Alternative Technologies

METHODOLOGIES IN MULTIDISCIPLINARY MODELING

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I. INTRODUCTION

When we talk or think about anything, we are building models. Whether one is attempting to explain a particular set of experimental results or engaging in a diplomatic conference with representatives of another culture, a model of the empirical system is established and used to guide further progress. Whenever two or more disciplines or even two or more individuals are involved in the modeling process, the result will be a multidisciplinary model. Even though we may think of models in these very loosely defined terms, it is desirable to have a more precise definition. We attempt here to define a model by explicating a modeling procedure. Faced with the need to model an observation set (a set of empirical data), is there a methodology which leads to a clearly defined model: one which allows for modification and for extension into a theory? We believe that such a methodology does exist and hope that what is presented here will serve as a useful attempt to define that methodology.

The construction of a model must not be taken lightly if any process that might be construed as deductive reasoning is to follow or if one wishes to use the model as a means of communicating. When two or more people use what they believe to be the same model, difficulties frequently arise due to differences in the use of "common" terms. In addition, intended meanings may vary from moment to moment because of context sensitivity. Such use of context may even be deliberate. These ambiguities serve as a means of motivating the rejoinders of everyday conversation, but are not desirable when the precision of either deductive reasoning or informative communication is in question.

Unless clearly stated and agreed upon definitions, assumptions, and rules are consciously established through a well-understood methodology, the coherence of the modeling attempt will gradually deteriorate until there is no possiblity that precise communication can proceed. The desire, perhaps the need, to specify a topic in a manner which minimizes the likelihood of such a communicative disjuncture is largely what motivates science. Hence the topic of methodologies in multidisciplinary modeling is an important one.

For the purposes of the discussion which follows, a model can be anything which is used to represent, in coherent fashion, the subject of either discussion or thought. Whenever a model is used, a representation of the external or internal subject may be said to have been formed or cognized. The faithfulness of the representation is a measure of the value of the model.

Admittedly, even this connotative definition of a model is rather loose, however the procedure by which one builds a model must be quite strict. There are many constraints within the procedure. At the same time, the procedural degrees of freedom are sufficiently arbitrary and numerous to allow the desired explanatory power. It is the procedure that really defines what a model is, and in this sense, a model is a fundamental concept, being operationally defined. The only rigorous definition that we can provide is a denotative statement that "this, this, this, and this" process should go into the making of a model. Thus, we will attempt to provide the operational definition of a model in the following discussion.

The methodology put forth here is better treated as a procedural diagnostic than as being either prescriptive or descriptive. It will answer the question, "What are the parts of the modeling process which, if omitted, lead to insurmountable difficulties?" We will describe a model as consisting of three parts which will be detailed in turn: the epistemological framework, the representational framework, and a procedureal framework. In addition, we will take a look at a means of representing the modeling procedure. This will allow us to examine the connection between a model, an empirical theory, and a world view. Finally we will mention some of the special properties of a multidisciplinary model and indicate a few practical methods by which the methodology espoused here may be implemented. Although many of the details of the methodology to be outlined below will seem obvious, they are none-the-less non-trivial.

In summary then, we are interested primarily in a system of syntax detailed in such a way as to allow connection with a system of pragmatics and with a system of semantics. These topics will be explored in future papers.

II. THE EPISTEMOLOGICAL FRAMEWORK

The construction of a proper model begins with the formulation of an epistemological framework. An epistemological framework is a set of loosely defined agreements which are made explicit by those who will be injecting information into the model. In some sense, what each individual brings into the modeling process at this point is dependent upon other models - upon a certain predisposition. All observations are in terms of some prior model and these observations have been categorized in some way or other. These categories and the prior models must remain implicit in the epistemological framework. They remain enfolded within the model to be developed, usually implicit and undetailed.

As an example of this enfolding of models, consider a model of inventory at a fruit stand. The structure of the inventory model is largely dependent on how one chooses to aggregate the fruit: whether into apples and oranges or fruit and non-fruit, whether the units are crates or pounds. This method of categorization is a model of a small portion of the world which is enfolded into the model of inventory. Similarly, there is a model of the universals of grammer which is enfolded into the model of fruit aggregation. We can trace the enfoldings back through evolutionary models to a cosmological model. There is then either a natural limit or a regressive enfolding depending on whether one's cosmology is closed or open-ended. These details of the enfolding are relegated to an implicit pragmatics as soon as those engaged in the modeling specify their intent.

