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# SYSTEMS MODELS FOR TRANSPORTATION PROBLEMS
## Volume I: Introducing a Systems Science for Transportation Planning



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FINAL REPORT



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16. Abstract


In this introductory portion of a systems science for transportation planning, which is based on the statistical physics of ensembles, a foundation is laid on how statistical mechanics, equilibrium thermodynamics, and near equilibrium thermodynamics can be used for systems other than the atoms and molecules of its standard application. Its relevance to living systems is indicated. To provide some insight to its application, three example systems are briefly discussed — rivers, the vascular system in mammals, and the development of the nervous system and the evolution of intelligence in the living system. The study then considers social nets. The likely problems of the social net, particularly as they bear on transportation and transportation research and development, are discussed.

This is Volume I of four volumes.

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# Preface

The objective of this research is the examination of urban transportations' problems through the development of physically based systems models which utilize the physical principles of statistical mechanics and irreversible thermodynamics.

In this first part of a final report, the foundations for such a systems' science modelling is put forth. This is necessary because the application of its basic notions to such a complex system as a social institution is novel.

But the report turns as quickly as possible to illustrate how transports strategy is achieved, by such physical systems' science, in a number of natural systems.

And then it takes up, with a first very coarse sweep, how the notions lead to a basis for modelling the future needs of a transportation system.

With this introductory report in hand, it should then be possible to approach the problem of more detailed urban system modelling.

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We wish to acknowledge Harrison Salisbury's permission to use excerpts from his book, To Peking - and Beyond. Namely the material is

## Table of Contents

## A. Some Systems Preliminaries

### 1. Credo

Our credo is contained in the following two statements. We state both because we believe both, and we believe them to be essential parts of our attempt to offer a scientific construct for the social institution of transportation within the social system known as our country.

### Purpose

A book review in the N. Y. Times[1] offers a reasonable literary descriptive statement about 'purpose' in social systems and their essential operational institutions. The particular system and the particular institution under discussion in the review is not part of our concern at this moment. Its perception of purpose in social systems is.

The review raises the question as to what a nation's health care system is for. It suggests that beyond the obvious answer that it must care and protect the populace in health and disease, a health care system permits society the opportunity to express its perceptions of people and their interrelationships. At one extreme, it can be treated as a purchasable commodity, one that must be packaged with all the technological skills of a modern industrialized market economy. Alternately it can be treated as one additional social utility. And somehow in the doctrine of social utility the purpose of a national society is to be discovered.

Namely the basic issue is how do we treat and care for others. And in answer to the question who these strangers are, who we must relate to and care for, the review suggests that the basic answer is Pogo's "He is us."

So the question that we ought to consider in the design of a health care system is how would we design it if we really felt that we were designing systems that we were intrinsically part of. That is the thrust of the review and the book it reviews.

Thus this review suggests that utilitarianism, the doctrine of the optimization of the useful as the best good for man and man's own self-interest embodies social purpose.

If the only basis for us to argue out systems' design were on this classical philosophic theme there would be little new that we could offer. Of course we are also human beings and are sensitive to man's needs and his aspirations. But our problem in this study is to find a much more deep seated basis for design of systems. We have developed some notions in one preliminary report.[2] Namely that purpose (results aimed at, not by accident) emerges from the essential physical requirements of a system. It is not a question of the useful but of the essential results that must take place if a system is internally encoded to sustain its life within its environment.

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[1] From H, J. Geiger, "Serve the People", a book review in N.Y. Times Book Review Section, p.4, March 17, 1974.

[2] A. Iberall, "A Systems Science Theoretic for Goals or the Engineering for Psychology, Sociology, and So Forth", Trans. ASME, J. Dyn. Syst. Meas., Control, 93, 206, 1971.

So as atomisms caught up in the statistical mechanical maelstrom known as a social system, we are obviously somewhat familiar with and empathetic toward results that have to be achieved, but the scientific foundation must be built beyond our empathy, although by possessing such empathy we may reveal our membership in the ensemble. The problem is what is the physical science for such ensemble processes.

## 2. Statistical Mechanics

It may surprise technical readers to find the previous statement offered as part of the essential physically based scientific structure that is being proposed to characterize the operational institution of a transportation system. In order to comprehend that, it is necessary to understand the statistical mechanics of an operational ensemble that makes up a viable system. A viable system, in brief, is one possessing a start up phase, a long life phase, and a dissolution phase. In its life phase, there is an essential preservation of form and function. That phase is based on the existence of energetically active essentially interchangeable atomisms or molecularities that wander motionally through a spatial field and interact energetically. Those properties are sufficient to qualify the system as a statistical mechanical ensemble subject to mechanical and thermodynamic laws. The keynote of that characterization is that a dynamic equilibrium is reached in the ensemble, independent of initial starting conditions, wherein the distribution function(i.e., the stationary statistical distribution in a phase space of positions and movements) depends only on a limited number of invariants, so-called summational invariants, of the interactions. These are quantities that are preserved upon interactional cycles among the atomisms. In a simple physical system of molecules, the summational invariants are those of mass, energy, and momentum. As one increases the physical-chemical complexity and proceeds toward higher organization, succeeding levels add a few more summational invariants. For example, chemical systems conserve independent major mass species, as well as total mass. Then, living systems conserve number distinct from mass in interactional cycles, i.e., cellular life begets cellular life is a central dogma of biology.

At the level of complex higher multiorganisms, e.g., mammals, the summational invariants are limited to what emerges out of a genetic heritage, namely what is commonly viewed as 'instinctual' performance plus the Pavlovian conditioned reflex (including so-called instrumental learning). The most advanced species of mammals, human primates, in addition has an internal coordination center that permits the use of speech and the easy use of abstractions at neural rates (recognition and transmission of rates of ten signals per second with error free information rates up to 25-50 bits per second). That, and a large memory bank, has made for an extensive epigenetically transmittable heritage of learned performance. But the human in 'recent' Neolithic times adds one new summational invariant to the physics of his social ensembles, the metric of value or values, that was emergent from his new 'sapient' brain. That brain, 40,000 years ago, encompassed abstractions including speech, branching 'volition', culture, magico-religion. For 30,000 years that served man, the hunter-gatherer. Ten thousand years ago, with a change in climate, and the development of a new style of living, where both man and new plants domesticate, the notion of values that man's mind had carried becomes caught up in a social convection as a formal metric for value-in-trade. That emergence of that notion as a hard systems metric confronts the would-be scientist of the social system of man with both the so-called idealistic and materialistic view of historical development.

The authors are thorough-going reductionists. This has required facing, in a variety of fields, a materialism that is both deterministic and stochastic. This has strained theory building. Finally, in hydrodynamic fields (irreversible thermodynamics) a foundation has been found that permits both results to be true (namely how turbulence can be both deterministic and stochastic). It has involved a combination of non-conservative thermodynamically consistent mechanics and nonlinear mathematics. Turned into the social field, surprisingly, it has been both the materialistic and mythic (or mystic) character of man's history, as expressed by Toynbee (particularly Vol. 12 in his life work An Outline of History), that we find ourselves most empathetic with. Thus our appeal is made from a very specific physical notion of how systems work.

## 3. Problems of Imperfect Specifications

That our point of view should not be considered mystic, we will try to offer a clue or small vision to our point of view.

The engineer has been taught by the scientist and mathematician that he can analyze a system when he has as many degrees of freedom (or variables) as he has equations, and thus he can use a network representation in which each loop represents a degree of freedom and equation. He is left with the problem of identifying the equivalent loops in any particular field that concerns him.

We are concerned with distributed fields. These seem to have an infinte number of degrees of freedom. Nevertheless, given 'adequate' boundary conditions, if the partial differential equation set is linear, there are reasonable conditions under which the solution is unique and thereby computable.

But we have implied that it is only non-conservative nonlinear physical theory that can be at the base of viable systems. Thus we likely do not have unique conditions for solution. In fact solutions seem to emerge out of the possibility of nearly equally indifferent branching paths. (See for example, R. Thom, Structural Stability and Morphogenesis, Addison-Wesley, 1974.)

We can describe at least part of the dilemma in the following terms: Suppose we have a set in which there are more equations than variables, what happens? We are not concerned with mathematical problems, but physical. We submit that what happens physically is that the system 'cracks' open and produces new variables. It is 'shocked'. Instead of the apparent existing lumped variables viewed in the description, new internal variables will appear until a parity is achieved.

On the other hand, suppose there are more variables than equations. We submit that the system finds new modes of operation of equally indifferent energetic paths and fills up the phase space.

## 4. Resolution

The emergence of the human brain in homo sapiens sapiens 40,000 years ago, took that animal operating in his ecological milieu and converted him into a superb hunter and roamer. After 30,000 years, at the end of an ice age, on a rising temperature curve, that cognitive animal began agriculture in and around fixed settlements. But that left him with the additional equation that described the summational invariant of value. How should he conduct his life? He is no longer governed only by more limited branchings of a fixed genetic code. He now has to satisfy epigenetic (learned) branchings. Does this leave him 'free'? No, it only gives him more constraints to satisfy.

Our concern is to provide a value-free science to social man who has to be bound by physical law, including values. And that is what we shall offer to the problem of how he can deal with the motional - transportational - aspects of life around the fixed settlements that he began to inhabit 10,000 years ago.

Note that in pre-Neolithic times, man, the hunter-gatherer, had to learn to read the face of the earth and how, when, and where to wander on that face in search of the essentials of life, those minimal summational invariants which he had to satisfy as a living species. Of course he was bound by his primate heritage, and that meant a rather specific kind of local roaming range. 'Transportation' problems and patterns already existed, but these hardly require any complex formalism that would interest any others than ethologists But with post-Neolithic fixed precipitated-in-place agricultural settlements, two kinds of transport problems came into existence. One involved the formal patterned plan for the local community life and its circulation. The second involved the circulation among a group of communities engaged in trade, by value-in-trade, either because of some real or perceived lack of self-sufficiency in all materials and fluxes involved in the summational invariants of living systems. With both the former and the latter patterns of movement begins the transportation problem.

We do not believe that the development of transport and circulation patterns were unique, namely that some specific limited linear equation (e.g., the homogeneous Laplacian or the inhomogeneous Poisson equation) describes the pattern. Instead, as in René Thom's theory of 'catastrophies', by more than one branching possibility, we believe men fill the appropriate phase space with a reasonable sample of all possible configurations. The limitations are, as in Willard Gibbs' canonical ensembles, that all possible circulations that satisfy comparable energetics are plausible.

But we are not engaged in a purely scholarly study. Thus, tho interesting, a detailed and deep history of how post-Neolithic societies filled up the geometric dimensions of their phase space with all kinds of transportation systems and all kinds of vehicles cannot become our problem. Rather we implicitly assume such information exists and can be recovered when necessary. Instead we will attempt to direct our attention to the more 'near terminal forest' systems' problems, when social ensembles become so dense in population and land occupancy that the transportation system becomes a significant element in the rate governing process time constants and in the materials and energetic fluxes.

But even at that, there are two levels of attention we will have to give to the problem. On the top, we will be concerned with the general systems' description at which all interacting subsystems aspects of the social continuum are involved. On the bottom we will be concerned with technical limitations - the engineering and physics of processes and structures design - which govern our capability for resolving our transportation problem.

