

# 1995-1996 ESSAYS ON COMPLEXITY

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# 1995-1996 ESSAY ON COMPLEXITY

James H. Brown  
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## PREFACE

**This document is a collection of papers published in 1995 or 1996. The papers presented here all deal with complexity, from different perspectives. All of them are part of the conceptual underpinning for Interactive Management.**

The first paper shows empirical results in the study of group behavior. It shows that when groups of people work together to try to resolve complexity, a major handicap invariably exists: each individual has a quite different perspective on the problematic situation. This phenomenon is called "Spreadthink". It takes its place with another well-known phenomenon affecting group behavior: "Groupthink", described by Janis, and illustrated in practice in government and industry by various authors. These group phenomena illustrate why it is necessary to apply well-designed methodologies for use with groups, and support the contention that computer assistance is required to structure aggregated knowledge of groups of individuals.

The second paper argues that complexity should be a dominating factor in systems science. Because it is not so perceived, much of today's systems science work is largely irrelevant to improvement of organizational practices.

The third paper is the prescriptive complement to the first paper. It explains how systems science can be greatly enhanced if the role of structural thinking is understood, and if structural thinking is permitted to play a much greater role in systems science than it presently occupies.

The fourth paper recognizes and describes five schools of thought about complexity. The Structure-Based School is described as the superior of the five schools of thought.

The fifth paper describes the "Corporate Observatorium", a facility envisaged as the primary infrastructure for learning about problematic situations in organizations, in which the full power of products of structurally-based investigations, using the plan described in the third paper, is dedicated to effective learning.

The sixth paper presents only the body of a considerably longer document. This paper is intended to show how today's university can enhance greatly the quality of its offerings, if appropriate infrastructure based in the kind of work reported here is provided, and if the faculty are given incentives to improve the quality of what is offered in higher education.

The last paper is a tongue-in-cheek discussion of a new field which I call "mentomology", the study of "mindbugs". This paper describes numerous mindbugs which play a role in human thought comparable to that played by software "bugs" in computing.

The author will appreciate comments or criticism, which can be sent to his email address: [jnwarfield@aol.com](mailto:jnwarfield@aol.com). This email address is expected to continue until December of 1997.



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# **SPREADTHINK:**

## **EXPLAINING INEFFECTIVE GROUPS**

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## **SPREADTHINK:**

### **EXPLAINING INEFFECTIVE GROUPS**

#### **ABSTRACT**

**E**xtended testing of the performance of small groups working with complex issues has revealed the pervasive existence of a phenomenon which is here named "Spreadthink". This phenomenon accounts for world-wide ineffectiveness of groups of people trying to work together to resolve complex issues under conditions that neither recognize nor compensate for Spreadthink.

Since Spreadthink is an immobilizing phenomenon, it deserves widespread attention and appropriate compensatory action by leaders, managers, and administrators wherever complex issues are under serious consideration in organizations.

Concurrent with the testing that uncovered and documented Spreadthink, measures that can be taken to overcome the effects of Spreadthink have been tested. The evidence that would prove the effectiveness of these measures is equal in extent, but much less quantitative in nature than the evidence that supports the presence of Spreadthink. Nevertheless, a significant case can be made to the effect that *if* Spreadthink can be overcome in a particular situation, the system of management called Interactive Management provides the capability to overcome it in that situation.

**KEY WORDS:** Clanthink, Complexity, Groups, Groupthink, Interactive Management, Nominal Group Technique, Organizations, Spreadthink, Structural Thinking



# SPREADTHINK

## EXPLAINING INEFFECTIVE GROUPS

### ABSTRACT

Extended testing of the performance of small groups working with complex issues has revealed the pervasive existence of a phenomenon which is here named "spreadthink". This phenomenon accounts for world-wide ineffectiveness of groups of people trying to work together to resolve complex issues under conditions that neither recognize nor compensate for spreadthink.

Since spreadthink is an internalizing phenomenon, it develops widespread attention and expression over extremely varied by leaders, managers, and administrators wherever complex issues are to be seriously considered in organizations.

Consistent with the theory that organized and documented spreadthink, phenomena that can be used to overcome the effects of spreadthink have been tested. The evidence that would prove the effectiveness of these measures is found in a report that much less quantitative in nature than the evidence that supports the presence of spreadthink. Nevertheless, a significant case can be made in the field that spreadthink can be overcome in a particular situation, the system of management called Interactive Management provides the capability to overcome it in that situation.

**KEY WORDS:** Leadership, Communication, Group, Organizational, Interactive Management, Problem Solving, Group Technique, Organization, Systems, Spreadthink, Thinking

"Spreadthink" refers to the demonstrated fact that when a group of individuals is working on a complex issue in a facilitated group activity, the views of the individual members of the group on the relative importance of issue-relevant ideas (usually component problems and/or proposed action options) will be literally "spread all over the map".

## RESEARCH ON SMALL GROUPS

The distinguishing feature of Spreadthink is that it is always present in all group activity involving complex issues, if the collective knowledge of the group members is representative of the full context and scope pertaining to the complex issue. Moreover, its effects are always the same: to present to any oversight body that is hoping to receive recommendations for action on a complex issue a widely divergent set of viewpoints, without any consensus on any of the components.

Since research on small groups has been going on for at least forty years, the question might arise as to why it is only very recently that Spreadthink has been discovered. The response to this question is that small group research has been bounded by certain limitations that precluded such a discovery.

The literature of small group research is scattered among many journals in a variety of disciplines. A broad overview of small group research describes the limited scope of prior research, and indicates that small group research needs to be redirected (Broome and Fulbright, 1994). Had the previous research supplied an adequate understanding of why small groups are invariably ineffective in working on complex issues, the ineffective performance of such groups would probably not be regularly in the public eye.

While past research on small groups has been valuable in gaining numerous insights into such groups, even if 10,000 papers had been published to describe and analyze small group activity, the results would only be applicable at the *scale of difficulty* involved in the topics dealt with in such activity. The past research has invariably been severely limited in terms of the *scale of difficulty* of issues dealt with.

Another shortcoming of small group research is that *research on the group* generally is the dominant concern that drives the activity. This tends to make the research contrived and artificial. That may be responsible for a lack of significant motivation on the part of participants to make progress on an issue that may have no direct relevance to the future of the participants and/or their organizations. By contrast, in the research reported here, the primary focus of the group work was *to get results on a complex issue*. The empirical data forthcoming from this research is a byproduct of the methodologies applied to enable the groups to grapple with complex issues. One result of this is that the powerful impact of issue-related motivation of group members is present to lend integrity and credibility to the results, insofar as their relevance to future applications is concerned.

## THE SPREADTHINK PACKAGE OF LAWS OF COMPLEXITY

While the discovery of Spreadthink occurred as a result of examination of empirical data accruing from numerous group activities, it took place within a much larger context. That context involved a study of complexity that has been going on for over a quarter century. This study has produced a set of Laws of Complexity (Warfield, 1995) whose number has been steadily growing, and which has now reached seventeen. Six of these Laws of Complexity describe or explain origins of Spreadthink. They are referred to as the "Spreadthink Package of Laws".

Spreadthink can be viewed as a short name for the content of these two Laws of Complexity:

- The Law of Inherent Conflict--which asserts that no matter what the complex issue and no matter what the group involved, there will always be significant conflict in interpreting what is important in resolving that issue.
- The Law of Diverse Beliefs--which asserts that at the outset of an investigation of a complex issue, members of the group will have quite diverse beliefs about the issue.

These four Laws of Complexity lend insight into the origins of Spreadthink:

- The Law of Limits--which relates to the inability of any individual to carry out the investigation and integration required to achieve, individually, without scientific assistance, a valid overview and in-depth understanding of a complex situation (because of individual inability to do more than sample the situation in time and space, and to construct relationships among diverse factors in the situation).
- The Law of Organizational Linguistics--which relates to the inadequacy of organizational language to supply the conceptual terminology in which to couch a proper viewpoint of a complex situation (because of the spontaneity of language, the unsystematic invention of new language for new situations, the ambiguity in existing language, the linearity of prose, and the existence of varying levels of compaction in language when moving across hierarchical levels in the organization).
- The Law of Structural Underconceptualization--which explains why individuals and groups cannot properly structure complex issues when they are working in the normal group setting and environment (because of the large number of systematic operations required to structure complex issues; the necessity of maintaining logical consistency in the face of this large number; the continued use of methodology that is only appropriate for ordinary, not complex, situations; and the common practice of limiting structure to hierarchical forms, instead of hybrid forms involving both hierarchies and cycles).
- The Law of Requisite Saliency--which asserts that people do not organize ideas well on the basis of relative saliency, this being borne out by data showing how individuals vote on relative



importance of ideas, to be visited shortly.

["Spurious saliency" has been called one of the three primary reasons for poor intellectual productivity (Boulding, 1966).]

## THE CONSEQUENCES OF SPREADTHINK

The predictable incidence of Spreadthink and the supporting empirical evidence from its study (to be described herein) lead to certain conclusions:

- *If nothing is done to resolve the difficulties caused by Spreadthink, there will be no consensus among individual members of the group on any course of action, unless that consensus is (falsely) reached through Groupthink (Janis, 1982) or Clanthink (Warfield and Teigen, 1993) or a combination of them.*

- *Not only is there no consensus among individual members of the group upon a course of action, but there is almost always no majority view on whether any problem facing the group or any proposed course of action is among the most important.*

- *Although often invoked as a prioritizing criterion by individuals or groups, importance is not even a suitable criterion for reaching a majority point of view or a consensus.*

- *Facilitators who try to bring groups to a majority view or a consensus without the aid of some methodology that resolves the difficulties caused by Spreadthink may well be driving the group to Groupthink or Clanthink, and thus helping to arrive at a decision that lacks individual support and, usually, lacks substance.*

## ORIGINS OF SPREADTHINK DATA

Spreadthink data are of two types. The first type, called "existence data", simply consists of data to show the existence of Spreadthink. The second type, called "recovery data", shows that it is possible to recover from the chaotic, immobilizing conditions that characterize Spreadthink by using a specific group learning process called "Interpretive Structural Modeling" (Warfield, 1976), which is a part of a management system called "Interactive Management" (Warfield and Cárdenas, 1994).

### HOW ARE SPREADTHINK EXISTENCE DATA OBTAINED?

All Spreadthink existence data are obtained through the same process: application of four steps from the well-known group process called Nominal Group Technique (NGT) (Delbecq, et al, 1975). With NGT, Step 1 is the silent generation of ideas on paper by group members in response to a previously-

designed triggering question. Step 2 is a round-robin gathering of the ideas carried out by a facilitator, who arranges that all the ideas appear on the wall in a highly-visible array for the entire group. Step 3 is the facilitated clarification of the ideas appearing on the wall through systematic group dialog. Step 3 (which is often omitted from other methodologies for gathering ideas from groups) has been clearly established through many repeated instances as critical in regard to assuring that most of the group members understand most of the ideas that are on the wall. There is always a significant amount of discussion in this clarification section of NGT, revealing that at the beginning the group members do not understand the same thing when they read the same statement.

It is only after this clarification step has been completed that Step 4 in NGT is carried out. In this step, each member is asked *individually* (without consulting other members or revealing votes to other members), to select the five "most important" ideas, and to rank these ideas in relative order of importance. **The data from these voting records confirm the presence of Spreadthink.**

### EMPIRICAL EXISTENCE DATA ON SPREADTHINK

While existence data on Spreadthink are always obtained by using NGT, this use of NGT is within a larger process context. Specifically, the context is the process called "Interactive Management". Data on 43 Interactive Management Workshops involving the use of the Nominal Group Technique have been published previously (Warfield, 1990). Table 1 is adapted from the previous publication. It shows, for each case, (a) how many ideas were generated and clarified in the session, (b) how many of those ideas were "selected", i.e., chosen by individual members of groups as being in the top five according to relative importance, (c) what percentage of the ideas generated were selected, and (d) the Departure Ratio. The Departure Ratio is found by dividing the number of Individually Selected Ideas by 5. If the group were in perfect agreement on the five most important ideas from those generated and clarified, the Departure Ratio would be 1. The more the Departure Ratio exceeds 1, the greater the disagreement among members of a particular group on the relative importance of the ideas which they generated and clarified.

Table 2 shows the averages of the values given in Table 1. Suppose that Table 2 describes a representative session. How does Table 2 support the concept of Spreadthink? Look at the average values representing 43 sessions. With an average number of 64 ideas being generated and clarified, individual participants selected 35 of these ideas (55% of the total generated and clarified) as being in the most important 5 ideas in the set of 64. If the members were in perfect accord on the most important ideas, each would have selected the same 5 (only 8% of the total generated and clarified). The last column in the Table quantifies the departure from unanimity. If all members had selected the same 5 ideas as the most important, the number in the last column would be 1. The value in the last column is 7, showing that *seven times as many ideas were selected by the individual members as would be found if the group were totally agreed on what were the most important ideas*. A very large spread can be seen in points of view among members of the group, based solely on the average values.

**TABLE 1. DATA ON NOMINAL GROUP TECHNIQUE APPLICATIONS**

<b>Case Number</b>	<b>Number of Ideas Generated and Clarified</b>	<b>Number of Ideas Individually Selected</b>	<b>Selected Ideas as a Percent of Ideas Generated</b>	<b>Departure Ratio [One Fifth of the Number of Selected Ideas]</b>
1	56	28	50	5.6
2	67	35	52	7
3	68	36	53	7.2
4	42	20	48	4
5	48	31	65	6.2
6	79	36	46	7.2
7	54	26	48	5.2
8	59	46	78	9.2
9	64	40	63	8
10	101	43	43	8.6
11	50	28	56	5.6
12	84	55	65	11
13	92	67	73	13.4
14	58	29	50	5.8
15	36	24	67	4.8
16	47	31	66	6.2
17	49	29	59	5.8
18	43	21	49	4.2
19	96	44	46	8.8
20	64	48	75	9.6
21	71	48	68	9.6
22	52	35	67	7



23	57	30	53	6
24	37	19	51	3.8
25	56	35	63	7
26	74	45	61	9
27	80	44	55	8.8
28	45	22	49	4.4
29	127	34	27	6.8
30	51	26	51	5.2
31	58	40	69	8
32	93	34	37	6.8
33	82	35	43	7
34	44	26	59	5.2
35	36	23	64	4.6
36	78	32	41	6.4
37	67	37	55	7.4
38	67	29	43	5.8
39	58	26	45	5.2
40	57	24	42	4.8
41	66	28	42	5.6
42	58	30	52	6
43	90	32	36	6.4

If the last column of Table 1 is inspected, it can be seen that the Departure Ratios range from a minimum of 3.8 to a maximum of 13.4. The value of 3.8 (Case 24) comes closest of all to showing unanimity of opinion, but even in that case the individual members chose 19 of the relatively small set of 37 ideas generated and clarified (over half), as lying in the top 5. For the value of 13.4 (Case 13) members had 92 ideas to choose from, and selected 67 of these (73%) as lying in the top 5!

***Study of these data shows that points of view are "spread all over the map", which is the basic idea of Spreadthink.***

Table 2. Average Data from 43 Applications of the Nominal Group Technique			
Ideas Generated	Ideas Selected	Percent Selected	Departure Ratio
64	35	55	7

(Investigators who might wish to verify the results just described can do so by creating conditions similar to those involved in the foregoing. An investigator should keep in mind that the above data represent work on complex issues, that the context involves a motivated group working on such an issue with a facilitator who is experienced in the use of NGT, and that the steps up to and including the individual voting in the NGT need to be carefully followed to assure that methodological departures do not corrupt the data. Moreover, because the NGT is carried out in the larger context of an IM Workshop, which means that NGT is an intermediate, rather than final, step in the group challenge; the data will be most reliable if attained in that larger context.)

Two other quantitative assessments emphasize further the nature of Spreadthink. One assessment examines the number of selected ideas which received (a) only one vote from the group members, or (b) at most two votes from the group members, expressed as a percentage of the total number of selected ideas. Table 3 shows data from two Interactive Management Workshops conducted at a major corporation during 1993 and 1994. Table 4 shows data from these same sessions studied to see which (if any) ideas were thought sufficiently important by the group to give them a majority vote.

TABLE 3. ASSESSING HOW MANY SELECTED IDEAS RECEIVED JUST ONE OR TWO VOTES					
Case Number	Number of ideas generated and clarified	Number of ideas selected: ideas in the top 5 in terms of importance	Percent of selected ideas receiving only one vote	Percent of selected ideas receiving at most two votes	Departure Ratio [One fifth of the number of selected ideas]
1	78	42	43%	65%	8.4
2	76	37	30%	48%	7.4
3	76	34	37%	53%	6.8
4	35	27	17%	29%	5.4

It can be seen from Table 3 that the percent of selected ideas receiving only one or two votes ranged from a minimum of 29% to a maximum of 65%, with the mean value being 49%. Also for these four workshops (whose data are not included in Table 1 or 2), the Departure Ratio averaged 7, the value found earlier when averaged over more than forty workshops.

Now imagine that in spite of the relatively large Departure Ratio indicated in Tables 1-3, one could determine that there were a few ideas thought sufficiently important by individual members that these few ideas would receive *at least* a majority vote (i.e., more than 50% of the votes) from the group members. (Unfortunately this measure of possible agreement was not recognized as significant in the early research upon which Tables 1 and 2 were based. However, once Spreadthink was recognized, the idea of looking to see if any or how many ideas received a majority vote from group members was recognized as significant. Therefore in recent activity involving Interactive Management this has been investigated.)

Table 4 shows data from the same two Interactive Management Workshops conducted during 1993 and 1994, as were involved in furnishing data for Table 3.

<b>TABLE 4. ASSESSING MAJORITY AGREEMENT ON IMPORTANCE OF GENERATED AND CLARIFIED IDEAS</b>				
<b>Case Number</b>	<b>Number of ideas generated and clarified</b>	<b>Number of ideas selected: ideas in the top 5 in terms of importance</b>	<b>Number of selected ideas receiving a majority vote</b>	<b>Percent of total votes received by idea receiving most votes</b>
1	78	42	None out of 42	2 ideas received 31%
2	76	37	None out of 37	2 ideas received 36%
3	76	34	None out of 34	1 idea received 50%
4	35	27	None out of 27	2 ideas received 50%

Notably, not a single idea received a majority vote in any of the four cases. From the grand total of 140 ideas selected in the four cases, only 3 ideas (about 2% of the ideas selected) received as many as 50% of the total votes. From the grand total of 265 ideas generated, the 3 ideas receiving as many as 50% of the total votes represent only 1% of the ideas generated.

With such small percentages of the selected ideas receiving votes from team members, it can be seen that the effect of Spreadthink is to inhibit development of any significant agreement on recommendations from the working group.



## INTERACTIVE MANAGEMENT WORKSHOPS

Each NGT activity from which existence data were obtained was part of a larger organized activity, called an "Interactive Management Workshop". Because the application of NGT is invariably followed by applying another methodology called "Interpretive Structural Modeling" (ISM), and because ISM is the learning methodology that provides a means of overcoming the impact of Spreadthink, it is important to appreciate that these two methodologies are integrative components of the Interactive Management (IM) process. Without an introductory understanding of IM, an explanation of the recovery data cannot be understood.

In the research reported here, situations in which participants gathered in a small group to work on a complex issue were characterized by these features:

- The rationale for initiating group work is either that *a complex issue threatens the organization*, or that *working to take advantage of a significant visualized opportunity* has been intractable to normal organizational processes, including normal meetings of relevant groups.
- The participants are chosen for *their specific knowledge of the issue*, and for the most part will be affected by any attempted resolution that is implemented.
- The role of the participants has been explained to them before and at the time of initiation of the group work. It is a single-dimensional role of *providing their expertise in the service of the issue being considered* by responding to questions posed to them, discussing such responses with fellow-participants and, ultimately, voting their individual points of view.
- Participants understand before they arrive that a process called Interactive Management (IM) will be used, and that *they will be engaged in an IM Workshop*, in which the Workshop staff will be responsible for providing and managing the overall process to be used, including the previously-chosen subprocesses.
- The *space in which the IM Workshop will be carried out* will be either (a) a specially designed facility, where the environment and technological assists used have been incorporated into the facility design; OR (b) a specially-chosen space, where the environment and technological assists used have been set up before the group arrived, to be organized as closely as possible like the specially-designed facility.
- An *experienced IM Workshop staff* conducts the Workshop.
- Before the group met, an *IM Workshop Plan* was prepared by an IM staff member, in collaboration with an individual who represents the small group's parent organization. This individual, called the Broker, provides the direct link between the sponsor organization and the IM staff. This plan follows a relatively rigid outline that has been repeatedly tested and improved, and all of its contents are accessible to the small group participants before they arrive to work as a group

(providing opportunity for discussion and possible amendment before the Workshop).

- Detailed *records are kept of all group products*, and interim reports are given to the group participants as they proceed through the multiple-day IM Workshop. Frequently, the entire proceedings are videotaped to provide educational documentation and opportunity to make amendments later, if appropriate.

- While the group process will have various component subprocesses established in the IM Plan, based on the outcomes sought from the work, each subprocess will be well-defined, and will have been used many times in prior Workshops. Specific types of issue-relevant information will be produced by participants for each subprocess used. The results obtained in this way can be subjected to scientific analysis and interpretation after the Workshop has ended. As a result of this, after a large number of IM Workshops has been held, it becomes possible to do *comparison studies* that can reveal what *invariances* appear to be present from group to group and from issue to issue. As such studies build in size, scope, and duration, they become part of the basis for scientific assessment of the work of small groups on complex issues.

## STRUCTURAL THINKING

IM Workshops are designed to facilitate "structural thinking". Structural thinking, in its most elaborately researched form, is responsive to the requirement that any contextual implication of linguistic components shall be elaborated in detail, in order to uncover defective suppositions (consciously held and stipulable) and/or presuppositions (unconsciously held and not articulated); and to the requirements that displayed products of structural thinking lend themselves to referential transparency; that the structural thinking be marked by thinking in articulated sets and articulated relationships, patterns, and systems; and that the processes applied in structural thinking shall be open at scale (i.e., not limited in application to some predetermined scope or dimensionality). **These and other evaluation criteria relate to the Laws of Complexity, discovered during a twenty-five year period of research on complexity.** The Spreadthink Package, discussed previously, arose from this research.

Structural thinking is an activity that is supported in the IM process and, specifically, is made possible by the use of ISM. The discussion of how structural thinking overcomes the impact of Spreadthink will be offered in a companion paper in which existence data will be overlaid on recovery data to show the effects of group learning in developing a strong majority point of view toward a complex issue.

