a lethal and

competitive environment. This is tied to the philosophical understanding of risk and uncertainty as concepts balanced against mass, redundancy and safety instead of paralyzing constructs which imply the superiority of the absence of action. Finally, incorporation of engineering design philosophy allows a pragmatic understanding and serious study of methodologies, strategy control, and the understanding of multiple methodologies.

An understanding of the Jones' methodology of moving through (and iterating within) the divergent, transformative, and convergent explicates the Dr. Ryan model currently being incorporated into doctrine. Dr. Ryan's model clearly describes what should happen in the Environmental Space, the Problem Space, and the Solution Space, but he has little time in doctrine to explain the relevant cognitive models. A study of Jones' methodology explains in detail the cognitive requirements for each of these three natural phases of design. Divergence incorporates creative thinking, the use of post-modern philosophy, searching for answers and new questions. Understanding transformation requires an education on the requirements for generating the creative spark, and the methods which might assist in that endeavor. Convergence is the understanding that the need to produce mandates a sorting and prioritizing of information, determining relevance, and applying known physical and cognitive constraints to make a design presentable and realistic. Furthermore, understanding each of these as singular methodologies allows room for a greater education on the great variety of other useful design methodologies. Education of the many available methodologies in design facilitates creativity in strategy control and empowers the design team leader to utilize either knowledge of a known rigid strategy or use of creative adaptation in design strategy.

Finally, understanding design as an extension of engineering philosophy and methodology suggests that the designer should study the "design tactics" and methods associated with engineering. The first design tactic is the creation of the design team, selecting the right size and composition, all of which is greatly informed by engineering design theories. The second design tactic is to structure an interaction with the sponsor, or with key stakeholders. An understanding of the influence of a variety of stakeholders recommends use of the Design Charrette which is so traditional in engineering design. Finally, an open-

minded acceptance that engineering design theories could influence current design philosophy allows for the consideration of the many design team methods developed by designers in the past two centuries.[209]

Recommendations

The Army should codify a definition of design that is operable and exportable to the force. Creative discussion on the meaning of design will not halt with definition; just as "center of gravity" and "operations" are always in debate, so will be "design" once defined. The Army must clearly and doctrinally explain the strengths and weaknesses of traditional design philosophy, and publicly make the argument that design is the next evolution of the military craft. The Army should explain clearly that traditional commander centric approaches are no longer suitable at the operational and strategic levels, and that design methodologies can assist in solving the emerging interpersonal and methodological issues that exist in a complex strategic problem set.

The School of Advanced Military studies should teach Engineering Design Theory and briefly touch engineering philosophy to counter-balance the current artistic and architectural tone of design. SAMS should also incorporate an education of the various design methodologies into the extensive design education. SAMS should then educate students on the various components of "how" to design, not to prescribe but to educate in order to produce balanced students that can flexibly engage complex problems. The faculty at SAMS should study the Design Research Institute's academic journals and "plug in" to current academic and industry developments in design theory if design is to ever be an operational concept.

There is a historical balance between military art and military science. This balance dominates military theory. The military artist is an experienced and discerning historian, observing and describing operations and context as a form of operational art appreciation. The military scientist finds fixed models

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[209] These methods, as well as known traps in design, are explicated in Appendix I.

in these observations, and applies rational analysis to the eternal truths of warfare in a prescriptive manner. Military professionals operate somewhere between these two poles, which often snag theorists in the horns of this false dichotomy. This unconscious balance of art and science is the military craft, executed with great intellect and informed by extensive experience. In all fields, craft evolves into design. Working unknowingly in the realm of single authorship and artistic philosophy is possible, but out of the awareness of a better approach and the high stakes of the military context creates a moral responsibility. As the nation asks the military to work increasingly in the social and political domains, a moral imperative emerges to harness the strengths of design philosophy. By specifically engaging Engineering Design Theory, the military will be able to utilize a design philosophy which is well developed, clear, highly exportable, and historically extremely effective.

APPENDIX I – DESIGN TACTICS

"Design Tactics"

This appendix attempts to illustrate some of the design tactics, and to identify where to find further information on each method.

Discourse

The most natural and most abused method of group design is the discourse. This is a free and open exchange of ideas and viewpoints by the members of the design team who are working through one of the cognitive phases of design. Discourse is very useful in the divergent phase of design cognition, and becomes more unwieldy when the design moves to cognitive convergence. Pahl and Bietz identify three discursive methods, but there are dozens. The three identified by Pahl and Bietz are the study of physical processes (functions required of the design), systematic discourse occurring in categories of thought associated with the design, or discourse focused on a catalog of solutions to previous and similar problems.[210] In any of these cases, the key to either discourse or brainstorming is the use of an experienced recorder to both capture and organize the information presented by the group.

Brainstorming

The second most traditional intuitive method is brainstorming, originally suggested in engineering design by the group psychologist Osborn in 1963.[211] Brainstorm is reliant on memory stimulation and idea association, and involves a group of people examining a design in an unbounded manner to generate ideas.They recommend brainstorming when "no practical solution principle has been discovered, they physical process underlying a possible solution has not yet been identified, there is a general feeling that deadlock has been reached, or a radical departure from the conventional approach is

[210] Pahl and Bietz, *Engineering Design*, 83-93.

