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this is a Preface page for the paper, with quote from Brent.

FOUNDATIONS OF THOUGHT 1

John N. Warfield

"Abstract forms of relation are objects of a mathematical inquiry called the logic of relations (or relatives), which Peirce began to examine in 1870 with his "Description of a Notation for the Logic of Relatives". By 1885 he had proposed what Hans Herzberger has called 'Peirce's remarkable theorem', that there are only three fundamental kinds of relations: monadic, dyadic, and triadic; that by combining triads, all relations of a greater number than three can be generated; and that all those of a greater number than three can be reduced to triads. Since, in addition, triads cannot be reduced to dyads, nor dyads to monads, monads, dyads, and triads constitute the fundamental categories of relations. At the same time, triads are made up of dyads and monads, and dyads of monads. Hence, in logical order, monads are first, dyads second, and triads third, which gives a second group of relations: first, second, and third. Hypostatic abstraction provides a third group of relations: firstness, secondness, and thirdness, which contain first, second, and third, which in their turn contain monads, dyads, and triads. Altogether, these elements constitute the abstract, formal mathematical categories and relations that constitute the elements of thought."

---Joseph Brent, CHARLES SANDERS PEIRCE: A LIFE, Bloomington, IN: Indiana University Press, 1993, page 331.

FOUNDATIONS OF THOUGHT

John N. Warfield

1.0 BEGINNINGS

Thought ***begins*** with a person, the ***Thinker***, which is a given. Thought ***continues*** with ***Received Language***, which is a given, though quite ***variable*** through time, as language develops both spontaneously and as a consequence of rigorous investigation. Thought is exercised by ***Reasoning Through Relationships,*** i.e., by exploration (ranging from spontaneous at one extreme to highly organized through application of concepts from formal logic at the other extreme). While thought may be propagated in the short run through a variety of means of expression, in the longer run it is communicated by ***Archival Representation.*** The Thinker, the Language, Reasoning Through Relationships, and Archival Representation are ***Universal Priors to all science.***

Without direction or system, thought is random and incoherent. Thinkers have thought about thinking for over 2,000 years. Some of those who have done so are regarded as ***(distant) colleagues*** in our investigation of the Foundations of Thought. They may be consulted, usually through their own writings, or through integrated interpretations of their writings; but only rarely by direct discussion, since most of them are no longer living.

It is well-known that the period around 400 B. C. marked the beginnings of careful study of language and knowledge, through the contributions of Socrates, Plato, and Aristotle. Likewise it is recognized that the beginnings of mathematics arose in this general time period through Euclid's work in geometry.

Nonetheless, from this beginning, a period of 2,000 years would elapse without any significant additions to formal aspects of language and knowledge. This period could be called ***the period of fixation with prose as the only medium of analysis.*** As long as prose (as distinct from mathematics and graphics) held sway, philosophers could scarcely go beyond the syllogism; and the capacity to use formalisms such as mathematics and graphics by joining these communication means with prose as a way to improve language and knowledge remained basically stagnant.

1.1 *Integrative Addition of Mathematics and Graphics.*

As history and practice has shown, the addition of mathematics and graphics to the repertoire of communication, in the absence of adequate discipline in how this is done, ***does not*** improve communication in any major way and may even make communication much more difficult. The essential requirement to be met when these two additional types are integratively added to the repertoire is that ***every communication that incorporates mathematics and/or graphics along with prose should be translatable uniquely into prose.*** Of course the purpose of this requirement is not to return to a full prose communication and eliminate the mathematics and graphics. Instead it is to force the user of the mathematics and graphics to learn to use those forms with a skill at least equivalent to that possessed by the user of prose, in order to require that the in-depth thought be reflected in those forms; instead of letting those forms mask in-depth communication requirements. As has been said several times, sheet music is a mixed form of communication using graphics that meets this requirement; and if it did not it would not be possible to communicate musical works across international boundaries and across the centuries.

The period from 1600 forward to the year 2000 was destined to be the period in which the formal aspects of language and knowledge developed dramatically, and made more feasible the achievement of goals sought initially by the ancient Greeks.

Today many basic questions raised by the ancient Greeks have been thoroughly encompassed by virtue of developments in the language of logic including the theory of relations, the recognition of the critical role of transitivity of relationships in logical inference, the use of the computer to provide organizational and representational capacity to information processing, and the incorporation of knowledge of human psychology in the design and conduct of processes of generating, organizing and interpreting information.

All of these developments have been supported by recently-developed (i.e., within the last 200 years) mathematics, including such areas as set theory, lattice theory, the theory of covers and partitions, Boolean recursion equations, Boolean matrix theory, and the association of these various theories with the theory of digraphs. The cumulative effect of these developments has been to provide a way of achieving depth in the resolution of questions raised by the ancient Greeks that has gone far beyond the cumulative developments of the first 2,000 years of study following the formulation of the questions.

Today it is feasible to deal with most of the key developments through the concept of the ***theory of modeling, with emphasis on the mathematics of modeling.*** However this emphasis on mathematics must be justified by providing a conceptual basis for the emphasis.
For this purpose, it is useful to note that ***groupthink*** (or its recently extended form, ***clanthink,*** see Sec. 5.3) is at work in promoting misinterpretation of what constitutes the mathematics of modeling and even of what modeling itself consists.

For this purpose, it is helpful to note that mathematics can be divided into these categories:

- Formal logic, which underpins other branches
- Discrete mathematics, consisting primarily of combinatorics and of statistics and discrete probability
- Continuum mathematics

The mathematics of modeling involves constructing ***connections*** between observed phenomena, noumena, and mathematical forms. These connections are of three major types: ***selection, association, and assignment.*** Sequential and iterative application of these unit acts can be described as ***mapping.***

In ***selection,*** a form or mathematical template is selected which will be connected to the phenomena and noumena. In **association,** a specific noumenon is associated with a particular, qualitative mathematical symbol. In **assignment**, a particular quantity is assigned to the symbol previously attached to the selection by association. The unit acts of association and assignment may be carried out many times in a given mapping or modeling activity.

The development of the foregoing line of thought has consumed many centuries, and reflects the work of many distant colleagues. Any subject can be explored through the "Golden Triad" *{Context, Content, Process}*. The distant colleagues made contributions in these three aspects of thinking.

1.1 Colleagues who Contributed to Context. [What is the context in which thinking occurs, and how does this context affect thinking?]

Some of the distant colleagues who contributed to the context of thinking are:

(c. 384-322 B. C.) Aristotle, b. Stagira, Greece

(1079-1142) Peter (Pierre) Abelard, b. in Nantes region of France

(1646-1716) Gottfried Leibniz, b. Leipzig , Germany

(1839-1914) Charles Sanders Pierce, b. in Cambridge, MA

(1861-1947) Alfred North Whitehead, b. Ramsgate, Kent, United Kingdom

(1862-1943) David Hilbert, b. in England, United Kingdom

(-) I. M. Bocheński (living in Switzerland)

1.2 Colleagues who Contributed to Content. [How can the content of thinking be articulated?]

Some of the distant colleagues who contributed to the content of thinking are:

(1815-1864) George Boole, b. in the United Kingdom.; taught at Queens College, Cork, Ireland

(-) Augustus De Morgan, contemporary of G. Boole, faculty member in London, England

(1821-1895) Arthur Cayley, b. Richmond, Surrey, United Kingdom

(1839-1914) Charles Sanders Pierce, b. Cambridge, MA

(1845-1918) Georg Cantor, b. St. Petersburg, Russia, of German ancestry

(1861-1947) Alfred North Whitehead, b. Ramsgate, Kent, United Kingdom

(-) Garrett Birkhoff, living in Cambridge, MA

1.3 Colleagues who Contributed to Process. [How can the process of thinking be formally articulated (though without regard to the physiological activity that goes on)?]