## GRAPHICAL REPRESENTATION OF EXISTENCE DATA

Application of structural thinking in IM Workshops enables Spreadthink data of the type presented in Tables 1-4 to be presented in a more dramatic way. Figure 1 presents graphically voting data from an IM Workshop. In Figure 1, the vertical axis shows the number of votes received by those

problems receiving votes which are designated along the horizontal axis in Figure 1. In this IM Workshop there were 14 participants. In order for a problem to receive a majority endorsement as lying among the 5 most important, the problem would have to receive 8 votes; meaning that the vertical bar for that problem would have to cross the 50% line drawn across the center of the Figure. **Note that not a single problem received a majority vote.**

A second way to portray NGT importance voting, and to illustrate Spreadthink, is shown in Figure 2. This IM Workshop had 13 participants. Each large rectangle in Figure 2 represents the five votes of one of 12 of the 13 participants. The smaller rectangles within the larger rectangles in Figure 2 each represent one of the problems receiving at least one vote in the NGT voting process. Where a smaller rectangle within a larger rectangle is shaded in black, that means that the participant corresponding to the larger rectangle voted for the problem represented by that smaller one. Full documentation is contained in a Summary Report to a research sponsor (Warfield, 1993).

By scanning Figure 2, the reader can easily see how **the voting patterns of the participants vary dramatically.**

Figures 1 and 2 offer graphic ways of displaying the presence of Spreadthink!

## RECOVERY DATA

In contrast to the Spreadthink effect, recovery data are drawn from applications of ISM. Voting occurs in each application of ISM. In every vote that identifies a structural relationship, at least a majority is obtained (and frequently there is unanimity). These instances will be described in a companion paper titled "Structural Thinking", to appear in a future issue of Systems Research. The individual who seeks to assist groups in arriving at a well-considered consensus will find that the use of ISM, in the framework of Interactive Management, will enable strong recovery to be made from the disabling effects of Spreadthink. This recovery occurs because of the mutual teaching-learning that participants collectively experience when using ISM (Kapelouzos, 1989).

## CONCLUSIONS

A phenomenon called Spreadthink is responsible for highly diluted outcomes from group effort to analyze and make recommendations concerning complex issues or system designs. In the absence of carefully considered effort that will bring about recovery from this situation, groups working on such issues or designs will be ineffective. *(It will be shown in a companion paper that recovery is possible through application of appropriate group process.)*



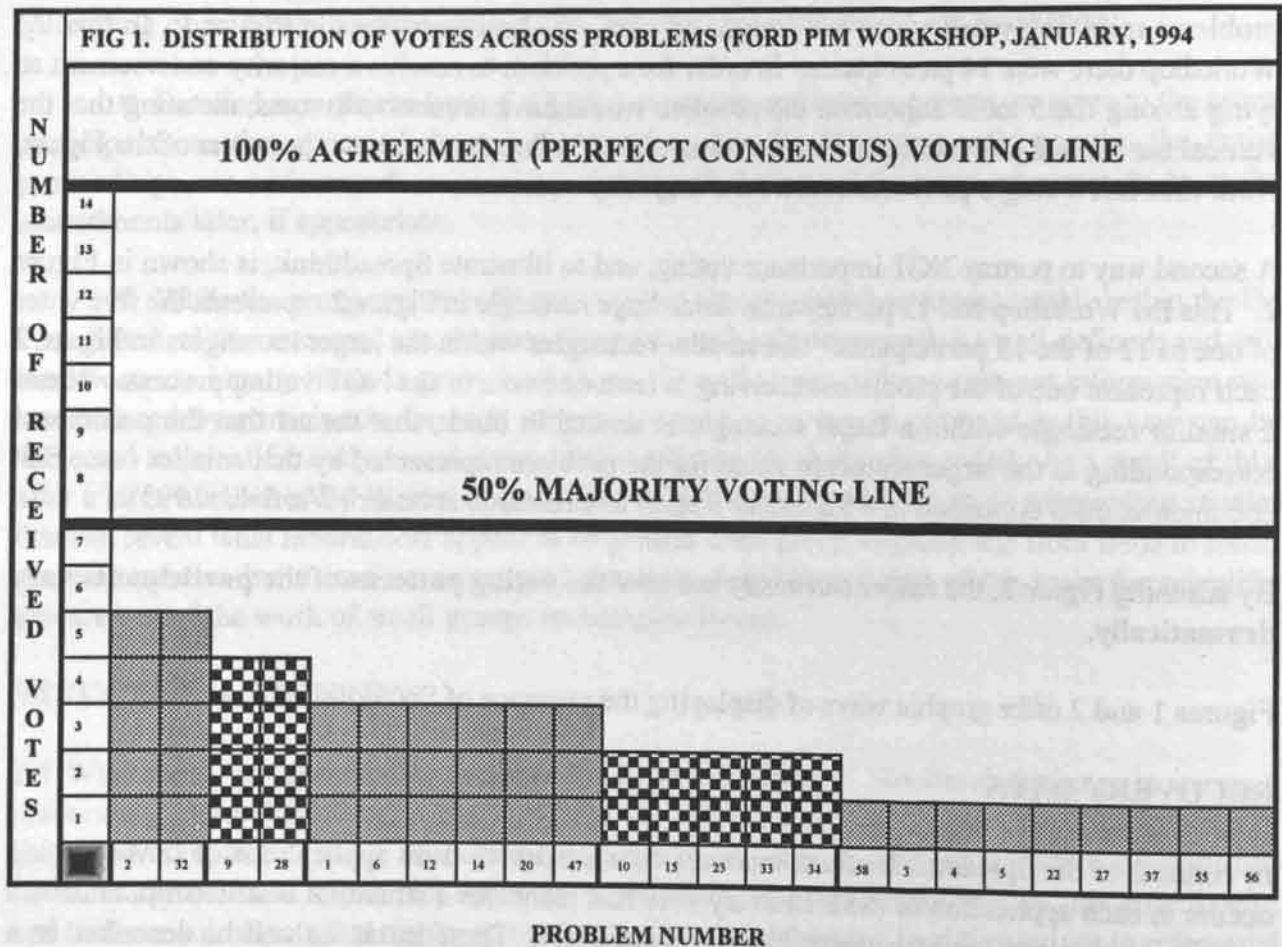


Figure 1 shows a bar chart of voting records for a project in which there were 14 participants. Each participant was asked to privately select 5 problems from a large set which that person thought were the 5 most important.

On this bar chart, the number of votes received is shown along the vertical axis. The problem number (e.g., Problem Number 2) is shown along the horizontal axis.

Any problem that received votes from at least 50% of the participants would show a bar that reaches or goes above the line labeled "50% majority voting line". Clearly no problem got even half of the possible votes, the maximum number being 5 votes, received by Problem 2 and Problem 32.

A total of 24 problems received votes. If everyone was in agreement, only 5 problems would have received votes, and each of them would have received 14 votes. The bars for these 5 problems would then reach to the line marked "100% Agreement (Perfect Consensus)".

This Figure is a graphical portrayal of "Spreadthink".





## ACKNOWLEDGMENTS

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# DEMANDS OF COMPLEXITY ON SYSTEMS SCIENCE

## ABSTRACT

There exists an unregulated collection of unrefined subject matter that is indefinitely referred to as "systems science". This body of knowledge has arisen over a period of about four decades from the work of scientists who strive to generate information that is relevant to many areas, such as academic disciplines or application areas. While there is much confusion about what this field consists of or what it is, there is consensus no argument among its adherents that this is an important and difficult field which is vital to the future of society. Some structure is proposed for this field, based on what has been learned about complexity.

## 1. PRELIMINARIES

### 1.1 ASSUMPTIONS

All models, the knowledge is constructed by human beings as collections of models, formal, informal, or hybrid (a mixture of formal and informal). Formal models are numerical, structural, or hybrid (a mixture of numerical and structural). Structural models are linear or non-linear. A linear structural model is described as a directed graph and a directed line can be drawn passing through all vertices and lines with the same direction.

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Space and mathematical models are of three major types: real, mathematical, and application-oriented. A real space is a mathematical space that has a correspondence between the mathematical space and the real world. A mathematical space is distinguished from any of its subspaces. An application-oriented space is like a real space, but serves for only for proper independent, and only can be applied to models. An application-oriented space is distinguished as a directed graph and a directed line can be drawn passing through all vertices and lines with the same direction.

Advances in understanding the demands of complexity involves the study of situations and systems. A situation is a set of conditions that exist in the situation, and (a) their complex organization of individuals, (b) the system described in the situation, and (c) their complex environment. A system is a set of all situations relevant to a given investigation.





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# DEMANDS OF COMPLEXITY ON SYSTEMS SCIENCE

## ABSTRACT

There exists an unintegrated collection of amorphous subject matter that is indefinitely referred to as "systems science". This body of knowledge has arisen over a period of about four decades from the work of scholars who desire to generalize information that is relevant to many areas, such as academic disciplines or application areas. While there is much confusion about what this field consists of at present, there is essentially no argument among its adherents that this is an important and difficult field which is vital to the future of society. Some structure is proposed for this field, based on what has been learned about complexity.

## 1. PRELIMINARIES

### 1.1 ASSUMPTIONS

All human knowledge is constructed by human beings as collections of models, formal, informal, or hybrid (a mixture of formal and informal). Formal models are numerant, structural, or hybrid (a mixture of numerant and structural). Structural models are linear or non-linear. A linear structural model is isomorphic to a directed graph, so that a directed line can be drawn passing through all vertexes and lines without touching any more than once.

Spaces are mathematical (heavily symbolic and programmable) of three major types: root, intermediate, and application-oriented. A root space is a mathematical space that forms a comprehensive framework for developing and positioning a formal model, as distinguished from any of its submodels. An intermediate space is like a root space, but serves for only for proper submodels, and may not be generalizable to models. An application-oriented space is idiosyncratic to a particular narrow-context application and, quite frequently, is very poorly suited to extension into lateral or more inclusive domains.

Amelioration of undesired consequences of complexity involves the study of situations and systems. A situation is a triad consisting of (a) a human component (an individual or an aggregation of individuals), (b) systems contained in the situation, and (c) their respective environments. A universe is a set of all situations relevant to a chosen investigation.

A system (following J. Willard Gibbs) [1] is **"any portion of the material universe which we choose to separate in thought from the rest of the universe for the purpose of considering and discussing the various changes which may occur within it under various conditions"**. (This definition is not generally known in the systems arena.)

A science is a body of evolving knowledge consisting of three variously-integrated components: foundations, theory, and methodology. (This definition is not generally known inside or outside the systems arena.) Foundations inform the theory and the theory informs the methodology. The volume of knowledge is smallest in the foundations and largest in the methodology. The domain of a science consists of the science and its applications. All science is evolutionary. Evolution typically occurs by comparing the congruence between the science and results observed in its applications.

## **1.2 SCALE OF COMPLEXITY**

In addition to Assumptions appearing in Sec. 1.1, it is assumed that there exists a "Scale of Complexity" such that a given situation can be positioned somewhere on the scale. Situations positioned in the leftmost region of the scale are called "ordinary situations". Situations positioned in the rightmost region of the scale are called "complex situations". It is further assumed that the number of perceived ordinary situations is much greater than the number of recognized complex situations.

## **1.3 HIGHER EDUCATION AND COMPLEXITY**

At present, the time spent on particular components of higher education is too small to admit careful analysis and design of complex situations. Instead, higher education thrives on incorporating large numbers of components in its student menu, each of which represents an ordinary situation. Of the many students who are able to comprehend large numbers of ordinary situations, some gradually acquire the confident belief that this prepares and qualifies them to work individually and comprehensively with complex situations. Unfortunately this belief is mistaken, because complex situations inherently do not lend themselves to use of the short-time, superficially-constructed models that characterize ordinary educational situations.

## **2. LAWS OF COMPLEXITY: INTERRELATIONS AND CONTEXTS**

As described elsewhere, seventeen Laws of Complexity have been discovered<sup>1</sup>. It is assumed that the reader either (a) has already studied these individual Laws or (b) is willing to suspend judgment on these Laws in order to allow the discussion to proceed. Figure 1 shows the Behavior-Outcomes matrix, such that the Laws whose titles appear in a particular matrix cell are particularly relevant to the type of situation represented by that cell.

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<sup>1</sup> The number reached 20 in 1997. All 20 are described in J. N. Warfield: (1997), "TwentyLaws of Complexity".

The behavioral (vertical) indexing deals with the individual, the group, the organization, and process; all aspects of human behavior. The Outcomes (horizontal) indexing refers to components of a generic kind of work program that is broadly relevant to human activity.

By aggregating all of the Laws that occur in a particular row, one can see which of the 17 Laws relate, for example, to the individual human being. By aggregating all of the Laws that occur in a particular column, one can see which of the 17 Laws relate, for example, to the description of a desired outcome.

In studying these Laws, it has been found helpful to recognize that some Laws can be most easily understood if other Laws have been studied first. Figure 2 shows a structural model conveying the pattern of study that recognizes these learning interactions. Submodels can be constructed from the structural model in Figure 2 to apply to any of the matrix entries, for purposes of developing learning sequences. For example, the learning sequence relevant to the individual would be comprised of four Laws studied in the following sequence: Triadic Compatibility (1A), Requisite Parsimony (1B), Limits (8B) and Requisite Saliency (8C). The learning sequence for process could be comprised of six Laws studied in the following sequence: Validation (4), Gradation (6), Universal Priors (7), Success and Failure (8D), Limits (8B), and Triadic Necessity and Sufficiency (11).

### 3. PEOPLE AND COMPLEXITY

Study of the behavioral components in Figure 1 has revealed that all three of the human components are seriously deficient when they attempt to apply what has been learned about ordinary situations to complex situations.

#### 3.1 THE INDIVIDUAL

The individual is subject to the restriction of scope reflected in the Law of Triadic Compatibility. This means that the individual cannot comprehensively deal with, in short term memory, interactions among four or more situational variables [2]. Processes designed to assist the individual to think through progressively the interactions among a variety of situational variables must reflect the contents of the Law of Requisite Parsimony. Both of these Laws contribute to understanding the limits on the individual. The Law of Requisite Saliency is amply illustrated by data taken from many Interactive Management projects [3].

The analysis just outlined can be repeated for each of the vertical and horizontal indexes, and then aggregated into an overall set of conclusions. This effort has been contributory to developing the practice called Interactive Management [3]. It incorporates process designs that are intended to minimize or annul undesirable impacts found when people try to apply approaches appropriate for ordinary situations to complex situations.



		OUTCOMES			
		DESCRIPTION	DIAGNOSIS	PRESCRIPTION (DESIGN)	IMPLEMENTATION
B E H A V I O R	INDIVID- UAL	<ul style="list-style-type: none"> <li>■ Limits</li> <li>■ Triadic Compatibility</li> </ul>		<ul style="list-style-type: none"> <li>■ Requisite Parsimony</li> <li>■ Requisite Saliency</li> </ul>	
	GROUP	<ul style="list-style-type: none"> <li>■ Limits</li> <li>■ Uncorrelated Extremes</li> </ul>	<ul style="list-style-type: none"> <li>■ Inherent Conflict</li> <li>■ Structural Underconceptualization</li> <li>■ Diverse Beliefs</li> </ul>	<ul style="list-style-type: none"> <li>■ Requisite Variety</li> </ul>	
	ORGANI- ZATION	<ul style="list-style-type: none"> <li>■ Limits</li> <li>■ Organizational Linguistics</li> </ul>	<ul style="list-style-type: none"> <li>■ Forced Substitution</li> <li>■ Precluded Resolution</li> </ul>		
	PROCESS	<ul style="list-style-type: none"> <li>■ Limits</li> <li>■ Triadic Necessity &amp; Sufficiency</li> <li>■ Universal Priors</li> </ul>	<ul style="list-style-type: none"> <li>■ Success &amp; Failure</li> <li>■ Universal Priors</li> </ul>		<ul style="list-style-type: none"> <li>■ Gradation</li> <li>■ Validation</li> </ul>

FIGURE 1 BEHAVIOR--OUTCOMES MATRIX



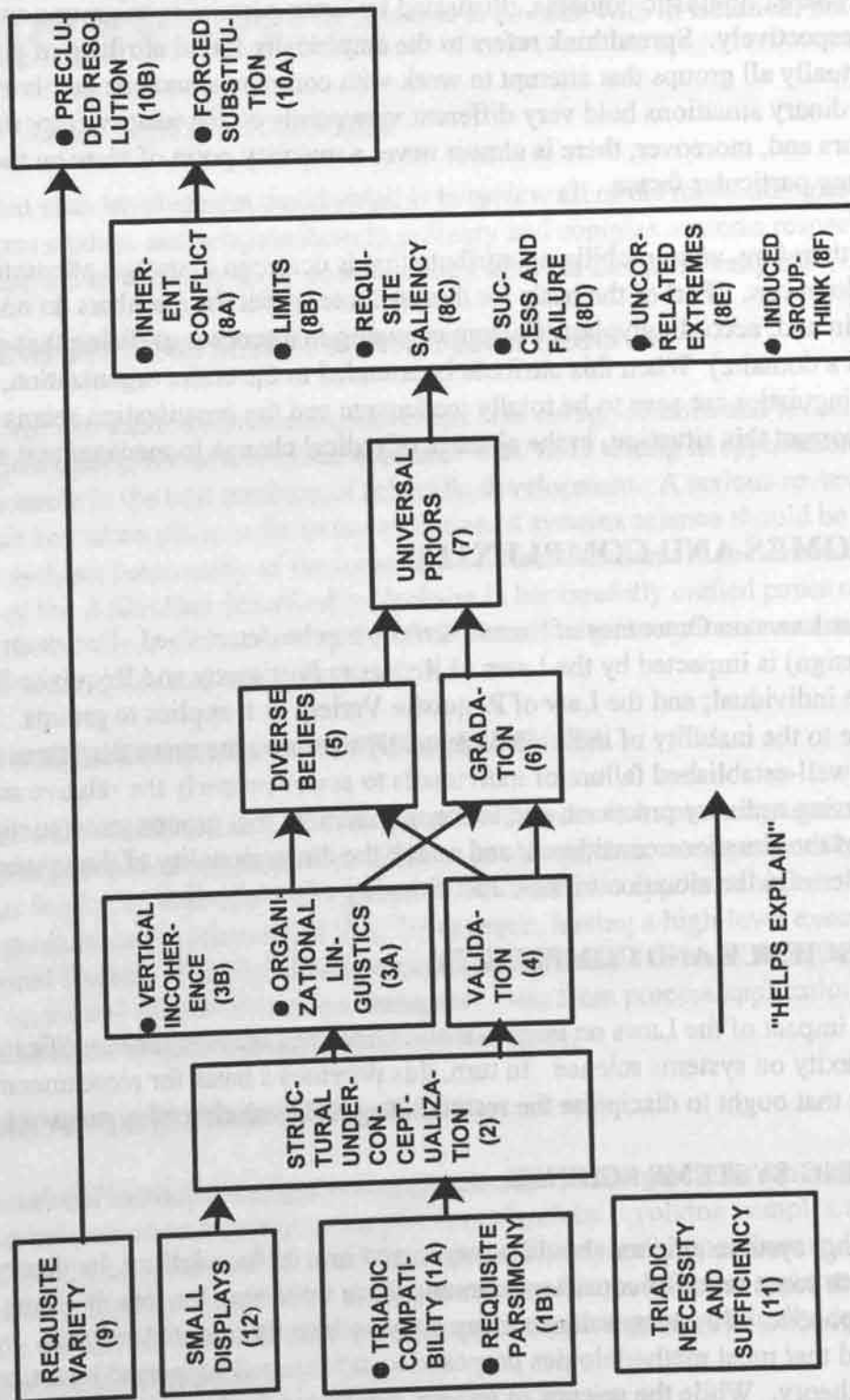


FIGURE 2. INTERACTIONS IN INTERPRETING LAWS OF COMPLEXITY. If a Law appears on the left of and connects to a Law to its right, then an understanding of the Law on the left is helpful in developing an understanding of the Law on the right. Laws that appear in the same box (with bullets in front of each Law in the box) are helpful in understanding all of the other Laws in the same box (they are in a "cycle").

### **3.2 GROUPS AND ORGANIZATIONS**

The corresponding difficulties with groups and organizations are, respectively, Spreadthink [4] and inadequate shared linguistic domains, illustrated by Laws pertaining to groups and organizations respectively. Spreadthink refers to the empirically found attribute of groups: members of virtually all groups that attempt to work with complex situations involving methods applicable to ordinary situations hold very different viewpoints on the relative importance of situational factors and, moreover, there is almost never a majority point of view on the importance of any particular factor.

Spreadthink is, therefore, an immobilizing attribute that is common to groups attempting to work with complex situations. (Part of the basis for this attribute is that the members do not share a linguistic domain and, accordingly, benefit from engaging in a process of dialog that enables creation of such a domain.) When this attribute is extended to the entire organization, the organizational linguistics are seen to be totally inadequate and the organization seems unable to do anything to correct this situation, in the absence of radical change in management style.

## **4. OUTCOMES AND COMPLEXITY**

The impact of the Laws on Outcomes of human activity can be determined. For example, Prescription (Design) is impacted by the Laws of Requisite Parsimony and Requisite Saliency, as they apply to the individual; and the Law of Requisite Variety as it applies to groups. These three Laws relate to the inability of individuals mentally to interrelate more than three things at a time, and to the well-established failure of individuals to assess properly the relative saliency of a set of concepts using ordinary practices; and to the requirement that groups strive to discover the dimensionality of the situations considered, and match the dimensionality of the system proposed to alleviate problems in the situation to the dimensionality of the situation.

### **4.1 SYSTEMS SCIENCE AND COMPLEXITY**

The study of the impact of the Laws on Behavior and Outcomes enables the identification of the impact of complexity on systems science. In turn, this provides a basis for recommending various practices that ought to discipline the restructuring and evolution of systems science.

### **4.2 ORGANIZING SYSTEMS SCIENCE.**

Generally speaking, systems science should be organized into its foundations, its theory, and its methodology, with some sense of consistency among these three components. It seems clear that the archival components of systems science today are very heavily oriented towards methodology, and that most methodologies proposed to date are not supported by articulated foundations and theory. While the science of generic design put forth by Warfield [5] may or may not be viewed by the systems community as well-conceived, at least a very strong effort has been made to organize this science along the lines mentioned, not leaving methodology to float on a choppy sea removed from its foundations.

#### **4.3 RELATING TO BEHAVIOR AND OUTCOMES.**

In the domain of complexity, systems science should be involved with both the horizontal and vertical index sets in Figure 1, not as components to be dealt with in isolation, but as topics to be integratively coupled.