[211] Ibid, 76.

required." They recommend between five and fifteen people, with a leader that only directs when dealing with organizational issues. It is also recommended that the group be as diverse as possible, and not hierarchically structured. They give specific prescriptions for procedure, to include explicitly stated that the participants shed their intellectual inhibitions, that there is no criticism, that all ideas are recorded and none are ignored, and that the session lasts no longer than 30-45 minutes.[212] Such a discussion seems mundane, but these are practical prescriptions which may help a novice Corps planner manage a planning team.

Problematizing

One design tactic is to identify the tension in the system. Problem solving theorists Reg Talbot and Robin Jacques developed this method and called it the problem identification game, or PIG.[213] Hayward refers to this phase as problematization in his monograph on design philosophy. Given the Talbot and Jacques method, one would use trigger words with the design team "conflict, contradiction, complication, chance, and similarity, etc" and have the team identify potentials, tensions and conflicts that emerge given the current knowledge of the system. Once potentials and tensions were identified, the team would then research further to determine if those issues affect the design or can be harnessed in the solution.

Draft Method

Another useful method for incorporation into a design charrette is the ability to create a coalition by submitting a draft design to the members of the charrette for revision and editing. Lawson champions this method when he states, "I have found that one of the most effective ways of making apparent the disparate needs of groups in multi-user buildings (designs) is to present the client committee with a sketch

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[212] Ibid, 77.

[213] Lawson, *How Designers Think*, 202.

design.[214] Jones also recommends this as a possible strategy, which involves stating objectives, compatibilities, and draft solutions at the outset as a form of forcing social interaction and criticism.[215] In fact, this method is currently in use by the SOCOM staff, which creates draft campaign designs on large Corel Draw sheets. Their method is to put the large plotter sheet in front of a senior General Officer, and then hand the General a marker to make revisions during the brief.[216]

Networking Method

However, draft solutions and sketched objectives are not the only socially focused design methods. A designer may also conduct interviews and investigations to gain visibility on the perspective of all the actors to whom the design will directly affect or have relevance. Furthermore, a designer might interview persons who have been in similar situations, if they are available. The military culture allows for commanders to gain situational awareness and visibility of the battlefield through a number of means. Likewise, the design team leader or designers must work to gain situational awareness, and to garner input from relevant parties. This process cannot be overstated, and will not only strengthen the process, but will build coalitions that will help to support the process. In this effort, the designer must not work to gain either compliance or support, but must actively seek constructive criticism and friction points. This is not a new process, nor is it unique to the military. Jones recommends interviewing all those who either have a stake in or are affected by a new design, as well as using questionnaires to gain understanding of the needs of the user.[217] When balanced with objective design methods, socially oriented methods are some of a designer's most potent tools.

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[214] Ibid, 48.

[215] Jones, *Design Methods*, 194. See Method 3.1 – Stating Objectives

[216] From COL Johnson, SOCOM planner, who briefed Seminar 6 of SAMS on 18 Dec 2008. The briefing was an illustration of SOCOM's use of design to create their global strategy.

[217] Jones, *Design Methods*, 214. Jones gives an in-depth discussion on how to direct a design focused conversation, what comments to solicit, and how to handle questionnaires. See design methods 3.4, 3.5, and 3.6.

Alexander's Function Model

Christopher Alexander's method "involved first listing all the requirements of a particular design problem, and then looking for interactions between these requirements."[218] This would be followed by determining positive or negative interactions between requirements and can be used as one method of exciting creative thinking and pattern understanding.[219] It is interesting to note that Alexander's method and Lawson's method of problem modeling are similar but inverse. Alexander (summarized) uses a listing of functions to spark creative transformation, while Lawson's model uses a listing of identified constraints to identify a generator. Pahl and Bietz echo Alexander's method applied to mechanical design, and they propose the creation of a function structure as a method for generating solution ideas.[220] If a problem can be analyzed in cause and effect relationships, then the explication of these relationships may be just as illustrative as identifying assemblages. A related causal model that is more forward leaning is the fault tree developed by mechanical engineers.[221] This is a method where the team lists everything that could go wrong in an inverse Murphy exercise, and then designs against this list of faults.[222] Taken together, the causal models should not form the basis of design, but serve to broaden our understanding of complex systems and may serve to generate creativity.

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[218] Lawson, *How Designers Think*, 75.

[219] Jones developed a method in 1965 that preceded Alexander's but was very similar and less widely known. Jones' Collaborative Strategy for Adaptable Architecture developed a list of options for each function or system objective, and allowed the client to pick from a menu – to essentially blend courses of action. This is very similar to Alexander's function list, but omitted the interaction between requirements. Jones, 156-166.

[220] Pahl and Bietz, *Engineering Design*, 149.

[221] A fault tree looks like a function tree – but describes the results if each component of the design were to fail, and then the compounded results if multiple faults fail. Such pragmatic thinking is pedantic, but can just as easily illustrate points of failure in social or military design.

[222] Pahl and Bietz, *Engineering Design*, 459. The Murphy exercise is an early engineering tool to list all the functions of a designed component. These functions are then cross referenced with material requirements and cost, etc, to help determine which components are consuming more money, space, or time than their relative function merits. This is different from optimization of parts, as it is not a mathematical exercise but a subjective evaluation by the design team who seeks to identify weak points in the design.