Some of the distant colleagues who contributed to the process of thinking are:

(1839-1914) Charles Sanders Pierce, b. Cambridge, MA

(1921-) Frank Harary, b. New York City, U. S. A.; Living in Ann Arbor, MI.

1.4 The Special Contributions of Charles Sanders Peirce.

The American philosopher, Charles Sanders Peirce (1839-1914), has provided a basis for removing randomness and incoherence from thought: a "Guidance System". Peirce made contributions to context, content, and process, and it is in integrating these aspects that Peirce was able to develop what we call the ***Peirce Guidance System.*** This paper refines and reorganizes the Peirce Guidance System (PGS) in the light of what is possible today.

Peirce was able to achieve this because he became aware of the contributions of those distant colleagues whose writings were available during his lifetime. Among those whose writings were available to Peirce were: Aristotle, Leibniz, Boole, and DeMorgan. From this group, Peirce expanded significantly the work begun in London by DeMorgan.

1.5 Mental Models and Virtual Worlds.

The individual person comes into contact with ideas through two basic processes, which are ***perception*** and ***conception***. In the former, the senses are activated by ***phenomena;*** while in the latter, the mind is activated by the origination of ideas from within, i.e., ***noumena*** are involved. The mental processing that produces an integration of perceptions of events triggered by phenomena or noumena produces ***Mental Models***, and the aggregate of all mental models held by one person is called the ***Virtual World*** of the individual. The individual acts from this as a base.

1.6 From Mental Models to External Forms.

The theory of modeling generally tends to emphasize what happens when one or more individuals construct mappings from the mental models into external forms. Among these external forms are such things as sculptures, paintings, drawn graphics, mathematical papers, blueprints, system designs, and prose writings. Iconic representations are seldom associated with mathematics, which is usually reserved for models that are defined in terms of the purpose: to document a system for the purpose of describing, exploring or predicting its behavior. A characteristic feature of such models is that they are described in some written language. Typically such models are a mix of prose, graphics, and mathematics. Frequently they present only partial aspects of the underlying mental models. Among the most important reasons for the incompleteness (or incorrectness) of such models is the matter of ***presuppositions*** held in the subconscious of the individual. Standing along with the presuppositions are (consciously-held) ***suppositions*** (which, while consciously recognized by the individual may, nonetheless, be incorrect). A fundamental issue in modeling has to do with the combined effect of modeling that does <u>not</u> articulate relevant material from the subconscious, along with the injection of incorrect information from the combination of presuppositions and suppositions. This combined effect can be described as ***underconceptualization***. Misconceptualization is a special case of underconceptualization. The latter implies errors of omission as well as commission.

By focusing upon the linguistic aspects of such models, it is possible to provide a partial overview of what is involved in model development and application.

1.7 Natural Language, Object Language, and Metalanguage.

We can start with the concept of "natural language". This is the language that is in everyday usage; having an alphabet, a set of punctuation marks, and a vocabulary of words. The latter forms the basis for archiving, which produces libraries full of publications. Throughout the first 2,000 years of the era beginning around 400 B. C., it was natural language that formed the basis for modeling. Whatever documentation appeared was subject to the vagaries of that natural language. Then, after Leibniz concluded that it was essential for scientific purposes that language not be taken as it arose, but rather created especially to serve the needs of scientists, a turn in direction gradually took place that brought about many changes. To the idea of a specially designed language (which we will call an "object language") can be added the idea of David Hilbert that the object language would be described by means of a metalanguage.

With these three ideas of natural language, object language, and metalanguage, we can say that for most purposes ***the natural language will be the metalanguage, and it will be used to describe and discuss the object language.*** This idea can be approached in several ways.

Figure 1 illustrates the idea that a natural language can be a metalanguage, and that it can encompass within its borders a number of different object languages. To compare the natural language with an object language, Table 1 lists key properties of a natural language, while Table 2 lists key properties of an object language.

Given the nature of object languages, it should be clear that, for example, an object language can be any of the following: (a) a well-defined branch of mathematics, (b) a high-level computer language, such as Pascal or Prolog, or (c) a machine language.

In the mathematics of language and knowledge, the object language of greatest interest will be an integrated combination of several of the object languages of mathematics (examples of which are shown in Table 3).

Natural Language = Metalanguage

(Object Language #1) (Object Language #2)

(Object Language #3) (Object Language #4)

(Object Language #5) (Object Language #6)

Figure 1. A Natural Language can be a Metalanguage, and can contain several Object Languages that are subject to different criteria than the natural language.

TABLE 1
PROPERTIES OF A NATURAL LANGUAGE

1. The language has a set of ***basic symbols*** (e.g., letters and numbers) and a system of ***functional symbols*** (e.g., punctuation, plus signs, etc.) used to form larger constructions from the basic symbols

2. The language contains ***entries,*** formed from the basic symbols

3. Each entry has a ***definition*** which is expressed in terms of other entries; and a typical entry will have ***many different definitions***

4. ***No effective control*** is exerted over the entries; anyone can introduce a new entry at any time, or give a new interpretation to an old entry

5. Entries are assigned to ***categories***; but anyone can place an entry in a new category at any time

TABLE 2
PROPERTIES OF AN OBJECT LANGUAGE

1. The language has a set of ***basic symbols*** and a system of ***functional symbols*** used to form larger constructions from the basic symbols

2. The language contains ***entries*** formed from the basic symbols

3. Each entry can have at most ***one definition***

4. The language is ***very restrictive*** on new entries

5. The language is ***integratively controlled***

6. There is a small set of entries called ***primitives*** that are named, but are undefined

7. There is a set of entries called ***non-primitives***, which are named, and which are defined, in general, by a combination of primitives and non-primitives

8. Entries defined only in terms of primitives are called ***direct derivatives***

1.8 Identifying Some Object Languages.

Is it possible to point to some examples of an object language? We can do so, but only if we are not too careful to test the object language against the properties listed in Table 2. (The theory and practice of the design of object languages are still in their infancy.)

Table 3 lists some possible candidates for the title: "object language".

TABLE 3 **SOME POSSIBLE OBJECT LANGUAGES**
Boolean Algebra
Set Theory
Digraph Theory
Matrix Theory
Theory of Relations
APL
Pascal
Cobol
C
Ordinary Algebra
Arithmetic

Rather than explore each of these to see whether it might meet the conditions given in Table 2, let us instead look at some aspects of some of them from the point of view of history of their development.

In looking at Table 2 one might say, ***"Well, it's easy to invent an object language. We will just specify a set of basic symbols, throw in some functional symbols, construct some entries, and close the books on the language."***

What has been the actual situation with respect to the development of some of the candidates listed in Table 3? We can see from studying ***the history of the introduction of symbols*** that several hundred years elapse as symbols evolve. This should make clear to us that the development of good object languages may also require several hundred years, because there is more involved than just the development of symbols.

1.9 Evolution of Mathematical Notation.

Certainly a key part of the development of an object language would be the development of its notation. D. B. McIntyre [1] has studied the development of mathematical notation, and has given us the information in Table 4.