There are five basic agreements to the eistemological framework. Each of these agreements must be present if the modeling attempt is to be successful. First, there must be an agreement of cooperative communications (a la Grice).* Cooperative communications consists of three sub-agreements. There must be an initial sub-agreement that only commonly defined terms will be used. Communication must begin with terms in everyday use. If there is a failure to use such terms and treat them as being fundamental, then an attempt to define complex terms (derived concepts) will certainly fail. By treating common terms as fundamental, a loosely defined terminology is permitted as operational definitions evolve. This concept is somewhat akin to a koan. A definition is given as "such and such" and then three sentences later may be given as "not such and such but so and so is closer to what is meant". In this way, by going back and forth between several distinct and specific definitions, terms come to be clearly and precisely defined in an operational sense. In general then, fundamental terms are contextually defined.

There must be a sub-agreement as to which terms will be used as fundamental terms and which terms will be treated as derived terms. Terms such as "and", "the", and"or" are among the most commonly used terms and most people have a pretty good sense of what they mean, even though these terms may have very preeise deinitions in the mathematical or logical sense and these definitions may not be known. Through an agreement as to which terms are to be treated as fundamental and which terms are to be derived* eventually the more precise terms can be specified through the operationally defined terms.

The final sub-agreement of the agreement of cooperative communications is an agreement of pertinence. This agreement imposes a bilateral condition. In any communication, each party must agree not to attempt to mislead the other or to entertain irrelevant information. Convereely, it is assumed that any statement, understood or not, is pertinent and as such each party must attempt to achieve a relevant interpretation.

Before any great progress can be made on the model, there must be an agreement of intent. Those engaged in the modeling must specify what it is that they wish to model. The first of these refers to the object of the modeling by reference only. For instance, it is here that inventory or quantum electrodynamics is chosen as the subject to be modeled. This agreement is closely related to the third major agreement within the epistemological framework, agreement of observation.

Once the intent has been agreed upon, there must be agreement as

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*Per Gram-Schmidt such an agreement often suffices to define the operational space.

to what observations constitute the relevant system observables. The _agreement of observation_ defines observables, specifies to what extent observables can be distinguished, and the method by which they are to be distinguished. In other words, when distinguished. In other words, when modeling inventory, shall apples and oranges be taken as the system observables or shall the numbers on a tally sheet be used as the system observables? Lack of such an agreement will lead to a breakdown in communications when falsification of postulates is required within the procedural framework.

The fourth major agreement within the epistemological framework is the _agreement of explicit assumptions_. There must be an agreement to clearly specify and agree upon all the assumptions. If a single assumption is left out of the modeling process, eventually it will be used implicitly. The use of implicit assumptions leads to misunderstandings and disagreements (as well as accidental creativity). The most trivial of assumptions must be stated explicitly. In the usual case however, it is the most non-trivial assumptions which are overlooked, the most important being those of an existential nature. For example, the existential postulate, the distinction between what is "out there" and what is "in here", is rarely specified. Where is the boundary assumed to be? The particular answer is not as important methodologically as is the fact that the question need be answered. The same thing applies when the assumption is made that there is an "in here" or an "out there", and that there is a boundary between them (Descartes' dualism). These are probably the most important assumptions that can be made.

An interesting effect often takes place when one is willing to either give up the boundary or to let it "float free". Many processes seen as being devoid of explanation or perhaps too complex to explain, become clear as soon as the boundary separating the system from its environment becomes non-rigid.* Where the boudary is placed can serve to either clarify or complicate the model that is built. For example, in a thermodynamic process, the conceptual placement of the isothermal wall can be critical. If the wall is placed down the center of a heat exchanger and the interest is in verifying the concept of conservation of energy, then many processes are taking place across the boundary - back and forth across the wall. In order to verify that energy is conserved in the system, each and every bit of heat flow must be taken into account. It becomes much less difficult to see that energy is conserved, however, if a bigger box is taken so that the entire heat exchanger is contained within it.

