ORGANIZING COMPLEXITY FROM THE BOTTOM UP

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ABSTRACT

A study of complexity extending over 30 years has produced almost a thousand computer files, papers, reports, records of conference presentations, and transparencies. Inspired by organizational projects carried out elsewhere which produced some exemplary organized material, the author undertook the task of producing categories that could assist in working with complexity.

Three complementary, but distinct, tasks were carried out to structure complexity, based on different parts of the available material.

♦   In the *first* approach, *20 Laws of Complexity* developed over the course of the research, were placed in five categories. Three of them involve human behavior: **Habitual Behavior**, **Physiological Behavior**, and **Organizational Behavior**; one category involves **Communication Media**; and one category involves **Mathematical Operations**.

♦   In the *second* approach, over *500 transparencies* were organized into 14 categories which, in turn, were organized into four areas. The four areas are: **Site of Applications**, **Applications of Science**, **Sciences**, and **Infrastructure of Science**.

♦   In the *third* approach, *21 essays on complexity* were organized into six categories. These are **Organizational Flaws, Linguistic Constraints, Views on Complexity, Science and Organizational Behavior, Organizational Enhancements, and University Redesign**.

The results of these three efforts are interpreted individually, and then jointly. It is thought that the results offer significant insights into complexity, helping to develop a vision of how to work with it effectively in government, industry, and education.

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ORGANIZING COMPLEXITY BY CATEGORIZING LAWS OF COMPLEXITY

The twenty Laws of Complexity are described in a paper that is presently under review for publication **[Warfield, 1997a].** I will just involve them by name only here, in the interests of facilitating comparisons with the results of the other two ways of organizing complexity.

Some of the Laws can reasonably be placed in more than one category. The following five categories have been chosen.

Type A. Three Categories Involving Human Behavior:

- **Habitual Behavior:** Constraints that human beings have imposed upon themselves, almost without thinking, evolved through prolonged activity.
- **Physiological Behavior**: Constraints on human behavior imposed by human physiology.
- **Organizational Behavior**: Aspects of human behavior that arise from their participation in organizations.

Type B. One Category Involving Communication Media.

- **Linguistics of Communication**: Matters that affect media of human communication, including various aspects of human written or oral communications.

Type C. One Category Involving Mathematical Operations.

- **Mathematical Determinations**: Laws arrived at by mathematical operations, whether theoretical or empirically-based, or in combination.

In principle, a few of these laws could be abolished over time, if habitual and organizational behavioral practices were adequately changed. Unless and until they are, the laws will stand.

Table 1 shows which laws are assigned to which categories. Also shown there is the percentage of the laws that have a basis in behavior (70%), in media (10%), and in mathematics (30%). Since none of the laws is based in the so-called "hard sciences", it is reasonably clear why technologists are unlikely to appreciate these laws, and are likely to make arbitrary judgments (often efficiency-based) that encroach on the domain of these laws.

TABLE 1. CATEGORIES OF LAWS OF COMPLEXITY: LAW OF ⇓⇓⇓⇓⇓⇓⇓	BEHAVIORALLY-BASED (70%)			MEDIA-BASED (10%)	MATHEMA-TICALLY BASED (30%)
	HABITUAL	PHYSIO-LOGICAL	ORGANIZA-TIONAL		
1A Triadic Compatibility		X			X
1B Requisite Parsimony		X			
2 Structural Underconceptualization	X	X		X	
3A Organizational Linguistics			X		
3B Vertical Incoherence			X		
4 Validation					X
5 Diverse Beliefs	X				
6 Gradation					X
7 Universal Priors	X				
8A Inherent Conflict	X				
8B Limits		X			
8C Requisite Saliency	X	X			
8D Success and Failure					X
8E Uncorrelated Extremes					X
8F Induced Groupthink	X		X		
9 Requisite Variety					X
10A Forced Substitution			X		
10B Precluded Resolution			X		
11 Triadic Necessity and Sufficiency					X
12 Small Displays	X			X	

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ORGANIZING COMPLEXITY BY CATEGORIZING TRANSPARENCIES

In October of 1997, I decided to try to categorize some transparencies that I had prepared over the years. My interest was in those transparencies that, in some way or other, related to my 30-year study of complexity[1].