#### **4.4 DOMAINS OF METHODOLOGIES**

One form that such involvement could entail is to review all of the methodologies proposed for use in systems studies, and relegate them to ordinary and complex systems respectively, by demonstrating either that they do or do not comply with the Laws of Complexity.

#### **4.5 TESTING SYSTEMS SCIENCE IN APPLICATIONS**

A second form that such involvement could entail is to recognize once and for all the need to couple proposed contributions to systems science with valid testing in applications, and to begin to close the circle in the best tradition of scientific development. A serious review of the extent to which this has taken place so far in the evolution of systems science should be carried out to remind the systems community of the importance of this tradition. In the absence of such testing, all of the difficulties described by Jackson in his carefully crafted paper on fads [6] will prevent systems science from attaining the kind of credibility it requires to assume an often-sought position of prominence in human affairs.

#### **4.6 EMPHASIZING PROCESS IN ORGANIZATIONS**

Systems scientists need feedback from applications in order to improve systems science. Experience suggests that organizations will have to change their management style in order to provide this feedback. One approach that could be taken is to appoint a high-level executive to oversee organizational processes just like, for example, having a high-level executive to oversee organizational finance. The high-level process executive could oversee the specialized training of a set of appointed mid-level process managers. Data from process applications could then be collected and made available to improve systems science.

#### **4.7 IMPROVING SYSTEMS EDUCATION**

Some educational institutions might recognize the need to reorganize in order to provide the specialized infrastructure required to support investigations involving complex situations [7]. If graduates could emerge that understand the impact of complexity upon human life, conceivably they might not only take the positive actions needed to design effective systems, but also they might stifle the extensive and ill-founded attempts to impose poor politically-designed systems upon long-suffering populations.

#### **4.8 IMPROVING MODELING**

Finally, perhaps the greatest positive impact on systems science that could be envisaged would



be the improvement of system modeling. Far too much emphasis is presently placed on numerant modeling unsupported by the relevant structural models. One of the most malevolent practices currently applied involves the attempt to force nonlinear structural models into inherently linear prose. This practice has to be broadly recognized as destructive to systems science. So it is necessary to place much more emphasis upon structural models than in the past. But that, in itself, will not be appropriate unless the systems community recognizes that ad hoc structural models do not communicate, and are simply another form of inappropriate communication. The use of hybrid models must be subjected to strong intellectual discipline of the type that a strong systems science would provide. Inherent in this practice will be the basing of structural models in root spaces. An especially significant root space is that founded in the Theory of Relations initiated by Augustus De Morgan in London, England, in the first half of the nineteenth century.

## 5. SUMMARY

Systems scientists should adopt a disciplined approach to systems science, in the interests of having a science that enables it to be responsive to complex situations. This approach should enhance significantly the access to this science of practitioners in industry and government, by organizing systems science so that it becomes much less opaque. Methodology will probably always make up the largest part of systems science, but methodology that is not archivally connected to foundations and theory, but rather is often dependent on unarticulated rationale (and therefore, inaccessible for validation or improvement), and which is subject to highly ambiguous interpretation, must begin to receive official frowns from the leadership in the systems community, no matter how much what they are doing may involve such methodology.

The potential benefit to society from a strong systems science cannot be realized unless the universities redesign themselves to provide appropriate infrastructure for applying selected components of systems science to complex situations. Government and industry organizations will continue to work with poorly-designed and publicly-mistrusted large systems until such time as they begin to administer systems-based processes in a manner at least as prominent as that which they apply to managing organizational finance and marketing.

The seventeen Laws of Complexity discovered so far, and those likely to be discovered as time passes can, with further probing and validation, provide a major part of the systems science of tomorrow. Until more candidates are proposed, the already documented science of generic design and its accompanying practice through Interactive Management can serve as a way of managing complexity; since these advances are responsive to the Laws of Complexity.

The bad news is that at the present time few of the demands of complexity on systems science are being met. The good news is that, because of the bad news, there is a wide arena of opportunity for substantial improvement in systems science and for significant increases in its application.



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# STRUCTURAL THINKING: ORGANIZING COMPLEXITY THROUGH DISCIPLINED ACTIVITY

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KEY WORDS: systems methodology, analysis, Structural Thinking, Interactive Management, Synthesis, groups

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## STRUCTURAL THINKING:

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## **STRUCTURAL THINKING: ORGANIZING COMPLEXITY THROUGH DISCIPLINED ACTIVITY**

### **ABSTRACT**

In today's world, large-scale systems are frequently involved in levels of complexity that have a serious and global impact on productivity. A Context Model is set forth that facilitates a new definition of complexity, providing a background against which a science of complexity can be developed, and describing an empirical process from which the complexity of any particular situation can be quantified through a Situation Complexity Index. In moving toward a science of complexity, the desirability of incorporating semiotics as a component of the science is indicated, because of the contributions semiotics makes to understanding the foundations and ubiquity of modeling. In the development of models, as semiotics indicates, the connection between what is being modeled and the language of description in the model is critical. Structural analysis clarifies the inappropriateness of models comprised only of prose to convey a description of a complex situation. Illustrative examples from the practice of Interactive Management (a system of management that supports the development and interpretation of structural models of complex situations, and design of improved systems) show the significance of Structural Thinking as the primary intellectual mode required to manage or cope with complexity. Group activity that would otherwise be invalidated by Spreadthink, is converted into a powerful approach to in-depth learning about a complex situation, which then provides a well-supported foundation for an organized attack to bring a complex situation under control.

**KEY WORDS:** systems, complexity, semiotics, Structural Thinking, Interactive Management, Spreadthink, groups

# STRUCTURAL THINKING: ORGANIZING COMPLEXITY THROUGH DIRECTED ACTIVITY

## ABSTRACT

In today's world, large-scale systems are frequently involved in levels of complexity that have a profound and global impact on humanity. A Global Model is not forth that facilitates a new definition of complexity, providing a background against which a science of complexity can be developed, and describing an empirical process that allows the complexity of any particular situation can be described through a Situation Complexity Index. In moving toward a science of complexity, the desirability of incorporating complexity as a component of the science is indicated because of the contribution complexity makes to understanding the foundations and stability of modeling. In the development of models, the connection between what is being modeled and the language of description in the model is critical. Structural analysis clarifies the interrelationships of models compared only of how to convey a description of a complex situation. Illustrative examples from the practice of business management (a system of management that supports the development and interpretation of structural models of complex situations, and design of systems) show the significance of Structural Thinking as the primary intellectual mode required to manage change with complexity. Group activity that would otherwise be considered by Structural Thinking is converted into a powerful approach to the depth learning about a complex situation which then provides a well-supported foundation for an organized attack to bring a complex situation under control.

KEY WORDS: systems complexity, structural thinking, interactive management, structural group

At least two kinds of evidence tell us today that it is time to come to grips with complexity as a social concern, and as a source of disasters and of low productivity.

**Macro Evidence:** One kind of evidence arises out of views of the society as a whole, where the presence and impact of complexity is evidenced by the number and variety of large systems that have invaded the lives of everyone (Warfield, 1994), and which serve both as aids and as constraints; e.g., a health care system intended to help people with medical care, but accompanied by huge expenditures that threaten to overwhelm governmental agencies by taking over most of their budgets; thereby preventing adequate funding of other human activities such as education. It is also evidenced in the form of large-scale life-threatening disasters, such as Chernobyl and Bhopal, and lesser disasters involving financial matters, such as the recent (and very expensive) savings and loan crisis in the United States.

**Micro Evidence:** A second kind of evidence has been developed in studies of group work involving Interactive Management (Warfield and Cárdenas, 1994), in which groups strive, on the one hand, to describe and diagnose large systems and, on the other hand, to prescribe and implement remedial approaches to dysfunctional large systems.

**Looking to Science for Help:** In many areas of human life, science is looked to for ways out of dilemmas; however where complexity is involved, the present modest search for an appropriate science seems to be highly disorganized, and to involve considerable false starts and misdirection. At least three avowed approaches appear to be in process at this time. One is the approach that is based in chaos theory. A second is an approach based in adaptive systems, with a strong biological component, as espoused by the Santa Fe Institute. The third is the approach taken here, which is rooted primarily in integrated knowledge of human behavior, philosophy, and technology. It is not intended here to compare these or other approaches that may have been overlooked. Instead, it is intended to build the case that the approach taken here, applying concepts of generic design and Interactive Management, offers a tested, systematic way to manage complexity in many situations.

**Forming a Context:** Any science of complexity would appear to benefit if it were based in a Context Model; i.e., a foundational situation within which complexity can be adequately defined; and which can also be closely related to human affairs. Without such a model, the subject of complexity would appear to drift around in space without an anchor, and would not be subject even to reasonable critiques of the content of any science, much less subject to assessment in terms of its impact in specific situations in society.

**Drawing on Existing Science:** It would also seem to be appropriate that a science of complexity draw on any other relevant sciences that might be more highly organized, so that it would not be necessary to create every aspect of a science of complexity, but rather only to add and integrate those aspects that seem not to be adequately treated in older sciences. With this in mind, a Context Model for studying complexity is introduced, which includes components drawn from both social observation and detailed work involving studies of applications that used Interactive Management. The **components of the Context Model** are: (a) the "complex situation" as a basic unit of study, (b) origins of low productivity when working with complexity,

(c) necessary and sufficient conditions for the presence of complexity, and (d) the developing science of semiotics, which is viewed as a basic part of any science of complexity that may be developed.

**Origins of Low Productivity:** Five major categories are viewed as origins of low productivity in complex situations. These are:

- *Behavioral* (including individual, group, and organizational behavior)
- *Representational* (involving how complex systems are described in documentation)
- *Informational* (involving how relevant context is gathered for the complex situation)
- *Infrastructural* (involving support systems for human beings which incorporate the kind of support that is needed when working with complexity)
- *Relational Processing* (which has to do with how processes of assessing relationships among components of a complex situation can be successful)

Table 1 presents these five categories and components within the categories.

It is appropriate to consider in detail how the categories and components in Table 1 affect productivity. But the challenge to explicate that subject can best be met after a Context Model for Complexity has been defined.

**Looking Ahead:** After the Context Model has been illuminated, a brief indication of the history and relevance of the science of semiotics will be given, that points the way toward specific areas requiring further development. One such area is the connection between language and complexity, which will highlight the inadequacy of prose as the primary means of working with complexity. If prose is inadequate, attention must be given to other kinds of representational models. A discussion of modeling is presented that develops the necessity of structural modeling as a means of illuminating and working with complex systems, all the way from the point of description to the point of implementation of change. Structural modeling is a means to improve Structural Thinking, which is seen as the principal avenue to attaining a healthy and utilitarian approach to the study of complexity. The management system called "Interactive Management" has been tested in many settings, as a support system for Structural Thinking. Outcomes from representative applications are studied in detail as a way of showing how the origins of low productivity in working with complexity can be overcome. The entire system is dedicated to resolving simultaneously problems dealing with individual, group, and organizational behavior.



**TABLE 1. ORIGINS OF LOW PRODUCTIVITY WHEN WORKING WITH COMPLEX ISSUES**

## **A. BEHAVIORAL**

### **A1. INDIVIDUAL**

- Unproductive Emulation (Boulding, 1966)
- Spurious Saliency (Boulding, 1966)
- Limits on Relational Processing
- Ambiguous Representations

### **A2. GROUP**

- Unsystematic Discussion
- Lack of Shared Linguistic Domain
- Spreadthink
- Groupthink
- Clanthink
- Guruthink

### **A3. ORGANIZATIONAL**

- Cultural Lag (Boulding, 1966)

## **B. REPRESENTATIONAL**

- Linearity of Prose
- Nonlinearity of System Aspects
- Lack of Shared Linguistic Domain
- Linguistic Mutations Across Organizational Levels
- Ignorance of Prose-Graphic Hybrid Forms
- Undisciplined Use of Ambiguous Graphics
- Unawareness of Well-Defined Structural Types
- Undisciplined Invention of Nomenclature
- Unawareness of Pervasive Impact of the Foregoing

## **C. INFORMATIONAL**

- No Sampling
- Weak (Individual) Sampling
- Stronger (Group) Sampling
- Unawareness of Sampling Deficiencies

## **D. INFRASTRUCTURAL**

- Badly Designed Group Work Space
- Display Space far too Small
- Unsystematic or Poorly-Chosen Group Process
- Untrained Group Support Staff
- Misuse of Computers
- Inadequate Enabling Resources
- Mismanagement of Resources

## **E. RELATIONAL PROCESSING**

- INDIVIDUAL--The Magical Number Three
- GROUP--Unsystematic Discussion Groups
- ORGANIZATION--Lack of Strong Shared Linguistic Domain

If the complex situation can be adequately studied, and appropriate recommendations can be developed, then the whole organization may come into play in implementation. In order to make this effective, the organization needs to be viewed as a multi-level system with historically inadequate provisions for communication at interface levels in the organization. The implications of Structural Thinking for the organization are that targeted approaches to enhanced communication need to be made at these interface levels, and consequently they need to be budgeted along with the other organizational levels.

The entire approach to complexity is heavily colored by past experiences, including those that demonstrate the dysfunctional aspects of group behavior involving matters such as Groupthink and Spreadthink (Warfield, 1995). It is possible that Groupthink may become active, leading to poorly conceived results, but it is inevitable that Spreadthink will be present and, if left uncorrected, will by itself assure that any desirable outcomes involving good management of complexity will be statistical aberrations, also known as "good luck".

## 1. A CONTEXT MODEL FOR COMPLEXITY

Complexity is an attribute of a situation necessarily containing a certain irreducible set of components, which are referred to as the "necessary conditions" for complexity. Identification of these components corresponds to describing a Context Model of a complex situation. Once the nature of this Context Model is clear, a search for sufficient conditions for the presence of complexity becomes possible. The reader is reminded that sufficient conditions need not be necessary conditions. While no deletion can take place from a parsimonious formulation of necessary conditions, a variety of possibilities may be determined as sufficient conditions; hence the formulation of a single sufficient condition given here may later be replaced to gain more refined discriminatory power as new empirical evidence becomes available.

Table 2 gives necessary and sufficient conditions for complexity to be present in a situation. Three of the necessary conditions are described as "primary", and the other four are described as "secondary". While all are necessary, the secondary conditions are present as a consequence of the presence of the primary conditions. A single sufficient condition is given, based upon an analysis of an extensive amount of data derived by applying the system called "Interactive Management (IM)" (Warfield and Cárdenas, 1994) to situations generally considered to be complex by the individuals involved with the situations.

The following definition summarizes the foregoing:

***Necessary and sufficient conditions that a situation be complex are that the situation contains seven components: (a) a human presence, (b) a generic purpose associated with the human presence, (c) exercise of system inquiry by the human presence, (d) human purpose-related infrastructure to make possible the system inquiry, (e) system-related environment, (f) sensing apertures for space-time sampling of the situation by the human presence, and (g) cognition on the part of the human presence; and that the Situation Complexity Index (SCI) shall have a value of at least 100, where:  $SCI = (N/7)(V/5)(K/10) = (1/350) NVK$ .***

**TABLE 2. NECESSARY AND SUFFICIENT CONDITIONS FOR COMPLEXITY TO BE PRESENT IN A SITUATION**

PRIMARY NECESSARY CONDITIONS		SECONDARY NECESSARY CONDITIONS		SUFFICIENT CONDITION
A Human Presence	<p>Complexity is a component of that presence. At any given time its extent and intensity is always assessed in relation to that human presence. The character of complexity is subject to change if there is any change in the human presence.</p> <p>The Human Presence will typically consist of one of the following:</p> <ul style="list-style-type: none"> <li>■ A single individual</li> <li>■ A small group</li> <li>■ An organization</li> </ul>	An Infrastructure Associated with the Human Presence	An Infrastructure associated with the Human Presence, identifiable as any components of the environment of the Human Presence that affect the capacity of the Human Presence to conduct System Inquiry effectively.	<p>The Situational Complexity Index shall be at least 100.</p> <p>Suppose that group members (a) generate and clarify (using the Nominal Group Technique) a set of N problems, (b) vote individually to select problems lying among the top five in importance, which collectively add up to V problems, (c) incorporate M of the selected V problems in a Problematique (using the Interpretive Structural Modeling process), which then contains K dyadic aggravation relationships among the M problems.</p> <p>Then the Index is given by</p> $SCI = (1/350) NMK$ <p>NOTE: M should equal V if time permits, otherwise <math>M &lt; V</math>.</p>
A Generic Purpose	The Human Presence must exhibit a generic purpose: to become knowledgeable about a system.	An Environment Associated with the System	The System Environment is identifiable as a set of components that have an effect upon the System	
Exercise of System Inquiry	The Generic Purpose must be exercised in the form of System Inquiry. (The definition of "system" was clarified by the great American scientist J. Willard Gibbs as follows: "any portion of the material universe which we choose to separate in thought from the rest of the universe for the purpose of considering and discussing the various changes which may occur within it under various conditions".)	A Sensing Aperture Through Which the Human Presence Gathers Signs as Time-Space Samples from the System	Time-Space Sampling (through a Sensing Aperture) associated with the System Inquiry, reflects the fact that the Human Presence can only conduct System Inquiry in a sampling mode through a Sensing Aperture. In part, complexity arises out of limited access to the system which is the subject of inquiry.	
		Cognition Occurring Within the Human Presence as an Outcome of the System Inquiry	Cognition refers to the learning that goes on in the Human Presence.	

This version of Table 2 corrects errors in the published version.



To understand the Situation Complexity Index, one needs to understand certain subprocesses applied in Interactive Management. Experience with IM has involved, in virtually every instance, a group process that produces (a) a set of problems involved in the system, (b) an Important Problem Subset (IPS) of the problems, comprised of those that are individually selected by participants as lying in the top five members of the problem set in importance, and (c) a pattern of aggravative relationships among those problems called a "Problematique" (Warfield, 1994). Measures arising from these products can be applied to give a practical definition of a sufficient condition for complexity. Suppose that the group generates and clarifies, using the Nominal Group Technique (Delbecq, et al, 1975) a set of  $N$  problems (for which  $N = 7$  would correspond to the "magical number" (Miller, 1956)). Then suppose that individual voting on the top five, when the results are aggregated, produces an IPS that contains  $V$  problems (which, if  $V = 5$ , would represent group unanimity on relative importance of problems). Next, suppose that  $M$  problems chosen from the IPS are incorporated in a Problematique (since there will not always be time to include the entire IPS), using the Interpretive Structural Modeling process (Warfield, 1976 and 1994), and that this Problematique contains  $K$  dyadic relationships among the  $M$  selected problems (which, if  $V = M = 5$  corresponds to  $K = 10$ , provided the relationship is structurally linear). Then the numbers  $N$ ,  $V$ , and  $K$  can be entered into the SCI formula, and the numerical value of the index can be determined. (Note that if  $N = 7$ ,  $V = 5$ , and  $K = 10$ , the value of SCI is 1. This set of values represents a reference set, against which higher values such as  $SCI = 100$ , can be compared).

**Example:** An application might involve  $N = 64$  problems, of which 35 might be selected by individualized voting. The value of  $V = 35$  allows determination of the theoretical maximum and minimum number of dyadic relationships in this situation. (The maximum possible number would be  $K = 1,190$  if every problem aggravated every other problem; while the minimum possible would be 0 if no problem aggravated any other problems. None of the hundreds of situations studied has ever yielded a value of  $K$  anywhere near the minimum value of 0; and the maximum value has never been attained, although in a few situations, values of  $K$  close to the maximum were found.) Suppose that in the typical application  $K = 100$  and  $M = V$ . Then the value of SCI would be approximately 640, placing the example well into the domain of complex situations. **End of Example.**

## 2. SEMIOTICS AND COMPLEXITY

The chronology of development of semiotics (the science of signs) is not necessarily fully available. Still certain highlights are very evident. A clear beginning was uncovered within the past decade through the scholarship of the American philosopher John Deely, who determined that a Portuguese scholar named John Poinsett recognized the importance of the subject, and began writing about it in the 17th century (Deely, 1990). Until Deely's discovery, it was generally assumed that semiotics was first conceived by the American philosopher, Charles Sanders Peirce, who studied this subject at length and created most of the fundamental concepts of the subject (Goudge, 1950). A definitive biography of Peirce has recently been published (Brent, 1993) after a delay of over 30 years related to inaccessibility of much of the relevant information. A modern contributor to the field is Umberto Eco, who appears to be more widely



recognized in this field than either Poincaré or Peirce (Eco, 1984).

The consequences of past failure to incorporate semiotic thinking in various fields, including science, management, and engineering, are very significant. These fields are still dominated by poor foundational assumptions that account for the widespread maintenance of dysfunctional beliefs and practices in these fields: a situation that ultimately will be corrected through the use of Structural Thinking. One of the main contributions of semiotics is that it is constructively responsive to many questions studied by philosophers for centuries, and provides a sound logical basis for eliminating many widely-held misconceptions about "objective" science. Semiotics successfully ties human attributes to the development and organization of knowledge, in a manner consistent with Peirce's philosophy of science and Polanyi's view of "personal knowledge" (Polanyi, 1958). Semiotics supports conceptually groups of people working on complex issues in its portrayal of the perceptual basis underlying all science. In effect, the integration of the knowledge held by group members can be seen as the organization of samples of information independently gathered through sensory apertures, one per observer. In modern language, semiotics elevates "modeling" to the pinnacle of human efforts to understand what is going on, and to develop systematically an approach to coping with the complexities of modern living through improved understanding of systems and system design. But in elevating modeling to that pinnacle, it does not justify the continuance of many practices often associated with modeling. Instead, semiotics orients modeling along lines that, unfortunately, are unfamiliar to most of the modeling community, who continue studiously to avoid critical inspection and revision of underlying assumptions.

### 3. COMPLEXITY AND LANGUAGE

In portraying complexity through writing, prose is a "Procrustean Bed". (Procrustes, the famous mythical giant, operated an inn for overnight travelers. If the traveler was too large for the bed, Procrustes simply chopped off any parts that hung over the edge of the bed. If the traveler was too small for the bed, Procrustes stretched the traveler to fit the bed.)

**The fundamental reason for the unsuitability of prose to portray complexity is its structural linearity.** Figure 1 indicates the linearity of prose in several of its subdivisions, which can range from letters of the alphabet to multi-volume collections. Typical linear structures are shown in Figure 1. Figure 2 shows a typical Problematique (the "AP Problematique"), whose structure is readily seen to be far from linear. If one were forced to present the contents of Figure 2 only in prose, the communicability of the complexity of the structural relationships shown in the Problematique would be severely degraded.