As a second example consider the clustering problem as shown in Figure 1. If it is desired to form a linear dichotomy separating the "+'s" and the "-'s", it obviously makes no sense to place the boundary as a straight line. If, however, the boundary is placed as shown in Figure 2, then a "simple" coordinate transformation

* The boundary calculus of topology is useful here.

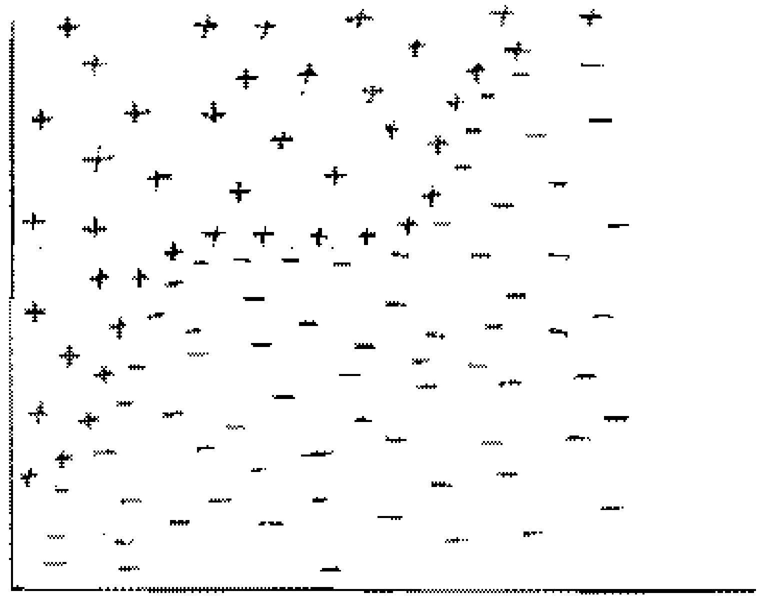

Figure 1

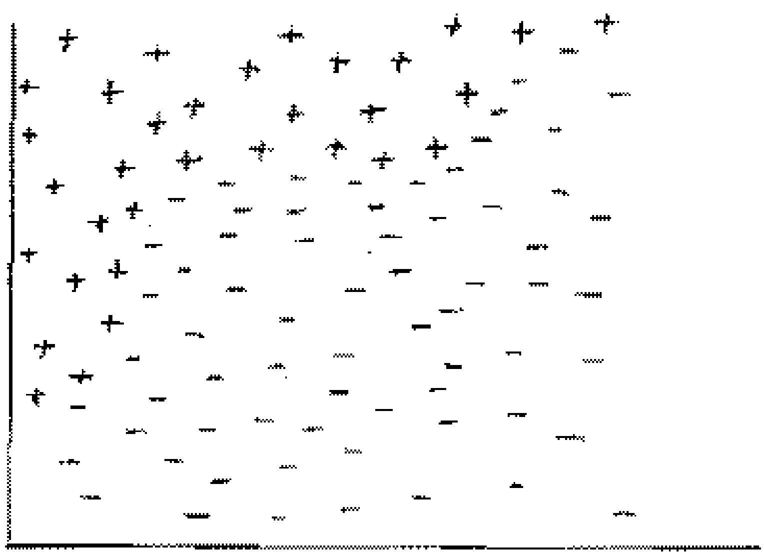

Figure 2

makes the "linearity" straightforward.*

From agreement to specify each assumption comes a hypothetical framework which answers, for the moment and with no certainty, existential questions of the sort "do I exist?". For instance, one might state the answer as "I will assume, for the purposes of this endeavor, that I do exist". When one engages in modeling, paradoxes are the usual result without meticulous regard for what are normally implicit assumptions. This is especially important when members of different cultures are providing information as input to the model. Metaphysical assumptions must be included within the epistemological framework. It is equally important that the statements be recognized as assumptions and that they can not be proven any more than any assumption or statement within the epistemological framework can be proven.

Very often, as will be seen in the procedural framework, it is desirable to return to these assumptions and tweak the epistemological framework with them in order to optimize a bulky, confusing, or unworkable model. Often the assumption which accomplishes this feat is the one which places the existential boundary. Note, for example, that physicists often make these assumptions implicitly. Bohr and Heinsenberg were at odds on the point of whether there was or was not an inside/outside dichotomy. Bohr interpreted complementarity as a statement that observations were an artifact of mind, not of the outside world, where as Heisenberg interpreted uncertainty as a statement that the two could not be separated.