In deciding to do that, I was influenced by results from two projects:

- *Redesign of the US Defense Acquisition System*
- *Redesign of the ITESM Systems Engineering Curriculum*

The first of these was carried out under the leadership of Professor Henry Alberts of the US Defense Systems Management College. He involved several hundred program managers in that project, which has been documented in detail in his Ph. D. dissertation **[Alberts, 199X]**. One measure of the success of that project is that much of what was done was enacted into law by the US Congress ("The Federal Acquisition Streamlining Act of 1994").

In that project, Henry was able to describe a three-level categorization of results, as follows:

- **678 Problems** *with the acquisition system*
- **20 Categories**, *into which those Problems were placed*
- **6 Areas**, *into which the 20 Categories were placed*

What we see here amounts to a **3-level inclusion hierarchy**, which was developed from the bottom up. First the 678 Problems were identified. Then they were put into the 20 Categories, which were named and described. Finally those 20 Categories were put into 6 Areas.

I decided that I would call this hierarchical structure the "Alberts Pattern". It was my feeling that perhaps a similar pattern might apply in other problematic situations, and that the highest- quality product very likely would result by working from the grass roots up to the high-level administrative domain, thereby avoiding the common tendency to adopt preconceived categories at the outset and later try to fit components into them..

Then, a few months later, my long-time colleague, Professor Roxana Cárdenas of ITESM (the Instituto Politecnico y de Estudios Superiores de Monterrey, a leading private institution in Mexico), carried out a project in collaboration with José C. Rivas that involved more than a hundred students in the Systems Engineering program. The students were asked to redesign their curriculum in the light of what they had learned during their educational program **[Cárdenas and Rivas, 1995]** using methods very similar to those used by Professor Alberts.

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[1] Various bibliographies detailing the research are identified or detailed on various sites in the World Wide Web. Here are three: http://www.gmu.edu/departments/t-iasis, http://www.gmu.edu/departments/tipp/faculty/warfield/warfield.htm, http://www.statewave.com/tier1_4_/BIBWARF.htm.

That project produced the following:

- *270 Design Options*
- *20 Categories*, *into which those Options were placed*
- *4 Areas*, *into which the 20 Categories were placed*

Once again, a **3-level inclusion hierarchy** was developed from the bottom up. With these well-documented results in hand, I asked myself this question: *"Suppose I structured the more-than-five-hundred transparencies that I had developed in studying complexity, what kind of structure would I find?"*

Proceeding to carry out this bottom-up effort, I found the following **3-level inclusion hierarchy**:

- *538 Transparencies* *on Complexity*
- *14 Categories*
- *4 Areas*, *into which the 14 Categories were placed*

PRESENTING THE DETAILED RESULTS OF THE SECOND CATEGORIZATIONS

Now I would like first **to present the results** of my work and then **to interpret the results** in the light of the structures achieved. Table 2, the "Inclusion Structure for Four Areas of Complexity", shows the 14 Categories as they appear contained within the 4 Areas. In the science of generic design **[Warfield, 1994]**, this type of structure is called a "Field" and, in this instance, could be referred to as the "Field of Complexity". As can be seen in Table 2, the 4 Areas, and their respective contents can be summarized as follows:

- *Infrastructure of Science* (5 Categories, or about 36%)
- *Sciences* (4 Categories, or about 29%)
- *Applications of Science* (3 Categories or about 21%)
- *Site of Applications* (2 Categories, or about 14%)

Following Table 2, I offer an interpretation of these 4 Areas.