Affordance Theory

A giant in the design industry, R A Meier has been teaching and writing on design from Yale for the last forty years. He expands the functions oriented design method and focuses instead on Donald Norman's Affordance Theory.[223] This departure is one of many that are based in Alexander's work that constructively critique the work and expand on Alexander's function based model.[224] The affordance model admits that any design may have unintended aspects. A function based model examines the purpose and cause and effect of the design. The affordance methodology "is able to describe intended as well as unintended aspects of the product"[225] There are a number of ways to accomplish this prophetic thinking, but RA Meier suggests using a matrix that shows the relationship between components, functions, and unintended functions. The critical component of this theory is that it allows for the complex behavior of humans and attempts to determine previously unexpected user-design and design-design interfaces. By listing unintended consequences of a design, or even a hypothetical solution, one may generate helpful boundaries or ideas to help form a design. This is similar in practice to Pahl and Bietz's negation technique described below, but focuses on affordances instead of intended functions.

Broadbent Method

In 1973 – the influential design theorist Geoffrey Broadbent wrote a descriptive work, which was so convincing as to become prescriptive in the architectural culture.[226] What became known as Broadbent's method is a series of four cognitive spaces. The design team may engage these spaces in

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[223] R A Maier, "Rethinking Design Theory", 2. Norman, Donald *The Design of Everday Things.* This book is a landmark work on design theory. Donald Norman is the Director of the Institute for Cognitive Sciences at University of California, San Diego. R A Meir succinctly summarizes his affordance theory in his article aimed more directly at social systems than artifacts.

[224] Tschumi, *Architecture and Disjunction*, 4. *Architecture and Disjunction* has a complete discussion of the efficacy of the function model and the resulting counter-thoeries in the introduction.

[225] R A Maier, "Rethinking Design Theory", 3.

[226] Broadbent, G. (1973. *Design in Architecture.* New York, John Wiley). 343. Also in Lawson, *How Designers Think*, 203. Lawson distills the methodology from the original work.

parallel or in series, depending on team organization, resources, and dynamics. Each design would then be examined from a pragmatic, iconic, analogical, and canonic cognitive spaces. The pragmatic team would examine the design in a straightforward and physical manner, attempting to deal with the obvious problems directly using the available means. The iconic team would look at historical and existing solutions, and use them to generate a creative response to the need identified in the current design. The canonic team would apply doctrine, rules, and cognitive geometry to the problem in an attempt to generate a creative solution.[227] The analogical team would use analogies from other fields or from nature to spark a creative transformation. By either engaging these one at a time or in tandem, a design team may derive several draft concept to assist in transformation.

Parallel and Collaborative Planning

Doctrinal parallel planning, not to be confused with collaborative planning, can be another design tactic. This is similar to the Broadbent method in the use of teams in tandem, but differs by dividing cognition by either hierarchical level or branch function. Separate design teams would devise separate solutions to a specific design problem, and then compare design solutions in the charrette to determine the best possible design core concept. This is related to but inverse to alternative generation design. In alternative generation design, the team either brainstorm's or knowledge harvests a large number of possible solutions, and then divides to develop the solutions before convening in a charrette. Either method allows the harnessing of small group creativity to influence the design of the larger planning group in a collaborative manner.

[227] Geometry in Broadbent is used loosely – and refers more to the conception of space and time in the manner of Jomini than the physical relational geometry one might associate with architecture.

Narratives

Another tactic is to use the methodology of storytelling.[228] This is an individual exercise of writing a pair of narratives. The first narrative is the story of the situation, as it currently exists. The second narrative is the telling of a future story. These narratives are then read by a third party, using the two narratives as forms, to craft the function that would be required to resolve the tension between the situation space and the problem space stories.[229] Any of the three narratives can be a tactic for developing creativity. The steps of the narrative are then: identification of the situation, negotiation or reconciliation of the conflict, and then the writing of the problem and solution views. However, Lawson's understanding of narrative process is one of many. Christopher Jones recommends starting to write in the solution space, and then proceeding to the problem space. Whichever form the team decides to utilize, the design method of authoring a narrative can often aid in moving a team through the transformative phase.

Framing

Another more recent design method is the creation of a "frame" to create an understanding of the problem and the system containing the problem. This method evolved from Jones' boundary searching method, in which the limits of acceptable solutions were used to converge the design process.[230] The use of these boundaries to spark creativity was first introduced by Donald Schön in 1984, who intentionally describes framing in vague and elevated language.[231] However, as Lawson describes "The idea is none

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[228] Lawson, *How Designers Think*, 205.

[229] Ibid, 271 - Lawson writes that "the problem view is expressed generally in the form of needs, desires, wishes and requirements. The solution view on the other hand is expressed in terms of physicality of materials, forms, systems and components." He goes on to relate the difference between the two as a transformative tool when he states that a useful tactic is to "see it (the design process) as a dialogue, a conversation, a negotiation between what is desired and what can be realized."[229]

[230] Jones, *Design Methods*, 134. When discussing the use of a narrative, Jones recommends, "The final outcome of designing has to be assumed before the means of achieving it can be explored."

[231] Schon, D. A. (1984). "Problems, frames and perspectives on designing". *Design Studies* 5(3): 132-136. This well known author of the Reflective Practitioner wrote about learning and cognition in a manner that heavily impacted the design community.

the less useful for its vagueness, and we might note in passing that vague language is often helpful in the more sensitive periods of negotiations."[232] It is important not to confuse frames with cognitive space. Cognitive space is a divergent process of opening a problem to examine a complex system in an unbounded manner. Frames intentionally bound either a system, or an artifact or activity. Schön's point is that these boundaries can serve as generators themselves in many design problems. Used in this manner, the framing is not a divergent method of examining a problem, but a transformative method of generating creativity through acknowledgement of boundary. Jones goes further to recommend boundary shifting to reveal unknown solutions during the transformative phase.[233] Referred to as re-framing, an intentional shifting of assumed boundaries, sometimes radically, may reveal solutions that become central to the transformative phase.