Some of the boxes in the problematique involve more than one of the members of the IPS. Each problem number in these boxes is preceded by a bullet. The subset of problems contained in a single bullet-box is called a *cycle*, e.g. problems 33 and 43 at the extreme left of the problematique in Figure 2. Every problem in a cycle aggravates all other problems in that cycle and all the problems arrow-oriented to the right of the cycle.

# FIGURE 1 THE LINEAR (PRECEDENCE) STRUCTURE OF ENGLISH PROSE

## EXAMPLE:

Letters: {c, a, t}

Relationship: 'directly precedes'  
represented by

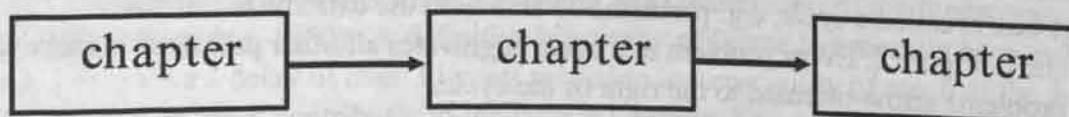
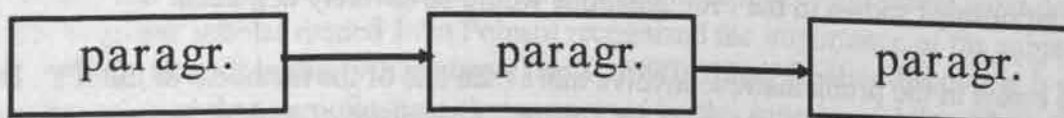
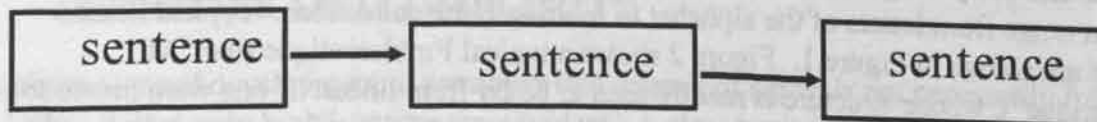
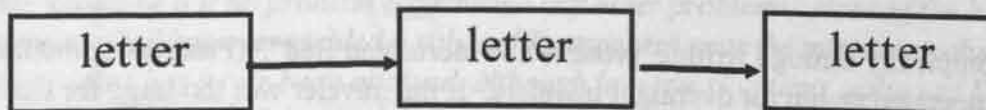
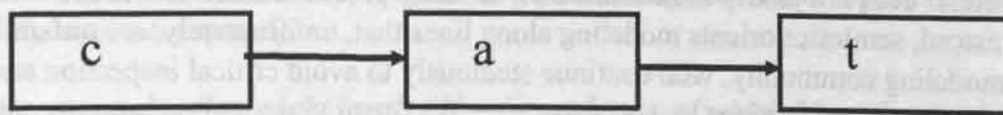
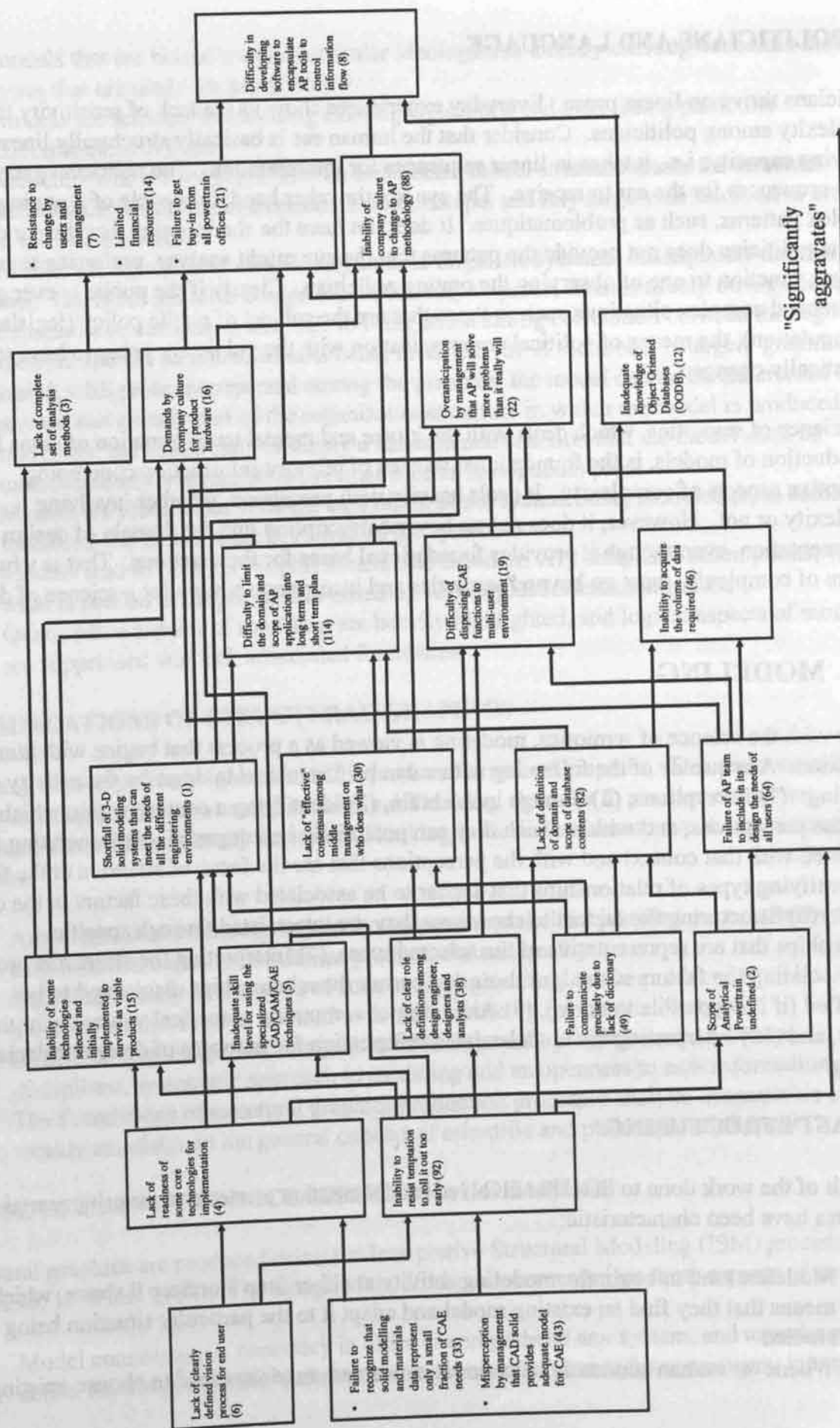


FIG. 2 AP PROBLEMATIQUE





### 3.1 POLITICIANS AND LANGUAGE

Politicians thrive on linear prose. Everyday experiences show us the lack of sensitivity to complexity among politicians. Consider that the human ear is basically structurally linear in its receiving capacity; i.e., it takes in linear sequences for interpretation. The politician generates linear sequences for the ear to receive. The eye, on the other hand, is capable of scanning complex patterns, such as problematiques. It does not have the shortcoming that the ear displays. But the politician does not provide the patterns that the eye might analyze, preferring to reduce the eye's function to one of observing the orating politician. Clearly if the public is ever going to comprehend complex situations such as those that are the subject of public policy (legislation and regulation), the means of political communication with the public are going to have to be dramatically changed.

The science of semiotics, which deals with the intake and mental transformation of signs leading to production of models, is the foundational science of relevant information concerning descriptive aspects of complexity. It deals heavily with perception, whether involving complexity or not. However, it does not go beyond description into the domain of design and implementation, even though it provides foundational bases for these actions. That is why a science of complexity must go beyond semiotics and incorporate a basis for a science of design.

## 4. MODELING

In line with the science of semiotics, modeling is viewed as a process that begins with human perception. A sequence of the following nature can be formulated to describe the activity of modeling: (1) Perceptions, (2) Storage in the brain, (3) Identifying a context within which to place the perceptions, and within which they can potentially be integrated, (4) Generating factors associated with that context and with the perceptions that are the focus of attention at the time, (5) Identifying types of relationships that appear to be associated with these factors in the chosen context, (6) Structuring the factors to show how they are interrelated through specific relationships that are representative of the selected types, (7) Interpreting the structures produced, (8) Associating the factors with algorithms that permit the relationships discovered to be quantified (if it is possible to do so), (9) Assigning or computing numerical values to/for the factors, and (10) Interpreting the model-related information for purposes of design or decision-making.

### 4.1 PAST STRUCTURING

In much of the work done to date that involved model creation or model structuring, certain attributes have been characteristic:

- Modelers tend to begin the modeling activity at either Step 8 or Step 9 above, which means that they find an existing model and adapt it to the particular situation being studied
- Whenever human economic behavior is concerned, modelers tend to choose existing



models that are biased toward particular ideologies or already-existing economic model types that are ready for use at Step 9

- Models are selected by choosing existing algorithms and then fitting particular circumstances to them
- Modelers who do not begin with an established model structure create the structure individually with little discussion of relationships, and rely largely on intuition to arrive at the model structure
- Models are represented using idiosyncratic linguistic systems, inadequately defined, so that: (a) If the model is comprised exclusively of prose, it tends to rely on high-level metaphors or categories, and fails to bring about strong correlation between the high-level rhetoric and the details of what is being modeled, (b) If the model is largely graphics-based, with prose interspersed among the graphics, the model cannot be understood by anyone not already part of the organizational culture in which the model is produced and, moreover, the model fails to satisfy a fundamental criterion that the model shall be unambiguously translatable into (what is often ambiguous) prose
- Models are often taken to be the equivalent of the system being modeled or, in some instances, the model itself is viewed as the system
- Models tend to be highly sophisticated, and based on very simplistic assumptions; when what is needed is simple models based on very sophisticated assumptions
- Quantitative aspects of modeling are heavily highlighted, and logical aspects of models are suppressed and lack articulated foundation

## 4.2 FOUNDATIONS OF STRUCTURAL GRAPHICS

Structural Thinking is only in evidence if it produces structural graphics. This requirement could be seen as a significant constraint on Structural Thinking. In order to avoid constraining influences, the process whereby Structural Thinking is carried out must have these primary attributes:

- Any constraints arbitrarily imposed on the process shall be justified only on the basis of demonstrated capacity to enhance productivity and quality
- Sufficient variety in the types of structural graphics that can be produced shall be available so that there is no need to force-fit thinking into restrictive types
- Structural graphics production processes shall attain a proper balance between a disciplined, systematic approach to modeling and an openness to new information
- The foundations of structural graphics production processes shall be unassailable or only weakly assailable in the general context of scientific and philosophical thought

## 4.3 USE OF ISM TO PRODUCE STRUCTURAL GRAPHICS

Structural graphics are produced using the Interpretive Structural Modeling (ISM) process (Warfield, 1976 and 1994). The design of the ISM process recognizes these aspects of modeling:

- Model consistency is necessary in order to comprehend any system, and to make possible action recommendations; therefore the process must provide for consistency in modeling

- Achievement of model consistency in the development of models is subject to severe human intellectual limitations, therefore machines must be used to ensure that the human achieves model consistency
- The role of the machine in assuring model consistency is limited only to assuring consistency of relationships envisaged by human beings
- The more the human beings involved encompass through their collective knowledge and experience the context of the situation involved and the scope of the joint effort to be carried out in model development, the more likely their integrated knowledge about complex situations will be found reliable
- A variety of relationship types should be admitted and, within the types, a variety of specific instances shall be admitted
- Where models require more than one type of relationship (i.e., composite relationships), complexity requires the composition to be done from component to composite
- The physical representation of relationships should be carried out for maximum readability
- All structures produced should be unambiguously translatable into prose, requiring that chosen symbol systems shall not introduce uncertainty or opacity

Among other things, these requirements indicate that structural graphics are founded in branches of mathematics, allowing computers to assist in developing, modifying, laying out, communicating, and interpreting structural graphics.

## 5. STRUCTURAL THINKING

Structural Thinking, **by definition**, integrates the following attributes. Practitioners:

- develop sets by generating and clarifying members of the sets
- focus on selected relationships for organizing information about the developed sets
- explore the relationships among the members of the developed sets in great detail
- produce logically consistent relationships among the members of the developed sets
- specify the structural features of the relationships in generic terms that enable effective interpretations to be developed
- allow comparisons of relative complexity to be made among relationships
- forego exclusive use of prose as the means of representing structural features of the relationships, instead producing designed types of visual patterns for interpretation
- use computer assistance in developing, organizing, and representing the relationships
- are indifferent to the scale of the topic being considered, because the methods used in Structural Thinking are open at scale
- enjoy a self-documenting process
- use a process that incorporates what is known about formal logic

### 5.1 STRUCTURAL THINKING EMPHASIZES RELATIONAL THINKING

The term "structure" as a base for the phrase "Structural Thinking" refers to the relational

patterns that are involved among members of a set or system. Structural Thinking emphasizes relational thinking as its primary distinguishing attribute. Still, relational thinking has an existence outside the domain of Structural Thinking, e.g., when it is used microscopically to produce prose that often does not recognize the total sweep of the structure that can be created through Structural Thinking.

While the term "Structural Thinking" might be interpreted by some readers to mean thinking that leads to familiar forms of engineering graphics, this is not the case. The patterns produced by Structural Thinking, as defined, necessarily possess the property of being unambiguously translatable into prose. A high percentage of familiar engineering graphics lacks this property because the graphics involve arbitrary and idiosyncratic aspects that are not communicated to the viewer by the symbols on the structure. The patterns produced by Structural Thinking, as defined, combine the intuitive and the rational in a single format, and every symbol on such patterns has a well-defined meaning which contributes to the translatability of the pattern into prose. [The only widely-known graphic that shares these features is sheet music. The latter is well-known to communicate across national boundaries and across the centuries.]

## **5.2 RELATIONSHIP TYPES AND EXAMPLES**

To make the ISM process sufficiently versatile, i.e., to provide variety in relationship types and in relationships within those types, a study was carried out to identify types of relationships that are dominant in the English language. Table 3 shows the results of this study of classifications along with examples of the various types. Table 3 shows "aggravates" as an example of a relationship of the "Influence" type. This relationship is applied in developing Problematiques. Some other relationships in Table 3 correspond to other established structural types (Warfield, 1994).

## **6. INTERACTIVE MANAGEMENT (IM) WORKSHOPS**

As seen in the preceding description of Structural Thinking, it is a complex and comprehensive approach to organizing knowledge, not readily followed in the absence of an overarching process that enables and facilitates Structural Thinking, while aggregating at the same time the documentation required to portray the outcomes of the process. The process that supports Structural Thinking is called Interactive Management (IM). While IM is a three-phase process, the primary support for Structural Thinking occurs in the second phase, involving IM Workshops. Hundreds of such workshops have been held in many locations. Both aggregate and individual data, as well as workshop reports, have been accumulated to provide reference material and to lend credibility to assertions about the efficacy and attributes of Interactive Management. In the following, a particular IM Workshop will be discussed that should lend insight into both the processes used and some of the startling results that have been discovered by studying outcomes of such workshops.



TABLE 3. TYPES OF RELATIONSHIPS AND EXAMPLES OF EACH TYPE

DEFINITIVE	COMPARATIVE	INFLUENCE	TEMPORAL	SPATIAL	MATHEMATICAL
Includes Is Included in Implies Is a member of Covers Is a partition of Is necessary for Is sufficient for Is in the same category as Is assigned to Is associated with Is reachable from Is isomorphic with	Is greater than Is heavier than Is preferred to Is of higher priority than Is of equal or higher priority than Is more useful than Is more important than Is more critical than Requires more space than	Causes Affects Aggravates Enhances Supports Confirms Weakens Strengthens Is dependent on Modifies Is a partial cause of	Must precede Must follow Precedes Precedes or coincides with Requires more time than Overlaps in time with Is disjoint in time with	Lies east of Lies west of Lies to the right of Lies to the left of Lies above Lies below Has a component that lies to the left of Crosses in a plane	Is a function of Affects the likelihood of Can be computed from Is computable from Is disjoint with Has a non-zero intersection with Equals Is greater than Is less than Is greater than or equal to Is congruent with Is a cover of Is a partition of Is a greatest lower bound for



## 6.1 WORKSHOP ACTIVITY AND PRODUCTS

A three-day Interactive Management (IM) Workshop was held in Dearborn, Michigan, during May 19-21, 1993, involving three of the members of the Rapid Response Manufacturing (RRM) Consortium (representatives of Ford Motor Company, General Motors, and Texas Instruments). Later a report was prepared showing what transpired, and interpreting the products of the Workshop. In the RRM Workshop, the activity involved the production of the following:

- **A Problem Set.** Production of a Problem Set consisting of those problems that the Participants anticipated would be encountered in developing a variant design process. This Problem Set included 81 member problems. The methodology used to develop this set was the widely-used Nominal Group Technique (NGT). Among other things, this facilitated group process requires that participants vote individually and anonymously in writing on problem importance in the manner to be described next.
- **Votes on Problem Importance.** Each Participant identified, from the Problem Set having  $N = 81$  members, those 5 problems that were perceived as most important. Since there were 13 participants in this RRM workshop, this voting produced 13 subsets of the Problem Set, one for each participant. The voting thereby identified the Important Problem Subset (IPS), consisting of all those that received a vote from any Participant. The number of problems in the IPS (which is a subset of the Problem Set) was  $V = 42$ . Furthermore, following the well-established NGT procedure, each Participant ranked the five problems as being (1) the most important, (2) the second most important, etc., down to (5) the fifth most important.
- **The RRM Problematique** In response to many queries to the group, each representing a particular instantiation of a Generic Question identified in the Workshop Plan, each posed by the computer containing the ISM software and the IPS generated by the participants, it was possible for the group of participants to develop the RRM Problematique. This is a structure that reveals how each problem in the more highly ranked  $M = 29$  problems in the IPS relates to each other member of this subset containing 29 problems.
- **Numerical Interpretation of the RRM Problematique** When drawn as an "influence structure", it is possible to construct a numerical interpretation of the RRM Problematique. This interpretation allows computation of the following numerical interpretants:
  - *Activity Score*--a numerical value computed for each problem based on the amount of interaction it displays with other problems, without regard to whether a problem aggravates other problems or is aggravated (i.e., made worse) by other problems
  - *Influence Score*--a signed numerical value computed for each problem based on the extent to which it aggravates other problems or is aggravated by other problems. A positive score is indicative of the ability of a problem to aggravate other problems; while a negative score is indicative of the vulnerability of a problem to being aggravated by other problems

## 6.2 THE IMAGE OF THE RRM PROBLEMATIQUE

In view of the fact that some problems are much more active than others in interactions, and that some problems become heavy aggravators ("World-Class Aggravators"), while other problems are heavily aggravated ("World-Class Aggravatees"), it is quite clear from the structural analysis of the problematique that problems differ dramatically in terms both of the **number** of and the **nature** of their interactions with other problems.

One might anticipate (incorrectly, in view of Spreadthink), that such interactions would be felt heavily in the NGT voting described earlier in this article. In order to test this idea, one may remove the arrows and other data from a problematique, and just show a kind of "image" of the problematique. One may then incorporate data in the boxes on this image to facilitate interpretation of the interactions among the problems.

The problematique structure is a graphical portrayal of the fact that some problems in the IPS aggravate (make more severe) other problems in the IPS. This aggravation relationship (one of many that could be selected from Table 3) is portrayed on the problematique by the existence of a directed path (directed by an arrow or a set of arrows) from one problem (the aggravator) to another problem (the one aggravated by the aggravator). Figure 3 shows the "image" of the RRM problematique (i.e., an outline of it from which the problem statements have been deleted). Each problem is represented by an identifying number. The problem number is in bold italic, to distinguish it from the scores associated with it.

Shown in each cell in Figure 3 are three values associated with the problem contained in the cell. The W Score is a Weighted Importance Score computed from the NGT voting results. This score is determined before the problematique is constructed, and does not reflect the learning that takes place in developing the problematique. The I Score is the Influence Score, based upon the problematique structure. The A Score is the Activity Score, also based upon the problematique structure.

A high Weighted Importance Score (16 was the maximum, Problem P68) assigned to a problem means that the votes of the participants rated that problem as very important. A high positive Influence Score (26 was the maximum, the cycle of P3, P18, and P78) means that a given problem aggravates many other problems, while a high negative Influence Score (-25 was the maximum in absolute value, P44) means that a given problem is aggravated by many other problems. A high Activity Score (26 was the maximum, P44) means that the problem is heavily involved in aggravation, and may aggravate many problems while being aggravated by many problems. A low Activity Score (3 was the minimum, P49) means that the problem interacts with relatively few other problems.