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INFRASTRUCTURE OF SCIENCE	SCIENCES	APPLICATIONS OF SCIENCE	SITE OF APPLICATIONS
• Thought Leaders	• Chronologies	• Educational Practices	• Local Infrastructure
• Formalisms	• Empirical Evidence	• Models	• Organizations
• Language	• Laws	• Processes	
• Human Attributes	• Types of science		
• Reasoning Through Relationships			

Table 2. INCLUSION STRUCTURE FOR FOUR AREAS OF COMPLEXITY

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INTERPRETING THE RESULTS OF THE SECOND CATEGORIZATIONS

I will interpret the content of Table 2 beginning at the right of the table. That is where most practitioners are interested, i.e., in what goes on on the "shop floor" so to speak. Then I will proceed from right to left, moving slowly away from the applications toward the leftmost category, The Infrastructure of Science. Notably, the number of components increases steadily in moving from right to left. This tells me that I have been striving to produce more fundamental results than have been available in the past, while striving constantly to link those results to what practitioners require in order to work effectively with complexity.

Site of Applications. Throughout my study of complexity, I have identified the organization as the site where complexity is dealt with. The basic reason for this is that inherently complexity is beyond the scope of the isolated individual. The organization, as used in this context, could be small or large, but generally speaking it is the larger organization that has the resources to work with complexity systematically.

But the mere fact that a large organization may be involved is not sufficient to define the working environment. The main reason for this is that the large organization almost never recognizes the infrastructural requirements demanded by complexity **[Warfield, 1996a]**.

Applications of Science. Just as the organizational infrastructure is almost never adequate for working with complexity, it is also true that the scientific basis for what goes on is seldom given any overt consideration. This is true whether the organization is a corporation involved with complexity, a government involved with sociotechnical systems that are high in complexity, or whether it is an educational establishment locked into long-existing patterns. The latter provides the educational experience for the other two, which accounts for the institutionalized indifference to the application of relevant science when complexity is involved.

More and more it is being recognized that human beings constantly create and work with various kinds of models of what is perceived (e.g., mental, graphical, mathematical). The construction of all such models relies upon processes, and these processes usually either stem directly from educational practices, or are heavily correlated with them. As a rule the educational establishment controls the makeup and contents of archival literature, which is traditionally the site of scientific publication. As Charles S. Peirce articulated very well, the quality of a science depends upon the continuing attention given to it by a dedicated "community of scholars".

While it is true that, at long last, the subject of complexity has become the focal point of some investigation and or archival publication; regrettably, the prevailing definition of complexity in academic establishments is drawn far too narrowly **[Warfield, 1996b]**. Specifically, it suffers from acceptance of unjustified (and unjustifiable) assumptions such as these:

A1. THE SITE OF COMPLEXITY. COMPLEXITY IS INHERENTLY LOCATED IN (i.e., IS A PROPERTY OF) THE

SYSTEM UNDER OBSERVATION.

A2. NO NEED FOR EMPIRICAL EVIDENCE. THERE IS NO NEED FOR EMPIRICAL EVIDENCE TO SUPPORT DEFINITIONS OR PRACTICES.

A3. PRESUMED GREAT BREADTH OF APPLICATION OF MATHEMATICAL FORMALISMS and/or METAPHORS ACCOMPANYING THEM. THE SEVERAL MATHEMATICAL FORMALISMS, EACH OF WHICH IN THE ORIGINAL FORMULATION EMBODIES AXIOMS, POSTULATES, ASSUMPTIONS, ETC., UPON WHICH THE FORMALISMS ARE BASED; ARE APPLICABLE TO REPRESENT A VERY BROAD CLASS OF SYSTEMS, WHICH JUSTIFIES THE CHOICE OF THE TERM "COMPLEXITY" TO APPLY ACROSS THE BOARD.

A.4 THE ADEQUACY OF NATURAL LANGUAGE. THE NATURAL LANGUAGE IS ADEQUATE TO REPRESENT AND RESOLVE COMPLEXITY.

A5. NORMAL PROCESSES ARE SUFFICIENT. COMPREHENSION AND/OR RESOLUTION OF COMPLEXITY CAN OCCUR BY USING THE NORMAL PROCESSES FROM TECHNICAL OR ACADEMIC AREAS.