Assemblages

Another method adopted rather mechanistically by the Art of Design is that of using the concept of assemblages, proposed first by Deleuze and Guattari in their book *A Thousand Plateaus*.[234] Assemblages are mutually beneficial and interdependent actors, artifacts, or relationships that affect the system. Identification of existing assemblages can be as useful as identifying potentials and trends, and may assist in the creative portion of the transformative phase. Taking time in design to make key assemblages explicit can be a useful design method, but, like any icon, should not dominate the design nor the creative function of the design team.[235]

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[232] Lawson, *How Designers Think*, 276

[233] Jones, *Design Methods*, 325.

[234] Deleuze & Guattarri, *A Thousand Plateaus*, 22.

[235] The discussion on Assemblages is vital, and MAJ Ed Hayward describes their impact on design cognition admirably. However, the attractiveness of this model can become its own unhealthy generating device. Over-reliance on any single method is not recommended.

Mechanism Design Theory

Very similar to assemblages is the use of Mechanism Design Theory. In a primer on Mechanism Design Theory, the Royal Swedish Academy of Sciences writes, "Mechanism design theory provides a coherent framework for analyzing a great variety of institutions, or "allocation mechanisms", with a focus on the problems associated with incentives and private information in gaming".[236] Essentially, a mechanism is an assemblage that either intentionally or unintentionally interacts with a society of hosts. Instead of a bipolar assemblage which emerged through complex need and interdependence, this Nobel Economic Prize (2007) winning theory discusses designing social mechanisms which meet complex needs and address interdependence for entire societies. Identification of social mechanisms using this theory can also help to explicate potentials and trends in a problem, and may enable transformative creativity.

Engineering Creativity Techniques

As early operative authors on engineering design, Pahl and Bietz describe the existing traditional engineering creativity techniques.[237] The first is a divergent process of "persistent questions", known to some as meta-questioning. The second is the method of negation, or creating a hypothetical solution, reducing that solution to its *necessary* components, and then critiquing and nullifying each component in order to generate ideas. This is very similar to Woodson's traditional preliminary design method, in which an early design faces a murder board, which forces mutation into a mature design.[238] Their third traditionally utilized design method is to envision small forward steps that might improve the system imperceptibly, and evaluate each steps feasibility and ability to compound with other activities. This is

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[236] Royal Swedish Academy of Sciences, *Mechanism Design Theory*, 1.

[237] Pahl and Bietz, *Engineering Design*, 56-59.

[238] Woodson, *Introduction to Engineering Design*, 125.

the inverse of a fourth traditional design method, which is essentially reverse engineering.239 Factorization is a traditional design method when dealing with social systems. Factorization is the breaking of a complex system into assemblages, actors, potentials, etc to analyze solutions based on sub-functions. Finally, Pahl and Bietz recommend systematic variation, which requires the designer to compare a solution theory with the current situation, and variations systematically addressed.[240] This differs from negation only in that it is more positive and prescriptive from its inception. The first two methods are clearly intended for cognitive divergence, while the other three could be either divergent or transformative.

Traditional Creativity Techniques

Before the recorded development of engineering design theory, there were more traditional creativity techniques latent within the design community. Pahl and Bietz explicate these simple, early, but often effective and overlooked early design cognitive patterns.[241] The first and most conventional method is to harnessing existing information to generate creativity. This process is an early and basic version of the more sophisticated Broadbent method. For identification of solution generators within existing knowledge, Pahl and Bietz describe a four stage process. This starts with a literature search of similar design problems, then an analysis of natural systems and existing technical systems to determine analogies, and finally the use of experimental studies.[242][243] Pahl and Bietz do not describe all the

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[239] Reverse Engineering is the common method of drafting the solution first, and then dissembling the solution into its required components using a variety of categorizations (function, space, strength, etc – based on the design project).

[240] There are many noted commonalities between the traditional engineering theory methods described herein and other methods in this monograph. Pahl and Bietz worked to describe social methods already inherent in the engineering community. Therefore, several of these traditional methods, presented here descriptively, have been re-presented in a refined prescriptive method by later authors. An example is the similarity between factorization and Christopher Alexander's function model, or the similarity between preliminary design method and negation.

[241] Pahl and Bietz, *Engineering Design*, 73-75.

[242] From Pahl and Bietz, *Engineering Design*, 75 "Rodenacker in particular lays great stress on the importance of experimental studies, arguing that design can be interpreted as the reversal of physical experiment."

traditional cognitive paths that might induce creation and solutions, but their analysis does demonstrate that earlier generations of designers have successfully addressed overcoming the transformative stage to enable design.

Method 635

German problem solving theorist Bernd Rohrbach developed a method related to brainstorming, called Method 635.[244]

> **"After familiarizing themselves with the task and after careful analysis, each of six participants is asked to write down three rough solutions in the form of keywords. After some time, the solutions are handed to the participant's neighbor who, after reading the previous suggestions, enters three further solutions or developments. This process is continued until each original set of three solutions has been completed or developed through association by the five other participants."[245]**

This method is quick, effective, and requires no leadership influence, but may stifle creativity by circumventing verbal communication. However, when a design team is stuck in discourse, this may break the deadlock.