And the time and space scale will have to be the 'now' of the next decade (a half generation time constant) and for the next 70 years (three generation time constants); and the space scale of a medium to large urban center, to the nation as a whole.

### B. A More Detailed Systems' Content

### 5. Summational Invariants, Equilibrium Distribution Function, Equations of State and Constitutive Relations, Equations of Change - The Content of an Irreversible Thermodynamics

It is a mathematical and physical reason that the summational invariants furnish the only basis for a scientific description, by physical law, of physical systems.

A full detailed mathematical description cannot be assayed here. It is not appropriate. But its descriptive outline will be briefly suggested, and some reference sources given to permit those who wish to follow the arguments there in fuller detail.

1. Given Newtonian mechanics

2. Given an ensemble of like active atomisms that preserve their form and freely exchange energy (nuclear particles, molecular particles, cells, people, stars, galaxies), and that show attractive forces at long distance and repulsive forces at short distance (The attractive forces are required to assemble them into ensemble. The repulsive forces are required to prevent them from dissolving into each other.)

3. Given such an ensemble contained by some boundary condition; or bound to some spatial domain or substrate.

4. As a result of interactional collisions, the motion of the atomisms will be distributed in an abstract phase space which will consist of its geometric displacements and their velocities. In physics, all matter atomisms possess mass, and it turns out that suitable canonical variables include the momentum - the product of mass and velocity - rather than just velocity. However, except for that scale change, we will refer to momentum or velocity indifferently. That law of distribution (of all ensembles like the given ensemble) is known as Liouville's theorem for the conservation of density (probability of occupancy) in phase (space).

5. For dilute ensemble concentrations (namely if the atomisms have large mean free paths of motion between collisions), one can sum up throughout the phase space of all ensembles to determine the dynamic restrictions that exist on any one atomism chosen at random as a result of the average interactions of all other atomisms in all other like ensembles. Namely one obtains the Boltzmann equation for the single particle distribution function.

6. The solution of that equation of equilibrium, for the case of dilute ensemble concentrations, is the Maxwell-Boltzmann distribution function. It states that the density of atomisms is uniformly distributed throughout the boundary space; that there is a common measure of average local kinetic energy, the temperature, which is uniformly distributed throughout the boundary space;

that the kinetic energy (the square of velocity) is distributed as a Gaussian distribution.

7. More fundamentally, it is found that the distribution function is only made up of those conservations that remain invariant under the cycles of collision that transform state into state. These are the summational invariants. In the most elementary collisional cycles (one like-atomistic species, whose atomisms are everlasting), these are the summational invariants of mass (the sum of masses are conserved), energy, momentum.

8. With added complexity, e.g., non dilute species, a much more complex form may exist for the distribution function, but it will still be made up of the summational invariants. If there is more than one atomistic species (including chemical change among these species), there will be added summational invariants of conservations of mass species for each mean constituent found.

9. Living species add another summational invariant. This is not a characteristic of the individual, as an ensemble, but of the species as an ensemble. Generation begets generation. Namely by a process of division or sexual reproduction, the conservation of the species occurs. This generalization takes place because conservation of number and mass are distinct process degrees of freedom in the complex living system.

10. Modern man, past the Neolithic transition to agriculture and fixed settlement, has added one new summational invariant, that of value-in-trade. As a result of interactional collision, value-in-trade, a notion purely in the mind, is conserved. It arises because the human is no longer tied only by a simpler genetic forcing function, but now has a time delayed, deferred memory and cognition system, which can invent abstractions. The first abstractions of 'tool' and high speed communicational 'speech' led the way toward discovery of this new degree-of-freedom to provide a decision-making forcing function that directed convection.

11. The single particle distribution function can provide the basis for determining various equilibrium measures of the ensemble. Such integrating averages lead to the equation of state of the ensemble, e.g., a statement of how momentum, energy, and mass are related in the total ensemble. Also it can lead to a statement of all other thermodynamic (really thermostatic) potentials which can be related to these fundamental potentials -e.g., Gibbs' free energy, entropy, enthalpy.

12. There is a new theme which has only been fully realized in a formal sense in the past few decades. If the statistical mechanics of an equilibrium ensemble is based on the dynamic fluctuations arising from collisions, there is a large dynamic phase space 'near-equilibrium' that can continue to be described out of the same construct. This is the domain of near equilibrium (or non-equilibrium) irreversible thermodynamics. Namely if there are 'small' gradients (this will represent either variations of mean conditions in space from one region to another, the literal meaning of a gradient, or variations in mean conditions from one period of them to another), whose variation is somehow smaller than the statistical mechanical fluctuations, those variations can be described, in the form of perturbations, as laws of change.

To give the issue some easy picturable substance, imagine a bank teller performing thousands of 'penny' transactions per day. The equilibrium thermostatics might be imagined caught up in the statement that all of his transactions must balance 'to the penny' each day. The irreversible thermodynamics would permit one to visualize the net daily flows in and out of the bank, as long as they were not too large a fraction of the total input (or output) transactions that each teller was performing.

Since in a statistical mechanical sense, the measure of transactions is the mean free path (the distance an atomism moves, on the average, before engaging in a collisional or transactional interaction) and the relaxation time (the time, on the average, between such interactions), these measures are useful to characterize the calmer fields of a near continuum overall systems thermodynamics.

If the atomistic mean free path $\delta$ is small compared to the physical dimensions of the field D

$$\frac{\delta}{D} \ll 1$$

and if the atomistic relaxation time $\tau$ is amall compared to the shortest process time P (e.g., imagined as a short term process period) of concern to the field

$$\frac{\tau}{P} \ll 1$$

then the field acts like a continuum and can be described by continuum mechanics and irreversible thermodynamics. Namely in the first place, it will have a near equilibrium distribution function, an equation of state, and irreversible thermodynamic equations of change. That is, the local summational invariants (of mass, energy, momentum - say per unit volume) will change in accordance with large field processes. These large field processes will involve transport processes and transport coefficients.

Thus, for a single atomistic species, these equations of change will read like -

| | | |
|---|---|---|
| momentum will change because (in a local region) | a gradient of pressure which is otherwise maintained is imposed on the local ensemble | and momentum is transported into the local ensemble by other local ensembles by their fluctuating distribution function characteristics |
| ordered kinetic energy will change because (entropy in a local region) | heat is transported into the local ensemble by other local ensembles by their fluctuation distribution function characteristics | and the mechanical order of energy is dissipated locally into heat |

| the density of matter will change because (in a local region) | material can locally converge because of elastic storage | and matter can diffuse in any gradients of mass (But this is for more than one mass species) |
| --- | --- | --- |

13. Summarizing our construct: Interacting ensemble of like active atomisms attractive at long distance and repulsive at short distance; near equilibrium as indicated by the Liouville theorem of conservation of probability density in phase space; the Boltzmann single particle densitv function; the single particle atomistic distribution function; the thermostatic time-averaged equation of state and other thermodynamic potential resultants; the resulting equations of change achieved by averaging over summational invariants results in an equation set in which the underlying atomisms do not appear. The equations are describable by self-consistent macroscopic variables. There is a broad dynamic range of phenomena for which the set holds. It encompasses both fields that have relaxed very near to thermodynamic equilibrium and ones that are close enough. The former is illustrated by a laminar flow field, the latter by a turbulent flow field.

For a collection of a single atomistic species, the equation set looks like

equations of change

$$\rho \frac{DV_i}{Dt} = -\nabla p + \mu\nabla^2 V_i + (\frac{1}{3}\mu + \lambda)\nabla \sum_{j=1}^{3} \frac{\partial V_j}{\partial x_j} \qquad i = 1,2,3$$

$$\rho T \frac{DS}{Dt} = k\nabla^2 T + \mu \sum_{j=1}^{3}\sum_{i=1}^{3} \frac{\partial V_i}{dx_j}\left[\frac{\partial V_i}{\partial x_j} + \frac{\partial V_j}{\partial x_i}\right] - \left[\frac{2}{3}\mu - \lambda\right]\left[\nabla \sum_{k=1}^{3} \frac{\partial V_k}{\partial x_k}\right]^2$$

$$\frac{D\rho}{Dt} = -\rho \sum_{i=1}^{3}\left[\frac{\partial V_i}{\partial x_i}\right]$$

thermostatic equations (constitutive relations)

$$d\rho = \frac{\gamma}{C^2}\, dp - \alpha\rho\, dT$$

$$dS = \frac{C_p}{T}\, dT - \frac{\alpha}{\rho}\, dp$$

compatibility constraint

$$\alpha T = \frac{\gamma - 1}{\alpha}\frac{C_p}{C^2}$$

continuum limitations

$$\frac{\nu}{CD}\left[1+\lambda/\mu\right] \leq 0.1$$

$$\frac{\nu\omega}{C^2}\left[1+\lambda/\mu\right] \leq 0.1$$

$$\frac{\lambda}{\mu} \leq 5 \qquad \text{(mobility limitation).}$$

These are the irreversible thermodynamic equations for hydrodynamic fields

$\rho$ = fluid density

$V_i$ = fluid velocity

$t$ = time

$p$ = fluid pressure

$x_i$ = coordinates $(x_1, x_2, x_3)$

$\nabla = \bar{i}\frac{\partial}{\partial x} + \bar{j}\frac{\partial}{\partial y} + \bar{k}\frac{\partial}{\partial z}$

$\bar{i},\bar{j},\bar{k}$ = unit vectors

$\mu$ = shear viscosity

$\lambda$ = bulk viscosity

$T$ = absolute fluid temperature

$S$ = fluid entropy

$k$ = thermal conductivity

$\gamma$ = specific heat ratio

$C$ = velocity of propagation (of sound)

$\alpha$ = coefficient of thermal expansion

$C_p$ = specific heat at constant pressure

$D$ = a characteristic dimension of the field

$\omega$ = a characteristic high frequency that might be found in the field

While a highly technical set, it is the minimum set that shows all real continuum characteristics that are coupled to its underlying fluctuating atomisms. It involves two independent kinds of variables - $t$, $x_i$; three kinds of dependent dynamic variables - $V_i$, $p$, $T$; two independent thermostatic variables - $p_o$, $T_o$ (mean states); four thermostatic parameters - $\alpha$, $C_p$, $\gamma$, $C$ ; three transport parameters - $\mu$, $\lambda$, $k$.

It also contains the more detailed statement of continuum limitations; namely that the effective mean free path can be one tenth of the field dimensions, and the effective relaxation time can be one tenth of the fastest period of concern in the field. Beyond these limitations, one finds the atomistic fluctuations beginning to make themselves evident.

The limitation on the bulk to shear viscosity is of another sort. The shear viscosity measures the transport of translational momentum from local ensemble to local ensemble. The bulk viscosity represents transport of internal energetic organization of the atomism. More precisely the ratio $\lambda/\mu$ is the ratio of internal action to the sum of internal and translational action. Action is a technical physics term denoting the product of energy and time. Thus the ratio is the ratio of energy bound up internally to the total energy of the atomism (in atomic physics, each mobile degree of freedom is associated with kT/2 energy, k here is Boltzmann's constant), times the internal relaxation time to the translational relaxation time.