The impact of these dysfunctional assumptions can be overcome, if the recommendations presented in a document titled "THE WANDWAVER SOLUTION" are adopted (see http://www.gmu.edu/departments/t-iasis).

Sciences. As interpreted in this member of the set of 4 Areas, Sciences, as bodies of knowledge, are often categorized into types, the most common types being coarsely described as "hard" or "soft". Either type contains (or ought to contain)

- A chronology (hopefully explicit, but usually implicit) of how the science has evolved
- The Laws that have been uncovered to reflect the components of knowledge that have been produced
- Empirical evidence that justifies the designation as "law".

The chronologies are seldom articulated explicitly, but are part of the culture of a given discipline or area of study, and are extractable (sometimes with great difficulty, due to extensive linguistic pollution) from the relevant archival journals.

It is often true that little or no recourse is made to a science, at least in many domains. Even when recourse is made, the effort is often frustrated by inadequate integration of individual disciplines, let alone by integration of the areas of study that go across disciplines, or the areas that are beyond the scope of the disciplines.

Infrastructure of Science. Now we encounter a topic called "The Infrastructure of Science". I have coined this phrase in full recognition that this topic, amazingly, has been little-studied, and may actually not be recognizable to scientists. Scientists are often so obsessed with meaningless terms such as "objectivity", and are so intellectually imprisoned by poorly-thought-through-images of what science is, that such a concept as this may escape their vision entirely. Yet it must be intuitively of some importance to them, in view of the fact that institutional resources are often poorly administered when it comes to creating high-quality infrastructure for intellectual pursuits.

The history of science shows that many great discoveries emanated from individuals who were not

only poorly supported in terms of infrastructure, but who sometimes were actively abused, or even slaughtered by forces that despise high-quality thinking. It is said, for example, that Lavoisier (a lawyer, turned scientist) was denied even the opportunity to spend 30 days organizing his last research papers by a judge who condemned him immediately to the guillotine, saying that France really did not need intellectuals.

What we see when we study the infrastructural requirements of science in general are the requirement for language to support the integrated literary and graphical construction of the products of scientific research. While this was clearly recognized centuries ago by Gottfried Leibniz, the concept is treated in an ad hoc way by the newer so-called "sciences" such as computer science and management science. Representatives of these areas mostly do not recognize that the linguistic base for articulation of reasoning is highly restricted, and so proceed to ignore it while developing ad hoc constructions free of the discipline that comes from adhering to the recognized linguistic basis developed by George Boole, Augustus De Morgan, Charles Sanders Peirce, and others, in the nineteenth century.

The idea that formalisms are essential as a base for high-quality communication is critical, and the collection of existing formalisms drawn from thought leaders, provides an elegant basis for the creation of sound linguistic bases for the areas that have become prominent in the twentieth century. The most critical single area in science is the area of reasoning through relationships, by which is the meant the systematic construction of those patterns of logic that underlie and support extended developments into areas of practice including, when necessary, quantification of previously-developed qualitative conceptualizations.

To understand why such areas are neglected, one must turn to a study of human attributes, for it is these attributes that traditionally either provide the necessary infrastructure (when it is present), or deny it in deference to mischievous forms of behavior that underlie the modern superficial "sciences". Wherever one sees "science" being applied without an adequate intellectual base, one can look to the components of the Infrastructure of Science as set forth here, as a way to discover why the available products do not meet the requirements of complexity.

Having said all of the foregoing, one may note that the choice of people to be described as "Thought Leaders" is the key to determining precisely the nature of the Infrastructure of Science that must be created in order to:

- Produce the requisite science to underpin the applications that have become integral to modern-day life and tp
- Support high-quality applications in software design, organizational design, conflict resolution, and the design of broad-based legislation to cope with societal issues.

Most of the key thought leaders whose work has provided the basis for a science of complexity, and whose contributions are identified, are named in Appendix 1 of THE WANDWAVER SOLUTION, previously mentioned as being located in a document on the World Wide Web.