TABLE 4
FIRST APPEARANCE OF MATHEMATICAL SYMBOLS IN PRINT

PROSE STATEMENT	***SYMBOL***	***SOURCE***	***YEAR***
Plus, Minus	+ -	Wioman	1489
Equals	=	Recorde	1557
Times	×	Oughtred	1631
Greater Than, Less Than	> <	Harriott	1631
Exponentiation	A^{iii}	Hume	1636
Greater Than or Equal to, Less Than or Equal to	≥ ≤	Wallis	1655
Division	÷	Rahn	1659
Summation	∑	Euler	1755
Factorial	!	Kramp	1808
Absolute Value	$\|a\|$	Weierstrass	1841
Membership	∈	Peano	1889
Negation	~	Peano	1893
Logic Or	∨	Whitehead and Russell	1909
Logic And	∧	Tarski	1933

More perspective on the introduction of symbols has been given by I. M. Bocheński [2]. He includes an "Index of Logic Symbols" which takes up three pages (541-544) in his book. Also on page 319 he compares symbols introduced by McColl, Peano, Russell, Hilbert, and Łukasiewicz. Table 5 incorporates some of the additional information provided in [2].

TABLE 5
ADDITIONAL INFORMATION ON MATHEMATICAL SYMBOLS

PROSE STATEMENT	*SYMBOL*	*SOURCE*	*YEAR*
Is Related to	R	De Morgan	1847
Negation	Overbar on a letter	Hilbert and Ackermann	1928
Equivalence	Three lines, one above another	Frege and Russell	Not given
Logic And	$\cap$	Peano	1889
Logic Or	$\cup$	Peano	1889
Not Both	$\vert$	Sheffer	1928

As we see how the symbols evolve, and how different authors have chosen different symbols, we can appreciate the difficulty in formally constructing an object language, and in using symbols that correlate with the mathematical literature.

This poses some special problems in constructing a mathematics of modeling, because this mathematics seems to demand the use of a number of different object languages.

1.10 Interfaces Between Languages.

When two different languages are to be used in a given context, where does one stop and another begin?

Suppose, for example, we talk about arithmetic. Arithmetic can be thought of as an object language. In learning arithmetic, we learn various terms that have only one meaning in this object language such as "times", "plus", etc. Yet we are taught arithmetic by teachers and books that use words from the natural language. If we can identify those entries that are unique to the object language, and then see ***what other words are needed*** to present that language, we will call this latter group the "interface with the natural language". The German mathematician, Landau, has written a book that comes very close to presenting arithmetic as an object language, and identifies the interface with natural language [3]. Unfortunately we cannot find similarly well-done books that deal with some other object languages.

It is conceivable that several object languages can share the same interface with the natural language. However we cannot demonstrate rigorously that this has been done. It is also appropriate to think of a certain object language that depends on a second object language to produce an interface that gives the set of primitives to the first object language. We will illustrate this idea soon.

1.11 Object Languages of Modeling.

Figure 2 shows a structure that indicates relationships among certain languages. Figure 2 can be used as a guide to learning some of these languages. If there is a directed path from the name of one language, say A to another, say B, Figure 2 is meant to indicate that that language A provides primitives to language B.

What are primitives to language B may, however, be non-primitives in language A. And in any case, all languages indicated in Figure 2 have ancestry in the natural language.

Figure 2 is not a rigorous result of careful research. However we will see that there is a progression in learning the several languages that follows the directional indicators in Figure 2. We will organize the learning of these languages around Figure 2!

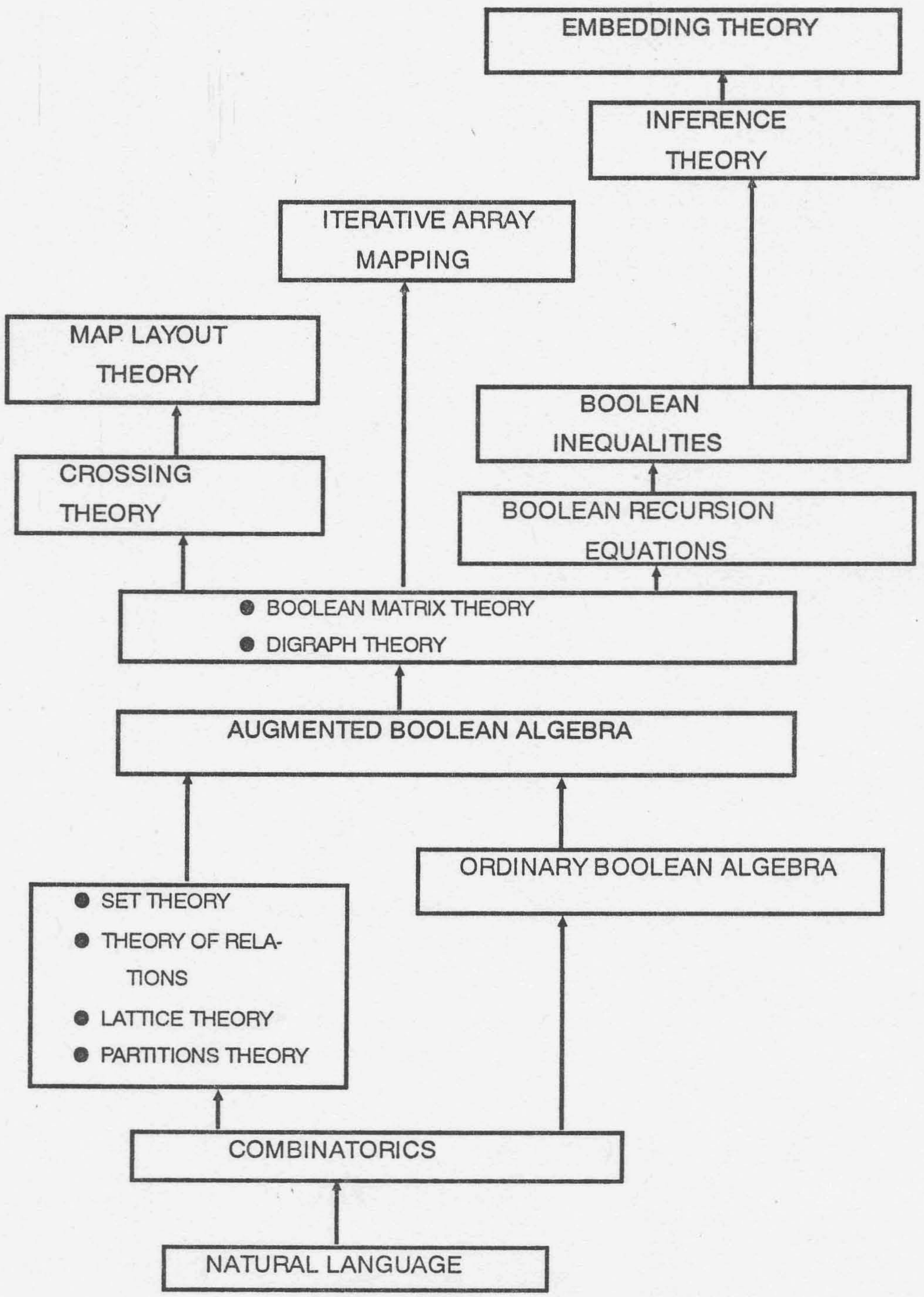

Figure 2. Dependency Sequence. Lower elements connected to higher elements contribute to explaining and understanding the higher elements. Elements in the same box help clarify each other.