The solution of such sets do not concern us now. It is sufficient that such sets exist and can be solved and experimentally tested.[1] A salient character of that field at the macroscopic field level, and as we have shown at the atomistic near equilibrium level, is that there are only two kinds of local dynamic processes taking place - the incoherent process (random walk) of diffusion; and the coherent process (connected communication) of wave propagation. In addition, in the field in the large, because of the nonlinear connection, there is unstabilizing convection. It is the instability convection of momentum swept into the local field, as compared to the momentum that can be absorbed by translation, that results in the Reynolds number transition to turbulence.

## 6. Social Physics - Application to 'Modern' Post-Neolithic Societies

Thus we are now up to the application to the physics of society.

We have begun such studies, under NASA (biophysics) and Army sponsorship. We do not propose to repeat that work here. We can provide references to that material. Our biophysics work may be captured in (4), (5), (6), (7), (8). Our introductory sociophysis can be captured in (9), (10), (11), (12), (13), (14). The bridging can be found in (15), (16).

In these latter sources, we have indicated the character of the individual human atomisms (see (6) or (16) for a key article on behavior)[2] Their behavior may be visualized as a ring of action modes which the individual human atomism threads.

As a member of a mammalian species, the kinds of behavior which emerges, in which the individual is caught up in resonant group behavior, has been identified ethologically by Scott (17).

- ingestive behavior
- eliminative behavior
- sexual behavior
- care-giving behavior
- care-soliciting behavior
- shelter-seeking behavior
- investigative behavior
- allelomimetic behavior (behaving like the rest of the group)
- agonistic behavior (conflict behavior, both aggressive and defensive).

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[1] References are given in (1). Additional experimental tests are found in (2), and (3).

[2] A technical note. In (16) we have indicated that for systems which have a large bulk viscosity, namely internal energy, it is not very useful to think about the momentum form of the equation of motion. That deals largely with the translational momentum. We have proposed that one thinks instead of an integrated form of that equation which becomes the action equation (energy-time product fragments). This appears in the form of action modes that the individual shows - a variety of mean free path and relaxation time actions. That is what the content of the references provide.

Iberall and McCulloch (6,16) have identified 20 fairly specific modes by which the human behaves. The character of modes is more fully discussed in a forthcoming article (18).

| | |
|---|---|
| sleeps | becomes euphoric |
| works | drinks |
| interpersonally attends | voids |
| eats | angers |
| talks | escapes |
| attends | laughs |
| motor practises | aggresses |
| rests | fears, fights, flights |
| sexes | envies |
| becomes anxious | greeds |

As an autonomous system, the human atomism cycles through mean free path collision cycles to satisfy his fundamental thermodynamic constraints - of conservation of mass, mass species, energy, momentum (via modes), and - as a living species, which thereby connects him to the conservation of the species - population number (namely he reproduces). In our biological writings, we have identified many of the internal thermodynamic engines by which these constraints are satisfied operationally.

The human species, within operational ensembles of human atomisms, operates through the molecular modalities of hunting-gathering groups. Man, when organized into autonomous molecularities, started out as tool using, abstraction forming (in particular using speech) hunter-gatherers. Namely men were both carnivores and herbivores.

The genesis of their organization, as primates, is suggested by an article of Eisenberg, et al. (19).

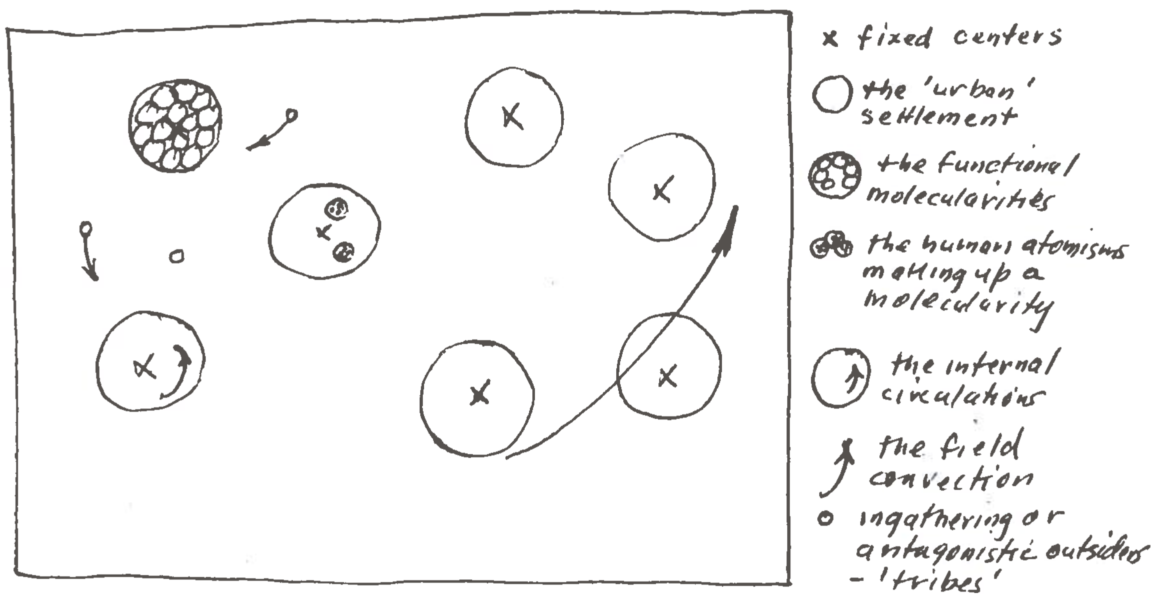
In (11,16), we have suggested that with the climatic warming of the past 12,000 years, man then precipitated into place by both domesticating and being domesticated by plants.

Our basic notion was that modern man, homo sapiens sapiens, was born and conditioned during the last 100,000 year ice age to deal with the following chain: an extensive yearly melting zone associated with the northern glaciers in Europe and Asia; seasonal photosynthesizing plants (e.g., grasses and grains) following that melting zone; grazers following the plants; small predators following the grazers and plants; predators following small predators, grazers, and plants; hunting-gathering man following predators, grazers and plants. That conditioned and selectivity bred man for 30,000 years (40,000 to 10,000 years ago). With warming, a 'hydrodynamic' dispersion took place.

The melting front rediffused into an extensive river-lake system. Plants - particularly some of the grasses and grains (with a double growing season) - took off after the water supply and established strong seasonal growing patterns. The grazers dispersed. The predators dispersed. Some men finally precipitated. They precipitated by attraction to fixed centers in which a variety of internal molecular behaviors (as an intensified division of labor) became possible. The dynamic stability was such (as a hydrodynamic Reynolds number instability) that both internal community flux streams developed as well as external flux streams.[1] To handle this large scale convective pattern, a new thermodynamic variable, value-in-trade, came into existence. The notion of value, as an abstraction, began with man (to be seen in his art, symbolizations, magico-religion, burial, initiation customs - all of which we have either hard or soft inferential evidence for - during the period 40,000 - 10,000 years ago). The notion of value-in-trade can be deduced from the very first fixed center constellations known - Anatolia and Armenia (21). The first material which can be traced in flux was obsidian as a tool material.

Thus from those fixed center beginnings of 10,000 years ago, trading constellations have existed, civilizations have begun.

As a picture, thus we call attention to the following:




A geographic field

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[1] We have described the dynamic process in (11) and (20). The essence of the matter is that a mobile molecular field - a fluid - becomes macroscopically unstable at a critical Reynolds number. At lower values, the field decays to a quiet near thermodynamic equilibrium laminar field. At higher values, it stirs up and maintains gross disturbances, turbulence, in the near thermodynamic equilibrium field. The criteria is $Re = V_{convection}/V_{diffusion}$. If the convective field sweeps in more energy than can be locally absorbed into internal mechanisms, it begins to develop large scale convective patterns.

What we are saying is that human atomisms are attracted within operational molecularities just as their primate ancestors were, and were structured just like their pre-Neolithic human ancestors were. The kinds of molecularities increase because of the cooperative social endeavor. It is still thermodynamic processes which are satisfied.

These molecularities are attracted to focal centers where the task of human thermodynamic autonomous living can take place. But the field is not fully stable. Because of value-in-trade, the convective pattern may be as extensive as the internal circulating pattern. Individual atomisms and molecularities may be caught up in both circulations.

The kinds of molecularities are richer than the simpler hunter-gatherer. Now there are about eleven such molecularities:

hunter
gatherer
scavenger
trader
agriculturist
deus ex machina (elite people energy organizer)
cognitors (abstractors, diviners, symbolizers)
nomad pastoralist
artisan
cog-in-the-machine
raider

The molecularity remains a group of comparable size to protohuman pre-Neolithic (Paleolithic) organization, namely perhaps 10-100 in size, clustering around 25. An individual atomism bonds with that number. The husband's and wife's and child's bonding groups differ.

With this brief introduction, (11, 12, 13, 14, 15,16) being a more detailed exposition of these ideas, we may indicate what the thermodynamics of post-Neolithic societies, as a science, is like, and how it may be conducted.

From the large bulk to shear viscosity ratio of the human (namely he ties up a large amount of his action - the product of energy and time - in internal modalities rather than external modalities), we cannot expect a very rapid relaxation to equilibrium. Rather, as we have shown with close neighbor liquid as compared to long mean free path gas organization (22), there are a number of approaches to near equilibrium, a sequence of inequalities. To cite a few:

<u>Human Physiological Relaxation Times</u>

0.1 second nervous impulse
6 second minimum attention set (likely CNS dominated)
100 second metabolic engine process (catecholamine dominated)
20 minute attention span (likely $CO_2$ dominated)
3-4 hour thermodynamic equilibrium (likely cortisol dominated)
24 hour primary activity cycle (dark-light dominated)
3-4 day metabolic governing (likely thyroid dominated)
30-60 day mood period (likely season dominated)
1 year epoch (climatic-seasonal domination)
10-20 year epoch (mini-career epoch-domination not clear, possibly growth changes, e.g., youthful growth, child rearing, career (molecularity) mastery, career practise, decline, systems degradation)

70 year life epoch (life span seems governed by one or more of a number of aging processes).

Social Communication Relaxation Times (Speculative)

1 day societal clock (day-night regularized)
2-3 day national response time (communicational unit)
7 day social week (endocrine governed, source uncertain)
30 day social attention span (likely seasonal atomistic epoch, possibly related to biological materials turnover)
1 year social epoch (ecologically dominated)
20 year generation times (nominal breeding time)
70 year social relaxation (individual memory can no longer reach)
300-500 year civilization epoch (coherence interval among connected centers)
2000 year large scale ideological metric.

Thus, for the individual, time soon melts into a continuum in which 'one day is like another'. Namely in a liquid equilibrium sense, in the order of three days most of the individual's process modalities have been exhibited.

But for society, while the daily process is quite prominent (living species are highly coordinated by the day-night cycle), and the yearly process is comparably prominent (because the human is equally dominated by the yearly ecological process - he cannot lose his tie to solar photosynthesis), the social memory - the source of bulk viscosity - has a time scale of the order of a generation, 20 years. Clearly what an individual knows at the end of a lifetime is considerably different than at the beginning. So he is a relaxation oscillator, not as an individual, but in the species. As an atomism, he moves the species along within his time slot with about 20 years measure. After about 3 generations worth - from child to adult to grandparent - the equilibrium time scale is moved along. Namely in that time scale, the near equilibrium of the transport coefficient of a bulk viscosity can have meaning.[1] And since the human is dominated by internal relaxation delays, it is the appropriate near equilibrium time constant for a social physics.