Delphi Method

The Delphi method is similar to Method 635 for breaking a deadlock. RAND developed this method in the late 1950's to creatively design future force structures. In iterations the team separately writes out starting points for solving a problem, instead of solutions. In the second iteration, all team members are given the anonymously produced list of starting points and asked to suggest a second step or further consideration. They continue to iterate through collectively suggested methods until reasonable solution generators emerge.[246] This is a successful method to force creativity and the original theory suggests that the participant's solutions will converge on the collectively understood most likely

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[243] Jones also recommends a thorough literature search for similar design problems as his method 3.2 – Jones, Design Methods, 201.

[244] Rohrbach, *Creative by rules - Method 635, a new technique for solving problems*, 73.

[245] Pahl and Bietz, *Engineering Design*, 184.

[246] Pahl and Bietz, *Engineering Design*, 79.

successful solution. This method can either break a discursive deadlock or initiate creativity in a group with stifled interaction.

Synectics

Synectics were developed by the well-known social psychologist William Gordon in the 1940's. This method is a more directed form of brainstorming. Synectics starts with a small team of about five to seven people, who are provided an analogy for the solution to the design in question. After the team leader presents the problem, and challenges familiar assumptions, the team then proceeds to analyze the usefulness of the analogy in complete "frankness and lack of inhibition or criticism".[247] The central concept being is analyzed, criticized, and developed if it survives. Following this exchange, the small group iterates through other analogies or central concepts to see which merit inclusion in a final design concept. This method is useful if a design team cannot foresee an end state or is stuck proceeding into the problem space.

The Gallery Method

The Gallery Method was developed by Hellfritz, and can lead to group creativity without "unduly lengthy discussions".[248] This is similar to knowledge harvesting, but more thorough. The design team splits into multiple groups or individuals and for 15 minutes they develop solutions that comprehensively include text and sketches. The teams then come together, discuss and brief one another, and hang the solutions on the wall for examination. Then they iterate, using the solution gallery to generate creativity. The team then iterates as many times as the team has remaining intellectual energy, until all ideas have been developed and reviewed. This is followed by selection of the most promising solutions for

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[247] Pahl and Bietz, *Engineering Design*, 80.

[248] Hellfritz, H., *Innovation via Galeriemethode* (Innovation via the Art Gallery Method), Koenistein, Taunus, 1978. Pahl and Bietz, *Engineering Design*, 79. Pahl and Bietz offer an English translation and summary of Hermann Hellfritz's method.

development, or selection of "potential solution characteristics that can be developed later using a discursive method."[249]

Solution First Methods

A method suggested by Woodson, although it may be simple brainstorming, is to ask the group the question "How Can I . . . "and then make a flow chart of provided answers.[250] This is similar to Jones' method of stating objectives at the inception of a design to work as a generator.[251] However, both of these methods can be hasty, as they often will move completely past the divergent phase and miss a great deal of the context and information required for a holistic solution. Both of these solutions oriented methods are appropriate for late in the transformative phase of design cognition.

Systems Engineering/Systems Testing

Woodson, Asimov and others recommend the use of systems engineering methods as an attempt to model the design as a system, with inputs and outputs. It is important to note that systems engineering is a complete methodology within the engineering philosophy. However, this does not preclude use of systems engineering methods applied within the framework of other methodologies. Systems engineering methods are also recommended by Jones as a rigid pre-planned method that is useful in finding a workable pattern and thinking in functions.[252] By categorizing inputs into intended and environmental, the design team can attempt to identify all the critical inputs to a system. Then the team would determine the outputs, both desirable and undesirable. This sketch could either allow complete analysis of an existing design, or lead to design modification to reduce undesirable outputs.[253]

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[249] Pahl and Bietz, *Engineering Design*, 79.

[250] Woodson, *Introduction to Engineering Design*, 63.

[251] Jones, *Design Methods*, 194.

[252] Ibid, 121.

[253] Woodson, *Introduction to Engineering Design*, 220.

Closely related to this approach is the systemic testing method. Systemic testing is a flexible and effective method of dealing with complexity, and all of SOD could be viewed as a systems testing technique. The original systems testing theory is, when dealing with complex adaptive systems, to either emplace or remove constraints to a system.[254] This is a common method among traffic engineers dealing with complex adaptive systems. Systems testing is the offspring of early engineering sensitivity and stability analysis.[255] If the designer can establish causality (which is the tricky part) then the systems test will lead to possible systemic solutions. While the critic may argue that causality can never be established in a complex adaptive system. However, it is important to remember that even Naveh's design, plan, act, learn model requires a causally based increase in knowledge to drive future action. The focus on learning instead of resolving is a useful mechanism to generate creativity.[256] Without repeating the discussion on determinism, indeterminism, and stochastic philosophies, it is sufficient to say that systems' testing is a sound method for developing systemic transformation. Systemic transformation (vs solutions) is defined traditionally in systems engineering as the iterative changing of a system, or removing of faults, to approach a more desirable future system.[257]

Traditional Design Method

Asimov's holistic design system reflects the mechanistic philosophies of design in the early 1960's, but is common enough to merit inclusion. The process proposed in his work Introduction to Design in 1962 was to determine a range of feasible solutions, select one as the preliminary design, hone

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[254] Jones, *Design Methods*, 246.