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2.0 BASIC ELEMENTS: THE PEIRCE GUIDANCE SYSTEM (PGS)

A. The ***Peirce Categories:*** Firstness, Secondness, and Thirdness form part of the foundation of the Peirce Guidance System.

B. Basic elements of the Peirce Guidance System are:

M	**used to represent a human "mediator"**
■	**used to represent a "phenomenon"**
●	**used to represent a "noumenon"**
□	**used to represent an "entity"**
$\in$	**used to represent membership in a "category"**
P	**used to represent the category "phenomena"**
N	**used to represent the category "noumena"**
E	**used to represent the category "entity"**

C. Some basic elements of the PGS are related as follows:

Definition 2.1. Membership. For all $\blacksquare$ it is true that

$$\blacksquare \in P \tag{1}$$

Definition 2.2. Membership. For all $\bullet$ it is true that

$$\bullet \in N \tag{2}$$

Definition 2.3. Membership.

$$E = P \cup N \tag{3}$$

where $\cup$ represents the union of the categories.

Definition 2.4. Signs. Phenomena, noumena, and hence entities, are origins of sensory perceptions that reach the Thinker; and these sensory perceptions are called "signs". **[Thus, when an individual says "I saw a fox", the individual is saying, in our language, that a sensory perception (sign) was produced in the individual because the fox appeared somewhere in the field of sensations of the individual. The sign produced by the fox is not the same thing as the fox, but the individual will take advantage of economy of language by saying "I saw a fox" instead of "I had a sensory perception which I interpreted to mean that a fox was in my field of vision". Whatever is taken in and retained by the individual, it is certainly not the fox, but rather it is a partial representation of the fox. Also what is retained is not the sign, but instead it is whatever outcome followed from internal processing of the sign.]**

3.0 THEOREM 1. ENTITIES

Theorem 1. For all $\blacksquare$, $\bullet$, and $\square$ it is true that

$$\blacksquare \in E \tag{4}$$
$$\bullet \in E \tag{5}$$
$$\square \in E \tag{6}$$

4.0 FOUNDATIONAL ASSUMPTIONS.

4.1. ***The Completeness Assumption.*** All that reaches the Thinker consists of sensory perceptions (signs) evoked in the Thinker from external and/or internal origins.

4.2. ***The Processing Assumption.*** Any sign or signs reaching the Thinker are processed by the Thinker, producing noumena. **[The results of such processing then become available as sensory perceptions; i.e., as new signs that are related in some way to signs processed previously.]**

4.3. ***The Mediator Repertory Assumption.*** The aggregation of all processing at any point in time constitutes the current Mediator Repertory which forms the base for mediator processing and behavior. ***This base is divided between the conscious and the subconscious.*** **[Another name for this Mediator Repertory is the "Virtual World of the Mediator.]**

4.4. ***The Nesting of Noumena.*** Any aggregation of noumena is a noumenon.

4.5 ***Thirdness.***

Definition 4.1 Thirdness. Thirdness refers to a processing relationship involving a human mediator, a referent entity, and a product of Processing, i.e.:

$$M\{\square \rightarrow X\} \tag{7}$$

where

X represents the product of the processing done by M acting on $\square$

where

$\rightarrow$ represents the act of processing

and where "referent entity" is either an entity in the Repertory of M or reaches M from outside the Repertory.

Definition 4.2 Triad. Thirdness involves the ordered triad $\{M, \square, X\}$.

Definition 4.3 Triadic Relationship. The ordered triad identified in Definition 4.2 is involved in a Triadic Relationship, which is denoted in Eq. (7) above.

4.6 ***Secondness.***

Definition 4.4 Secondness. Secondness refers to a relationship between two entities, i.e.,

$$E_1 \; R \; E_2 \tag{8}$$

where R refers to a specified relationship between the entities E_1 and E_2.

Definition 4.5 Dyad. Secondness involves the ordered dyad $\{E_1, E_2\}$

Definition 4.6 Dyadic Relationship. The ordered dyad defined in Definition 4.5 above is involved in a dyadic relationship, which is denoted in Eq. (8) above.

All dyads can be viewed as noumena which arise from triadic processing done by Mediators.

Definition 4.7 Fallibility. A key aspect of the PGS is the recognition of fallibility of the Mediator, and of the contribution to fallibility occasioned from these three factors:

- **Factor 1.** Defective Transference. The inevitable inability of a sign to convey comprehensively its own origin; i.e., the referent entity.

- **Factor 2.** Defective Processing of Signs. Received signs may be processed defectively during their interpretation.

- **Factor 3.** Integrated Cumulative Defects. There is a cumulative impact on the quality of the Virtual World arising from the ongoing activity involving Factors 1 and 2, so that over time the integrated cumulative defects produce Virtual Worlds that are a mix of adequate and inadequate noumena.

4.7 ***Firstness.***

Definition 4.8 Firstness. Firstness refers to an entity, and more specifically those attributes or features of that entity that are characteristic and persistent, and which enure to that entity without regard to any other entities. **[In this respect, Firstness might be called the Aristotle/Peirce category; in which Firstness relates to what Aristotle designated as the "essences" of an entity, as opposed to the "accidentals"--those features that may or may not enure to the entity, but which are not definitive of the entity.]**

Definition 4.9 Monad. A monad involves only the single entity, but the entity is assumed to have features which distinguish it; for without such features there is no evident way in which an entity can be considered distinctly.

Definition 4.10 Monadic Relationship. A monadic relationship is a relationship that is self-referent; i.e., it relates the attributes or features of an entity to itself.

No monad and no monadic relationship can ever be known to be precisely identified. The identification of a monad requires that a means of exploring attributes be available, but this requires the establishment of a relationship between the monad and the inquirer. But then the conditions under which the monad is to be identified no longer obtain. This situation is analogous to the Heisenberg Uncertainty Principle from physics which holds that it is not possible to establish with absolute precision both the position and the velocity of a physical object.

5.0 STRUCTURAL THINKING

5.1 *Spontaneous and Structural Thinking.*

Lying more or less at the extremes of thinking, spontaneous thinking and structural thinking are two very different types. Academic society appears to victimize itself by sustaining a skizophrenic demeanor toward these types (evidenced, for example, by the failure to incorporate formally the modern version of Western logical forms into all of its research activity). On the one hand, spontaneous thinking is viewed as a liberating influence of the type so valued in liberal studies, and incidentally aligning with long-suffering humanity's urge to be free. While on the other hand, the influence of science makes it evident that certain aspects of the universe are not free but rather are describable in highly-structured terms. Furthermore there is every indication that the universe could not exist without these highly-structured restrictions upon various forms of behavior, such as the motion of the planets. Yet structured thinking incidentally aligns itself (at least intuitively) with the long term scourge of political dictatorship, abuse of human rights, rigidity, and other forms of offensive behavior.

In his study of exceptional people, Maslow noted the prominent ability of these people to "shift gears". They could adapt their behavior to the situation. They could be serious on demand and playful on demand. And it was their own demand to which they responded.

Is it not the extreme mark of being free that one can choose one's own mode of thinking, moving at will from high levels of spontaneous thinking to the most rigorous levels of structured thinking? If so, one must note that there is a distinct dissymmetry between these two extremes. Spontaneous thinking is a free good, so to speak, with which every human is endowed. Structured thinking, on the other hand, is not free and can only be developed through a period of intense cultivation.

Wherever disciplined behavior is warranted, criteria furnish the basis for understanding, evaluation, and the behavior itself.