But many would object to that scale being free of detail. That is true in both a good and bad point of view.

First, note that it clarifies an endless philosophic debate about social determinism versus social 'free will'. Simply by having applied the notions of statistical mechanics, we have been able to point out that no determinism could apply to less than 70 year periods. Thus much of the pro- and anti- Marxian arguments have simply missed the first primitive limitation that a deterministic physics places on ensemble interaction.

Second, it has the force of being confronted by an inquisitive but still somewhat immature adolescent (a future leader, Alexander, etc.?) as to what

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[1] Just as in gases or liquids, the notion of a shear viscosity or thermal conductivity, or mass diffusivity can have meaning for periods longer than the relaxation of $10^{-10}$ seconds. Here we have to 'buy' the slower process relaxation of humans.

course he should take in life. One can point out that he will be dead in 70 years - a very high probability prediction - and that there are many courses leading to that end point. Then by analysis of the dynamic constraints - cultural, economic, ecological, others - it is possible to specify somewhat optimal choice paths for that individual. These will be each subject to some optimization notion, e.g., how to select the maximally stress-free life, or a life leading to greatest riches, or the most adventure filled life, etc. Namely adolescents clearly often make such choices with lesser guidance than a full fledged study might provide.

The selection of such 'optimal' strategies does not give a guaranteed success path. It gives one of high contingent probability. It is in that sense we offer this kind of model for strategic planning.

It is based on the notion of a near equilibrium distribution function that defines a fairly broad 'minimum'. Thus choices all made from near the minimum 'potential well' are associated with equal probabilities of occurrence, and thus more than one optimization criterion can be applied.

Third, there is a 'life' to materials and structures comparable to the human's. We do not believe this to be an accident. Both lifetimes are entwined by selection. Thus for economic purposes commonly 'major' materials are supposed to have a near generation lifetime; they tend to linger on longer to near 50 years. We believe that this is associated with the vaguely defined Kondratiev cycle in economics.

Thus our American factories, structures, etc. are more nearly of 1925 vintage (building boom) than most would immediately decide on. Of course the post World War II epoch of 1945-1950 was another building era.

Fourth, our notion is that if one provides a 'near thermodynamic equilibrium' projection for the order of 70 years, then for the shorter term kinetic fluctuations of the daily, yearly, 10-20 year character, one can fill these scales with the more common engineering network models. Such models are valid as long as they don't violate thermodynamic constraints too much and they sum up in time to become part of the noise.

So, if this spirit is accepted, we can get on with thermodynamic modelling.

But at the present time we are not prepared yet to write fully analytic equations. Thus we have to use the strategy of near equilibrium kinetic fluctuations. What we have done in liquid theory is shown that Stokes-Einstein diffusion steps are good enough to carry us to near equilibrium in perhaps 3 such steps. For social phenomena, the generation time is representative of a Stokes-Einstein diffusion step, which will then relax to equilibrium in say 70 years. So these diffusional steps are our unit time scales.

But, we must stress again, society is not a liquid melting pot, but a plastic mixing pot. Thus the three generation time scale does not wipe out memory of the thixotropic origin of the molecularity. It mixes the occupational molecularities and their atomistic occupancies into a sort of mottled or striped mass - like a mixed bread dough, or taffy, or asphalt material.

Its internal structure is not crystalline, but quasi-crystalline.

Spatially, the roaming range of the molecularity remains about 1000 square mile, the diameter spanned by the daily walking range of a human. That hasn't changed since pre-Neolithic times. However now with augmented transport (of mass) and communications (of energy flux), that range may be divided (e.g., a bit in N.Y., in California, in Florida, in Europe, is an extreme example.)

A very primitive check on these numbers and of the character of the theory, is that if the underlying notions are valid, the diffusive time scale, namely the velocity of passage of new ideas because of value-in-trade (and the human cognitive and abstractional capabilities) is of the order of one roaming distance (e.g., 20 miles) per generation (20 years), or 1 mile per year. This number has been demonstrated to be the diffusional velocity for metallurgy, pottery, agriculture, even population.

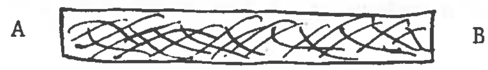
This does not mean that every idea is impeded from earth diffusion for the order of 5000 years per continent. It is meant to suggest that transfers from 'culturally' bound entity to culturally bound entity takes a generation, on the average, to bridge. (Recall that culture has as its core meaning the assemblage of epigenetic artifacts, all of the added 'man-made' extensions in the case of human culture, that are used in the conduct of the life processes. Thus the ideas we are talking about are related to such significant changes.)

On the other hand, with poor convection, some regions may be isolated and bypassed and show delays up to 5000 years.

Thus - our notion - with convective circulations having started around value-in-trade among more than one civilizational center 10,000 years ago, there has been an unbroken canvas of civilization for that period of time. It is not that the canvas hasn't stretched and shrunk and been distorted, but the main currents have continued unbroken around the world. Namely it was freely in organized cooperative motion over the Eurasian continent and northern Africa unbroken; an offshoot of man travelled in pre Neolithic times (Martin: about 13,000-14,000 years ago from Asia; others: earlier, possibly a 25,000 year ago slot) to the Americas. Very possibly an independent start up of civilizational cultures began there which was only joined up to the Eurasian canvas about 500 years ago. It has now essentially spread to all the occupiable land masses. While we visualize these processes as diffusive - wave propagative physical processes, they are played out against a very inhomogeneous ecological field. Thus the 'history' of man is not a smooth simple boundary condition problem. It is for that inhomogeneous field problem that we are concerned with prognosticative description.

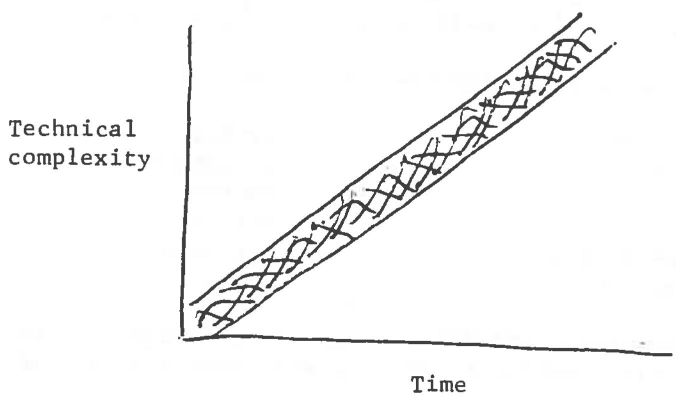
If man did not have his coordination center, his 'history' would be a very slow near genetic evolution as his long term pressure moderately interacted with the existing ecological species (in the balance of ecology, species eat and are eaten. Namely they aggress and defend, and thereby change the geophysical-geochemical-biochemical-hydrological earth character.) But his coordination center and memory speeded up the epigenetic evolution. As a result of his characteristics, we can view history as consisting of the following: Prior to 500 years earlier, man carries an 'archaic' view of his group history. The past 500 years of interaction forms the mixing pot of his cultural relations. The last 70 years is his near equilibrium relaxation to his current operational behavior (i.e., from grandparents mid-life to one's own mid-life). 'Now', we face the dynamic extrapolation to the next 70 year relaxation. What is going to change is the epigenetic character of technology.

A unit of communication, a simple sentence (in an Iberall sense), is a rope. Namely a weaving together of many complex threads in a complex series-parallel array, so as to span A to B (here to there, hence to thence).

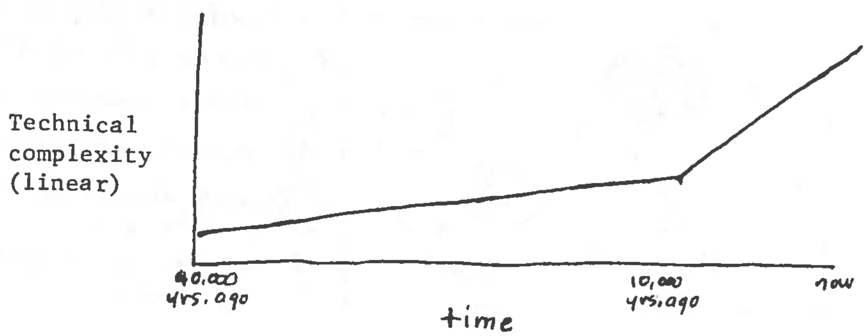



It is tied together by diffusions and wave propagations, coherent and incoherent elements, frictional slips and elastic couplings.

Technology, or the development of human technology is a rope This is a complexity-time space




It is linear - for the past 10,000 years (since fixed settlement agriculture). It may very well have been linear before with a lower slope, i.e.,




The 'current' 10,000 year history has been linear. Technical complexity is at this moment undefined in metric. What the rope and its thread show is a great variety of 'sudden' discoveries, each ariving at the level at which previous technical complexity has reached epigenetically. The total increment of technical complexity is thus the sum of all of these small bits that are added piece by piece. Just as Gamow showed that stellar processes along the main sequence furnished the arrow of time for cosmology, we can now assert that the development of technological complexity is the arrow of time for modern man's epigenetic unfolding.

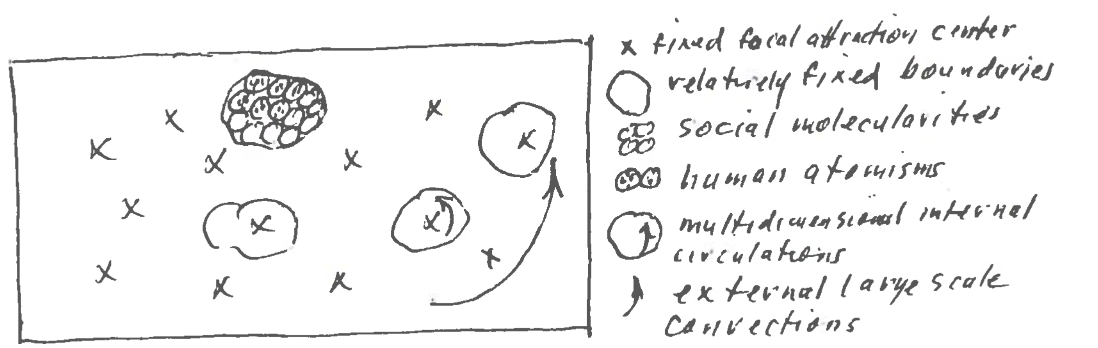
The intrinsic reason for the linearity was furnished in a note sounded by H. Slavin. Namely there are always two views or outlooks toward the existing status of almost every epigenetic time - one, either that things are on the verge of exploding and the future knowledge will explode epigenetically; two, that we have just about reached the saturation limitation of knowledge. Between these two, the future 'always' seems to emerge emanatively 'linearly'. Namely at each point we remain left with the epigenetic ability to make about the same amount of 'progress' or gain in technological complexity.