[255] Asimow, *Introduction to Design*, 26 + 27. These early design methods directly spawned systems testing, and much of the philosophical underpinnings of SOD. The concept is that a method of testing could focus on changing the feasible inputs to the system and analyze how the system reacts. This is still based on a Western model of causality.

[256] This is reflected in BG (Ret) Wass de Czege's article on SOD. BG Wass de Czege notes "An important aim of design is to develop a more comprehensive appreciation of the situation than we as a military institution now can". This focus on learning is the basis for the Systemic Testing design models.

[257] Jones, *Design Methods*, 316.

that design into a detailed design, and then move to planning.[258] This method is very similar to Page's cumulative strategy, developed in the 1960's, which proceeds logically from a stage of analysis and evaluation to a rigid stage of synthesis. It is probable that Page's cumulative strategy in the early 1960's was the forefather of the military decision making process.[259] Interestingly, this early model cognitively mirrors MDMP, with one short divergent phase, followed immediately by a series of convergent phases and then planning. Any officer on an MDMP staff , frustrated with a rapid COA selection by the S-3, might understand Jones' comment on design in 1977: "the principle of deciding the form of the whole before the details have been explored outside the mind of the chief designer does not work in novel situations for which the necessary experience cannot be contained within the mind of one person."[260] This is a direct challenge to a commander-centric philosophy that was inherent in early design theory. It also clearly shows why a common understanding of design morphology is so critical to move "outside the mind of the chief designer".

Data Reduction

It is still common in military design to find data reduction oriented design methods. In the military and especially counterinsurgency context, these are based on traditional interaction matrices, and interaction networks. The interaction matrix allows a data based catalogue of all the interactions of different actors, artifacts, and functions and allows for a quantitative evaluation of those interactions. The interaction net, developed by Minsky in 1963 (and appearing again in JP 5.0 forty years later) is a graphical representation of the interaction matrix, and can be useful to illuminate complicated interactions.[261] These are just two modes of data reduction that can help illuminate design issues.

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[258] Asimow, *Introduction to Design*, 15-17.

[259] Jones, *Design Methods*, 149-155.

[260] Ibid, 24.

[261] Ibid, 309.

Unselective data reduction is when one starts the method (say, interaction net) before you decide how to analyze the output. Selective data reduction occurs when you decide how to analyze it (ex. The critical tolerances) before you start recording data. There are also longitudinal (historical and time dependant) or lateral (geographically based or quantitative) data reduction models. While any of these models may be illustrative in design, nearly all data reduction models are very difficult to use in communicating with design partners. This is especially true in complex systems when the data resolution is so dense as to be difficult to display visually.

Other Convergent Methods

Many of the above stated methods are for the divergent or transformative phase. However, there are also multiple methods that are appropriate to the convergent phase, but must still precede planning. One such method is to create checklists or question lists, which ensure that the design does not proceed with cognitive gaps. An excellent list of questions related to SOD designs can be found in Kettie Davisons monograph, in Appendix I. Other convergent methods are to determine evaluation criteria and specifications upon which the planning (which will follow the design) will be evaluated. This becomes useful when authoring a design or planning guidance that requires convergent, clear, and concise communications.

Design Traps.

Lawson is careful to outline some of the pitfalls of design, which he calls "Design Traps".[262] The category trap is reminiscent of the Broadbent iconic solution, and is when a novice designer applies a mechanical and historically contiguous solution to a unique and complex problem. The puzzle trap is when the design team creates a cognitive dilemma resulting in no correct or even acceptable answer to a design problem based on unchallenged constraints. The number trap is when a design team becomes

[262] Lawson, *How Designers Think*, 220-228.

obsessed with the numerical evaluation of either requirements or solutions (the military body count paradigm). The icon trap is when the design becomes product oriented and the medium or output skews the solution. The image trap occurs when a single generator image overwhelms the creative thinking of the design team. Lawson also warns that design groups may adapt unhealthy roles that become too powerful or too habitual – all of which can suppress deviance and originality.[263] There are an infinite number of ways a design team can become stuck, but understanding the common traps that occur in engineering design will help in avoiding pitfalls.

These pitfalls become visible when the designer sees the creation of a design as a series of interactions, or "conversations". This differs from dialogue in that dialogue is between the designer and the users or the sponsor. Lawson makes a unique point when he defines design as a conversation between the lone designer and the medium of design. In military terms, part of the design interaction is between the designer and the power point or five-paragraph OPORD. Because this is just as relevant as any other discourse in design (if not more), it is important that the designer carefully select his desired medium as he develops his design. Some mediums may conversationally reject the idea the design is trying to communicate, requiring the designer to flexibly change medium to communicate and record the ideas of design. When the medium dominates the design, this reflects the icon trap so commonly experienced by architectural and engineering firms. The designer must characteristically be flexible in medium selection, from the beginning of the design and throughout the process.

Woodson also outlines some of the most common hindrances to design.[264] Several were already mentioned, such as mental rigidity or too little knowledge. Three of his five are particularly characteristic to military environments. One is hostile surroundings, when a culture or climate is not receptive to new ideas. Because of the hierarchical and conservative nature of the military, the culture is commonly (based

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[263] Lawson, *How Designers Think*, 247.

[264] Woodson, *Introduction to Engineering Design*, 92.

on the unit) not receptive to new concepts. Another is anxiety, which is a common byproduct of designing in wartime. Finally, and pervasively, excessive busyness is a recorded detractor of creative energy which is common in the Army.