Structural thinking, in its most elaborately researched form, is responsive to the requirements that contextual implication (Ketner) be elaborated at length in order to uncover presuppositions and suppositions; to the requirement that displayed consequences of structural reasoning lend themselves to referential transparency; that the structural thinking be marked by thinking in articulated sets and articulated systems; and that the methodology applied in such thinking shall be open at scale (i.e., not limited to predetermined scope or dimensionality).

It is the ability to combine the best features of structural thinking with the best features of spontaneity that will mark the unusual human being.

5.2 *Belief Fixing*

A central concern for all forms of management or administration is the defective nature of belief systems held by managers or administrators and how the defects in these systems translate into decisions that lead to bad consequences for the many.

While discontent with decisions of powerful people is as old as recorded history, it is only recently that the analysis of belief systems has reached a point where sufficient understanding has been attained to make possible a systematic program aimed at changing defective belief systems.

Attention to belief systems and ways to change them is being noted in a wide variety of literature from diverse sources. Given the compartmentalization of society, it is likely that most of those who find discussions of this subject will not be aware of the diverse nature of these sources, and will think that what they are reading is a unique manifestation of a point of view.

The Peirce Guidance System includes the contribution of Peirce as to how belief is fixed. The four methods cited were: authority, tenacity, metaphysics, and science. Of these, the attributes seen as distinctive in science were: (a) the importance of validating ideas against perceived phenomena and (b) the persistence of this validation through time by an ongoing, socially and scientifically responsible, "community of scholars". These are distinctive because the authoritarian is not interested in validation, tenacity is not oriented toward validation, and metaphysics precludes the possibility of validation.

5.3 *Groupthink and Clanthink.*

The concept of "groupthink" has been described by Professor I. L. Janis as follows:

"The eight symptoms of groupthink are: (1) an illusion of invulnerability, shared by most or all of the members, (2) collective efforts to rationalize in order to discount warnings, (3) an unquestioned belief in the group's inherent morality, (4) stereotyped views of rivals and enemies, (5) direct pressure on any member who expresses strong arguments against any of the group's stereotypes, illusions, or commitments, (6)

self-censorship of deviations, (7) a shared illusion of unanimity...augmented by the false assumption that silence means consent, and (8) the emergence of self-appointed mindguards..."

Groupthink, so defined, reflects the observed situation where a group of people accept a certain point of view even though, if confronted with that point of view separately from the group and, perhaps, in a different context, no member or very few members of the group would accept that point of view.

The few specific situations where groupthink has been studied typically involve a crisis situation and a reaction of the group to that situation. The situation typically persists for a relatively short period of time, and typically involves a modest period of time during which the reaction takes place.

It is believed that no one has attempted to put units of measure on groupthink, but if one did so it conceivably could be done with three units:

- Number of people involved
- Duration of the incident
- Surface area of the earth in which the relevant activity transpired

In terms of these units, one might find a typical situation to involve 10 or fewer people, a few hours to a few weeks, and a few square miles. If we constructed a hyphenated unit of the form people-days-square miles, a typical number might be 1000, formed by multiplying 10 people times 10 days times 10 square miles. Or if a logarithmic measure (to the base 10) were used, a typical measure might be 3 (found by taking the logarithm of 1000).

Because groupthink is a very valuable concept in considering the behavior of small groups, it seems inappropriate to try to redefine it to apply to situations where the scale is much larger; e.g., to a situation involving, say, a hundred million people, a hundred years, and a million square miles; which would involve a logarithmic measure of 16.

Still, in viewing human behavior on a much larger scale, it seems clear that many of the features of groupthink could be taken to apply to these larger situations; either just as formulated by Janis, or with some modifications that might involve additional features.

For this reason, the term "clanthink" has been chosen to use as a descriptor of what might be called the "big brother" of "groupthink".

5.3.1 The Tenascope. Suppose we agreed to call the logarithmic measure outlined above by the name "tenascope", a term that can be formed by starting with "tenacity scope" and collapsing the words together to eliminate a few letters and form a single word. [One reason for choosing the word "tenacity" in this context is that it is one of the four methods chosen by Charles Sanders Peirce to explain how belief is fixed.]

Then we could say that groupthink applies to situations whose tenascope is on the order of 3 to 5, while clanscope applies to situations whose tenascope is higher than 5 and whose upper limit is determined only by the limitations of population, time and space.

If, for example, we chose to examine the belief in a flat earth, this belief having persisted for perhaps 10,000 years, involving perhaps 100,000,000 people, and persisting throughout that portion of the earth's surface that was occupied by living people, we might imagine that the tenascope of flat earth was on the order of 15 to 20; numbers not that much larger than 3, but certainly representing a dramatically different scope in the population, time, and space; a characteristic brought about by the use of logarithmic measure.

A question that might appropriately be raised is this: of what value are terms like "clanthink" and "tenascope"? Here is a tentative answer. We are seeing major upheavals in many parts of the world, especially with respect to organizations. Think about such names as these: IBM, Sears, General Motors, Yugoslavia, the U. S. S. R., Burroughs, Savings and Loan Associations, Watergate, Irangate, Iraq, the United States Congress private bank and post office, South Africa.

In mentioning these names, one notes that some are nations, some are corporations, and some are situations that arose in government. But they all have in common that they began in positions of relative strength and became involved in situations where the major beliefs that supported their activity placed them in uncommon positions and became the basis for considerable loss of credibility.

5.3.2 Culture. It seems, therefore, at least of some possible significance to consider the thought that while the term "culture" might be used as a point of entry to analysis of these and other situations, it may also be appropriate to consider the idea that "clanthink" could be a major part of the cultural situation in all of these situations; and that if we could learn to anticipate or recognize such situations earlier in their evolution, perhaps by discovering how to observe at different values of "tenascope", ameliorative action might be taken that would not have to wait for the onset of disaster, shame, or loss of credibility.

It is also appropriate to note that the ability of people to discuss and study a phenomenon often depends on bringing that phenomenon into consciousness, which frequently can occur by the choice of a single word to represent the phenomenon.

Furthermore, in considering the thought that in every single attempt that might be made to weaken the impact of clanthink one could expect that the people involved might tend to become enraged at each other, thinking that the individuals involved are simply pressing an unpopular point of view; when the real enemy that all ought to be concerned with is clanthink. In other words, clanthink as a concept becomes the rationale for motivating a reasoned discussion, so that the external enemy becomes the target of wrath as opposed to the partners in dialog.

5.4 *The Magical Number Three*

5.4.1 Weak Capability to Form Deep Logic Patterns Perhaps the most significant characterization of all for the human being is that of weak capability, when acting without enhancement of intellectual powers, to formulate deep logic; brought about, in part, by the small Span of Immediate Recall (SIR). As Miller [8] and Simon [9] and others have demonstrated, the human being can only bring to mind from short term memory about seven items at a time. (The prominence of the number seven in a variety of measures of human performance led to its designation by Miller as the "magical number"). Table 2.1 shows some typical measures for the SIR [10].

Unlike many results from social science, the results obtained by Miller and Simon and others can be tested directly by any individual using the methods that they have described, working with the individual's own mind. In this way the individual can gain an appreciation for the matters being discussed through direct experience, as opposed merely to reading about it.

While there may be rare exceptions, most people do well to manage seven-digit telephone numbers and have trouble with sixteen-digit credit card numbers. The fact that people with "photographic memory" may depart substantially from the norm is not evidence that the norm is not accurate; only that not every single individual conforms to the norm. The two-headed calf in the carnival also represents an anomaly, but does not prove that all calves are two-headed.