So of the eleven molecularities that we operate with

agriculturalist
pastoralist
raider
trader
cog-in-the-machine
deus ex machina
artisan
scavanger
hunter
gatherer
cognitor

the technological complexity that faces, regardless of where we are in the post 10,000 year history, remains still a linear emanation from where one is.

1. Thus we start any round model for a 70 year (3 generation plastic-like mix) social relaxation from a mixing pot picture




The large scale location of fixed centers, boundaries, molecularities, convections have a coherence at 'civilizational' level, of the order of 500 years. The earlier 500 year picture provides the mixing pot patterning of behavior which represents the culture. The check list balance has to be of

mass species
momentum (as modal behavior)

energy
population
value-in-trade

Society is made up of two populations - the mass of people, and the deus-ex-machina elites who can govern people-energy. The latter are a small group who are precipitated out of the existing operating conditions. They are hyper-kinetic. They are governed by their own interests. In the end, they regard all plants, materials, fluxes, animals, humans - as domesticable entities. On with the game - of life!

Now what does the game of social life consist of? Note, out of the past 500 year cultural heritage, there have been fixed focal attraction centers developed. These have ecological reasons for being. They have become chained among a series of nearby focal centers, 'friendlies', with whom the centers can exchange mass and energy fluxes by value-in-trade. Each center will encompass a considerable number of operational molecularities. At the level of a moderate number of such centers, a constellation, conditions for a living near equilibrium are established. How?

Basically by encompassing a basic check list of mass, energy, and service fluxes that need to be satisfied. How these are satisfied is largely determined ecologically and by the 500 year cultural heritage. <u>There is not one pattern</u>. Any that fit will do.

So, as a prototype as such chains we offer[1]

| | |
|---|---|
| shelters | motor power |
| clothing | transport |
| food | defense |
| water | artisanship (technological) |
| sanitary disposal | male-female human population |
| material supply | governance |
| fuel energy | |

Namely, given a human male-female population, they can be organized into shelter builders and maintainers, clothing makers, food growers, and transformers, water suppliers, waste disposers, material procurers and transformers, fuel energy procurers, motor power suppliers, transport suppliers, defense suppliers, and artisians. But these roles do not occur by themselves. There must be an elite governance to organize the chains so that they keep working.

But these urban centers require more governing energetics than the 25 person (10-200 person) pre Neolithic hunter-gatherer society. Its basic difference is that storages-in-time are essential. And it is quite clear that

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[1] Note, we are inventing the equivalent of a social chemistry. Thus because of its primitive state, we will talk of the equivalent of 3Å molecules, as a prototype, in spite of the fact that molecules exist with numbers from 1 to $10^6$. Nevertheless there are basically two populations - inorganic molecules in the molecular weight range up to 200, centered on 50; and large organic molecules. It is similar simplifications in notions we deal with here.

the time units are the day (not much different than earlier societies), the year (much more serious because of the dependence on crops), and the generation. The long time storage organization requires holding idée fixe in the mind's storage bins for long periods of time. It is only value-in-trade in substantial amounts that can provide the gradient metrics. And so organization and change of the generation time scale becomes the slowly changing way of life.

Each generation transmits a heritage to the next generation. But it is the chemical and electrochemical characteristics of the human central nervous system that govern the patterning of that transmission. One must surmise that 30,000 years of hunter-gathering, while it may not have produced large genetic changes, certainly bred selectively 'emotional'[1] characteristics. We have proposed what seems to be the emergent order.

If physiological survivorship is involved, the priority of hungers. as excitations to modal motor action, is likely:

> oxygen demand, medium temperature range, sensory input, motor freedom, water, food, gravity, sexual discharge.

If marginal survival is assured, the priority of excitations that change the modal outlook likely are:

> high speed motor excitation (combined effects of displacement, velocity, and acceleration below the pain threshold); high speed sensory excitation (the priorities are visual, tactile, oral, olfactory); wide contrast food excitation; extensive erotic excitement; command-control of other systems, particularly human.

The history of the entire period of 10,000 years of post-Neolithic man is not really difficult to learn - in principle - although in practise it is. The difficulty is that no one has assembled the kalaidoscope of images required, largely as space-time maps of the essential variables required for thermodynamic understanding. Oh yes, it is of some merit to drop the names of a few popularizing sources (the danger is enormous to keep extending the list to show scholarship, enthusiasm, and the compulsion to make sure that you can see through any one writer's bias or limitations of knowledge.) So we offer (11, 13, 14, 15, 23, 24, 25, 26, 27, 28, 29, 30). While that might have seemed to be a casual dropping (or dripping) of offerings, any reader who will slog his way through will have some feel for the canvas and fluctuational nature of that canvas of man's history. He may then go on to more specialized, perhaps even 'better' history in details, but at least he will have a world view of the experimental content of the history of interactions for which we propose a science.

In particular, we wish to scientifically 'bias' his view toward the fluctuating molecularities which are caught up again and again in larger civiliza-

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[1]If pure physiological chains refer to chemical and chemoelectric chains that are internal to the organism, with the ambient condition as boundary conditions, behavioral chains refer to such chains that are completed with external links. Thus 'emotional' here refers to behavioral properties where external links are particularly selected.

tional entities; in the larger and longer scale that makes up these civilizational entities; on how elites tend to dominate and drive these civilizational entities; that regardless of how they drive and consider their efforts unique, somehow elites seem to be involved in both the building up of the civilizational patterns in an early phase and in the tearing down in the latter phase; that over the 10,000 years of post Neolithic history, the essential patterns of living, as far as the human atomisms are concerned, have essentially not changed; that the only changing character one can detect is the 'linear' diffusion rope of technology; that the academic historian has stressed literacy too much in describing the measures of 'importance' of civilizations;[1] that the basic processes - over and over again - remained local diffusion and wave propagation, and larger scale convection, but with a mixing whose 'cultural' character never decayed with less than 500 year time constants; that the governing style of these larger scale civilizational entities does not matter.[2]

Thus, it is our contention, given an age and a region with its ecology and its cultural heritage and its archaic view of the more remote past, any human elite (namely a highly energetic '**charismatic**' individual - the charisma refers to his ability to bind disparate things, including people, into a functioning group under his notion of leadership), in a statistical mechanical sense (namely it is not the case that this one individual may succeed or fail, but what would happen to an ensemble of such cases.)[3] can develop a governance that fits the conservations that will work - for a time. The problem we are concerned with now, is given our prejudices (and we do have prejudices - specifically we are democratically, humanistically, intellectually inclined, tending more to a radical - conservative eclecticism as we age), can we provide the artisan - technician - bureaucratic - rational guides for the future that indicates the higher probability avenues into the future.[4]

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[1]Note that the 'civilizational' patterns existed prior to written records of 5500 years ago; that such dominant patterns as the Mongols (nearly 2500 years), and the Celts (approximately 1000 years), etc., existed over large territories contiguous to literary (writing) 'civilizations' without any difficulty in knowing or asserting their controls.

[2]As Aristotle said there are the rules of the one, the few, or the many.

[3]Some would not regard such a statement as 'deterministic', and it is not as an individual prediction. Statistical mechanics deals with the probabilities that emerge from dynamic interactions in which certain conservations must hold. At the present we are still feeling our way to the formalism. Nevertheless, the statements here, not yet fully quantified, are such probability statements. Namely there is a high probability of fulfilling leadership conditions that will function. As we have intimated, such conditions do not last forever. Neither a Hitler, or Mao, or Alexander, not even a Phillips (e.g., Southern conservative coalition) can succeed indefinitely. In 500 years, empires come tumbling down.

[4]Again this involves no contradiction between will and inevitability, "Yes you are going to die, oh man", but how is open. The fatalist perhaps Eastern view, may be that all paths lead to your fate. But the scientific view is that there are likelihoods associated with each branch. Systems - living systems, all systems - select low global paths. They have to. They cannot afford the sustained energetics of high roads indefinitely. Thus the ever continuing relaxation toward near thermodynamic equilibrium.

But elites dominate for impulsive periods less than the order of a generation. If we are to do 'long range' prediction, we are not doing it for a particular elite (although we are forever faced with the problem of finding a patron, a "Pharoah in Egypt who knew Joseph"). Thus we must integrate over the likely future to arrive at a notion of where the elites of the next three generations may take our national moiety and the rest of the world, so that we can see what kind of future we can plan for.

That sentence has no infinite mysteries. It is the standard one particle distribution function problem. We have had to average over all many body interactions to where we have a notion of what their average state is like, because that is the state <u>on the average</u> which our next few near equilibrium relaxations will have to deal with. That philosophy of the future 'is's' of society has to substitute for the 'oughts'. Only what can fit the constraints can emerge. Oh yes, you can put a little 'body English' on the future but not much.

This notion is neither pro - nor anti-revolutionist, pro - or anti-reactionary, pro - or anti-radical. It requires the metaphysical belief that man, as are all other systems, is caught up in the physical chains that dominate all the systems above and below him and that in related fashion dominate him. Obviously, there are many scientists and non scientists - who won't believe that, but we doubt that very many of them have the ability to provide constructive predictive science for any subject.

So, in recapitulation and summary again of a near equilibrium 3 generation time constant kinetic computation for a large scale space-time national moiety caught up in a civilizational web, we propose the following:

1. With regard to the archaic period (1000-500 years before present), trace the diffusional, propagational, convective influx of ideas, living systems, energies and materials into the domain of interest, and also its boundary domains. Relate their evolution and precipitations to the ecological conditions in the region.

The patterning style is with regard to

shelters<br>clothing<br>food<br>water<br>sanitary disposal<br>material supply<br>fuel energy<br>motor power<br>transport<br>defense<br>technological artisanship<br>human population<br>other living species symbiosis<br>governance<br>value-in-trade

Summarize the 'value' system of the moiety (its self-image of how it regards itself and the rest of the world). This is an instructive task, for it may require more work on the part of the summarizer in uncovering how many layers and what is the minimum statement required.

2. Apply that entire apparatus as a boundary condition to the subsequent enculturation period (500 years to the present). In particular trace the

same evaluation, precipitation and diffusions for this period. However pay more attention to the formation of the molecules organization.

Under each compartment, summarize the 'cultural' content of those compartments. Summarize the 'value' system of the moiety. Also summarize the distorted view of the value system of the previous civilizational fluctuation, for 'now' that value system, instead of presenting the current 'cultural' view of the society presents the mythos, the mystical ethos of the society.

3. Use that entire apparatus as a boundary condition for the last three generation fluctuation (70 years to the present). Namely it is good run-in practise to provide a more detailed view of the current society.

But now the chain must be as structured as for the future. Namely the order is:

given the past as boundary condition

retrospectively prognosticate outward the 'linear' technological forecast. (There is no reason that a 200 year time scale shouldn't be adopted. The ticklish issue is then to cut that into 'thirds', i.e., what might be the next 70 year segment.)

estimate what kind of elites would be precipitated to take advantage of the forthcoming technology.

estimate how these interacting elites might incrementally change the course of the life patterning style - shelters, clothing, etc.

estimate how the large mass of populace would react to such incremental life style patternings and thereby change their style of living to conform.

estimate how the population rate would change (namely how the populace would reconsider breeding rates) Make any corrections in your forecasts that its future 'now' has indicated is necessary. This will provide some corrections but also some notion of your forecasting errors. (It is only considerable experience with such computations that will minimize the errors.) That exercise should project the recent past into the present with some notion of the incremental changes that have been made within the cultural and value systems of the moiety.