Specifying the assumptions by which an individual abides is a good way to examine their worldview. Unless one questions the assumptions that are made, arguments will tend to persist without either party understanding why. Care must be taken as these are not assumptions which people intrinsicly conceptualize in the same way. It is necessary to know where others stand on these points before precise communication is possible.

The fifth agreement of the epistemological framework is essentially a variation of <u>Ockham's Razor</u>. First, the participants must accept an <u>agreement of minimal generality</u>, that is, to state assumptions which are more encompassing rather than those which are so specific as to encompass very little. On the other hand, the assumptions must not be so general that excessive use of the razor is required later on. Second, an <u>agreement of elegance</u> must be met. Assumptions must not be stated unless absolutely required for model. It is assumed that the modeling procedure has been considerably focused at this point by having specified separable which questions are of interest and which

* A calculus of clustering is assumed: Namely is that a structure such as that shown in Figure 2 implies the need for an as yet undefined paramenter - in other words, the parameters are separable if and only if the number of orthonormal parameters is sufficient.

questions will be allowed. Thus the assumptions stated here are not just a list of all the details that are relevant. Rather they are the assumptions which may be stated in such a manner as to incorporate as much as is possible without being so general as to incorporate the unnecessary. The Razor is thus used as a test to distinguish pertinent and relevant material from non-pertinent and irrelevant or extraneous material. Given the assumptions already stated, one asks whether or not each new assumption is needed or whether it is already contained within the framework. In other words, is the freedom to do such and such already available? One practical method by which the Razor may be implemented is to overproliferate, introduce variety, allow degenerate description, and then filter or reduce. In this way one ends up with the maximum information and the minimum noise.

The assumptions that are outlined at this point are not incompatible if they refer to the same circumstances in different ways. Thus the level of modeling is not atomic. Rather, they will refer to separate worldviews (belief systems), each shaping the structure of thought differently. Since it is difficult to think in two different ways at the same time, it is desirable to specify the assumptions of a single worldview.

III. THE REPRESENTATIONAL FRAMEWORK

The representational framwork consists of two sets: a set of symbols and a set of rules of manipulation. These sets are chosen subjectively from equivalent sets in order to simplify the particular modeling task. Given any two abstract collections of symbols (abstract in the sense that no objective meaning has been assigned to the symbols), the collections are said to be equivalent if they have the same cardinality (number of elements). Two sets of rules of manipulation are equivalent if there is a one-to-one and onto relationship between them. Any two rules are equivalent if they manipulate the same symbols in the same way. Even though the expressions of the rule may appear different, they are operationally equivalent so long as every interpretation and implementation of the expression produces the same manipulation of an equivalent set of symbols.

If and only if there exists no relationship between the rules of manipulation (i.e. the rules form an orthogonal set - are uncoupled) will the representational framework produce a linear model. The rules of manipulation must also be complete in the sense that no proper subset of the set of symbols is closed under the rules of manipulation. The set of symbols is itself closed under the rules of manipulation. Of course, the rules must be self-consistent. Whatever the framework chosen, we are constrained by the necessity of sufficient richness to allow complete representation of the system being modeled. The representational framework is thus an abstract formalism.

There exists a plethora of equivalent representations. Equivalent as used here does not mean "same". It means the same information and the same structure are intrinsic to both. Mathematically speak-ing this is an isomorphism (an order-preserving transformation) having a one-to-one and onto correspondence. Structure, order, and information are not lost in an isomorphic transformation. This does not mean that the visible or apparent structures of one representation will be as visible in an equivalent representation, since this is a subjective interpreted feature.

Although the initial choice of a representational framework is quite arbitrary, there will always be an optimal representation within the constraints of choice for those involved in the modeling effort. For example, some may find it easier to work with arabic numerals as distinguished from roman numerals. The logical structure of these two numerical representation schemes is quite equivalent (excluding the zero symbol) and the choice is objectively arbitrary. It is solely a matter of which representation is subjectively the simpler or less complex*. The first choices of a representational framework may lead to a model which is found to be too complex to be of practical use.