## 6.3 STRUCTURAL ANALYSIS OF A PROBLEMATIQUE

Various structural data can be extracted from a problematique, regardless of the nature of the problems represented on the problematique. Some of the data have been incorporated in Figure 3, which introduced the image of the problematique. Although the RRM Problematique

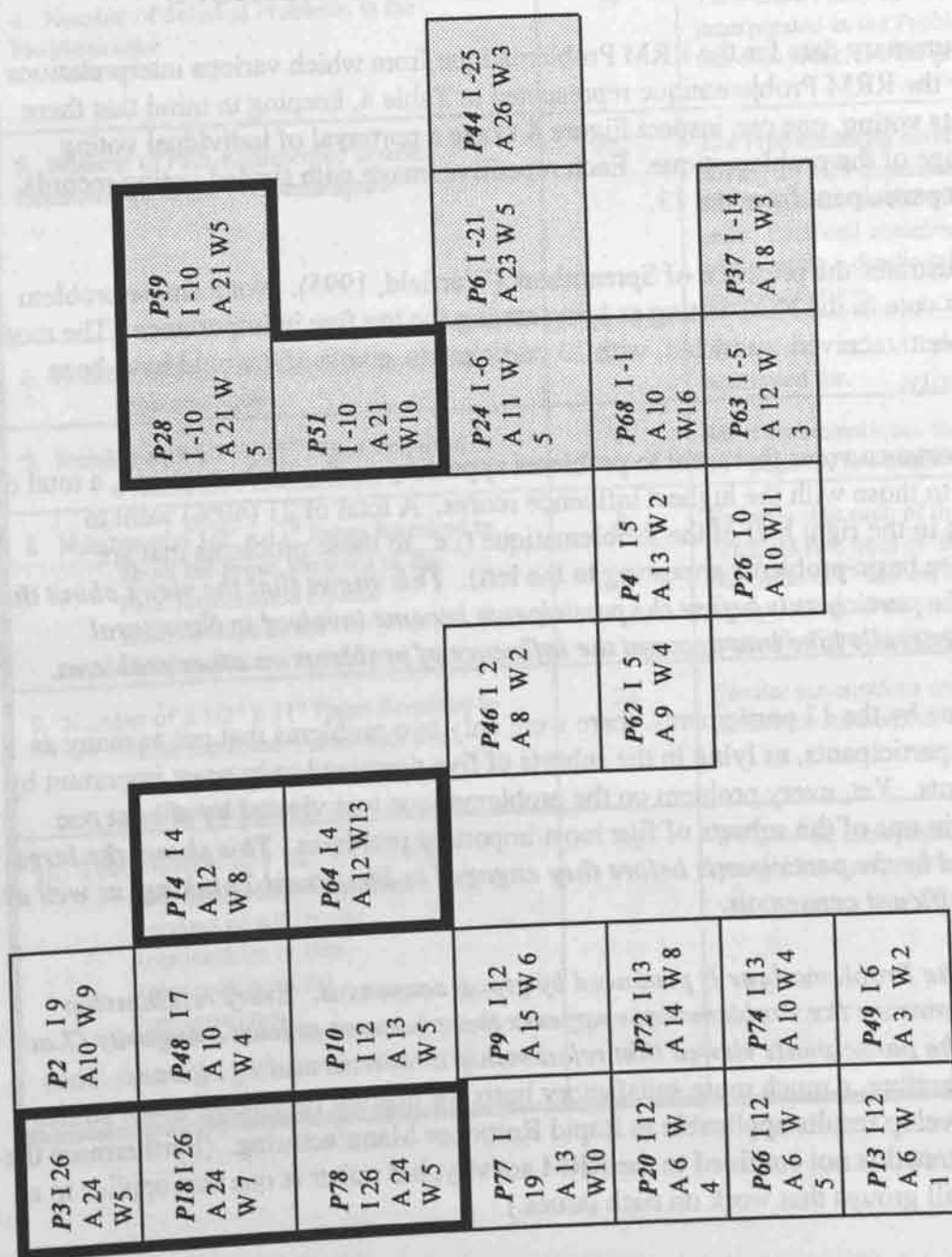


Figure 3. Image of the RRM Problematique showing relevant data for each problem appearing on the problematique. Problem number appears in bold italic; e.g., ***P3*** refers to Problem 3. Associated with each problem number is its Influence Score, Activity Score, and NGT Weighted Importance Score. For example, Problem ***P3*** has an Influence Score of 26, an Activity Score of 24, and an NGT Weighted Importance Score of 5. Shaded cells represent problems with negative Influence Scores. Problems enclosed by heavy lines are in cycles.



represented by its image in Figure 3 contains only  $M = 29$  problems from the original set of  $N = 81$ , nevertheless the problematique portrays a total of  $K = 202$  relationships among the subset of 29--each being of the form "A aggravates B"! The Situation Complexity Index is 1,964.

When individuals are asked to estimate the number of relationships portrayed on such a map, they usually grossly underestimate the number. The information content of the problematique is highly dense, requiring that persons who wish to use the problematique as a guide to decision-making undergo some instruction in how to read problematiques, just as they required instruction in learning how to read English (though not as prolonged a course of instruction as people undergo in learning to read prose).

#### 6.4 NGT VOTING PATTERNS OVERLAID ON THE PROBLEMATIQUE

Table 4 provides summary data for the RRM Problematique from which various interpretations can be drawn. For the RRM Problematique represented in Table 4, keeping in mind that there were 13 participants voting, one can inspect Figure 4 to see a portrayal of individual voting patterns on the image of the problematique. Each repetitive image with shaded voting records corresponds to one participant from the 13.

Figure 4 clearly illustrates the presence of Spreadthink (Warfield, 1995). Not a single problem received a majority vote in the NGT voting as lying among the top five in importance. The most votes that any problem received was 4 but, with 13 participants, a vote of 7 would have been required for a majority.

Of the 53 total importance votes that went to problems appearing on the Problematique, a total of only 9 (17%) went to those with the highest influence scores. A total of 21 (40%) went to problems appearing in the right half of the Problematique (i.e., to those problems that are symptomatic of more basic problems appearing to the left). *This shows that the views about the problems held by the participants before the participants became involved in Structural Thinking did not generally take into account the influence of problems on other problems.*

From the voting done by the 13 participants, there were only two problems that got as many as four votes from the participants, as lying in the subsets of five perceived to be most important by individual participants. Yet, every problem on the problematique was viewed by at least one participant as lying in one of the subsets of five most important problems. *This shows the large variety of views held by the participants before they engaged in Structural Thinking, as well as the lack of any significant consensus.*

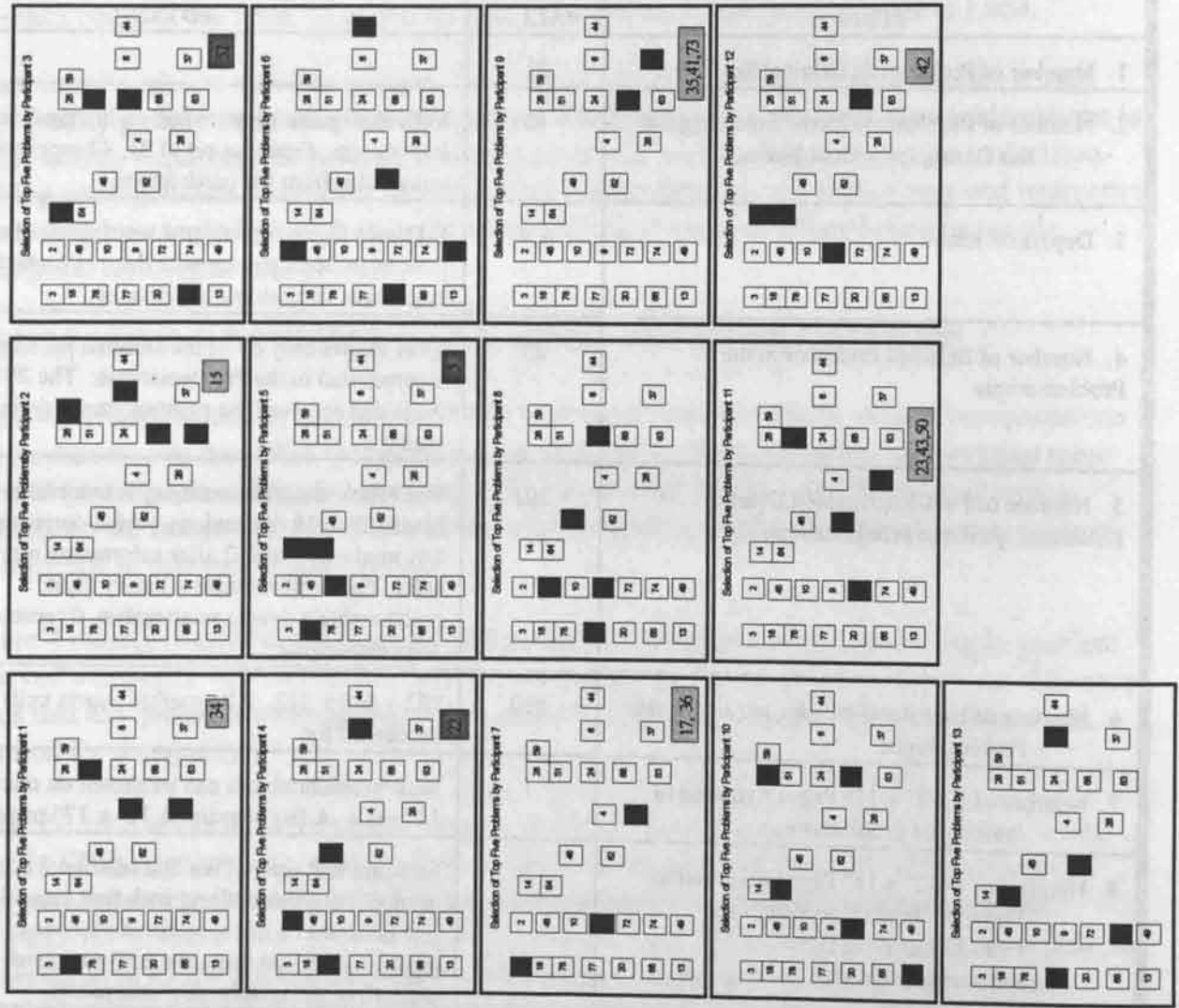
On the other hand, *the Problematique is produced by group consensus. Every relationship among problems shown on the Problematique appears there because at least a majority (7 or more out of 13) of the participants viewed that relationship as correct and significant.* The Problematique is, therefore, a much more satisfactory basis for making judgments about strategy for proceeding to develop results applicable to Rapid Response Manufacturing. (Furthermore the conclusion just illustrated is not confined to the RRM activity, but rather is one that applies to all complex issues and all groups that work on such issues.)



**TABLE 4. DATA PERTAINING TO THE RRM PROBLEMATIQUE**

ITEM	VALUE	NOTES
1. Number of Problems in Original Set	81	
2. Number of Problems Selected from Original Set During Individual Voting	42	Individual participants voted on the top 5 in importance. From the set of 81, 42 received one or more votes from the participants.
3. Departure Ratio	8.4	8.4 times as many problems were selected as would have been, if all participants were in perfect agreement on problem importance.
4. Number of Selected Problems in the Problematique	29	Time allows only 29 of the selected problems to be incorporated in the Problematique. The 29 were those that received the greatest emphasis in the voting.
5. Number of Path-Represented Dyadic Relationships in the Problematique	202	The Problematique corresponds to a binary matrix having 29 x 29 dimensions, which corresponds to 841 total cells, or 812 after subtracting main-diagonal cells. Each cell contains a binary digit; 1 representing a dyadic relationship, 0 representing non-relationship.
6. Number of Non-Relationships Implied in the Problematique	610	$202 + 610 = 812$ . All possible matrix cells are accounted for.
7. Number of 8 1/2" x 11" Pages Required to Present the Problematique	1	Most problematques can be shown on one 8 1/2" x 11" page. A few require an 11" x 17" page.
8. Number of 8 1/2" x 11" Pages Required to Show the Prose Versions of the Path-Represented Dyadic Relationships in the Problematique	8	Estimate that each of the 202 relational statements occupies two lines of text with font size 10. Each line takes 0.17 inches, so about 50 lines of text make a page. With 404 lines, we arrive at about 8 pages to print all of the relationship statements.
9. Number of 8 1/2" x 11" Pages Required to Show the Prose Versions of the Non-Relationships Implied in the Problematique	24	Similar assumptions are made as in Item 8 to determine the number of pages required.
10. Total Number of 8 1/2" x 11" Pages Required to Show the Prose Versions of All Dyadic Relationships or Non-Relationships in the Problematique	32	$8 + 24 = 32$ total pages of text needed to print out the prose statements represented on the problematique.
11. Conservative Value for the Graphical Advantage	32	

Figure 4. Individual Participant Voting Patterns for Top Five Problems in Importance



Each major rectangle represents one participant's individualized, anonymous voting record for the most important five problems. The shaded cells represent the participant's votes. Unshaded cells were not selected by the participant.

Cells that show votes but do not appear on the problematique are shown in boxes to the lower right of each major rectangle.

One participant voted for seven problems.

Wide variation in participant views is clearly shown by the wide variability in voting patterns.

## 6.5 USING FIGURE 3 TO INTERPRET THE SITUATION

The use of Figure 3 to interpret the complex situation provides benefits that can scarcely be obtained by any other route. It is worth reviewing why this is so. First of all, careful planning was carried out before the group ever met, including the design of the key questions to which the group would respond. The group responses would include identification of problems to be faced and overcome in the complex situation. Once the problems were identified, the group would engage in several hours of clarification of the problems. After reasonably good understanding was attained, the group participants would then vote individually on which five of the problems were seen as the most important ones. The collection of problems that received votes then were entered into the computer, and the group was successively questioned concerning whether one problem would aggravate another. With extensive discussion and voting, ultimately the group arrived at the problematique.

Following the meeting, structural analysis of the problematique was carried out to arrive at influence scores and activity scores. Also weighted scores were computed from the participant voting. The image of the problematique was constructed, and all scores were placed on this image. At that point, the image becomes a data source for analyzing the complex situation, using all of the data shown on the image.

The strictly numerical approach to interpretation of the complex situation is not intended to provide a complete set of final conclusions. It would be a mistake to take this interpretation as final. On the other hand, the numerical interpretation contains a very significant amount of information, and should be used to the fullest to produce interpretation. The question then arises: how should this interpretation be viewed?

The interpretation produces a **set of hypotheses**, founded in the variety of available data, which can later be used in connection with the detailed problem statements to validate or invalidate the hypotheses. Experience shows that the vast majority of the hypotheses are validated in the follow-up to the interpretations produced.

To facilitate the following discussion, the notation (P: I, A, W) represents a given problem, its Influence Score, its Attribute Score, and its Weighted NGT Voting Score, keeping in mind that all of this information is aggregated in Figure 3. Also three Zones are identified in Figure 3: the Left Zone, the Center Zone, and the Right Zone. The Right Zone is shaded in Figure 3, and includes only problems whose Influence Score is Negative. The Left Zone is here defined as the first two stages (involving 14 problems). The center Zone includes stages 3, 4, and 5--i.e., all problems not contained in either the Left Zone or the Right Zone.

What approach is taken to formulate these hypotheses? The following guidelines represent the answer to this question:

- **Type 1: Critical Problems in the Left Zone.** Look for boxes in Figure 3 for which all scores are high. The maximum possible values would appear as (P: 26, 24, 16). (No problem has this set of scores.)



- **Type 2: Underrated Problems in the Left Zone.** Look for boxes in the Left Zone of Figure 3 where the first two scores are high and the third score is low.
- **Type 3: Overrated Problems Outside the Left Zone.** Look for problems outside the Left Zone in Figure 3 where the first score is either low or high but negative, and the other scores are high.
- **Type 4: Problems in Cycles.** Look for problems in cycles.
- **Type 5: High Activity Problems in the Central Zone.** Look for high activity problems in the Central Zone (which will then have low influence scores).
- **Type 6: High-Weighted Score Problems, in Any Zone.** Look for problems that have high weighted NGT voting scores, no matter where they appear.

Table 5 presents an interpretation for each of these six problem types, first in general form applicable to any problematique image, and then in specific form for the problematique image given in Figure 3.

## 7. LEVELS OF SITUATIONAL THINKING IN LARGE ORGANIZATIONS

Structural Thinking is normally achieved with a small group of participants (perhaps 8 to at most 20), sometimes accompanied by a group of observers (whose participation is significantly limited). Yet in large organizations there may be many hierarchical levels of personnel, and communication both within some level and among hierarchical levels may pose major burdens to the organization; especially to organizational decision-making.

Whenever systems are involved in organizational thinking, and especially when major product designs are involved, it is very helpful to formalize the concept of "organizational levels". One such concept presumes the necessity of at least seven levels, including "interface levels", as follows:

- **Level 1: *The Overview Level*** (the most general level, involving the highest-ranked officials in the organization) where general organizational directions should be set, and where major financial decisions should be made.
- **Level 2: *The Overview-System Interface Level*** (involving the interface between high-level management and those systems-oriented practitioners who will conceive and oversee system development in the organization).
- **Level 3: *The System Level*** (where systems-oriented practitioners conceive system designs, correlated with high-level organizational policy, as might be set forth by conscientious individuals operating at Level 1).
- **Level 4: *The System-Subsystem Interface Level*** (where division of effort is determined, and where linkages between subsystems and the system are conceived, documented, and amended when necessary).
- **Level 5: *The Subsystem Level*** (of which there could be several, hierarchically arranged).
- **Level 6: *The Subsystem-Component Interface Level*** (where linkages among components and subsystems are conceived, documented, and implemented).



- **Level 7: The Component Level** (where the fundamental constituents of the system are determined, selected, tested, and tied into subsystem design activity).

**TABLE 5. INTERPRETATION OF PROBLEMATIQUE VIA PROBLEM TYPES**

PROB. TYPE	GENERAL INTERPRETATION	SPECIFIC INTERPRETATION
1 <b>CRITICAL</b> L(eft)	This problem type has high influence, aggravates many other problems, and is rated as among the most important by the group. <b>Conclusion:</b> Consequently it deserves immediate, high-priority attention.	There are no problems of this type in Figure 3.
2 <b>UNDER-RATED</b> L	This problem type has high influence, aggravates many other problems, and was not recognized as among the most important by the group. <b>Hypothesis:</b> This problem deserves immediate, high-priority attention. The group should reevaluate the importance in the light of interactions.	The Hypothesis should be tested for these problems:  (P3, 26, 24, 5), (P18, 26, 24, 7), (P78, 26, 24, 5)
3 <b>OVERRATED</b> C(enter), R(ight)	This problem type received a high NGT importance score, which could be accurate since it interacts heavily, but because it does not aggravate many other problems it is probably not as important for the moment at least, as the group imagined. <b>Hypothesis:</b> Action on this problem should very likely be deferred until some later time.	The Hypothesis should be tested for these problems:  (P64, 4, 12, 13), (P26, 0, 10, 11), (P68, -1, 10, 16), (P51, -10, 21, 20)
4 <b>CYCLIC</b> L, C, R	Problems in cycles aggravate each other. <b>Hypothesis:</b> Problems in cycles should be acted on collectively, and this should be recognized in team assignments.	The Hypothesis should be tested for these cycles: (P3, P18, P78), (P14, P64), (P28, P51, P59)
5 <b>HIGH ACTIVITY</b> C	Problems of this type are both aggravated by other problems and aggravative to other problems, even though their influence may not be high. <b>Hypothesis:</b> The interactions involving these problems should be studied in detail, and recognized in choosing personnel for task forces	There are no problems of this type in the Central Zone of Figure 3.
6 <b>HIGH-WEIGHT</b> L, C, R	This type of problem was thought to be quite important in the NGT voting, but this voting has been shown to be unreliable. <b>Hypothesis:</b> Interactions involving these problems should be studied carefully and their importance should be reevaluated in the light of the interactions.	The Hypothesis should be tested for these problems: (P77, 19, 13, 10), (P64, 4, 12, 13), (P26, 0, 10, 11), (P51, -10, 21, 10), and (P68, -1, 10, 16); noting that of this set, all but P77 occur earlier in this Table.

What typically happens in large organizations is that the odd-numbered levels are budgeted, and correspond to particular formalized subdivisions of the organization. The even-numbered levels (Interface Levels) typically are not budgeted. However it is at the Interface Levels that linguistic variations are heavily felt. High-level management at Level 1 typically converses in metaphors, categories, and numbers. At the other extreme, at Level 7, the conversations typically take place in highly-technical language particularized to individual system components. Budgeting should allocate funds to the Interface Levels, with the understanding that the organization's linguistic differences need to be worked out extensively at these Levels, where vital information flows affect the desired continuity of organizational effort.

The importance of Structural Thinking becomes especially apparent when it is noticed that effective and consistent communication across these organizational levels is critical to success. In the absence of the insight, logic, linguistics, relationships, and definitive conceptualization furnished by Structural Thinking; the capacity of organizations to be chaotic and internally divisive is guaranteed to be tapped, and to be effective in lowering productivity and quality. Accordingly Structural Thinking needs to be done at all of the odd-numbered organizational levels, and communicated through the even-numbered interfaces.

One of the greatest benefits of Structural Thinking is to enable the organization to carry out comprehensive designs of work programs involving all relevant subdivisions of the organization. Such designs evolve from the application of Interactive Management to the development of corrective options for resolving the problems, using the insight gained through development and study of the problematique. The options will range from specific task definition to the definition of task sequences, as has been seen in many applications (Warfield and Cárdenas, 1994).

## **8. BENEFITS OF STRUCTURAL THINKING**

What are the benefits of Structural Thinking, as envisaged from the foregoing discussions? To discuss this subject comprehensively, recall that the following topics have been discussed and clarified in connection with improving productivity in complex situations:

### **8.1 COMPLEXITY AND PRODUCTIVITY**

- Complexity as a source of social damage and low productivity
- A science of complexity as a potential source of remedy for the unwanted impacts of complexity.
- The need for a Context Model in which to embed complexity studies.
- The origins of low productivity in complex situations.
- The assessment of situations to verify that they are complex.

### **8.2 SEMIOTICS, COMPLEXITY, LANGUAGE, AND MODELING**

- The relevance of the science of semiotics to the study of complexity.
- The lack of support from semiotics for current common practices.

- The effect of language on the study of complex situations.
- The problematique as a key descriptor of a complex situation.
- The common practice of omitting key steps in model construction.

### 8.3 STRUCTURAL THINKING, STRUCTURAL GRAPHICS, AND INTERACTIVE MANAGEMENT

- The foundations of structural graphics.
- The use of Interpretive Structural Modeling (ISM) to produce structural graphics.
- The nature of Structural Thinking.
- The necessity of computer help in developing the relationship patterns required in Structural Thinking.
- The role of Interactive Management in providing help to Structural Thinking.

### 8.4 INTERPRETATION AND IMPLEMENTATION

- Structural Analysis of the problematique as a means of generating hypotheses for developing insight.
- The role of Structural Thinking in eliminating Spreadthink.
- The role of Interactive Management in organizational learning through Structural Thinking, especially at Interface Levels.
- Understanding how to design work programs to overcome complexity.

### 8.5 BENEFITS AND CONNECTIONS

Benefits of Structural Thinking are identified through an understanding of the four major headings just given and the connections among them. Beginning with **Interpretation and Implementation**, it has been shown that the problematique is a key factor in learning how a large set of problems is interrelated, and in determining how priorities should be assigned in designing work programs, including work sequences. The problematique is developed in a group setting as part of the application of Interactive Management. It is a pattern that represents the relationships among the problems, and every single component relationship represents a majority view of the group (and often total consensus). **This is in stark contrast with views arising from Spreadthink that is in command until the problematique has been produced.** *The organization benefits* by replacing confusion, chaotic differences of viewpoint, and lack of any organized plan with common views as to how to proceed, and a work plan to move ahead on the basis of deep understanding. These results connect directly to **Structural Thinking, Structural Graphics, and Interactive Management**, because it is the combination of these three factors that enables the **Interpretation and Implementation** to occur. *The organization benefits* by understanding why these factors should be put in place in order to interpret the complex situation and to implement remedial measures. Because this combination of factors is novel for most modelers, *the modeling community can benefit* from understanding the contributions of semiotics to thinking about how to model, as well as what limits the quality of modeling activity. This recognition should motivate significant changes in the philosophy and practice of modeling. In recognizing the interactions among **Semiotics, Complexity, Language, and Modeling**, *the*



*academic community can gain the benefit* of modifying academic programs to reflect these interactions. For example, it should be abundantly clear that much greater emphasis needs to be placed upon the construction of structural graphics because of the structural nonlinearity of the patterns required to understand complex systems, and the virtual impossibility (or at least, the major difficulty) of constructing and conveying such patterns of nonlinearity using a prose language that is inherently linear in all of its levels. Finally *the society may benefit* from the broader understanding that **Complexity and Productivity** are strongly coupled, that it is possible even to derive a numerical measure of complexity for comparing situations, and that the system of Interactive Management makes possible a very deep understanding of complex situations, while enabling rational processes to be designed to cope with that complexity.