4. With the more detailed boundary condition of the past 70 years, perform the same computation round for the next 70 year period. Namely make a linear technological forecast, etc.

The essence of the modelling is: (a) A 'knowledgeable' forecast of the technological future. This is not so much a prediction of what will happen as an estimate of the complex of all notions that will have their turn at bat with some apriori assignments of probabilities. The number of rights and wrongs aren't as significant as the patterned coloration that arises from the average potential changes. That is why the future only emerges diffusively within the bounds of a 'rope'. (b) A'knowledgeable' forecast of the technical content of elite decisions (i.e., all of the technical aspects of managing an orchestrated human entity of which the elite is the mobilizer of its people energy. Namely the elite orchestrates molecularities. He is more than a pre-Neolithic tribal leader of one molecularity of 25.)

Both of these 'knowledgeabilities' must be based on a good knowledge of the mythic and cultural heritage of the moiety and its governing civilization.

But this is as far as we may permit this first round of theory to take us. We have gone somewhat further in forecast in (14, 23).

[A very basic question that must be answered is why does the irreversible thermodynamics of this system - the human social system - require such an elaborate specification of its prior 'thixotropic' history, e.g., its mythic and cultural characterization? We will supply two answers. The first, an engineering answer, is to suppose that one has only a limited experience with the relation between alloying and heat treating a bar of steel, and its subsequent use application to a stress-strain pattern. We suggest that it is necessary to use all the detailed science one has to trace the correlation. The second, as a more fundamental scientific answer, is to consider an enclosed liter of gas or liquid. To fully characterize its state, in principle, one need only name its molecular constituents, its temperature, and the applied pressure. In a homogeneous crystalline solid - if there were no domain limitations - the same status might be possible. However, because of more than one crystalline stability, it might be necessary to indicate which state emerged. Issues of metastability of competing states have arisen with order-disorder theory. It turns out that the homogeneous crystalline state is not likely. Thus dislocations and domains emerge. The characterization of state now requires some knowledge of its thixotropic history - of formation out of a melt, its heat treatment, its cold working, etc. Does this pay? Yes, with some engineering experience, a rather precise specification of state, properties, expected behavior can be provided.

At most, one has a polycrystalline homogeneity. It is no longer homogeneous at minimal crystal unit cell dimensions, which constitute the 'molecularities' of the solid crystalline state. (The molecularities are made up of the regular arrangement of different atomisms.) Instead, a larger scale systems 'molecularity' arises. There are polycrystalline units made up of microscopic but small crystalline arrays. Thus now the character of a mixing pot (precipitating out of the melt, and being formed and reformed by its conditioning treatment, its past history), the mixing pot inhomogeneity of a society emerges. In society, it is even somewhat more complex than the regular polycrystalline structure of a simple metallic alloy. It has the character of heat treatable and cold workable amorphous mixes, which exist by a variety of macroscopic bindings of its local detailed structure. It is both our lack of experience with these mixing pot solids and its heterogeneous nature that poses the requirement for extensive prior history specification.

Can it be done at all by science? Yes, this is an early view of such a science. It has some chance for success because it has a scientific overview, and has been able to identify the atomistic and molecular structure. Clearly, it is a modelling attempt.]

Thus we now turn, in first round, to the technical 'network' aspects of transport, particularly as it fits our social thermodynamic modelling.

## C. Narrowing of Focus to Transport

### 7. Materials Transport - Example of Systems Logics

Our thermodynamic position was clear. The momentum equation, for a system whose energetic fluctuations are largely expressed internally, operates by modes. All systems operate by modes, but we have identified a number of different kinds of systems. There are two near homogeneous states of matter - gaseous, and liquid. The liquid already (in x-ray spectroscopy) begins to show the formalisms of the solid state. We then find inhomogeneous states of matter - the solid state, and beyond, the vitreous, the living state, the plastic state, and then a variety of mixed states. The social system is such a mixed state. It is a plastic-elastic mixing pot state of matter. It has precipitated out many inhomogeneous formal structures which behave as mixtures of structure and function.[1]

We have indicated the modes. In post Neolithic society they include transportation.

We intend no great scholarly study, but clearly in man's first 30,000 years of existence, as hunter-gatherer, man was dominated by the energetics of food. Namely a near daily energetic balance had to be struck. (Not literally every day, but seriously not put off for more than a few days.) Thus his behavior was dominated by a daily roaming range, which therefore could not be much more than a 25 mile radius circle. Further that roaming range could and did have a seasonal excursion.

As such, except for range, the problem was no different for any other living species, animal or plant. The basic problem is a slow motional process that fits the performance of daily modalities, with a seasonal variation. The basic motional paths are in accordance with some driving potential gradients, e.g., in the case of plants, a water gradient, solar days of sunlight, nutrients. Thus circulation patterns that fit the ecology emerge.

A recent scientific article (31), admittedly for a particular case - the motion of bacteria - provides a clue on how gradient motion may be established. Namely it can be done by temporal processing. The author tried to test whether bacteria detect a space gradient between attractive and repulsive chemical signals or operate in time. Their motions are straight (mean free path?) swims, alternating with fixed angular veerings. By 'suddenly' changing the chemical content of the field, he was able to show that what changed was the straight path length, namely in a favorable milieu, they swam longer in a straight line. Thus the effect in a spatial gradient field is to move toward the more favored pole.

We are quire pleased with the result. It is similar in philosophy to the temporal processing notions that one of our colleagues, Brian Goodwin, has been advocating and demonstrating for the axis of biological growth.

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[1] Our general view, per a view of point particles acted upon in translation, namely a simple gas kinetic view, is one of function. But then these atomisms aggregate and bind up in shorter or longer states. These internal degrees of freedom represent our beginning notion of form or formal process. Man precipitates institutions and uses materials in such formal chains.

Thus as a general strategy, we view the formation of transport coefficients, e.g.,

$$y = kx$$

(examples? Ohm's law for metallic electrical resistors, Newton's law of cooling, thermal conductivity, shear viscosity of a fluid) as a local thermodynamic engine process which either leads to a simple homogeneous diffusion, or <u>if internally coded</u> (e.g., by a nervous system or other clocking process), can provide a directed diffusion.

But the motional diffusion need not be homogeneous even when directed. It may be quantized or discrete. Thus spatial paths may wear in.

We will depart from proto-human wandering paths and offer the notions from two complex system's transport logics that we have solved. The point is to show how a design algorithm may be found which solves the problem of dealing with thermodynamic and dynamic constraints, The two cases are the flow of rivers and the flow of material in the arterial system in mammals. These are two of the most complex transport systems found in nature.

<u>River Systems</u> River flow is the effect of impulsive precipitation of rainfall and delayed flow in the porous ground. The basic potential is gravity. Water flows down hill. But a river is not a homogeneous uniform flow of water in a fixed channel. A river is the complex interaction of the precipitation with the ground, whereby both seepage into the ground takes place, a channel for run-off is eroded, and a bed load of material is moved within the channel. A river is thus a dynamic entity whose flow is competent to move its bed load; and whose bed load is competent both to carve out and refill the channel.

That notion of a river moving its bed load was the foundation for du Boys' notion of a minimum shear stress at which a bed substrate would yield.[1] That notion has furnished the primitive basis for most views of a non Newtonian 'plastic' fluid, which has a minimum stress at which it begins to flow. The significance of this description is that it changes the entire notion of rivers as hydraulic channels which obey some more or less elementary hydrodynamic laws of flow to a complex transport system by which the irreversible thermodynamics of the hydrological and meteorological and geophysical cycle govern the operation of a system at near equilibrium.

We do not wish to dwell unnecessarily and too long on this system, but we want to use it to establish how transport conditions are satisfied. More details are to be found in our earlier studies (32). But we do want to stress its developmental logic.

1. At the longest time scale ($5 \times 10^9$ years), a sun and a planetary earth come into existence, where on the earth, temperature conditions favored formation of a geophysical solid core, a large water cover, some extruding solid land masses, and a gaseous atmosphere, largely of oxygen, nitrogen, with a few other gas constituents, wherein the water entered into a cycle of evaporating and condensing.

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[1] duBoys, Ann. Ponts et Chaussées, <u>18</u>, (5), 141, 1879

2. Because of the plastic-elastic earth, land mass movements - vertical and horizontal - with a time scale of about $10^8$ years have come into existence. At that scale land upheavals raise, fold, and crack the earth. Thus the precipitation characteristics of the condensible component of water find themselves concerned with gravitational run-off of these land masses. Thus a near equilibrium process, a thermodynamic engine chain begins to emerge, somehow dominated by the solar source and gravity.

| | | | | |
|---|---|---|---|---|
| Precipitation of water from atmosphere | = | evaporation of water from surface | + | run off from land |

3. But the run-off water - both physically and chemically interacting via water solubles - runs off the land by wearing in channels. These processes are at the $10^6$ - $10^7$ year scale. Namely the land upheaves ($10^8$ years); the waters playing at $10^6$ - $10^7$ year time scale, wear the land down. It is out of these slow past processes that we see the river system (as a transport system).

4. We were asked to describe that system as a synthetic hydrology. To bring this within a statistical mechanical, irreversible thermodynamic construct, we had to have the equivalent of an ergodic hypothesis. Our basic notion was that the class of all geological states of the earth land mass itself represented a nearly ergodic ensemble. Namely the changing geological states of the earth-river systems themselves were such an ensemble for the past $10^9$ years. On such topographically deformed two dimensional surfaces, that slowly changed in geological time, we had a mappable problem.

5. A land mass (e.g., the U.S.A.) could be mapped by altitude contours and the mean lines of rivers. The sets are not orthogonal, but very loosely so. (The basic physical theme is that water runs downhill, and that rivers do not conform exactly to 'lines of steepest descent' but meander among them.) The average precipitation intensity (a continuous variable, mappable on the space) at any point is either on a mappable river or will flow down to the river.

6. The fundamental physical premise we supplied was that yesteryear's rains (in geological time) determined today's rivers. [The importance of that notion for traffic flow cannot be overstressed. There is no one unique pattern that makes a river system. This longer term geological process can be seen by playing a stream of water from a faucet on members of an ensemble of like sand piles. 'Rivers' will be worn and sand distributed around. Each pattern is an example from an ergodic universe.] Thus for 'today', we must start from whatever river pattern 'yesterday' left.

7. We treated the shape of rivers as an abrasion process. Its basic property is that it must wear in a flood plain (a function of precipitation extremes) which was competent to allow low average velocity water flow (in the range 1-10 ft. per sec.). If the average velocity is too high, it scours out a more extensive cross-sectional area.

8. The river, between any two indexed points, increases its average flow in accordance with the mapped area that it drains. Namely one goes outward, from river stations, in the topographic map of the surface along lines of

steepest descent contours out to the ridge line separating the one river valley from the adjacent ones. That defines the drainage area betwen river stations.