But while the Miller-Simon studies showed that seven seems to be about the maximum in terms of immediate recall of ideas, they did not state explicitly what seems to be the most significant consequence: that people cannot reason simultaneously about the interactions of more than a small, limited number of factors. Nor did they extend this thought to express its implications for the design of systems that may have many parts, many of which interact, sometimes destructively.

5.4.2 High-Risk Technology, Combinatorics, and the "Magical Number" Perrow [11], in his study of high-risk technologies, concluded that the proper nomenclature for describing bad designs is precisely "high-risk technology, as represented in nuclear power plants, chemical plants, aircraft and air traffic control, ships, dams, nuclear weapons, space missions, and genetic engineering". He concluded that some of the disasters that arise in these areas are normal, and that they arise from "interactive complexity" and "tight coupling". Multiple failures arise that were not anticipated, and have unexpected effects. During the period of failure, what is happening may be incomprehensible. It may be discovered after the fact, through the work of a commission or other investigating body.

According to Perrow, "operator error" is high on the list of factors said to be causal, accounting for 60% to 80% of the accidents. Perrow argues that such a designation masks the underlying causes, and that the primary cause is unanticipated system behavior arising from multiple failures.

Combinatorial mathematics tells us something about how many different combinations may be formed from a given set of elements. It is possible to count the number of interactions. It is possible to count the number of combinations, and the number of ways in which a system having a given number of parts may be conceptually partitioned into subsystems. Some have said that it is combinatorial complexity that is at the root of many problems. But suppose now that the resources and time were available to explore all the combinations, and that some combinations involved hundreds of elements. Is it reasonable to suppose that the mind of a human being could simultaneously and systematically run through an analysis of these hundreds, when it can only bring seven ideas into its sphere at a time?

Because of human mental limitations, the idea of modularization of systems in ways that are compatible with the limitations of the mind will have to be a critical part of any science of design. Equally clearly it is necessary to quantify this limitation, in order both to avoid the potential human performance penalty of underestimating it and the potentially more severe catastrophic system failures that would stem from underestimating it.

It is well known in mathematics that if one is dealing with a set of items, having cardinality N (cardinality representing the total count of the items, i.e., their number), then there is automatically and inevitably another collection of items that becomes attached, this being the combinations of the individual members of the initial set. If S1 is the original set, there is another set S2 called the power set of S1. And if S1 has cardinality N, then S2 has cardinality 2 to the power N. So, for example, if the cardinality of S1 is 3, the cardinality of S2 is 8. But the power set always contains the empty set, which need not be considered. Consequently if S1 contains 3 members, the effective number of members in the power set S2 is 7, or precisely the so-called "magical number" of Miller [8].

The implication of this is that if one is presented with or recalls three concepts, and if these concepts interact in all combinations, the individual is implicitly dealing with seven concepts, and may even need to have help to always recall these combinations along with the original three members, whenever the individual is striving to analyze interdependence among members. This is why Warfield suggested that perhaps it is the number three, rather than the number seven, that is the fundamental "magical number" [10].

It becomes critical to recognize that no matter what finite number of elements is involved, it is always possible, if one systematically structures them, to work with groups of no more than three elements, through the effort of so organizing the ideas and so arranging them that three and only three are presented for any small period of consideration.

5.4.3 Triadic Compatibility The Law of Triadic Compatibility quantifies the limitations of short-term memory as they relate to human decision making:

The human mind is compatible with the demand to explore interactions among a set of three elements, because it can recall and operate with seven concepts, these being the three

elements and their four combinations; but capacity cannot be presumed for a set that both has four members and for which those members interact.

A Corollary to this Law is the Principle of Division by Threes. This Principle asserts that:

Iterative division of a concept as a means of analysis is mind compatible if each division produces at most three components, thereby creating a tree with 1 element at the top, at most 3 elements at the second level, at most nine at the third level, and so on.

The incapacity of the mind to work with more than a limited number of concepts at a time will hereafter be designated as a component of the idea of "bounded rationality". And the idea of finding ways to rationalize human problem-solving processes and thought processes with this limitation will be one of the primary factors in the development of the Science of Generic Design. The connection between the recognition of this limitation and self-imposed humility in human behavior that involves the welfare of other human beings should not be overlooked. This behavioral feature may well determine whether the earth survives or is destroyed.

5.5 ***Linguistic Activity***
- 5.5.1 Naming
- 5.5.2 Generating
- 5.5.3 Organizing
  - 5.5.3.1 Dividing
    - i) Proionic
    - ii) Non-Proionic
  - 5.5.3.2 Subsuming
    - i) Proionic
    - ii) Non-Proionic
- 5.5.4 Displaying
- 5.5.5 Interpreting
- 5.5.6 Applying

5.6 ***Linguistic Domains***

5.6.1 Multiple Characterizations of Language Language, the second Universal Prior to all science, can be characterized in several ways, for purposes of considering its role in a science of design. Among these are its characterization in terms of Basic Types, Composites formed from the Basic Types, natural language or designed language, object language or metalanguage, and types of terms that become part of the language of design. Through these varied characterizations, one strives to arrive at a set of criteria for a language of design, against which proposed languages may be evaluated.

5.6.2 Language and Philosophy Language has been at the heart of philosophical studies for over two millennia. In the first two millennia of philosophical studies, natural language was taken as a given, and the philosopher was expected to do rather precise qualitative work with imprecise natural language. Leibniz recognized the need for a specially-designed language to serve as a way to upgrade the quality of scientific communication [1]. Boole, De Morgan, Frege, Peirce, and others developed and extended a language of logic, characterized by the capacity to work explicitly with relationships within a logic framework called the Theory of Relations. This made possible the design of languages that can be shared by people and machines in synergistic ways.

Lavoisier provided credibility to the idea that the wise use of language is critical to science, when he attributed his success in chemistry to his desire to improve the language of that science. Willard Gibbs said "mathematics is a language."

David Hilbert added to philosophical thought the dyad of object language and metalanguage. His thought was that while one can design an object language, e.g., for a branch of science, it is still necessary to have another language to talk about the object language. The concept of metalanguage for this purpose was accepted as an important insight for communication.

Whitehead and Russell undertook to show that formal logic could be used to provide the basis for mathematics. Lewis and Langford [12] indicated that this goal was achieved, and that its achievement would be recognized as a magnificent event in the history of thought.

Gödel showed that formal languages did not contain the necessary attributes to allow that the set of possible theorems formulatable in such languages could likewise be proved in such languages. Each formal language was thereby declared to be deficient in terms of establishing its own sufficiency. This established the idea of a sequence of languages, each being designed to overcome some but not all of the deficiencies of its predecessors in the sequence. This, in turn, led to the point of view that (impossibly) an infinite sequence of designed languages would be necessary, in some sense, to fulfill all the possible language requirements. On the other hand, the attributes of natural language differ from those of formal languages. Thus it can presently be conjectured and ultimately can be demonstrated that careful design of an object language can be augmented, with natural language serving as a metalanguage, to produce a very powerful means of achieving high-quality communication and documentation.

5.6.3 Basic and Composite Language Types Written language can be described as consisting of certain types. The types have to do with distinctions among the types of notation or characters that are used to formulate the communications. The types also have to do with distinctions among the means of human reception of them. Written language is serial in nature, and is received sequentially by the eyes, and in the same way the prose that is used in speaking is received sequentially by the ear. Sequential reception, by itself, recognizes only sequential structure; i.e., one element following upon another element. The very manner of presenting the information forces whatever structure might ultimately be imposed to forego the use of vision (for written prose) and hearing (for oral prose).