At the beginning of the modeling effort, there may be only a hint of this complexity. As one works toward the goals of the model, even initial simplicity may turn out to entail considerable complexity. When this occurs, it is desirable to return to the representational framework and change to a parallel or equivalent representation which serves to simplify the point of difficulty. Note that one's cultural biases, training, talents, etc., all play a part in the choice of a representational framework and even more so in adjusting the choice later. If there is personal competition, then the psychological (and financial, political, professional, etc.) threat of having one's investment overlooked is quite real when an equivalent representation is proposed as being more optimal. There is thus a psychological hurdle which must be overcome in the modeling process, as it is not unusual for human beings to become ego-attached to whatever they think about for more than a few milliseconds.

IV. THE PROCEDURAL FRAMEWORK

Within the procedural framework, the relationship between empiricism and the proposed metalanguage is explored and the metalanguage is established. There has been a good deal of confusion about the relationship between empiricism and metalanguage. Hopefully a bit of it can be alleviated. One mistake that is often made is to treat the logic of thought and the logic of observation as though they were equivalent to the logic proposed by Boole, the class calculus of the propositional logic. This mistake was initially encouraged by the way in which Boole introduced the propositional logic, namely as the logic of thought statement was intended to as one of fact: this is the way people

* see Feynman, The Character of Physical Law

think and it can be applied to anything.

Since we are attempting to specify an appropriate metalanguage care must be taken with such points. We must be very careful about the rules of logic used when we talk about the model, refer to it, i.e. how we think. If we think as Boole said, then the laws of thought are absolutely impervious to the environment observed. Everything is compatible and can be simultaneously observed. There are no logical constraints upon what can and can not be observed. The laws of thought are fixed and everything is logically related to everything else in these and only these ways.

It is far better to treat Boole's viewpoint as an hypothesis. Boole assumed that the processes and the content of thought were separable, that they were not coupled in any way. Such a logic may not be adequate, even as a metalanguage, as, for example, when modeling indistinguishables. In this case there is a difference between the cardinal and ordinal numbers that the logic must take into account.

If we treat Boole's viewpoint as a hypothesis, then there is liberty to manipulate (tweak) the metalanguage until something close to the logic of thought is finally established as a more useful, almost "universal" (marginally grand), metalanguage. We may characterize thought in a different way (use a different set of axioms), if we wish, as long as the axioms of the system thus created are clearly stated. The validity of our characterization will then be subject to empirical validation.

How can empiricism specify which metalinguistic choice is appropriate for a particular model? Within the procedural framework one looks to experience and observation to answer the questions. In particular this is done by distinguishing between falsifiable and unfalsifiable postulates. Those postulates which are not falsificable may be taken as axioms of the metalanguage and this leads to predictablity within the model. Those postulates which are falsifiable lead to changes within the epistemological or representational frameworks. There is always the possiblity that within the metalanguage there exist postulates whose usefulness in the real world - although functioning well within the metalanguage - can be neither verified nor falsified. These statements are Godelian in nature and serve as an indication of the richness of the formalism.The (Newtonian) scientific method is often useful in working with the metalanguage. It functions best in propositional form. The first step is to state a proposition which is an inductive postulate based on common knowledge. This postulate is quite arbitrary. It may be either a wild statement or a safe one. At this point in the process there exists a unique condition. This first proposition is based upon random observations. It is a summation of many observations

* It might be said that the metalanguage then constitutes a final topology in its conceptual beginnings.

over the past. The ordering between observations has been smeared, guided only by contextual need and experimental aesthetics. The nature of this smearing is precisely the relationship between the natural ordering of the universe and that of the subspace which is being modeled (if one assumes that these things exist).

This unique instance in the modeling process will not recur if an axiomatic procedural framework is closely followed. The postulate is formed within the context of the chosen metalanguage. For example, if a twelve volt battery is connected to a nine volt light builb, the claim that the bulb will burn out is reasonable. This is a statement based on random observations - empirical and informal predictability, experience - even though it is a testable one. It is not based upon notes in some carefully dated notebook, but upon experience, intuitions, experience with other models, various psychological factors, etc. There are factors included within the postulate which have not been analyzed. The statement need not be based entirely upon empiricism, the point is that one does not arrive at this relatively general postulate in any systematic way. As the model is completed, this postulate will forever be viewed as being inductive or ideosyncratic within the framework. It is neither predictable nor algorithmicly describable and is frequently regarded as fortuitous (or perhaps frustratingly unlucky when the model that results is of little value).