9. For the average run-off from that area, namely how much the average river flow has increased between any two stations, we have provided the following theory: The river and land contours and land permeability have been marked in geological time. The ground permeability has been further modified by more recent climatic conditions, perhaps of the order of $10^2$ years, involving freezing-thawing and plant growth concomitants of these changes. But 'now', e.g., in the past 10 years or so, there has been an average precipitation P on that drainage area. We have to deal with the question of causality. Of that precipitation P how much runs off R, how much evaporates E? We submit the topology provided furnishes the answer.

Imagine all of P equal to R. Then solving the ground water flow problem (which we did in (32)), one will find that a free flow water surface would break out far above the river contour. By successive reductions of P by E, namely P-E, one finally finds that R = P-E, which will just break out at the river contour. Namely the river today is itself the indicator of the average run-off of the areas it drains. That is, just the average river contour itself determines the average gain in run-off per station, and thus, in sum, how much finally drains to the oceans. This notion provides a theory of the water table (namely rivers mark the breakout of the water table).

10. In this model (tested in (32)), evaporation is thus the residue of P-R. We show then how E = P-R determines the average humidity of the region, by a novel boundary layer theory. The boundary layer, we show, is the height of the cloud cover at approximately the triple point temperature of water (the temperature lapse rate is about 3°F per thousand feet). Also precipitation is independently caused by large scale meteorological processes. (We show that the average humidity and precipitation are coupled. The model is simple. A pot lid that covers a saturated space would show no dripping. If the pot is now shook, so that an average dripping 'precipitation' took place e.g., suppose it were somewhat cooled, then the humidity would drop below 100%, so that the evaporation inside the pot could equal the precipitation). Thus we have coupled the hydrological cycle to the meteorological cycle. [This is a very basic illustration of what are the irreversible thermodynamic issues. It is not really possible to do the hydrological cycle independent of the meteorological cycle. But as the net effect of the decompositions that we did, we managed to isolate the meteorological inputs down to the nonlinear operational modalities by which the composite system worked. Most specifically we were able to show that impulsive rainfall, tending to follow a seasonal pattern, related to a large scale limit cycle tidal oscillations of the atmosphere in the 6-12-24 hour range so that, when coupled with the solar constant, one found a psychrometric process governing the heat transfer of the greenhouse effect - reradiation from the clouds at lower temperature than received radiation - and the mass transfer by evaporation from the ground. The Bowen ratio, expressing the status of the psychrometric process, was found to come very close to psychrometric equilibrium in a matter of weeks. This then measures the real first near equilibrium process for the hydrological-meteorological process. At longer term, the yearly seasonal variations tend to govern as a solar drive.]

11. Then, as one final piece, since the interaction of ground waters,

loosening and carrying bed load to the river, with the ground determined the sedimentary bed load that the river would have to carry (although a good theory is not in existence), and the river competence to carry bed load was limited to low velocity, one was left with the requirement that the river adjust something to carry its run-off, and provide its average velocity that could carry its average bed-load. (This is quite real. When the river doesn't have the competence, it silts up.) What has to be adjusted for a given effective shear force of the bottom of the river(governed by the force needed to move the bed load, not by viscosity of water. Namely as Richardson showed, there must be an effective viscosity which develops with a sedimentation law of atmosphere) is the effective downhill slope of the river. But the mean channel path is already carved. What can be adjusted? Why the meander rate. Namely the river meanders with arc length s which is longer than the nominal river path $\ell$. (The detailed mechanism has to do with how one side of a river erodes and the other side silts up. This is another example of nonlinear instability.)

12. So, all in all, by a series of very active modal processes, all part of the total irreversible thermodynamic cycle, and markedly of an inhomogeneous nature, the hydrological transport cycle emerges in the ground.

<u>Arterial Systems</u> The second example we wish to touch on briefly is the arterial flow system in the mammal. We have worked out its design characteristics for a 7 decade range - from 3 gm shrews to 120,000 kg whales. Our descriptive notions for this system are interesting because they contain further clues on the self organizing competence of a system to start up in accorance with irreversible thermodynamic principles.

1. Given in utero, a beating fetal heart and a mammalian kidney, we have indicated a hydrodynamic path by which the major design and transport characteristics of a mammal can unfold without a genetic code. The genetic code, expressing itself in cellular characteristics, then is relieved of large scale systems' development, and instead can then much more easily flesh out the details.

2. The stability issue is much like that in the sands and rocks of hydrological development. Here the medium is a gel and the developing force is a Bernoulli pressure pulse ($1/2\ \rho V^2$).

3. The pulse develops a cavity of circulating and returning fluid to the asymmetric valved heart. This cavity grows to a domed region (the ascending aorta) as a result of the pulsing pressure. Because the cavity contains circulating oxygenated blood, it becomes lined with cells that can survive off of that supply. The cavity forms a characteristic number of branching elongated cavities out of the continuing hydrodynamic instability. They have about a 20 to 1 length to diameter ratio. They too become lined with cells. The geometry and topology (e.g., wall thickness to diameter, 20 to 1 length to diamter ratio, 6 branches) arise becuase of the limiting resistance of cells to dimensional stress. Thus the cavities enlarge to reduce the stress to an 'elastic limit'. Each branch continues to branch 6-fold, in each case ending in an equal bifurcation. At all such levels formed, both the mean velocity (and therefore total branching cross-sectional area) and pressure pulse remain constant. Thus the geometry and topology remain unchanged except for diminution in size. The reason is that at all these levels only the dynamic and static pressure dominate. Since all mammals are coded for the same static pressure

by the design of the mammalian kidney (100 mm Hg), the scheme - except for the base heart rate which encodes the particular size mammal - holds through all mammalian tissue.

But then an absolute size (1 mm tubes) is reached at which viscous losses begin to make themselves evident. The higher sized reaches were all propagation zones for blood pressure. Now we approach the distribution zone. [Notice that long distance transport is distinct from local distribution; yet both are faired together with a very similar kind of developmental logic.] The same branching rules hold, but the flow area proliferates as a zone develops, made up of a number of branching levels in which viscous drag governs. This zone is common to all mammals, and in fact is shown to provide the limiting design architecture for small mammals (i.e., the size of shrews). The design limit arises because chemical homeostasis (regulation of internal chemical constituents) against chemical uptake requires blood delivery of materials proportional to velocity, whereas the blood delivery against viscous resistance is proportional also to velocity, and the mammalian pressure (100 mm) then in fact determines the velocity. We have characterized that local process design by the catchphrase that at the local distribution level all mammals are a "shrub full of shrews".

4. Having basically provided a system that 'distributes' to the neighborhood [What? Three major flux streams. It distributes enabling pressure to the local region - not any longer the 100 mm Hg supply pressure, but perhaps 1/3 to 1/2 for control purposes under autonomic, namely automatic, nervous control, which then leaves about 25 mm Hg for transport at each local subscriber station. It distributes oxygen which was carried by the blood stream through the hemoglobin carrier. That supply is delivered to local subscribers via a cyclic gating; namely the hemoglobin carrier works in a periodic delivery cycle, governed by demand. Then the third flux stream are the various material supplies - fuel (glucose, free fatty acids), long distance operational signals via the blood borne hormones, other required material ions.], the issue is how should the local subscribers be supplied with the operational necessities being carried by the blood? The technique is a street-wise perfusion. Basically, a porous medium flow is supplied. But if it were a completely open porous medium, the streets would be flooded. Instead the subscribers were first permitted - in laying out the development - to line the blood supply. Thus two kinds of systems emerged. First it boiled down to all cells that would lie within a diffusable distance of the blood - oxygen supply (30 μm). That becomes the primary yardstick of local design. Then there were those cell structures that lined the blood channel. All of this descriptive picture relates to the very local free porous medium 'capillary perfusion zone'. Such a capillary channel has a diameter of about 5 μm. It is lined by a thin pancake of cells about 1 μm thickness that span the channel around the circumference like catty-cornered squares abutting side by side. Their diagonals are the capillary circumference. Thus one finds a twin 45° spiral of a gap between cells. These gaps are the diffusional avenues of transport. Their width is determined by the balance between the electric forces that bond the cells together, and the hydrostatic pressure within the capillary. This makes the capillary a leaky sieve, instead of the fully wide open porous medium that it would be if these cells did not govern the transport.

5. Why the 25 mm Hg hydrostatic pressure? Since the CV system is essentially a closed system, except at this point (and later in its grounding in

the venous return system), there must be some basis for determining the pressure. The physics is the osmotic pressure developed by a semi-permeable membrane. The cells lining and communicating, via ducts, with the arterial system develop large protein molecules into the blood stream. These cannot leak out through the gap. Thus there is little or no protein outside of the capillary system. The little that may get out is returned by a parallel pumping system, the lymphatic network. That difference in protein concentration (protein concentration is chemically regulated inside) produces an equilibrating 25 mm Hg approximately. Namely the system blows up like a balloon to that pressure, being pumped peristaltically on the high side by the heart, and dropping through arteriolar resistors to the leaky capillary system. As this 25 mm Hg is dropped a transport mechanism develops which is competent to perform all the exchanges through the avenue gaps - all small molecular systems then can be functionally delivered - oxygen, fuel, water exchange, metabolites, electrolytes.

6. The detailed engine mechanisms whereby local subscribers perform their function is not our present concern [They are the 'people' of the complex societally bound organism]. Suffice it to say that we have demonstrated a physics of rolling contacts at catalytically active walls which create local 'chemical' engines which can make, break, and exchange ionic and covalent bands.

While we realize full well that these sustems' descriptions are removed from human transportation systems, we really do not believe that any thoughtful person won't be struck by the very many provocative systems' themes, relations, and laws that are exhibited in these most complex transport subsystems, both part of a large thermodynamic engine process - one, the near equilibrium of the earth's surface heat engine; two, the near equilibrium of the operative 'complex' living organism's oxidative engine.

Evolution of Command-Control Systems in Life Thus at the expense of being thought even further out, we would like to reference one more systems' source. It is the character of the command-control nervous system in living organisms. We have not developed a fully adequate model, although we are working at it at a slow pace.[1]

But an excellent elementary review source is by Elliott (36), a neuroanatomical master. The point of summarizing that source is because it presents the reader with some notion of the richness by which command-control strategies have emerged in a variety of viable living systems. The point is to illustrate dead-ends, and break-outs. Many systems of control can work. Some permit greater patterning freedom and complexity. We cannot judge, except from our very insular anthropomorphic view, what is or should be 'best'.

1. Prospectus - a knowledge of the science of the brain, while difficult to relate directly to human affairs, can thrust us toward an understanding of how to deal with its chains and threads more constructively than by partisan theories and dogmas. Intelligence, as he will study and review it,

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[1] See (6), and a forthcoming chapter, "Physics offers a Cybernetic (Thermodynamic) View of Behavior - A Substitute to Reflexology" in E. Endroczi (ed.), Perspecrives in Psychobiology, in press 1975.

is the ability to cope with the world. Our human brain is the climax of a great developmental saga, the quest for intelligence.