## 9. SUMMARY AND CONCLUSIONS

A Context Model for complexity has been introduced within which a definition of complexity has been set forth, and its application to distinguishing ordinary situations from complex situations has been illustrated. The inadequacy of prose in formulating and representing complex situations has been illustrated, emphasizing the structural distinction between linear prose and nonlinear graphics, such as problematiques. A problematique is a representative attribute of a complex situation. Analysis of a problematique can not only suggest high-priority areas to be attacked immediately in the complex situation, but also can yield very specific hypotheses to be explored in developing further understanding of the complex situation.

Examples from the practice of Interactive Management illustrate the use of Structural Thinking, which is the primary intellectual mode required for people to manage complexity. Group activity that would otherwise be invalidated by the presence of Spreadthink, which is always present when groups work with complex situations, can be directed into the Structural Thinking mode by the use of Interactive Management, which then produces graphical products that convert the individual insights of group members into consensus patterns which are more than adequate to overcome the effects of Spreadthink.

The result of adopting Structural Thinking is to make giant steps along the road to high productivity and high quality in efforts to describe, diagnose, and redesign complex situations.

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# **FIVE SCHOOLS OF THOUGHT ABOUT COMPLEXITY: IMPLICATIONS FOR DESIGN AND PROCESS SCIENCE**

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**"sum, ergo cogito"**

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## ABSTRACT

### **FIVE SCHOOLS OF THOUGHT ABOUT COMPLEXITY: IMPLICATIONS FOR DESIGN AND PROCESS SCIENCE**

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The prevalence of complexity is a fact of life in virtually all aspects of system design today. Five schools of thought concerning complexity seem to be present in areas where people strive to gain more facility with difficult issues:

- Interdisciplinary "approaches" or "methods" (fostered by the Association for Integrative Studies, a predominantly liberal-arts faculty activity)
- Systems dynamics (fostered by Jay Forrester, Dennis Meadows, Peter Senge, and others closely associated with MIT)
- Chaos theory (arising in small groups in many locations)
- Adaptive Systems Theory (predominantly associated with the Santa Fe Institute)
- The Structure-Based school (developed by the author, his colleagues and associates)

A comparison of these five schools of thought is offered, in order to show the implications of them upon the development and application of design and process science. The following criteria of comparison are used: (a) how complexity is defined, (b) analysis versus synthesis, (c) potential for acquiring practical competence in coping with complexity, and (d) relationship to underlying formalisms that facilitate computer assistance in applications. Through these comparisons, the advantages and disadvantages of each school of thought can be clarified, and the possibilities of changes in the educational system to provide for the management of complexity in system design can be articulated.

# ABSTRACT

## FIVE SCHOOLS OF THOUGHT ABOUT COMPLEXITY: IMPLICATIONS FOR DESIGN AND PROCESS SCIENCE

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The purpose of this paper is to provide a critical review of the current state of the art in the field of complexity science. The paper is organized into five sections, each representing a different school of thought. The first section discusses the importance of complexity science in the context of design and process science. The second section discusses the importance of complexity science in the context of design and process science. The third section discusses the importance of complexity science in the context of design and process science. The fourth section discusses the importance of complexity science in the context of design and process science. The fifth section discusses the importance of complexity science in the context of design and process science.

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5. The importance of complexity science in the context of design and process science.

A comparison of the five schools of thought is provided in order to show the implications of each school of thought for design and process science. The following table compares the five schools of thought in terms of their views on the nature of complexity, the role of design, and the role of process science. The table shows that the five schools of thought have different views on the nature of complexity, the role of design, and the role of process science. The table also shows that the five schools of thought have different views on the relationship between design and process science. The table is organized into five columns, each representing a different school of thought. The rows represent the three issues: the nature of complexity, the role of design, and the role of process science. The table shows that the five schools of thought have different views on the nature of complexity, the role of design, and the role of process science. The table also shows that the five schools of thought have different views on the relationship between design and process science.

## 1. INTRODUCTION

Omar Khayyam (mathematician and astronomer, 1048-1122), speaking through the voice of Edward Fitzgerald (1809-1883), vented his frustration stemming from his attempts to get understanding, as follows:

"Myself when young did eagerly frequent  
Doctor and Saint, and heard great argument  
About it and about: but evermore  
Came out by that same door where in I went."

As D. W. Harding described the late contemporary French philosopher and chairman of the history of systems of thought at the Collège de France, Michel Foucault (1926-1984), in his masterpiece on the "archaeology of knowledge", believed

"that our own current intellectual life and systems of thought are built on assumptions profoundly taken for granted and not normally exposed to conscious inspection, and yet likely in time...to be discarded."

In amplifying that view, Foucault states that:

"The manifest discourse, therefore, is really no more than the repressive presence of what it does not say; and this 'not-said' is a hollow that undermines from within all that is said."

It is none too early to try to begin to correct the shortcomings in our knowledge that stem from bad ("not-said") assumptions, uncritically accepted and propagated, especially in academia. Too much is at stake. Yet, such acceptance seemingly continues its relentless advance, compounded by technologies that typically show little friendliness to their users.

At the present time there are at least five identifiable schools of thought about complexity<sup>2</sup>. By designating these five schools of thought, describing some of their defining attributes, and comparing them critically in terms of the potential consequences of adopting one of these seemingly-incompatible schools as the one that deserves our deep attention, it is hoped that the importance of gaining some consensus on which school deserves attention in our educational system and in society at large can be clarified. Table 1 identifies the five schools of thought about complexity.

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<sup>2</sup> Each of these schools is now being represented by a growing literature. Recently Charles François, a retired Belgian diplomat living in Buenos Aires, has completed a monumental work incorporating ideas from much of this literature. His Encyclopedia of General Systems and Cybernetics is planned for publication in 1997. Already this work contains 31 references to various authors discussing **chaos theory**; 60 references to authors discussing **complexity in general** but with emphasis on **adaptive systems theory**, and 10 references to authors discussing **systems dynamics**. Quoted in this work are descriptions in detail showing how authors disagree, often dramatically, on definitions and understandings, not only across these schools of thought, but within them as well.

## 2. THREE EQUATION-FAMILY-BASED (EFB) SCHOOLS OF THOUGHT

As Table 1 indicates, three of these schools of thought share two key attributes which enable them to be discussed as a group for comparison with other schools:

- They are founded in distinct, but long-established mathematical formalisms
- They all locate complexity in the system that is under observation

TABLE 1. SCHOOLS OF THOUGHT ABOUT COMPLEXITY		
NAME OF SCHOOL	UNDERLYING FORMALISM	WHERE COMPLEXITY LIES
CROSS-DISCIPLINE (CD)	None	Unidentified
SYSTEMS DYNAMICS	ORDINARY DIFFERENTIAL EQUATIONS	IN THE SYSTEM
CHAOS THEORY	ORDINARY NONLINEAR DIFFERENTIAL EQUATIONS	IN THE SYSTEM
ADAPTIVE SYSTEMS THEORY	PARTIAL DIFFERENTIAL EQUATIONS	IN THE SYSTEM
STRUCTURE-BASED	FORMAL WESTERN LOGIC, INCLUDING SET THEORY, THEORY OF RELATIONS, DIGRAPH THEORY, LATTICE THEORY, BOOLEAN METHODS, AND THE ALGEBRA OF PARTITIONS	IN THE MIND  [Much of the foundational work is represented by the works of Peirce, Piaget, Polanyi, and Vickers.]

Based on these two common attributes, one can build an argument to the effect that all three of them are well-described by the views of Omar, the Tentmaker, and Foucault, the philosopher. Each of these three schools is distinguished by the "not-said", which undermines them from within. Specifically, the "not-said" can refer to underlying, unstated, invalid assumptions, which include the following:

- **Invalid EFB Assumption #1--Breadth of Representation.** 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.
- **Invalid EFB Assumption #2--Breadth of Application.** These formalisms, or metaphorical formulations associated with them, can be applied to **many** systems other than those physical systems which stimulated the development of the original mathematical formalisms.
- **Invalid EFB Assumption #3--No Need for Empirical Evidence.** It is not important, when promoting any of these schools of thought, and enshrining them in academic curricula, to give evidence of successful applications to specific instances, that might support consigning the term "complexity" broadly to any or all of these three schools.



- **Invalid EFB Assumption #4--The Site of Complexity.** Complexity is inherently located in (i.e., is a property of) the system under observation.

Presumably these four invalid assumptions, and possibly others unstated in this paper, are thought to justify the usurpation of a term of potentially high scientific and engineering utility. This kind of inadvertent approach to development of a school of thought is not new. As the late Sir Geoffrey Vickers wrote, concerning the way the term "system" has largely come to mean "computer system" or "information system":

"It [the word 'system'] has...become so closely associated with man-made systems, technological design and computer science that the word 'system' is in danger of becoming unusable in the context of human history and culture. I seek to contribute something to its rescue and restoration. For we need it for understanding and for action in human and social contexts far too complex and imprecise to admit of formal modeling".

Similarly, I seek to try to rescue the term "complexity" and restore it to the level of generality that it requires, for "we need it for understanding and for action in human and social contexts...".

### 3. THE CROSS-DISCIPLINE (CD) SCHOOL

By far the largest school that connects (implicitly) to complexity is here labeled "the Cross-Discipline School". This school typically is found in academia, and is constantly being manifested in higher education, especially in the liberal arts and sciences, and in an expanding way in the education schools.

One of the most prominent manifestations of this school is found in the work of the Association for Integrative Studies which, in a professional and beneficial way, introduces and promotes interdisciplinary work in higher education. This school shuns formalism, and relates to complexity much in the same way as the null set relates to sets in general. The prevailing point of view is "benign neglect" of complexity. It is invariably dealt with covertly or implicitly, with an unstated, but seemingly prevailing (though unwarranted) assumption as follows:

- **Invalid CD Assumption #1--Simple Amalgamation of Disciplines.** Complexity can be dealt with very well, by just going from a single disciplinary base to a base involving more than one discipline, sometimes by just aggregating results from more than one, and in more difficult instances, integrating results from more than one. Nothing special is required beyond that.

While no documentation has been found to suggest that the CD School agrees with the EFB "Site of Complexity" Assumption, neither is there evidence of disagreement with it; and it is reasonable to suppose that it is shared among members of the CD School and the EFB Schools.

- **Other Shared Assumptions.** Another shared (and incorrect) assumption, and a key one relates to language: **Invalid Assumption: The Adequacy of Natural Language.** It is assumed that the natural language is adequate to represent and resolve complexity, through the methods associated with the EFB and CD schools. Here Foucault's "not-

said" unequivocally describes the situation. The bald assumption that language, as presently constituted, is adequate, is readily challenged, and readily can be shown to be wrong<sup>3</sup>. As Lavoisier found out in undertaking his study of chemistry, you can make a major advance in a field by just cleaning up its language. But no such effort has appeared in the CD school, nor in the EFB schools. The latter rely on the formalisms of mathematics which are reasonably definite but, as stated earlier, they say essentially nothing about the validity of the associations of concepts with those formalisms. The CD school almost universally relies on prose alone to represent and resolve complexity: a fatal flaw in the operations of this School.

- **Invalid Assumption: Normal Processes are Sufficient..** Another assumption shared by the EFB and the CD school is that **they can comprehend complexity and get in a position to take charge of it using the normal processes** that characterize their academic areas. Otherwise, why would they be so assiduous in pursuing it and creating it in public and private systems alike? But **complexity rules**. Complexity makes certain demands and, if these demands are ignored by observers, no amount of high-powered activity is likely to be effective<sup>4</sup>.

Before turning to the Structure-Based School, the nature of complexity must come into our view.

#### 4. THE MISPLACED ORIGIN

In his famous paper published in 1878, titled "How to Make our Ideas Clear", Charles Sanders Peirce talked about false distinctions that are sometimes made in discussing beliefs. He wrote the following:

"One singular deception of this sort, which often occurs, is to mistake the sensation produced by our own unclearness of thought for a character of the object we are thinking. Instead of perceiving that the obscurity is purely subjective, we fancy that we contemplate a quality of the object which is essentially mysterious..."

"...So long as this deception lasts, it obviously puts an impassable barrier in the way of perspicuous thinking; so that it equally interests the opponents of rational thought to perpetuate it, and its adherents to guard against it."

This idea can be paraphrased somewhat, and turned into a definition of "complexity". First of all, **it is surely true that the vast majority of modern thought about complexity perceives it to be a property of what is being observed, instead of being a subjective response to the not-understood**. The language itself clearly demonstrates this, in the common use of terms such as "complex system", and "complex problem". Yet it is easy to imagine this: if the human being had the mental power to comprehend everything that was viewed of any interest, there would be no such thing as a complex system or complex problem in the usual sense, or of complexity in

<sup>3</sup> J. N. Warfield (1995), "Procrustes is Alive and Well and Teaching Composition in the English Department", Fairfax, VA: IASIS, 35 pages (originally presented at the annual meeting of the Association for Integrative Studies, Phoenix, AZ, September 30, 1995).

<sup>4</sup> J. N. Warfield (1997), "Twenty Laws of Complexity: Studies in the Abuse of Reason", Fairfax, VA: IASIS.

the sense discussed here. Clearly then, the very existence of complexity is directly connected to human mental limitations. Complexity is not a property of what is being observed, but rather is "a sensation" arising out of our own "unclearness of thought", when we are engaged with what we are observing<sup>5</sup>.

While this definition may be thought surprising, one of its notable attributes is that it allows for the possibility that complexity may be reduced or even eliminated, by a process called "learning". This possibility may even be compatible with those who find the idea of a "learning organization" intriguing and valuable, even if they do not choose to pay any attention to the distinction between situations that are ordinary and situations described as complex, and to the implications thereof for design and process sciences!

## 5. THE STRUCTURE-BASED SCHOOL: EXPERIMENTAL STUDIES.

Experimental studies from the Structure-Based School, targeted to complexity, have been conducted through indirect means for over 20 years. These studies were carried out by facilitating the efforts of groups to resolve situations hypothesized to be complex, in the sense that no member of the group was assumed to understand the system being explored: an assumption easily seen to be valid by observing the groups in action. In carrying out these prolonged studies, with many groups, involving many systems, three **Definitive Features** were found to be present in all instances:

- *A Plethora of Component Problems.* Through group processes, many component problems relevant to the problematic situation were identified and clarified, each problem being one facet of the system under study.
- *Widespread Difference of Belief Concerning Relative Importance.* Individualized voting by members of the group displayed widespread difference of opinion among members on the relative importance of problems involved in the system being studied. (This pervasive condition has since been dubbed "Spreadthink"<sup>6</sup>).
- *Large Numbers of Dependencies Among the Selected Problems.* By structuring dependency relationships among the problems, it was discovered that there were large numbers of dependencies among the problems, which is characteristic of problems with systems that induce complexity in the minds of observers.

These three features have now been quantified to use as measures of complexity<sup>7</sup>.

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<sup>5</sup> Three publications present relevant material. They are: (1) G. A. Miller (1956), "The Magical Number Seven Plus or Minus Two: Some Limits on our Capacity for Processing Information", *Psychology Review* 63(2), 81-97; (2) H. A. Simon (1974), "How Big is a Chunk?", *Science* 183, February 8, 482-488, and (3) J. N. Warfield (1988), "The Magical Number Three Plus or Minus Zero", *Cybernetic and Systems* 19, 339-358.

<sup>6</sup> These three publications describe various aspects of variations in individual belief: (1) D. B. Yntema and G. E. Mueser (1960), "Remembering the Present States of a Number of Variables", *Journal of Experimental Psychology* 60(1), 18-22; Kenneth Boulding (1966), *The Impact of the Social Sciences*, New Brunswick, N. J.: Rutgers University Press (see especially "spurious saliency"; and "unproductive emulation"); and (3) J. N. Warfield (1995), "Spreadthink: Explaining Ineffective Groups", *Systems Research* 12(1), 5-14.

<sup>7</sup> S. M. Staley (1995), "Complexity Measurements of Systems Design", in *Integrated Design and Process Technology* (A. Ertas, C. V. Ramamoorthy, M. M. Tanik, I. I. Esat, F. Veniali, and Taleb-Bendiah, Editors), IDPT-Vol. 1., 153-161.



## 6. COMPLEXITY REDUCTION THROUGH STRUCTURAL THINKING

The Structure-Based School approach to resolving complexity is illustrated by experience with redesign of the U. S. Defense Acquisition System, using design and process contributions from the Structure-Based School<sup>1</sup>. Table 2 describes three levels in a vertically-integrated (inclusion) structure relevant to the problematic situation. The three levels are here described as the "Operational Level, the Tactical Level, and the Strategic Level". These names are chosen to reflect somewhat standard usage in the management of large organizations. This 3-level pattern is called "The Alberts Pattern" after its discoverer, Professor Henry Alberts<sup>2</sup>. A similar pattern, differing only in the numerical data, was discovered in a systems engineering curriculum study in Mexico<sup>3</sup>.

Table 2. Two Examples of the Alberts Pattern in Organizations			
Organization	Number of Elements (Operational Level)	Number of Element Categories (Tactical Level)	Number of Element Domains (Strategic Level)
U. S. Defense Acquisition System	678 problems	20 problem categories	6 problem domains
Instituto Tecnológico y de Estudios Superiores de Monterrey--Industrial and Systems Engineering	270 design options	20 design option categories	4 design option domains

In the Operational Level, as indicated in Table 2, 678 problems relative to system acquisition were collectively identified by more than 300 program managers who were active in defense acquisition management. In the Tactical Level, these 678 problems were placed in 20 tactical categories. Finally, in the Strategic Level, these 20 categories were placed in 6 strategic domains.

In his dissertation, Professor Alberts indicated that one of the two main objectives of his work was to use that work to **represent a prototype process for organizational redesign**, a very complex application of a designed process for reducing complexity. It is fair to say that **complexity was reduced dramatically as the work progressed through the three levels. When completed, a highly transparent representation of the acquisition system was available.** This allowed persons in the operational aspects of acquisition to relate the problems they work with every day to the higher-level categories; and vice versa. As a result, a redesign of the system could be carried out that reflected high visual capability in connecting design options to problems at all three levels. It is very likely that because of this extensive referential transparency, the relevant legislation passed by the U. S. Congress involved only minimal modification to the results coming from this work. The legislation, identified as Public Law 103-355, October 13, 1994, is cited as the "Federal Acquisition Streamlining Act of 1994".



A similar reduction in complexity occurred in the Mexican work. By developing the capacity to work back and forth among the three levels of the inclusion structure, from the very specific, to the general oversight areas, a coherent insight and correspondingly coherent approach to effective management of what had been relatively unmanageable becomes very feasible<sup>4</sup>.

## CONTINUITY IN AN AGE OF COMPLEXITY

### 7. SUMMARY

**Nature of Complexity.** Complexity is a state of mind, triggered into emergence by unsuccessful efforts to comprehend a system that is immersed in a problematic situation. Efforts to cope with or manage complexity are hampered by a variety of invalid assumptions that are associated with developing schools of thought about complexity. Most of these schools of thought lack any design concept as part of their formulation, being content to provide analyses only; and their process concepts are either absent, or are tied to mathematical formalisms that either are not connected adequately to systems of interest, or when connected are connected only through dubious metaphors, loosely formulated.

**Available Research Results.** Research results are available that correct the perceptions that have produced those bad assumptions. The research results provide a comprehensive approach to complexity, which is responsive to the demands of complexity.

**Acquiring Practical Competence.** The individual who scans the five schools of thought in search of a potential for acquiring practical competence in working with complexity will find it only in the Structure-Based school, for which an integrated scientific basis is available, corresponding design theory is present, processes for application are clearly defined, and numerous cases are available to illustrate the coherence of the foregoing.

**Remedial Efforts.** Educational institutions should recognize their role in helping overcome the bad impact of complexity on human systems. Practitioner organizations should take advantage of existing science and processes to provide remedies for overcoming unconstructive habits and cultural features that propagate invalid assumptions.

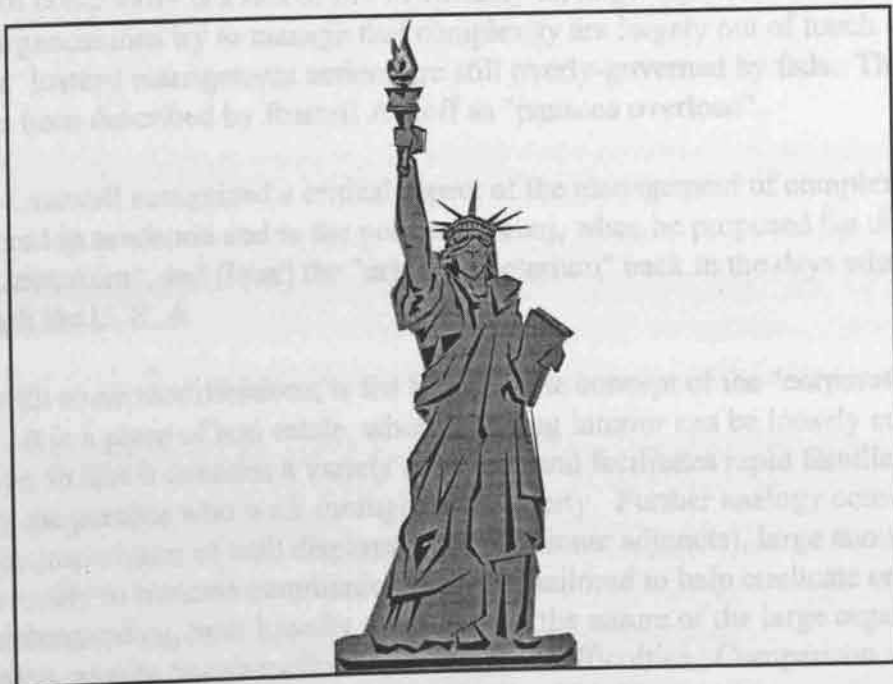


# THE CORPORATE OBSERVATORIUM: SUSTAINING MANAGEMENT COMMUNICATION AND CONTINUITY IN AN AGE OF COMPLEXITY

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**"The Corporate Observatorium: Sustaining Management Communication and Continuity in an Age of Complexity"**, in Tanik, M. M., et al (Eds.), Integrated Design and Process Technology, IDPT-Vol. 2, 1996. (Proc. Society for Design and Process Science, Austin, TX), 169-172.