The next step is to put forth a secondary, more specific, proposition (formulated as a question) about the inductive postulate. The inductive postulate is now treated as an axiom. A proposition derived from the inductive postulate and relating the rules of logic to the system observables is now formulated. This second proposition must be specific, stating what are and what are not observables.* Finally, the proposition is tested by the answer to that proposition, which is itself another proposition.

This most recent proposition is a postulate based upon directed observations. This is the first in a chain of deductive postulates. The entire process is then repeated indefinitely using the most recent postulate as the one to be tested. The result is a chain of propositions. The model constructing continues through this process until all the observables from the observation set have been exhaustively related to the representational framework. The axioms of the metalanguage are applied and reapplied. At some point it may become so diffiult to design a new testable postulate that the model is either complete (unlikely), modified in some way, or disposed of altogether. Thus the modeling process is either recursive or the Kuhnian revolutionary step is made.

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* Note that in the light of accepted physical theory, a useful criteria expresses observability in terms of the notion that possibles are at worst contraries whereas contradictions represent impossibilities.

The Kuhnian revolutionary step occurs whenever one of three events takes place. First, the observation set is not static in most real world modeling efforts. Thus, it is always possible that a new observation element will be added to the origiual observation set which can not be coherently accommodated within the present epistemological, representational, or procedural framework. Second, those involved in the modeling effort may experience a flash of insight and start anew with a different inductive postulate than was previously considered. Third, a parallel attempt at the modeling effort may prove more successful (either in fact or politically). In esch case a new inductive postulate is the result!

V. REPRESENTING THE MODELING PROCESS

The modeling process can be shown to have some interesting properties when represented in an abstract manner. It is reasonable to ask how a model is connected to an empirical theory and how the model behaves when the observation set undergoes some change or modification. We begin by defining a model M as a logical isomorphism to a fully-interpreted system FR. It consists of an abstract formalism F (the representational framework) which is defined as a logical calculus devoid of any meaning. The symbols of the formalism have relationships to each other but are without interpretation outside the formalism. The interpretation is closed within the operations defined within the formalism and no meaning is imputed explicitly to the symbols of the formalism. The symbols may, of course, evoke meaning implicitly.

The abstract formalism relates abstract symbols to the observables o within the obaervation set O attached to the epistemological framework via a metalanguage (as supplied in the procedural framework). Note that we use lowercase to represent the generalized elements of any part of the model. Thess elements may be (for example) the discrete elements of a set or the quantum elements of a quantum manifold. The rules of correspondence R serve to establish an internal coherence between the descriptive features of the formalism and the observation set. There is some sense in which one can refer to the rules of correspondence as that which establishes an ordering of the observables. O is also referred to as the universe of observables.

As an example, consider the modeling of a right triangle. There is, initially, the triangle itself, which is, in fact, a set of three straight line segments, as the observation set. There are the two sides and the hypotenuse. The abstract formalism may well consist of the symbols h, b, and c, with the abstract operations of +, $()^2$, and =, and the algorithm $(h)^2+(b)^2=(c)^2$. When one supplies the rules of correspondence, (having identified the appropraite observables) namely, that h represents the height of the triangle, b the length of the base and c the length of the hypotenuse, the F, O, and R define a model of a right triangle.

Generally, one models an empirical system with the hope that it will lead to an empirical theory. In defining an empirical theory T, we take the point of view that a theory must have predictive power. Thus an empirical theory (often referred to as a physical theory) is a partially-interpreted system which we denote by F_r. Terms within the formalism which are interpreted (that is, for which there exists a rule of correspondence) are called empirical terms denoted by f_e as distinguished from theoretical terms f_t which have no specific interpretation.*

The key factor which usually destroys a model is the lack of a logical isomorphism - there is usually a failure to provide a one-to-one correspondence between the terms of the formalism and the observation set or there is a failure to preserve the logical relationships observed between observables and thus, the correspondence is not onto. In the empirical world as seen by todays scientist, this is a fine principle , though not a necessary assumption - additional observations serve to decrease the feasible space. Within the theory T, the onto relation must still be satisfied; however, the correspondence may be one-to-many (or many-to-one). For example, it may be the case that terms used within the formalism of the theory are related to many observables which are lumped together, for the purposes of the theory, under a single reference term. On the other hand, it may be that there are observables which are related to a subset of lumped terms within the formalism.