APPENDIX II – Issue History of Design

'Forty Years of Design Research' – By Nigel Cross

The 40th anniversary of the founding of the Design Research Society falls in this year, 2006, and thus provides a suitable moment to reflect on the first forty years of design research. From the very beginning, the purpose of the DRS has always been stated clearly in its aims: 'to promote the study of and research into the process of designing in all its many fields'. Its purpose therefore is to act as a form of learned society, taking a domain independent viewof the process of designing.

The emergence of the Society lay in the success of the first 'Conference on Design Methods', which was held in London in 1962 (Jones and Thornley, 1963). That conference is generally regarded as the event which marked the launch of design methodology as a subject or field of enquiry, and the 'design methods movement'. In the UK the new movement developed through further conferences in the 1960s – 'The Design Method' in Birmingham, 1965 (Gregory, 1966), and 'Design Methods in Architecture', in Portsmouth, 1967 (Broadbent and Ward, 1969).

The origins of new design methods in the 1960s lay further back in the application of novel, 'scientific' methods to the novel and pressing problems of the 2nd World War– from which came operational research methods and management decision-making techniques – and in the development of creativity techniques in the 1950s. (The latter was partly, in the USA, in response to the launch of the first satellite, the Soviet Union's 'Sputnik', which seemed to convince American scientists and engineers that they lacked creativity.) The 1960s also saw the beginnings of computer programs for problem solving. The first design methods or methodology books appeared – Asimow (1962), Alexander (1964), Archer (1965), Jones (1970) – and the first creativity books – Gordon (1961), Osborn (1963).

A statement by Bruce Archer (1965) encapsulated what was going on:

The most fundamental challenge to conventional ideas on design has been the growing advocacy of systematic methods of problem solving, borrowed from computer techniques and management theory, for the assessment of design problems and the development of design solutions.

Moreover, Herbert Simon (1969) established the foundations for ‘a science of design’, which would be ‘a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process.’ In some senses, there was a desire to ‘scientise’ design in the1960s.

However, the 1970s became notable for the rejection of design methodology by many, including some of the early pioneers. Christopher Alexander said: ‘I’ve disassociated myself from the field... There is so little in what is called ‘design methods’ that has anything useful to say about how to design buildings that I never even read the literature anymore...I would say forget it, forget the whole thing’ (Alexander, 1971). And J. Christopher Jones said: ‘In the 1970s I reacted against design methods. I dislike the machine language, the behaviorism, the continual attempt to fix the whole of life into a logical framework’ (Jones, 1977).

These were pretty harsh things for the founding fathers to say about their offspring, and were potentially devastating to those who were still nurturing the infant. To put the quotations of Alexander and Jones into context it may be necessary to recall the social/cultural climate of the late-1960s – the campus revolutions, the new liberal humanism and rejection of previous values. But also it had to be acknowledged that there had been a lack of success in the application of ‘scientific’ methods to design. Fundamental issues were also raised by Rittel and Webber (1973), who characterised design and planning problems as ‘wicked’ problems, fundamentally un-amenable to the techniques of science and engineering, which dealt with ‘tame’problems.

Design methodology was saved, however, by Horst Rittel’s (1973) proposal of ‘generations’ of methods. He suggested that the developments of the 1960s had been only‘first generation’ methods (which naturally, with hindsight, seemed a bit simplistic, but nonetheless had been a necessary beginning) and that a new second generation wasbeginning to emerge. This suggestion was clever, because it let the methodologists escape from their commitment to inadequate ‘first generation’ methods, and it opened a vista of an endless future of generation upon generation of new methods.

Where the first generation of design methods was based on the application of systematic, rational, ‘scientific’ methods, the second generation moved away from attempts to optimise and from the

omnipotence of the designer (especially for ‘wicked problems’), towards recognition of satisfactory or appropriate solutions (Herbert Simon had even introduced the notion of ‘satisficing’) and an ‘argumentative’, participatory process in which designers are partners with the problem ‘owners’ (clients, customers, users, the community). However, this approach seemed to be more relevant to architecture and planning than engineering and industrial design, and meanwhile these fields were still developing their methodologies in somewhat different directions.

Engineering design methodology of the systematic variety developed strongly in the 1980s; for example, through ICED – the series of International Conferences on Engineering Design. The early developments were especially strong in Germany and Japan. (Although there may still have been only limited evidence of practical applications and results.) A series of books on engineering design methods and methodology began to appear. Just to mention some English language ones, these included Hubka (1982), Pahl and Beitz (1984), French (1985), Cross (1989), and Pugh (1991).

It should also be acknowledged that in the USA there were some important developments in design theory and methodology, including the publications of the Design Methods Group and the continuing series of conferences of the Environmental Design Research Association (EDRA).

The National Science Foundation initiative on design theory and methods (perhaps in response to German and Japanese progress – like the earlier response to Sputnik?) led to substantial growth in engineering design methodology in the late-1980s. The American Society of Mechanical Engineers (ASME) launched its series of conferences on Design Theory and Methodology.

In fact, after the doubts of the 1970s, the 1980s saw a period of substantial consolidation of design research. The constraining link with science was severed at the DRS conference on Design:Science:Method in 1980 (Jacques and Powell, 1981). Historical and current developments in design methodology were recorded in Cross (1984). A particularly significant development was the emergence of the first journals of design research. Just to refer, again, to English–language publications, DRS initiated *Design Studies* in 1979, *Design Issues* appeared in 1984, and *Research in Engineering Design* in 1989. Some significant books also appeared, with a new emphasis on design cognition signaled

from the architectural field in Lawson's *How Designers Think* (1980) and Rowe's *Design Thinking* (1987).