ORGANIZING COMPLEXITY BY CATEGORIZING ESSAYS ON COMPLEXITY

Late in 1997, I produced a compilation of 21 essays on complexity that I had written over a period of about 10 years as a spiral-bound collection titled "ESSAYS ON COMPLEXITY".

As an afterthought to this, I decided to try to categorize the essays, based on their central themes.

Table 3 shows the results of that effort. As can be seen there, the six categories that evolved from studying the essays are:

- **Organizational Flaws** (5 papers, about 24%). The components of this category are virtually all related to human behavior in organizations, often involving either too narrowly-based interpretations, or overemphasis on matters of low significance. They are reminiscent of Kenneth Boulding's three reasons for low intellectual productivity: Spurious Saliency, Unproductive Emulation, and Cultural Lag [Boulding, 19xx].

- **Linguistic Constraints** (1 paper, about 5%). This category emphasizes the inadequacy of prose as a sole medium of scientific and technical explanation. It stresses that the extremely heavy attention given to the teaching of the native tongue fails to recognize the Procrustean behavior of trying to force-fit knowledge into a linear medium that is fundamentally incompatible with what must be said.

- **Views on Complexity** (1 paper, about 5%). This category emphasizes the fact that today complexity is viewed via five different schools of thought, of which only the structure-based school takes advantage of the fundamental nature of relationships.

- **Science and Organizational Behavior** (3 papers, about 15%). This category emphasizes the failure of organizations to comprehend or take notice of available knowledge about how organizational behavior could be influenced by scientific findings of demonstrable significance, as illustrated in scholarly case studies of misadventures.

- **Organizational Enhancements** (10 papers, about 48%). This category (fortunately, the largest) aims at enhancing the capability of organizations to work with complexity.

- **University Redesign** (1 paper, about 5%). This category focuses upon what universities could do, if they were so inclined, to modify their infrastructure to accommodate what complexity demands, in order to be dealt with effectively.

Table 3. CATEGORIES FIELD: ESSAYS ON COMPLEXITY
(Showing how 21 essays on complexity are categorized, revealing the key areas of study)

A. ORGANI-ZATIONAL FLAWS	B. LINGUISTIC CONSTRAINTS	C. VIEWS ON COMPLEX-ITY	D. SCIENCE AND ORGANIZA-TIONAL BEHAVIOR	E. ORGANIZA-TIONAL ENHANCE-MENTS	F. UNIVERSITY REDESIGN
• Technomyopia Threatens Our National Security (1)	• Procrustes is Alive and Well and Teaching Composi-tion in the English Department (5)	• Five Schools of Thought About Complexity: (13)	• Spreadthink: Explaining Ineffective Groups (8)	•The Learning Organization: Its Relevance to Policymaking (3)	• The WAND-WAVER SOLU-TION: Creating the Great University (11)
• Some Magnificent Academic Trusels and Their Social Conditions (2)			• Demands of Complexity on Systems Science (9)	• Accelerating Productivity of Industrial Organizations (6)	
• Widely-Ignored Subtleties that are Critical to Decision-Making (4)			• Twenty Laws of Complexity: Studies in the Abuse of Reason (17)	• Structural Thinking: Organizing Complexity Through Disci- plined Activity (10)	
• Groupthink, Clanthink, Spreadthink, and Linkthink (7)				• The Corporate Observatorium: Sustaining Management Communication and Continuity....(14)	
• Mentomology: The Identification and Classification of Mindbugs (12)				• A Platform for Sociotechnical System Design (15)	
				•A Role for Formalisms in Integrative Studies (16)	
				• The Problematique: Evolution of an Idea (18)	
				• Readings for Bureaucrats (19)	
				• Seven Ways to Portray Complexity (20)	
				• A New Index of Complexity: The Aristotle Index (21)	

The letters of the alphabet assigned to the category names are for ease of reference only. The numbers associated with the titles of essays are assigned in the same sequence in which the articles appear in the spiral-bound document titled "ESSAYS ON COMPLEXITY".

REFERENCES

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