Regardless of whether the correspondence is many-to-one or one-to-many, the theory is an open (not closed) space and thus a prime target for further interpretation. It is from this property of theories that predictive power is obtained. The logical structures within the uninterpreted portion of the observation set (or formalism) predict that the same logical structures will be found within the corresponding formalism (or observation set). There is some question as to whether or not even a model can be shown to be a closed space. In the purist sense of the term, it can not if one's world view entails the belief that the universe is infinite or a continuum. For the sake of pragmatism then, it is desirable to treat the universe as being limited to the observation set agreed upon in the epistemological framework.

The time-dependent evolution of a model or of a theory is equivalent to the ways in which the model or theory may be modified without destroying the internal coherence properties of the model. A few properties of modification of models are universal and may be explored within our present representation. For example, transitivity: We let ϕ^1 represent a generalized modification operator. The precise form of the operator can not and need not be given. In addition we let $0^*=0+o$ where o is a single observable. That observable may be either an addition or a deletion (such as that which would be necessary if an observa-

* See Jauch on intrinsic versus extrinsic properties of models

tional element turned out to be falsely reported) to the original universe O or may be a null element. We define F* and f, R* and r, and T* and t in a similar fashion. It is interesting to note that a modification of O into O* necessitates a modification of R into R* and thus a modification of F into F*, via the modification operators ϕ^1, ϕ^2, and ϕ^3. Such a change is equivalent to a modification of N into N*. Thus the modification operator obeys the transitive law.

The question that next arises is whether or not the inverse operator similarly follows the transitive law and whether or not the inverse operator even exists in the general case. In other words, are there modifications such that a modification of the formalism necessitates a unique modification of the rules of correspondence and hence of the observation set? The answer is no. It is easy to see that a theory (which can result when a model is modified without due regard to the observation set) need not have (indeed can not have in a dualistic worldview) a unique correspondence to reality.

It is this fact that allows some theories to be evaluated as being more correct than others and hence for theories to fail. We can thus say that theories make either more correct or more incorrect predictions in comparison to competitive theories. If the predictions may be assumed to be correct, then it is not always the case that we can predict the specific observables which would verify the theory. One might say that this is due to the necessary graininess of the model and hence of the theory. Because we do not know (and can not know in a model that entails a dualistic worldview) all that there is to know and because this is reflected in the model, there are necessarily levels (hierarchical in structure) at which interpretation may be complete and the level of interpretation is chosen according to how much detail we wish to impose. We may, however, approximate the inverse modifications in such a manner that the result is locally correct. This approximation is possible only because the piecewise invertibility of the operator permits us to ignore global constraints that would be impossible to satisfy within the knowledge base and/or operator mathematice available. Thus the modification operator is said to be locally though not necessarily globally invertible.

The way in which a model behaves under modification is identical to the time-dependent behavior of the observation set, i.e., to the system dynamics. Similarly, we may explore the system statics by looking at the time-independent behavior of the model or the invariants under modification.* This technique is a powerful and very general tool in the modeling of empirical systems and the generation of empirical theories.

Attempting to define a world view is a difficult task in- and of-itself, one that is not appropriate here. We have, in passing,

*see von Weizacker on temporal logic

touched upon some of the details of a world view. In particular we have noted the importance of the epistemological framework, with its many assumptions, in approaching the modeling process. Perhaps in a more general way, we have noted the importance of the representational framework as the vehicle which provides for interpretation of the observation set in conjunction with the metalanguage. Here it was pointed out that an ordering relation is imposed upon the observation set. This is the key factor in a world view: the ordering relation. A detailed analysis of this proposition requires the invention of a calculus of ordering relations and, in particular, a generalized ordering relation that is not restricted to the familiar sequential orderings. This notion will be explored more fully in later papers.