By condensing concepts through the use of mathematical symbols, one is able to present more per symbol than is normally associated with prose. A given string of symbols may say much more mathematically in a given space than a prose string of the same length. Still the presentation is sequential. It is only the graphical or landscape type of presentation that inherently incorporates the capability of the eye to see the contained structural relationships that help the brain to comprehend organization.

Because of the kinds of distinctions just discussed, it seems appropriate to designate Prose, Mathematics, and Graphics as Basic Language Types. (In the following, Structural Graphics will be emphasized). But then it is also appropriate to consider the four possible combinations of these as the Composite Language Types. Table 2.2 lists the Basic and Composite Types and the functions of each Type.

By examining the attributes of the Basic and Composite Language Types, it becomes clear that language design for complex systems description and design requires the use of Composite Types. Especially it requires the Composite formed from a mix of structural graphics and prose. More specifically, what is required is a Graphically-Integrated Language System (GRAILS) [See Appendix 2 for some details of such a system.]. The attributes of the latter correlate greatly with requirements to interpret chains of formal logic. Correlating the limitations of the human being with requirements for language design sheds further insight upon the design of languages, allowing the development of a Criterion Set for Language Design (Sec. 2.5). It can be applied to design and assess a language for use in articulating and applying a science of generic design. The criterion set, naturally, is not harmonious with current ad hoc graphical languages [14], nor with their properties of being hopelessly insensitive to human cognitive burden.

5.6.4 Language for Design Especially notable in the world of design practice is the virtual absence of recognition of the central role of the human mind, of its limitations in processing information, and of the possibilities for major improvements when the design language and design practice take these matters into account. But only structural language of Type 5 in Table 2.2 can provide all the essential ingredients while not requiring user expertise in mathematics. Table 2.3 spells out requisites for language for Generic Design Science.

Table 2.4 identifies language requisites for mind-compatibility. This table anticipates attributes that will be more fully elaborated in the development of the Generic Design Science in Part II of this book. The concepts of cycle and deep/long logic will be further illuminated in the numerous examples of applications in Chapter 10.

5.6.5 Structural Aspects of Language Levels. For convenience, the components of any lattice can be aggregated into what are called "levels". By definition, a level is itself a set, comprised of those components that lie in the same relative position in the lattice, as indicated in Figure 2.11 for the synthesis lattice of Figure 2.10. This designation into levels is of great assistance when discussing the relationships in a hierarchy, using the hierarchy itself as a visual aid to the discussion. The benefits of this will be quite evident when working, for example, with hierarchies that involve many elements and numerous levels.

Figure 2.12 shows a lattice of communication alternatives. Here the three fundamental kinds of language are shown, and their combinations as well, in the form of a synthesis lattice. This lattice is the structural basis for Table 2.2, Language Types and Their Functions.

5.6.2 Creating

6.0 THE APPLICATIONS

6.1 ***Dividing: The Analysis Lattice (The Lattice of all Partitions of a Set S)***

The lattice shown in Figure 2.9 illustrates all of the partitions of a set S consisting of 3 elements. The set that is represented here is the set of three integers {1,2,3}.

A partition P of a set S consists of components called blocks. Every member of the set S is contained in exactly one block, so that the union of all the blocks consists of the set S. The two extreme partitions are P0, consisting of three blocks, one member of S being in each of the three blocks; and PI, consisting of a single block that contains all three members of S. The intermediate three partitions each contain two blocks, and the element contained in a block by itself differs from one partition to the next.

Given two partitions, they may take part in a relationship such that one and only one of the following holds: (a) one is greater than the other, (b) one is less than the other, (c) the two are equal, or (d) none of the foregoing is true. A partition is less than or equal to another if each and every block of the first one is contained in some block of the second one. This definition can be tested against Figure 2.9 to see that this digraph does show the relationship "is less than" among the five partitions shown in the Figure. An arrow joining two of them means that one is less than the other; while the absence of such an arrow between two of them means that neither is less than the other.

This particular lattice is called the "analysis lattice" for the set S. The reason for this name is that the lattice is the fundamental structural equivalent of the Aristotelian idea of division of a concept into its essences, which is the heart of analysis.

Theorem 8 in Appendix 1 shows that it is possible to use combinatorial mathematics to find the number of elements in the analysis lattice corresponding to a set of known cardinality.

6.2 ***Subsuming: The Synthesis Lattice (the Lattice of All Subsets of a Set S)***

Figure 2.10 shows another lattice. This time, however, the lattice portrays the structural equivalent of synthesis. Beginning with individual elements, labeled 1, 2, and 3, the elements are combined into pairs and then into a triple. The relationship portrayed by this lattice is "is contained in", with the lower members being contained in the upper level ones to which they connect. This lattice is called the "synthesis lattice".

What is the relationship between the analysis lattice and the synthesis lattice? At first, one might be inclined to think (mistakenly) that they are simply two ways of portraying the same thing. But this is clearly not true as one readily sees by comparing the two structures. They do not have the same number of elements in total, nor do they have the same number of elements in the several levels of the hierarchical lattice structure, in general.

One of the basic attributes of both lattices is that they represent an organization of information: something that is fundamental to science. Each lattice suggests a basic approach to the description of systems. One represents what happens when a system is divided into subsystems, represented by the partitions; and the other represents what happens when elements are combined into larger wholes.

Both lattices represent what are called non-proionic situations, in that identity is preserved among the various levels, without emerging elements. Proionic situations on the other hand involve the loss of identity and the emergence of new elements: situations that are not discussed in the mathematics of set theory.

The synthesis lattice represents structurally what was discussed previously. It shows for a given set all the members of the power set. Thus the synthesis lattice always contains a number of components equal to 2N, where N is the number of elements in the level of the lattice lying just above the null set. This structure then shows graphically what the mind must encompass in assessing a system comprised of 3 elements; or, for larger sized sets, what the mind must encompass in dealing with such larger sets.

6.3 *Designing*

6.4 *Implementing*

7.0 THE CRITERIA

7.1 *Suppositions and Presuppositions: Contextual Implications*

7.2 *Underconceptualization*

7.3 *Referential Transparency*

7.4 *Thinking in Sets*

7.5 *Thinking of Systems*

7.6 *Methodology That is Open at Scale*

8.0 STRUCTURAL TRANSFERS

9.0 CONCLUSIONS

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APPENDIX 1. THE SYSARIANS

There exist a number of ***academic areas*** that overlap because they represent some form of shared interest in ***systems***. At present we know of no term that can serve as a category that can encompass these areas. The absence of such a term presents a handicap to any discussion of these areas. Accordingly, we choose to call these areas the ***"Sysarians"***. The ***individuals*** who become identified with one or more of these areas have been called ***"Systemists"***. Besides the academic areas, one finds various societies involved with systems. These societies are often distinct from academic areas, i.e., they are organizations unafilliated with academia, and they will be called ***"Sysieties"***, a term chosen to reflect only that they are societies and the members of each share some interest in systems. Our purposes, in this article, are as follows:

- **Identify the Sysarians.** To identify the Sysarians, using the area titles the relevant Systemists have chosen

- **Identify Attributes of Each Sysarian.** To identify those attributes that accompany each particular Sysarian including, where feasible, the relevant academic geneology of each

- **Evaluate each Sysarian.** To assess the positive and negative aspects of the existence of each particular Sysarian

- **Associate Individuals with Each Sysarian.** To identify the types of people and, in some instances, specific Systemists that are associated with each particular Sysarian

- **Discuss Integration of Sysarians and/or Sysieties.** To consider the possible benefits of integrating of Sysarians and/or Sysieties, and to discuss some of the reasons why such integration is rare or non-existent

One should not assume that the Systemists necessarily have anything in common other than an interest in systems. Systemists from different Sysieties or Sysarians may have very strong differences of opinion on many topics, including what constitutes a system!