**"sum, ergo cogito"**

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# THE CORPORATE OBSERVATORY: SUSTAINING MANAGEMENT COMMUNICATION AND COMPLEXITY IN AN AGE OF COMPLEXITY

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## ABSTRACT

### **THE CORPORATE OBSERVATORIUM: SUSTAINING MANAGEMENT COMMUNICATION AND CONTINUITY IN THE AGE OF COMPLEXITY**

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The prevalence of complexity is a fact of life in virtually all large organizations. However the ways in which organizations try to manage that complexity are largely out of touch with relevant scholarly results. Instead management actions are still overly-governed by fads. This phenomenon has been described by Russell Ackoff as "panacea overload".

The late Harold Lasswell recognized a critical aspect of the management of complexity (essentially ignored in academia and in the political scene), when he proposed the development of the "social planetarium", and (later) the "urban planetarium" back in the days when cities were in turmoil through the U. S. A.

That proposal, with some modifications, is the basis for the concept of the "corporate observatorium". It is a piece of real estate, whose building interior can be loosely compared with that of the Louvre, in that it contains a variety of rooms, and facilitates rapid familiarization with their contents by the persons who walk through that property. Further analogy comes from the recognition of the importance of wall displays (with electronic adjuncts), large enough in size to preclude any necessity to truncate communications; and tailored to help eradicate or minimize complexity in understanding, both broadly and in depth, the nature of the large organization, its problems, its vision, and its ongoing efforts to resolve its difficulties. Comparison with the planetarium for envisaging a broad swatch of the sky is self-evident.

Seven critical forms of representation of complexity will be described briefly. Their significance in sustaining communication and organizational continuity via the corporate observatorium will be indicated. Potential application in higher education will also be briefly described.



## **THE CORPORATE OBSERVATORIUM: SUSTAINING MANAGEMENT COMMUNICATION AND CONTINUITY IN THE AGE OF COMPLEXITY**

In June of 1988, Professor Henry Alberts of the Defense Systems Management College, Fort Belvoir, Virginia, conducted an "Interactive Management Workshop" (Warfield and Cárdenas, 1994) on the subject "What do Technical Managers Do?" The participants in this activity were experienced program managers who oversee very large and expensive military systems development.

A little over eight years later, Professor Alberts walked down the aisle in London to receive his Ph. D. degree, majoring in systems science. This degree was awarded as a result of an extensive period of intermediate work that began in 1988, as indicated above, and culminated in 1994 with the passage of U. S. Public Law 103-355, the "Federal Acquisition Streamlining Act of 1994." A large number of Interactive Management Workshops managed by Professor Alberts provided the intermediate outcomes required.

There was little or no expectation in 1988 that the entire U. S. defense acquisition system could be systematically redesigned nor, if it could be, that such a design could find its way through the political establishment and replace mountains of prior U. S. code under which military acquisition had become the subject of intense distrust and large waste of resources.

Still, this work had answered "yes" to the following question:

"Is it possible to redesign a very large, expensive, significant public system, systematically, relatively remote from the normal political processes that produced the existing unsatisfactory system, and then get that old system replaced through the standard political mechanism?"

Having observed what had to be produced to comprehend and design such a large system, inevitably serious questions ensued, of which the following is of great present interest:

"How can people learn in depth what is involved in the design, operation, and amendment of very large, expensive systems, once such a design has been completed?"

This question may, also, have a positive answer. It may well be possible for many people to learn what is involved in designing, operating, and amending such a large system and, actually to understand in depth how it works. If so, there is every reason to believe that the means of achieving this can be adapted, with minimal conceptual change, to many other systems of importance to society. It is with this belief in mind, that the concept of "corporate

observatorium" is set forth here.

## 1. THE LASSWELL TRIAD

The possibility of broad-based learning about very large systems becomes more realistic when what is called here "The Lasswell Triad" is understood.

Harold Lasswell (1902-1978) was a political scientist, one of the foremost authorities in that field. As a faculty member, he taught law and political science at the University of Chicago, Yale, and elsewhere. Author of many books and papers, he originated key ideas relevant to the effective design and understanding of public policy, which remain essentially dormant today.

One of his key views he expressed as follows:

*"Our traditional patterns of problem-solving are flagrantly defective in presenting the future in ways that contribute insight and understanding"*

The Lasswell Triad is responsive to this view, in part. It consists of these three concepts:

- The decision seminar (taking place in a specially-designed facility) (Lasswell, 1960, 1971)
- The social planetarium (Lasswell, 1963)
- The prelegislature, or pre-congress (Lasswell, 1963)

In brief, here are the key ideas involved in this Triad, adapted to correlate with the latter part of this paper:

**1.1 The Situation Room.** First, a special facility needs to be put in place, where people can work together on design of complex policy (or other) issues, and where the display facilities have been carefully designed into the facility, so that they provide prominent ways for the participants to work with the future "in ways that contribute insight and understanding".

**1.2 The Prelegislature.** Second, this special facility should be used extensively to develop high-quality designs long before legislatures or corporate bodies ever meet to try to resolve some complex issue facing them by designing a new system (e.g., this is a sensible way to go about designing a health-care system to which the political establishment can repair for insights and such modifications as seem essential).

**1.3 The Observatorium.** Once the design has been accepted, the observatorium is designed and established so that people can walk through a sequential learning experience, in which they gain both an overview and an in-depth understanding of the system that has been designed and which, most likely, will be prominent in their own lives.

The observatorium is a piece of real estate, whose building interior can be loosely compared with that of the Louvre, in that it contains a variety of rooms, and facilitates rapid familiarization with



their contents by the persons who walk through that property. Further analogy comes from the recognition of the importance of wall displays (with electronic adjuncts), large enough in size to preclude any necessity to truncate communications; and tailored to help eradicate or minimize complexity in understanding, both broadly and in depth, the nature of the large organization, its problems, its vision, and its ongoing efforts to resolve its difficulties. Comparison with the planetarium for envisaging a broad swatch of the sky is self-evident.

The descriptions just given represent only modest deviations from the Lasswell Triad, but slight changes in nomenclature have been adopted for purposes of this paper.

Given that relatively little has been done with the Lasswell Triad, two questions might arise. The first might be: "Why?". Another might be, "Are there additions that have to be made that, when integrated with the Lasswell Triad, provide a practical means for enhancing greatly the design, management, amendment, and understanding of large, complex systems? This last question will now be answered: "Yes".

## **2. PREPARING FOR THE OBSERVATORIUM**

No one would expect that the observatorium would be brought into place unless the "art" required to fill it were available, and if the topic were of vital social importance.

It would, therefore, be important to have conceived and created the situation room required for effective group work, and to have conducted the necessary prelegislative activity to provide the raw display information for the observatorium.

A situation room of the type desired was developed in 1980, and has since been put into place in a variety of locations (Warfield, 1994). Rooms of this type provided the environment for the Alberts work, and for many other applications of Interactive Management (Warfield and Cárdenas, 1994). Thus the first essential preparation for the observatorium is complete.

The Alberts application, and other ongoing applications have and are providing the second essential raw display information.

What kinds of displays are required for the observatorium? These displays must meet stringent communication requirements. In brief, they must meet the demands of complexity for effective representation. This means, among other things, that they must be large, and they must cater to human visual requirements.

## **3. REPRESENTATION OF COMPLEXITY**

The Lasswell Triad clearly relies for its adoption and use, upon the availability of ways of representing complexity that place it within the realm of human comprehension.

There is a long-established penchant among scientists of all varieties to place everything possible in mathematical or numerical terms. Depending on the specific mathematics chosen, and the numerical forms adopted, the potential learner group for such representations is greatly reduced. Does this mean that only the mathematically-educated or the numerically adept can fill effective citizenship roles in a democracy, where public understanding is necessary for good decisions?

A prolonged study of complexity (Warfield, 1994) establishes that it is high-quality, graphical communication means which must be used if large, complex systems of the type studied by Alberts can be brought within the grasp of ordinary mortals.

Literally dozens of such defense-acquisition-specific representations were developed by Alberts and they provide the raw material which, if introduced appropriately into a "defense acquisition system observatorium" could provide the sequenced pattern of learning that even the Congress would require in order to understand the system beyond the confines of a few of their committees.

Prose alone is inadequate to portray complexity. Mathematics is often unavailable because mathematical language is restricted to a small percent of the population. For this reason, language components comprised of integrated prose-graphics representations enjoy unique potential for representing complexity.

Because of the desirability of taking advantage of computers to facilitate the development and production of such integrated representations, it is best if the prose-graphics representations are readily representable in computer algorithms, even if their utility for general communication is limited. Mappings from mathematical formats to graphical formats can often be readily done, although manual modification of graphics for readability may be necessary.

The following specific graphical representations have proved useful in representing complexity:

- **Arrow-Bullet Diagrams** (which are mappable from square binary matrices, and which correspond to digraphs)
- **Element-Relation Diagrams** (which are mappable from incidence matrices, and which correspond to bipartite relations)
- **Fields** (which are mappable from multiple, square binary matrices, and which correspond to multiple digraphs)
- **Profiles** (which correspond to multiple binary vectors, and also correspond to Boolean spaces)
- **Total Inclusion Structures** (which correspond to distributive lattices and to power sets of a given base set)
- **Partition Structures** (which correspond to the non-distributive lattices of all partitions of a base set)
- **DELTA Charts** (which are restricted to use with temporal relationships, and which sacrifice direct mathematical connections to versatility in applications)

Virtually no instruction is given in higher education even simply on how to read these high-quality, scientifically-based representations. On the other hand, it is very common to see low-quality instances of graphics types in use, where they communicate very little except, possibly, to their originators. These low-quality graphics are frequently adjuncts to a wide variety of proposed management strategies for dealing with complex situations. Over 20 of these have been discussed as "alleged panaceas" (Ackoff, 1995), who concludes that "very few of these panaceas have delivered all they promised to those who adopted them".

All of the scientifically-based representational types have been thoroughly explained, and many examples of their use in a wide variety of applications are available (Warfield, 1994). Most of these types were used in the Alberts dissertation (Alberts, 1995), and can be seen there as they related specifically to defense system acquisition. The same types were used to explore in a student design course, the redesign of a large systems curriculum (Cárdenas and Rivas, 1995), and to explore high-level design activities at Ford Motor Company, where aspects of the graphics representations facilitate computation of numerical indexes of complexity (Staley, 1995).

The exploration of the large systems curriculum can, itself, be a prototype for exploitation in academia, to open up curricula (e.g., public policy curricula currently heavily oriented to "policy analysis") to activities such as large-system design.

#### 4. SUMMARY

The first step in resolving issues related to large, complex systems, is to provide a well-designed situation room, equipped to enable groups to work together effectively. The second step is to carry out whatever prolonged design work is required, using processes proven to be effective, yielding visual displays of the system patterns that hold understanding of the logic underlying the system. The third step is to embed the results of the second step in the corporate observatorium, where insight into the large, complex system comes both at overview and detailed levels, according to the efforts put forth to comprehend what is seen in the sequenced displays.

The first two steps have been accomplished in a variety of settings. It remains to take up the challenge to develop the first corporate observatorium which may then become a prototype for its successors.

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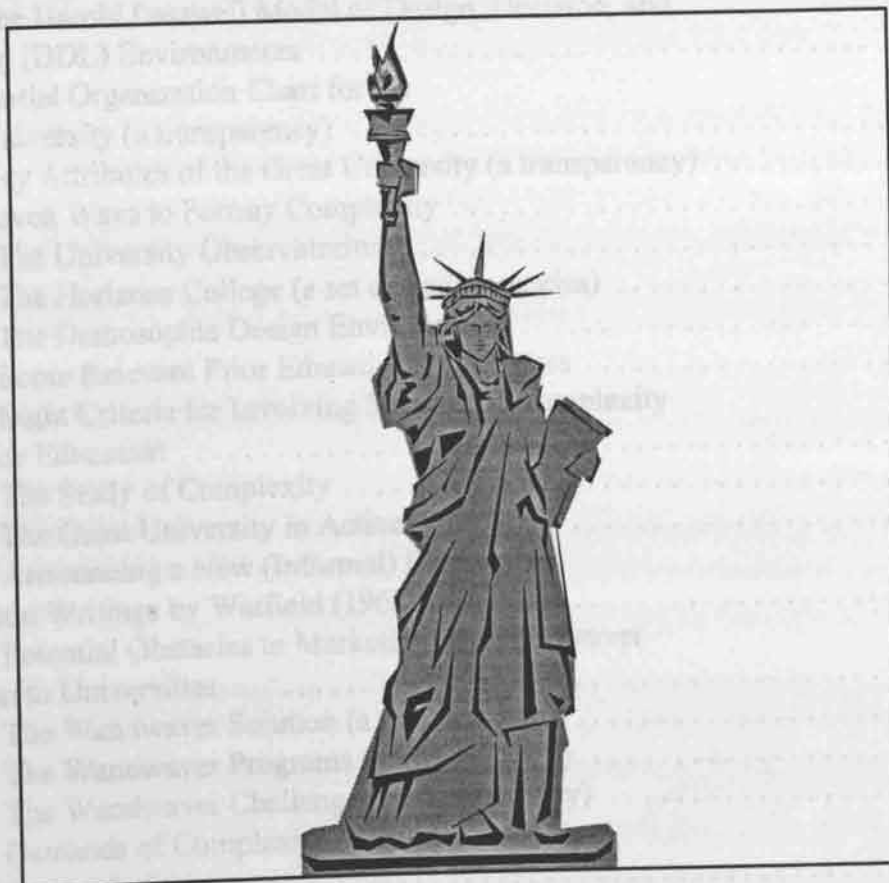
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# THE WANDWAVER SOLUTION

## Creating the Great University

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"sum, ergo cogito"

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## THE WANDWATER SOLUTION

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# THE WANDWAVER SOLUTION

## ABSTRACT<sup>1</sup>

John N. Warfield<sup>2</sup>

The Wandwaver Solution is a proposal and an unbudgeted plan for revolutionary change in the university (as an instrument of higher education around the world). While the change is revolutionary in scope, it can be achieved through well-defined, well-tested evolutionary processes, which minimize the costs of transformation while still carrying out essential functions.

The processes of change may require about five years to reach fruition. They are comprehensive. They involve all parts of the existing institution. To carry them out, new high-level functional units are required. These are the "University Observatory" and the "Process Leadership Division", both of which will be administered from the office of the President.

Most existing educational programs will continue to exist, but their practices and administration may change. One major new college will be created, called the Horizons College. All professional schools will be aggregated under a single Professional College. The traditional "university college" will be the University College, largely as before, but practices may change.

The proposal for change consists of seven major subdivisions.

- Background from scholarship and practice
- Research conclusions
- The Wandwaver Challenges
- The Wandwaver Vision
- The Wandwaver Programs
- The Wandwaver Schedule
- The Wandwaver Benefits

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<sup>1</sup> A significant amount of supporting material is given in the numerous appendices. To avoid interrupting the textual flow, yet indicating spots where these materials are relevant, brackets are inserted in the text to point the reader to the relevant material. The complete document, including all of the appendices not printed here, is presently available at the URL: <http://www.gmu.edu/departments/t-iasis/>.

<sup>2</sup> This work was enabled through multiple-year research support from the Ford Motor Company, Dearborn, Michigan, with special acknowledgment to Dr. Scott M. Staley of the Ford Research Laboratory. Other contributors are acknowledged at various points in this document.

# THE WANDWAVE SOLUTION

## ABSTRACT

John H. Wainwright

The Wandwaver Solution is a proposal and an integrated plan for revolutionary change in the university (as an instrument of higher education around the world). While the change is revolutionary in scope, it can be achieved through well-defined, well-tested evolutionary processes, which minimize the costs of transformation while still carrying out essential functions.

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The proposal for change consists of seven major subdivisions:

- Background from education and practice
- Research considerations
- The Wandwaver Challenge
- The Wandwaver Vision
- The Wandwaver Program
- The Wandwaver Schedule
- The Wandwaver Results

A detailed account of supporting research is given in the extensive appendices. The most important research data are contained in the appendices, including the research data presented in the main text. The research data are presented in the appendices, including the research data presented in the main text. The research data are presented in the appendices, including the research data presented in the main text.

## 1. BACKGROUND FROM SCHOLARSHIP AND PRACTICE.

Great thinkers from the past have studied processes of inquiry, human behavior related to thought and learning, ways of fixing belief, and pragmatic aspects of realistic outcomes in human development [*Nineteen of them are identified in Appendix 1, along with their contributions*].

A group of practitioners at various locations around the world tested these processes to determine the extent to which they are applicable to different situations and in different organizations and cultures [*Thirteen of them are identified in Appendix 2, along with their contributions. In that same Appendix, additional (living) contributors are identified along with their contributions*].

The ideas of these great thinkers have been integrated recently, i.e., amalgamated into a scientific base, and transformed into a set of systematic processes for learning and development [*Four books that summarize this development are identified and outlined in Appendix 3*]. It is this integration that provided the basis for the works of the practitioners identified in Appendix 2.

Much evidence exists to show that the conclusions finally reached from this work, extending over several decades, are directly applicable as key working components of the Wandwaver Solution. The evidence exists in extensive literature documentation, as well as in dozens of videotapes and reports.

## 2. RESEARCH CONCLUSIONS.

Today's university is, in some respects, very successful and, in other respects, a failure. Selective analysis and design strives to retain the best and eliminate the worst, while adding value throughout.

- The university has great strengths, drastically misused
- Opportunities to add value in educational practices are very large, but not recognized in existing programs
- The image that the institution projects to the public is only slightly less than disastrous, because it is highly inaccurate and inauthentic
- The organization of the university is remote from what is required to keep it effective as an institution
- It thrives on platitudinous statements, unmeasurable intentions, and unjustifiable practices
- It does virtually nothing to deal constructively with complexity in society, thereby avoiding what perhaps constitutes the major educational challenge of the present and the future
- It does not use, in its internal operations, even those practices that it teaches its students to use when they leave the institution
- As an institutional role model, it is a disaster, when it could be a beacon that teaches by its own practices

**The best aspect of the foregoing is this: the university is a highly-leveraged institution, open to massive improvement, if it can bring itself to take advantage of the Wandwaver Solution.** *[To facilitate this, various intellectual resources germane to the choice are presented in Appendix 4, under a variety of headings applicable to the choice.]*



### 3. WANDWAVER CHALLENGES.

Five challenges are set forth in moving to the new institution:

- **Develop authentic referential transparency.** Make the institution highly visible to all inquirers, internal and external alike, in terms of goals, programs, activities, and (especially) products
- **Become manageable.** Enhance manageability in two main directions:
  - As an organization
  - As a manageable, integrated body of knowledge
- **Become open at scale.** Break free of constraints that block inquiry related to knowledge areas caused by constraints of scale imposed by inadequate infrastructures and undesigned, unresponsive institutional processes
- **Provide a System Design Resource for Society.** Expand academic program offerings into the domain of large system design [with emphasis on sociotechnical systems, following the lead established in the books described in Appendix 2], to anticipate the purposes of an increasingly complex society, whose institutions can no longer respond to the challenges of today
- **Institutionalize the Conditions that Allow the Challenges to be Met.** Provide and sustain those new infrastructural and process resources that enable the challenges to be met.

#### 4. THE WANDWAVER VISION.

The Wandwaver Vision stems from the background research, with different parts of the Vision accruing from different scholars, being integrated into a final organizational form.

*The goals and objectives are largely taken from the work of Ralph Barton Perry [His work is summarized in Appendix 5, and discussed at length in the the book by Steinberg, cited there]:*

- The Primary Goal: to produce graduates who are highly-equipped to be effective citizens in a democracy
- The First Contributory Objective (**Inheritance**): to enable the graduate to attain a position of knowledgeability of the inheritance from the past
- The Second Contributory Objective (**Participation**): to enable the graduate to play a worthwhile role in the society of the times
- The Third Contributory Objective (**Contribution**): To enable the graduate to make worthwhile contributions to the future of society

To the foregoing, stemming directly from Ralph Barton Perry, **a fourth is added**. This fourth objective, seen as critical in enabling society to come to grips with complexity, and seen as an essential adjunct to make the foregoing material effective is:

- The Fourth Contributory Objective (**Integration**): To enable the graduate to integrate the inheritance, participation, and contribution, as a citizen in a free society

Achievement of the Integration objective is attained with the aid of a collection of ideas originated by the late Harold Lasswell. Lasswell's vision, though derived from a lifetime of study of the American political scene, is readily adaptable to any arena requiring human collaboration in overcoming complexity [*Appendix 6 summarizes the most essential Lasswell ideas.*]

The new institution is organized, so that each of the three Colleges accepts primary responsibility for one of the first three objectives, as follows:

- The University College: The Inheritance Objective
- The Professional College: The Participation Objective
- The Horizons College: The Contribution Objective

Responsibility for achieving the fourth objective is located in the office of the President, where its achievement is promoted, enabled, and enhanced by the Process Leadership Division. Moreover, the status at any time is revealed in the University Observatory, which is maintained by the Process Leadership Division. The primary way in which the Process Leadership Division gets the integration done is through processes involving representatives of all three of the Colleges, each contributing according to its primary educational role, as described below under the title "Wandwaver Programs" [*Appendix 7 shows a partial organizational chart of the Great University, arranged to fit the previous descriptions.*].

## 5. THE WANDWAVER PROGRAMS.

The Wandwaver Programs are statements of the actions that produce change. They are an integrated set of programs, aimed at the complete revolutionary change required.

The five principal Wandwaver Programs are the following:

- **Upgrade Knowledge Structure.** Every discipline in the University College and every discipline in the Professional College will upgrade the structure of its knowledge base, with the aid of the Process Leadership Division, and the Horizons College.

The types of products of the upgrade will be chosen from the "seven ways to portray complexity" [The seven ways found and tested to date to portray complexity are identified in **Appendix 9**]. Through this means, the following pattern types will be produced for every discipline:

- **Problematic:** the set of problems or issues that are relevant to society, which that discipline represents in its knowledge base, showing how these are interrelated
- **Intent Structure:** the set of objectives of the discipline, showing the pattern of how they are interrelated
- **Resolution Structure:** the pattern that shows, superimposed on the problematic, the chosen options for resolving the problematic (possibly over a very extended period of time)
- Such other structures as the discipline may choose

This collection will be called the "disciplinary context" for each discipline, and will be perpetually displayed in the University Observatory, where it will be updated as required.