VI. THE TECHNIQUES OF MULTIDISCIPLINARY MODELING: TACTICS

Consider the usual case of multidisciplinary modeling in which two or more individuals have non-overlapping knowledge or minimally-overlapping knowledge. This condition may be referred to as a restricted knowledge-base. We can idealize this situation by limiting the number of individuals to two, and by assuming an optimal knowledge-base, i.e., that two individuals share the same knowledge. In such a circumstance it is important to note that questions of separation will arise. Boundaries are now hazy and the individuals - in terms of the model - are no longer distinct. In a similar way, it should be noted that pragmatic purpose and historic accident are all that truly separate the sciences. The choice of separation is marked by arbitrary definitions and by the fact that it is easier to establish boundaries where there is a decrease in the level of knowledge.

Where questions of pragmatic purpose might arise, it is useful to restrict the modeling attempt temporarily to the formalism. Once the observation set has been specified (a joint task) and rules of correspondence have been drawn to the individual abstract formalisms (an individual task), there remains only the joint task of specifying the degree of isomorphism between the individual formalisms and this is trivial. It is sometimes then desirable to examine the use of a third and equivalent formalism which both parties agree to use for communication. We assume here that communication can occur. This is true only if a boundary can be conceptually placed about the two individuals and it is then possible to model what they jointly consider to be the observation set. Need we ever, for the purposes of representation, deal with anything other than the formalism? The answer is "No!". To do so would be a further and unnecessary complication to an already difficult task. For the model to evolve it is necessary to approach the model as though the formalism were all there was as reality, otherwise extraneous material is introduced into the task. By extraneous material we mean postulates, implicit assumptions, hypotheses, etc., about which there is not yet agreement. However, it is interesting to note that it is this extraneous material which helps to motivate change - the necessary uncertainty, misunderstanding, or feature of disagreement which promotes ongoing communication.

Models are difficult to build only because they require great attention to detail; they are nonetheless trivial. Theories are far from trivial, because it is difficult for two or more to agree upon theoretical terms, the interpretation of which is completely intrinsic. In general, there are four process steps in any modeling methodology, whether the model be a multidisciplinary model or not. they are: (1) agree, (2) observe, (3) formulate and (4) correspond.

Are there reasonable techniques for bridging the gaps which specialization produces in the professions or which are the result of a minimal knowledge base? Yes, a number of techniques are useful, but four stand out as being the basic guiding tactics. The first technique is to appeal to the common ground that always exists between individuals when specifying the fundamental concepts and terms, whether that common denominator is culture, goals, a specific field of interest, or simply that fact that all thn individuals are human beings. It is interesting to note, in this regard that a measure of the relative complexity of terms is simply the amount of the time it takes to reach a multually satisfying connotative meaning of those terms. This is, in turn, dependent upon whether others have or have not used the terms before and how much the terms have been used. When an individual expresses an outright objection to the propsed use of a term, it is an indication that they are using a different classification scheme - different categories. In general, it is desirable to choose terms in such a way that common denominators lead to commonly defined terms.

A second method is the iterative procedure. By restating what you believe someone said as those they has said it or evalnated it, it is possible obtain a critique which is rather ointed. A process of restatement and "re-critiqueing", even when several individuals are involved and from widely varying fields of interest, will eventually result in mutual agreement or at least lay bare pertinent conflicts.

A third method is the use of metaphor. This is a powerful tactic because of the close relationship between metaphor and model. A metaphor is essentially a model in which some of the "links" are missing - a relatively coarse model. Often, the model and the metaphor occur at different levels in the hierarchy of descriptive detsil. By treating the metaphor as though it were a model, a good deal of agreement can be reached in a short period of time and, after all, a multidisciplinary model is simply a great deal of detailed and cautious agreement between individuals and the empirical world.

A fourth method involves going from a model to a metaphor, playing with it, and then reducing back to the model level. As was stated earlier, a metaphor is nothing more than a low quality model. When there is adequate reason to believe that more detailed correspondence than has been given is possible, or when the circumstances of improper correspondence are such that they can be successfully ignored though acknowledged, a "model" with some of the rules of correspondence missing can be of considerable use. One can go from a model to a metaphor by simply increasing the cardinality of either the observation set or of the set of symbols within the formalism. Certainly this results in a theory, but need not be either acknowledged or treated formally as such. It is permissable to "cheat" at the interpretation rules of a metaphor in a manner unlike that which is possible with a formally acknowledged (and committed to) theory. Once one feels comfortable with the metaphor, it can be reduced or filtered back to a level of complexity that is formally a model.

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