IDENTIFYING THE SYSARIANS

While all Sysarians, by definition, share an interest in systems; the intensity, scope, focus, and other attributes of their interest will vary considerably. Therefore we will have to be rather systematic in order to make distinctions that will be of value in considering the evaluation of Sysarians and the possibilities of integrating Sysarians. This systematic activity begins with the identification of Sysarians and some of their habitats, given in Table 1.

TABLE 1. SYSARIANS AND SYSARIAN HABITATS		
SYSARIAN TITLE	**HABITAT TYPE**	**SPECIFIC HABITATS**
Anthropology	Liberal Arts & Sciences	
Astronomy	Liberal Arts & Sciences	
Automatic Control Systems	Engineering Schools	
Biological Systems	Liberal Arts & Sciences	
Computer-Aided Design and Engineering	Engineering Schools Manufacturing Industry	
Cybernetics	Uncertain	
Defense Systems	Government Agencies	
Economics Systems	Liberal Arts & Sciences	
General Systems	Uncertain	
Geography	Liberal Arts & Sciences	
Hierarchical Systems	Liberal Arts & Sciences	
Industrial Engineering	Engineering Schools	
Information Systems	Business Schools, Engineering Schools	
Integrative Studies	Liberal Arts & Sciences	
Living Systems	Univ. of the World	
Management Science	Business Schools	
Mathematics	Liberal Arts & Sciences, Engineering Schools	
Medicine	Medical Schools	
Operations Research (Operational Research)	Business Schools Engineering Schools	

Organization Studies	Business Schools	
Philosophy	Liberal Arts & Sciences	
Policy Sciences	Liberal Arts & Sciences Business Schools	
Psychology/Psychiatry	Liberal Arts & Sciences	
Social Systems	Liberal Arts & Sciences	
Software Systems	Business Schools Engineering Schools	
Systems Analysis	Business Schools Engineering Schools	
Systems Dynamics	Business Schools Engineering Schools	
Systems Engineering	Engineering Schools	
Systems Science	Liberal Arts & Sciences Engineering Schools Business Schools	

TABLE 2. SYSARIAN HABITATS AND SPECIFIC SYSARIANS

SYSARIAN TITLE	SPECIFIC HABITATS	PERSONS (SYSTEMISTS)
Anthropology	San Jose State University	Dr. William J. Reckmeyer
Astronomy		
Automatic Control Systems	George Mason University	Dr. Gerald Cook
Biological Systems		Dr. Ilya Prigogine
Computer-Aided Design and Engineering Systems		

Cybernetics	Old Dominion University Univ. of Pennsylvania Univ. of Ill., Chicago Cir. George Washington Univ. Univ. of Edinburgh United Kingdom France	Dr. Barry Clemson and Dr. Lawrence Richards Dr. Klaus Krippendorf Dr. Roger Conant Dr. Stuart Umpleby Dr. Fenton Robb Dr. John Rose Dr. Vallee
Defense Systems		
Economics Systems	Buenos Aires, Argentina Univ. of San Francisco	Dr. Enrique Herrscher Dr. Raymond Miller
General Systems	Polish Academy of Sciences Univ. of Calif. Sacramento University of Tokyo	Dr. Wojceich Gasparski Dr. John Van Gigch Dr. Ryo Hirasawa
Geography	George Mason University	Dr. Kingsley Haynes
Hierarchical Systems	Calif. State Poly./Pomona	Dr. Len Troncale
Industrial Engineering	University of Michigan Univ. of So. California	Dr. Chelsea C. White Dr. Gerald Nadler
Information Systems	Univ. of North Carolina University of Stockholm	Dr. Fred Brooks Dr. Kjell Samuelson
Integrative Studies	Miami University (of Ohio) Wayne State University	 Dr. Julie Klein
Living Systems		
Management Science		Dr. George Huber Dr. Gerritt Broekstra
Mathematics	Univ. of Cal. Berkeley	Dr. Lotfi Zadeh
Medicine		
Operations Research (Operational Research)	University of Virginia George Mason University	Dr. Dr.
Organization Studies		Dr. Stafford Beer
Philosophy	University of New Mexico McGill University University of Toronto	Dr. Archie Bahm Dr. Mario Bunge Dr. Irving Laszlo Dr. Wojiechowski

Policy Sciences		
Psychology/Psychiatry		
Social Systems	University of Pennsylvania Buenos Aires, Argentina Univ. of Amsterdam	Dr. Jean-Marc Choukron Dr. Charles François Dr. Gerard DeZeeuw
Software Systems	George Mason University	Dr. James Palmer
Systems Analysis		Dr. Amit Ghosal
Systems Dynamics	Univ. of So. California	Dr. Peter Gardner
Systems Engineering	George Mason University University of Michigan University of Lancaster	Dr. Andrew P. Sage Dr. Kan Chen Mr. Peter Checkland
Systems Science	SUNY Binghamton Portland State University Hull University City University of London	Dr. George Klir Dr. George Lendaris Dr. Michael Jackson Dr. Ross Janes

APPENDIX 2. THE SYSIETIES

APPENDIX 3. TRANSLATIONS OF SYMBOLIC EXPRESSIONS

[A partial history of the development of specific mathematical symbols is given in the book: I. M. Bochenski, A History of Formal Logic, New York: Chelsea, 1970.]

ITEM NO.	*SYMBOL*	*FIRST DEFINITION*	*SECOND DEFINITION*
1	+	Boolean addition	or
2	-	Subtraction	matrix subtraction
3	<	Is less than	Is antecedent to (with a specified relationship)
4	=	Is equal to	

Foundations of Thought. Pages 5-39 of Notebook #1 prepared for Mathematics of Modeling Workshop to be held July 1993.

John N. Warfield, IASIS, George Mason University, Fairfax, Virginia, 1993. 39p manuscript

Written as part of the study materials for a workshop to be held held June 21-July 2, 1993 at ITESM (Instituto Tecnologico y de Estudios Superiores de Monterrey) in Mexico.

I can't find the computer file holding the text of this manuscript, but an outline of the workshop is available in computer file 93outlin.wpd.

John said that the paper was begun in March 1993, and that it was still in an incomplete form, but he was printing it to use for the workshop coming in June.

Part 1 of the course was titled "Foundations of Thought" and Part 2 was titled "Mathematical and Graphical Aspects"

(There is no clear cut manuscript or transparency list for each of the three math of modeling courses. The material has all been lumped together over the years, Here is the list of the three courses:
July 27-31, 1992, a Workshop course for ITESM - titled "Mathematics for Modeling"
January 18-22, 1993, a Workshop course for TIPP (videotaped) - titled "Mathematics Modeling".
June 21-25, 1993, Workshop course for ITESM, followup on July 1992 course - titled " A Science of Design")

NOTE: A FOURTH Mathematics workshop was offered in June, 2000 which also used some of the materials from the earlier workshops.