- **Provide Institutional Visibility.** A dedicated building will be created and filled to become the University Observatory. All of the programs of the University, and all of the faculty plans for the future will be represented there to the extent practical. Because of its visibility, this component will provide an "invisible hand" (a la Adam Smith) to perturb the activities of the university as seemingly required by the changing world [Additional discussion of the Observatory is given in **Appendix 10**.]
- **Provide Process Leadership.** The university will maintain a group of people whose role is to provide process leadership, i.e., to design and conduct the processes needed to produce and sustain the Knowledge Structure Upgrades that are required. They will maintain the University Observatory, and are responsible for the quality of its display resources. This Division must bring about the necessary group working facilities, where the processes can be carried out efficiently and effectively.
- **Inaugurate the Horizons College.** There does not now exist anything like the Horizons College in any university [**Appendix 11** describes this College in more detail]. This



College must carry out design of the future, and to do so it must incorporate components of the Inheritance and it must respect current requirements of Participation. What should guide the Horizons College?

- It should use the framework of the Work Program for Complexity as the foundation for its organization and its activities.
- It should use the Science of Generic Design and the forthcoming book titled "THE WORK PROGRAM OF COMPLEXITY: FROM ORIGINS TO OUTCOMES" as the foundation for its learning programs.
- It should use Interactive Management [see **Appendix 3**] as the methodology for organizing contexts of complex situations, and for generating designs to resolve complex situations.
- It should continue to foster individual in-depth research within the larger contexts provided by products of Interactive Management and structural analyses.

The Horizons College has the greatest responsibility among the Colleges for remedying the educational deficiencies associated with complexity, both within the university and in the society at large.

The concept of this college draws heavily on ideas from a variety of scholars in different disciplines. Here are some of the most prominent contributors who are included in the more comprehensive list that appears in **Appendix 1**:

- Harold Lasswell--sociology, law, and political science
  - Charles Sanders Peirce--philosophy and logic
  - Alexander Pope--poet (An Essay on Criticism, in particular)
  - Michel Foucault--philosopher (The Archaeology of Knowledge, in particular)
  - Frank Harary--mathematician and graph theorist
  - David Hilbert--mathematician
- **Provide Appropriate Group Work Facilities.** Faculty and students who engage in the necessary group work involved in the Knowledge Structure Upgrade and in the design work of the Horizons College require appropriate group work facilities. Such facilities have been designed, tested, and found to be very supportive for high quality work.

Numerous group work facilities that are commercially promoted (e.g., "GroupSystems") are quite unsatisfactory. The appropriate facility is called "Demosophia" [A proposal appears in **Appendix 12** which describes this facility]. A complete construction plan is available. Facilities of this type can be visited (sometimes while in use) in Dearborn, Michigan; La Jolla, California; Honolulu, Hawaii; and to some extent in other locations. Photographs of such a facility in use are available for inspection. Dozens of videotapes are available showing a diverse set of groups working in such a facility on a diverse set of problems. Included are the reactions of the groups at the conclusion of the group work.]



## 6. THE WANDWAVER SCHEDULE.

A nominal schedule for implementing the Wandwaver Solution is as follows:

### ■ **Year One. Reorganizing, Prototyping, and Completing the Plan for Change.**

Because the institution requires time to adjust to the changes and to determine their acceptance, only modest changes will be visible in the first year. However, it is realistic to anticipate that these events can occur:

- Institutional acceptance of the Wandwaver Solution
- Completion of five-year budgets for change
- Draft of the plan for the University Observatory
- Appointment of principals in the Process Leadership Division
- Appointment of the principal administrator and inauguration of the Professional College
- Draft of a staffing plan for the Horizons College
- Selection of one or more departments to produce prototypical Knowledge Upgrade patterns for those departments, accompanied by explanatory material suitable for field testing in a mockup of a University Observatory space
- Expanded development of plans for the next few years
- Completion of this Abstract into a full plan for later years

### ■ **Year Two. Mounting the Integrated Program.** Various activities can be initiated in parallel:

- Expanded Knowledge Upgrade developments
- Construction of the Demosophia facilities
- Additional staffing for the Horizons College
- Completion of plans for and beginning of construction of the University Observatory (unless an existing facility can be adapted for this purpose)
- Test classes for students using the products as they become available

### ■ **Years Three to Five. Completion of the changes.**

## **7. THE WANDWAVER BENEFITS.**

There will be many beneficiaries of the Wandwaver Solution. Some of these, and the nature of the benefits to be achieved will be described next.

**7.1 Benefits to the Incoming Students and Their Parents.** The incoming student approaches the university with no useful comprehension of its programs. If the university establishes the Observatorium in the manner envisaged, a thoughtful tour through this building will given incoming students and their parents an unparalleled concept of what offerings the university has, their purpose, their connection to society, what the student might be interested in when attending college, and many other related matters.

**7.2 Benefits to Graduate Students.** Graduate students will be able to learn rapidly, through the faculty-written program information available in the Observatorium, just what faculty members are doing and how any given faculty member's work relates to academic programs and external applications. This should provide an unmatched opportunity for graduate students to develop insight into what might be attractive to them as research possibilities.

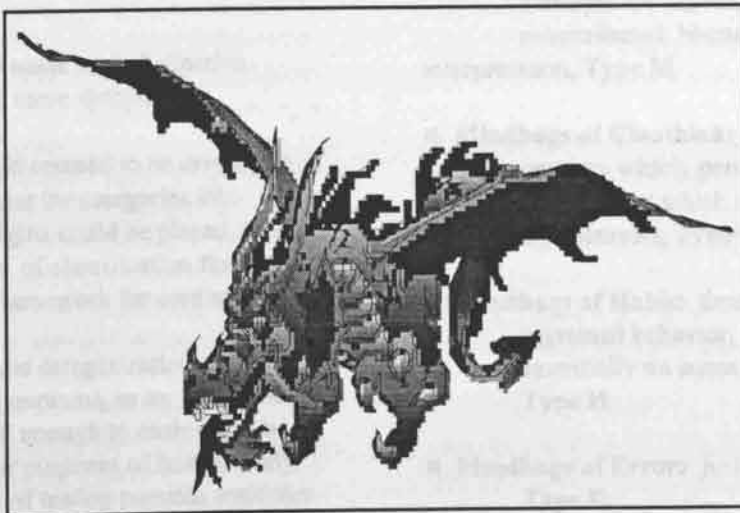
**7.3 Joint Benefits to Donors and the University.** Potential large donors to the university presently undergo the attention of "development" personnel, and the funds given often are not tied to what the main programs of the university might be. Many potential donors do not like the way in which their funds are sought, and would much prefer an opportunity to find their own way into areas where giving might be fruitful. The Observatorium will provide an unparalleled way for potential donors to get insight into what is going on, untainted by whatever bias might be brought to them from other sources.

**7.4 Benefits to Society as a Whole.** Society suffers greatly from inadequate formulations of major policy at the various levels of government. Students who will become leaders later in life gain no experience in policy formulation, through high-quality, systematic interactions. They do not know how to represent policy so that it can be understood (applying, for example, the seven ways of portraying complexity illustrated in this document). By creating the infrastructure to support Lasswell's ideas about policy formulation and pre-legislative activity, the university can take on a new, multi-dimensional leadership role in society of the type often given lip service and, perhaps, never achieved.

**7.5 Benefits to the Faculty.** In a typical university, the complexity of administering the institution often allows very bad decisions to be made that affect faculty in ways they did not anticipate, and cannot change after the fact. Anything that makes the whole institution much more visible will help faculty and administration alike to enhance greatly the way in which the institution is governed.

# MENTOMOLOGY

## THE IDENTIFICATION AND CLASSIFICATION OF MINDBUGS



A Microscopic Photograph of a Mindbug of Habit

© 1995 John N. Warfield





## THE BEGINNINGS OF MENTOMOLOGY

A few years ago, during a cruise on the Ship of State in the Sea of Knowledge, certain behaviorally-related symptoms appeared that seemed to be responsible for various unfortunate occurrences. Once these symptoms became overwhelmingly evident, a modest effort was undertaken to try to identify the origins of the symptoms.

As a result of the early years of study, a new discipline was initiated called "mentomology". The purposes to which this discipline was directed were as follows:

- To create a distinctive name that would designate the class of origins of the symptoms, if such origins could be identified
- To try to identify and name each distinctive origin of one or more symptoms
- If more than one origin seemed to be present, to identify and name the categories into which those origins could be placed, so as to start a system of classification that could provide some framework for continuing.
- Beyond the naming and categorization of the origins of the symptoms, to try to describe each origin well enough to enable it to be recognizable for purposes of further study, or for purposes of testing possible antidotes or remedial activities
- To study past discoveries or writings, to see whether any assistance could be found in the Sea of Knowledge and, if successful, to make the results known to the owners, the crew, and passengers on the Ship. If it turned out that cruises on the Ship of State continued to experience the same or similar symptoms, in spite of modest amelioratory measures, it was thought that perhaps ultimately mentomology might become a recognized academic discipline, possibly in a graduate school of business, or some other professional school, where Mentomology Science could be the basis for a masters' degree, such as M. M. A.

(Master of Mentomology Administration), or perhaps M. S. in M. S. or MS<sup>2</sup>.

The time has come to report on the early findings. The first purpose stated above has been satisfied. The apparent origins of the symptoms have been designated as "**mindbugs**" to bring the language in line with contemporary computer languages (in view of the fact that computers and people are becoming relatively indistinguishable in terms of functions and dysfunctions).

So far, twenty-five mindbugs have been identified. These are envisaged as falling within four categories, although so far it has not always been possible to consign a mindbug to just one category. Later refinements may allow this flaw to be corrected.

The categories identified so far are:

- **Mindbugs of Minsinterpretation:** those where concepts are misconstrued or misattributed, because of faulty interpretation, **Type M.**
- **Mindbugs of Clanthink:** those where concepts are very widely perceived to be correct, but which are demonstrably incorrect, **Type C.**
- **Mindbugs of Habit:** those which involve ingrained behavior, evinced with essentially no conscious thought, **Type H.**
- **Mindbugs of Error:** just plain mistakes, **Type E.**

A fifth category that is under consideration has been designated as "Mindbugs of Specific Human Shortcomings". This category is based on a hypothesis that there may be something inherent in people as people that causes mindbugs which can never be corrected. However it remains to be seen, as the field of mentomology develops, whether there really are uncorrectable Mindbugs. In studying this possibility, it is intended to allow all forms of technology to be applied as aids to the human being, and if this category is allowed to persist, it will only be because the postulated "specific human shortcomings" continue no matter what assistance is provided by any known form of technology (hard, soft, a combination, or otherwise). Whatever else may be true about this potential category, it does

seem to suggest a challenge to discover new ways to help overcome the impact of Mindbugs which might, otherwise, be thought to be fundamental to being a human.

In the following, Mindbugs are described. For each Mindbug, one or more identifying indexes is provided. Each index uses the type letter given above (M for Misinterpretation, C for Clanthink, etc.) and a number to identify the particular Mindbug within the Type. Where a Mindbug is at least temporarily assigned to more than one type, the several types are separately acknowledged<sup>1</sup>

## MINDBUGS

**Affinity to All-Encompassing Dichotomies (H3).** *The necessity of the academic propensity among philosophers to create dichotomies, and to choose one member of the dichotomy as superior to another, not recognizing the possibility that there is a continuum of which the two members may be at best end points.*

**Aversity to Budgeting for Interface Expenses (C7, E4, H2).** *What large organizations have budget line items that pay only for interactions among different divisions or components of the organization, whose staff is committed solely to the promotion and conduct of such interactions? What organizations reward particular managers solely for carrying out the function of interface management, allocating funds to those different organizational components solely to pay for the necessary interactions with other components? If there are such organizations, surely they are small in number, because the governing organization charts typically show functional responsibilities of the most well-defined type, such*

<sup>1</sup> The following two books, available directly from the publisher, are dedicated to means of overcoming the impact of Mindbugs:

■ John N. Warfield (1994), *A Science of Generic Design: Managing Complexity Through Systems Design*, Second Edition, Ames, IA: The Iowa State University Press, approx. 600 pages.

■ John N. Warfield and A. Roxana Cárdenas (1994), *A Handbook of Interactive Management*, Ames, IA: The Iowa State University Press, approx. 350 pages.

(In Europe, both are distributed by Eurospan, Covent Gardens, London, U. K.)

*that managers who have responsibilities for their own particular functions (even those whose products ultimately produce interactions with products developed through other functions for which others are responsible), nevertheless do not find it appropriate to fund interactions, because to do so might threaten their capability to carry out their internal functions.*

**Aversity to Deep Thought (H8).** *One of the most frequently noted aspects of high-level management behavior is that whatever is to be adjudicated must be presented (at least initially) on one page. No distinction can be made according to "depth" of thinking.*

*Sometimes such a one-pager can be followed up with a one-hour presentation, in which transparencies are the standard medium.*

*In either instance, the size of a normal sheet of paper is normally the defining concept of what kind of information can be offered. In some instances, a computer screen determines the size that is available to present a concept.*

**Confusing Prestige with Authoritativeness (M3).** *Huge financial rewards are available today to consulting organizations that assist clients in working with complexity. Some of these organizations have very high profiles. It is not unusual to see the expression the "prestigious X" in referring to these organizations. One must keep in mind that, if an organization is prestigious, it is often because of what went on there several decades into the past. The prestige may have come from pioneers who have long since died, and whose ideas were not even recognized at the time as being significant.*

**Failure to Distinguish Among Context, Content, and Process (H9).** *The context for human interaction, if left undefined, admits content-oriented dialog to be random, incoherent, rambling, unfocused; and may well cause dissension concerning the process being applied in the interaction. The process for human interaction, if left undefined, admits the content interaction to fly back and forth between discussions about what process ought to be used in respect to a particular topic; and may well allow context shifts to be made arbitrarily, as various misassociations are triggered, or as unarticulated interests emerge spontaneously. The content that can be produced may well be incoherent as participants shift from one context to another, and*

propose different process components.

**Indistinguished Affinity to Unstructured Discussion (C6, E3, H1).** *Unstructured discussion is widely practiced as a way of sharing thought, and as a means of providing instruction. Such discussion, when it involves the potential discussion of complex situations, with due attention to the Work Program of Complexity (Description, Diagnosis, Design, and Implementation) invariably rests solely upon the narrow shoulders of prose expression, which can be trusted only to the extent that linear presentation is capable both of capturing and communicating a complex set of relationships. Since prose alone lacks such a capability, the failure to distinguish, consciously, unstructured discussion that deals with complex situations from unstructured discussion that deals with ordinary situations is a clear indication of the presence of this Mindbug.*

**Insensitivity to Conceptual Scale (C4).** *Situations are not distinguished in terms of the relevance of their conceptual scale to human cognitive limitations, nor to the likely irrelevance of methods learned or experienced that apply to ordinary situations, when faced with complex situations.*

**Insensitivity to the Presence and Origins of Human Fallibility (C5).** *Insensitivity to the presence and origins of human fallibility is recognized by behavior that proceeds indiscriminately to base large-scale activity on fallible belief, and makes false assumptions about the capacity of the individual human being to reach an adequate perception of patterns involved in complex situations through ordinary thought processes.*

**Insensitivity to Role Distinctions (H5).** *Lack of understanding of how the various roles in a collaborative activity interact, in working toward common aspirations and fulfilling expectations, is a clear measure of insensitivity and, even more problematic, leaves open the possibility that in usurping the role of others, the miscreant's own responsibilities will not be carried out.*

**Insensitivity to the Significance of Information Flow Rates (H7).** *The ability of the human being to learn, absorb, follow, and interpret, incoming information cannot be imagined to be without limits. Otherwise, everything to be conveyed could be sent at the speed of light in one overpowering burst of communication. Thus it must be true that there is some limit (even if it differs from one person to*

*another), and this limit needs to be taken into account when genuine communication is intended. Very likely, effectiveness can be totally eliminated if the information flow rate is too fast.*

**Irresponsible Propagation of Underconceptualized Themes (E9).** *Reliance on authority opens the door to propagation of themes that are flawed by underconceptualization. It is one thing to blindly accept the voice of authority. At least such blind acceptance could be ultimately subjected to tests. But it is another thing to go further and propagate a theme, in the absence of any significant logical consideration.*

**Leaping to Misassociation (H4).** *Reflection and experience suggest that, in striving to comprehend a situation, the mind is often prone to leap to associations, in which an attribute often regarded as very beneficial in promoting creativity is applied to expand the domain of consideration, thereby suggesting either an extended form of relationship or a new approach to description or diagnosis, or a creative component of a sought design.*

*The same mental property, when undisciplined, leads to grave misunderstandings and interpretation. Leaping to misassociation can be one of the most common ways of misjudging the utterances of another person, and it is often very difficult to avoid this possibly-ingrained behavior.*

**Misassignment of Relative Saliency (E8).** *In a wonderful book<sup>2</sup>, Kenneth Boulding identified "spurious saliency" as one of the three primary reasons for poor intellectual productivity. Spurious saliency generally refers to a practice of misperceiving the relative importance which well-designed criteria would suggest should be attached to different situations from a particular set. Yntema and Mueser described results from psychology showing that individuals could do a lot better at dealing with several attributes of a single entity than they could in dealing with one attribute of several entities<sup>3</sup>. Misassignment of saliency apparently reflects a frequently-made error. This can be*

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<sup>2</sup> Kenneth Boulding (1966), *The Impact of the Social Sciences*, New Brunswick, NJ: Rutgers University Press.

<sup>3</sup> D. B. Yntema and G. E. Mueser (1960), "Remembering the Present States of a Number of Variables", *J. Exper. Psychology*, 60(1), 18-22.



described as the result of behavior that allows a superficial assessment to be made when several distinct entities are involved.

**Misattribution of Consensus (M6).** *Misattribution of consensus refers to a well-known aspect of what is called "groupthink" in the technical sense given by Janis<sup>4</sup>, and what is sometimes called "the Abilene Paradox" in business consulting. The unwillingness of members of a group to identify their own opposition to what is mistakenly perceived as a general agreement may result in a widespread belief that the members of the group all agree on something which, in truth, none of the members may believe.*

**Misconstruing Persistence as Validity (M7).** *If a certain concept has appeared to be widely accepted for a long time, it may be perceived and acted on as though it were a valid belief just because of its persistence, and without any corroborative, collateral evidence to support the belief; even when abundant evidence could be marshaled to show invalidity.*

**Misconstruing Philosophy as Ideology (and vice versa) (E7).** *Some people, in history, span the field of philosophy and other fields, such as sociology, psychology, political science, and management. In presenting their views, they are prone to mix philosophical considerations with political or management beliefs. As a result, it becomes difficult if not impossible to sort out the components. As a consequence, ideology is often described as philosophy, and philosophy may sometimes be called ideology, depending on how the critic views the material.*

**Misconstruing Structural Incompetence as Innate Incompetence (M5).** *"Structural incompetence"<sup>5</sup> was defined by a group of federal program managers as something to be strongly distinguished from innate incompetence. The latter refers to the inability of people to accomplish particular tasks because they*

*lack the requisite knowledge and ability. The former refers to their inability to accomplish particular tasks, for which they possess the requisite knowledge and ability, but still cannot accomplish these tasks because the situation in which they perform imposes upon them a constraining institutional structure that disenfranchises their capabilities.*

**Misconstruing Technology as Science (and vice versa) (C3, M4).** *Science progresses slowly. Technology progresses rapidly. They are mistakenly thought to march apace.*

**Misinterpretation of Linguistic Adequacy of Natural Language (C1, M1).** *The belief that natural language is adequate to describe, diagnose, and provide corrective designs to practices involving complexity.*

**Misinterpretation of Linguistic Adequacy of Object Languages (C2, M2).** *Object languages, following David Hilbert, are languages that are especially constructed to communicate about specialized knowledge. The most prominent of these languages, at present, are those that have been developed for use in constructing software for computers. Now that organizations which work with complexity are finding it necessary to turn to computers to manage the massive amounts of information required (often by law), they are learning how ineffective these object languages are for communicating about the substantive work that goes on in fields such as medicine, law, and economics. Thousands of consultants are now striving to sell contracts to large organizations to "help them" make the necessary changes. In the process, they strive to force the client to adopt significant linguistic components introduced by the contractor. They misinterpret the linguistic adequacy both internally and externally.*

**Mistaken Sense of Similarity (E6).** *Organizations, individuals, or concepts are placed in the same category in a mistaken belief that, because they are similar in some respects, decisions that are believed to be applicable to the category are applied to every member of the category.*

**Mistaken Sense of Uniqueness (E5).** *There seems to be a tendency for organizations and/or individuals to construe themselves to be unique. As a consequence of this, there is an unwillingness to apply systems of thought or practice, even though they may have been highly productive when applied*

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<sup>4</sup> I. L. Janis, *Stress, Attitudes, and Decisions*, New York: Praeger, 1982.

<sup>5</sup> This is essentially the same idea articulated in different terms by W. E. Deming, who discussed the matter in terms of where the fault lay for certain undesired outcomes in organizations; but the language of "structural incompetence" calls to mind the effect on the individual of organizations that are not designed to enable the accomplishment of the functions for which they are brought into existence.



elsewhere. The generality of concepts that underpins virtually all of physical science, and which is responsible for virtually all of its relevance in modern life, is thereby denied in areas that involve behavior.

**Susceptibility to the Fad of the Month (E1,H6).**

*The history of recent events in organizational development and management clearly shows a shower of fads. A fad is distinguishable because it comes into play like a meteor, and flashes across the sky at the same time that it is engaged in burning itself out, then it disappears, sometimes as abruptly as it appeared.*

**Unawareness of the Cumulative Impact of Many Colocated Mindbugs (E10).** *Mindbugs are located in the human nervous system; the conscious or the subconscious, perhaps mostly the latter. While they may individually create havoc, it is devastating to observe what they produce when acting in concert.*

**Unawareness of Imputed Structure (E2,H10).** *It is frequently true that model structure is smuggled into a model by constructing models based on formats that have a preassigned type of structure, such that a person using that particular format has already implicitly imputed that structure to the model, without ever considering the model structure independently of the kind of model chosen. For example, if a person builds a systems dynamic model to study the dynamics of a situation, the structure of that model necessarily conforms to the presuppositions associated with systems dynamics. Many modelers do not consider the development of model structure to be a step in the process of model development. Instead they bypass that step altogether, intuitively imputing a structure to the model without specific awareness that they are doing so.*

described as the search of scholars for a more meaningful approach to the study of the social and political systems of the world.

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