In the 1980s we saw the establishment of design as a coherent discipline of study in its own right, based on the view that design has its own things to know and its own ways of knowing them. This had been heralded in the very first issue of *Design Studies*, when we launched a series of articles on 'Design as a Discipline'. Bruce Archer again encapsulated the view in stating his new belief that 'there exists a designerly way of thinking and communicating that is both different from scientific and scholarly ways of thinking and communicating, and as powerful as scientific and scholarly methods of enquiry when applied to its own kinds of problems' (Archer, 1979). A little later, expanding the idea, Cross (1982) suggested that 'We need a research programme … At its core is a 'touch-stone theory' or idea – in our case the view that 'there are designerly ways of knowing'. (For further development of the programme see Cross, 2006.) Most significant of all, Donald Schön (1983) promoted the new view within his book *The Reflective Practitioner*, in which he sought to establish 'an epistemology of practice implicit in the artistic, intuitive processes which [design and other] practitioners bring tosituations of uncertainty, instability, uniqueness and value conflict.' Design as a discipline means design studied on its own terms, within its own rigorous culture, based on a reflective practice of designing.

It might be said that design research 'came of age' in the 1980s, since when we have seen a period of expansion through the 1990s right up to today. More new journals have appeared, such as *The Design Journal*, the *Journal of Design Research*, and *CoDesign*. There has also been a major growth in conferences, with not only a continuing series by DRS, but also series such as Design Thinking, Doctoral Education in Design, Design Computing and Cognition,

Design and Emotion, European Academy, the Asian Design Conferences, etc., etc. Design research now operates on a truly international scale, acknowledged in the cooperation of DRS with the Asian design research societies in the founding in 2005 of the International Association of Societies of Design Research. DRS itself celebrated its 40th anniversary with its largest conference yet, in Lisbon,

Portugal, in November 2006, for which this brief, and partial, history was prepared. Forty years on, design research is alive and well, and living in an increasing number of places.

Nigel Cross

President, Design Research Society

Nigel Cross is a leading international figure in the world of design research. With academic and practical backgrounds in architecture and industrial design, he has conducted research in computer-aided design, design methodology, and design cognition since the nineteen-sixties. His main current research is based on studies of expert and exceptional designers. He has been a member of the academic staff of the UK's pioneering, multi-media Open University since 1970, where he has been responsible for, or instrumental in, a wide range of distance-education courses in design and technology. Books by Professor Cross include *Designerly Ways of Knowing* (Springer, 2006), *Analysing Design Activity* (co-edited with Christiaans and Dorst; Wiley, 1996) and the third edition of his successful textbook on *Engineering Design Methods* (Wiley, 2000). Professor Cross is also Editor-in-Chief of the international journal of *Design Studies*. In 2005 he was honoured with the Lifetime Achievement Award of the Design Research Society. He is President of the Design Research Society, and of the International Association of Societies of Design Research.

Design Research Quarterly 1:2 Dec. 2006 – 4 – www.designresearchsociety.org

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APPENDIX III – An Example Design Syllabus

MECH 593 Design Theory and Methodology

Course Information { Winter 2007

www.mcgill.ca/cden/courses

Course Outline

Objective: To scrutinize the design process in its entirety, from problem definition to conceptualization to embodiment and realization, in a discipline-independent framework, with the purpose of gaining insight into the process from the most general viewpoint.

Contents:

I. Introduction: The nature of design as a creative engineering activity. The various models of the design process. History of design and design schools. The role of models in the design process at its various stages: logical and logico-mathematical at the conceptual stage; mathematical at the embodiment and detail stage. The role of optimization in the design process: Stochastic methods at the conceptual stage; mathematical-programming methods at the detail stage. The role of knowledge in design. Knowledge vs. information. Can knowledge be downloaded? Design representation. The role of expert systems in design. Design databases.

II. Conceptual Design

1. Concept generation: brainstorming; synectics; Inventive Problem Solving (IPS) aka TRIZ, its initials in Russian (\Teoriya Resheniya Izobretatelskikh Zadatch").

2. The polarity of the design concepts: disorder vs. order; complexity vs. simplicity. Information, entropy and noise. Measures of complexity.

III. Embodiment Design: steps; rules; and principles.

IV. Detail Design: steps; document preparation; product structure; drawing production, standards and organization; part lists; part identification; part-numbering; part characteristics; design communication; data-management; change-management; CAD and CAE tools.[265]

Operation: While the course is the responsibility of one single professor, invited speakers will address specific topics, some of which are discipline-dependent, as a means to concretize the rather abstract concepts in the syllabus.

Evaluation: The course is evaluated with a final project, that is conducted by the students individually. Projects are suggested by the instructor, but the students are encouraged to propose their own projects. Project proposals will be discussed early in the term, to allow students an early start. Progress reports are due periodically both in writing and by means of oral presentations. The ¯nal project is also reported in writing and orally.

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Recommended reading:

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[265] In a military design course – one would replace the Detail Design portion of the design education with training in either MDMP or JOPP, or any other tactical planning methodology.

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Marking Scheme: The ¯nal mark is based on the two progress reports (20% the ¯rst one,35% the second one) and the ¯nal report (45%).
1http://www.cden.ryerson.ca/DesignScience/

Notes:
2For more information see www.mcgill.ca/integrity

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