2. Sparks - from atoms to life organisms. Only carbon, among atoms, provides enough chemical scaffold for emergent intelligence. Out of its increasing molecular richness arose enzymes, competent to manufacture other large carbon molecules and nucleic acids, with competence to replicate itself and also make other molecules. The process spawns mutational variations. As these compete in life [thermodynamic] chains, there is a 'natural selection' of advantaged forms. This evolutionary development has led from sub-life to man. Each evolving form fits. As complexity develops, increasing intelligence is found [We will not dwell on the fact that more primitive species often remain quite fit in their ecological niche, so that evolution to more complexity often involves increasingly difficult and diverse requirements, which is the only 'justification' for requiring greater capability for coping with the world.] The chemical logic of development was gathering nuclei acids into gene groups, strung in ribbons as chromosomes, enclosed in a porous nuclear membrane to form a nucleus, with a surround of secondary enzymes and gel in which other molecules assembled operational substructures of organelles, enclosed by an outer membrane to form a cell, with a complex divisional system of reproduction after growth. This all-purpose living cell is 'halfway' between carbon atom and human brain. Its intelligence is clear It copes [as a viable autonomous thermodynamic engine system] quite well. Even at the level of primitive ameba, one finds an attraction (pleasure) - avoidance (pain) system.

Environmental input 'awareness' and systems' coordination is poor in ameba. It is only point excitation and vague reverberation [wave-like] that is available. But in some one-celled animals, e.g., paramecium, its hairlike 'oars' are coordinated by neuroneme strands. They respond to stimulus with transmitted chemical change. They coordinate the oars in waves. They act like primitive nerves, using chemical secretion.

This is the highest single cell intelligence. The next step requires some breakout in an evolutionary sense. The single cell, by its thermodynamic limitations, can't get bigger. "...beyond a certain size the cells would smother, starve, and poison themselves, as a growing metropolis..." Foldup for greater area? Too flabby.

3. How to build an animal with nerve cells - The breakout was to accumulate cells into communities. Chemical secretion sticks them together. Internally, they form cavities and channels to oxygenate and supply interior cells, and they specialize function. Groups of cells could conduct specific functions [social molecularities]. Communication and control was particularly advantaged. It could be specialized for the special groups of cells.

At the horrible example end, we have the sponges. To many cells have to open and close themselves. Thus sponges remain feeble scavengers, of low intelligence. "They are, in fact, rather like those 'cooperative' human tribes sometimes held up as models of virtue." Nor have they spawned any evolving line of higher intelligence, much less one leading to man. [Moral: Every time a major principle is adopted in thermodynamic engine system design, it does not mean that its evolutionary branching is rich and competent to cope with a wide range of conditions. The standard problem will be, over and over again how to do the most with what you have.]

Our ancestral line seems more related to hydra. In these animals, sensitive cells are not only individual doorkeepers but also pure detectors and message carriers. They convey messages to other community members to make a practical response. They developed nerve cells, which detect specialized stimuli and carry a chemoelectric impulse to a muscle or gland cell that it directed. This complex internal nerve cell, the neuron, has changed little from hydra to man.

The neuron cell body has two types of growth - branching dendrites which receive messages (from sensing cells or from other neurons), and a single axon, which may branch further down, that transmits to other neurons, or to controlled muscle or gland cell. What happens in higher species is proliferation of number and arrangement of basic neurons.

This evolution of individual neurons coordinated the cells that were specialized for function. In hydra, each neuron contacts a squad of muscle cells, but also its neuron neighbor to form a nerve net throughout the body. The stimulation of one neuron spreads propagatively throughout the animal to evoke a coordinated response. Beyond this, one finds the beginning of harmonizing policy in the net before acting. One fired neuron may produce only a weak animal reaction. A number being fired can sum (positive or negative) and produce a higher degree of action coordination.

Perhaps the nerve net coordination hasn't provided more intelligence than paramecium (for example hydra can not 'voluntarily' bring its tentacles together - it only responds to inputs), but the single-cell straight-jacket has been broken.

4. Behavior gains choice - The next break through is the synapse, an unidirectional valving gate from one neuron's axon tip to another's dendrite (or cell body). Now information bits can be mixed, and memory emerges. Directionality or polarization of information flow exists. Both excitatory and inhibitory nerve chains now exist. Chemical transmitter substances of synapses are called transmitter substances. Their buildup involves an electric threshold which message transmission must exceed. At this synapse (regardless of the precise chemo-electric form) is memory storage implicated.

How is body-wide control from single points solved? Each sensor neuron brings in messages and may branch to contact many (say 100) motor neurons carrying messages out to muscles, and each motor neuron may contact many (say 100) muscle fibers, its squad. Thus a squaring ($10^2 \times 10^2 = 10^4$) occurs with 2 such relays, not like the simple nerve net. If a third relay is added a cubing ($10^6$) occurs to reach muscle fibers. And four or five such ranks could reach up to dinosaur or whale size. These intermediate levels are adjustor neurons. [Or should we say transmission or propagation neurons? Note the absolute similarity in logic to what we have described in the arterial system development logic. We have provided some additional details in our second cybernetics article that has emerged out of a working relation with R. Llinas.] Adjustors increase with increasing intelligence. In the human, for example, a few times $10^6$ sensor neurons govern a few times $10^3$ motor neurons. In between are nearly $10^{11}$ adjustor neurons.

So in planaria, we begin to see the overlap in rank beyond rank of neurons to insure cooperation of all parts. But these are now arranged in subsystem patterns. The left eye-cups trigger different muscle patterns than the right. Injurious pricking contact gives a different response than a cool, smooth surface. Specialized low-threshold synapses develop, as reflex arcs to provide a fairly standard, specific reflex response. In the main that is all this level of intelligence can afford.

The reflex arcs are not completely independent. They may be separated by higher-threshold synapses, e.g., a feeding reflex can be overcome by a flight reflex. Summation of many synapses decides conflicts by routine policy. Thus policy becomes built in by natural selection. But it is not yet a personal experience acquired memory (synaptic, or otherwise), an epigenetic memory.

5. The successful cousins who failed - There are many lines, from worms to men, which have split off. The invertebrates are diverging creatures who all have a crippling flaw in intelligence. They have no vertebral column of bones; they lack the nervous system for which column and skull is only a casing. Vertebrates have a unified central nervous system, which culminates in a brain. Instead, invertebrates only have a ganglionic nervous system. That is, they have separate masses of neurons, called ganglia, loosely connected by nerve fiber strands, but largely independent, each with its own reflex arcs for local activity (earthworms, insects, octupuses). The ganglionic plan is efficient for quick results, and the system as a whole maintains concerted action by consultation under the chairmanship of the head ganglion. But the communication is only via a web of fiber bundles.

The invertebrates were evolutionarily successful. They dominated the earth for 1/2 billion years, they still make up 99% of all animal species. They were much more populous than our few thousand ancestral hominids per generation. What success is not theirs?

They are not creative, adventurous, or visionary. They have no free adaption; they do not learn from experience except in a very petty way. (Witness the bee battering a glass window in a room as compared to a cat.) Their size, life experience is stunted and fragmented. Their planned economics has many variants, but each is locked into fixed cycles.

One might note that many stable human cultures in the past have also petrified into ritual. Only the impact of barbarians from without has broken the hypnotic cycle. [And conversely taught the barbarians that they are tribes.] Evolution is not a guaranteed march along a highway, but a series of manifestations of disparate forlorn hopes. Could this be of relevance to man? [We believe yes. It is only the epigenetic unfolding of creative technology and the creative arts that opens man's future, regardless where the deus ex machina comes from, e.g., intellectuals or barbarians. Both identify novel arrangements. There is the considerable possibility that man may have exhausted his epigenetic competence in considerably less than another 25,000 years.]

6. Our grand-ancestor ground plan. Primitive vertebrates appeared at the same time as higher invertebrates in ancient oceans. The components - neuron, synapse, reflex arc - were the same. The new ground plan involved a neural tube. This continues with traceable logic right up to the human brain.

[We will break off the detailed description. It is sufficient to give the interested reader a notion of whether he wishes to acquire further nervous system command-control and communications insight. We will complete, by naming the remaining chapters.]

7. The autonomic nervous system. (Housekeeping support functions)
8. Sensation and senses - the gates to intelligence
9. Feeling is many senses, the lowest level of human awareness
10. Eyes and brain
11. Late coming senses - hearing and the brain
12. Some unfamiliar senses, gravity and motion change
13. Sense of smell (the mind's grade school level)
14. The triumph and dominance of the hemispheres
15. Intelligence in action - the motor system
16. The worm in your spine - reflex basis of action
17. The fish in your brain - lowest motor control
18. The mouse in your brain - basal ganglia and'instinctional' behavior (routines)
19. The computer in your brain - muscle teamwork and cerebellum
20. The borders of 'free' behavior - the motor cortex.
21. The loom of mind - cerebral hemisphere and cortex
22. The human dimension - cortex and speech
23. Beyond the brain - social intelligence.

Clearly what this book and its outline indicates is the biological theme

ontogeny recapitulates phylogeny

In our forthcoming cybernetics article mentioned previously (which we developed after many intensive conversations with our biological colleagues, F. Yates, R. Llinas) we underscored that theme as the only low global means that natural systems have for evolving further thermodynamic autonomous 'factories'. The key notion is contained in the idea that subassemblies cannot be efficiently stored. Thus one always starts to build from scratch.

Oh yes, in a working system, one can build subassemblies one place and ship to another. But in start up, it is only a blueprint which is shipped and the structural forms have to be built up from the most primitive formats.

ontogeny recapitulates phylogeny

With this introduction, we propose to approach the strategy for transportation systems. We intend to use all of the principles and notions we have touched on in these examples for our construct.

## 8. Transportation Strategy

Recall our social system model in post-Neolithic times: Population centers ingathered by some attractive force to isolated near equilibrium; various such centers, with convective circulation by virtue of value-in-trade; internal circulations among the internal molecularities in the population centers; motional paths of the human cellular atomisms.

Recall what always creates the inhomogeneous sustained patterns. It is a conflict between two force systems. One sweeps energy convectively into the region, the other absorbs energy locally by a diffusive transport. This physical theme must govern sustained ongoing nonlinear thermodynamic processes at every level.

So we start in at the lowest level of the fixed Neolithic settlement. (The level of internal civilizations in the household, the atomistic level, we will skip). From the first such organized settlements of a handful of acres, the layout has involved specialization of function by fixed structures and assigned areas, streets, roads.

What determines the form of the local Neolithic or post-Neolithic settlement? It always remains the same six factor complexes - the size of the ingathered population, the mythos of the ingatherers, their culture, the climate, the local ecology including geographic-geologic conditions, the technology. A local design is not exactly prescribed, but its general style is predictable, given those six factor complexes. (Namely if you name the character of the ingathered group and the local factors, you can surmise the nature of their settlement.)

What will take place in that settlement? The patterns by which the Iberall-McCulloch[1] atomistic modalities come off. But beyond the atomistic modalities, it is the molecular modalities which will come off. Namely, assuming that it is a fixed post-Neolithic settlement, one can begin to play the elite game of designing an operational settlement - given the six factor complexes. Possibly to convince the reader - only if he has or can assume elite 'get-it-done' characteristics - it is necessary to perform enough such designs on paper or in actuality to convince him that an effectively ergodic ensemble of settlements does emerge. Given these exercises as either start ups or on-going maintained settlements (i.e., with 3 generation 70 year projections), it is our premise that central tendency distributions can be found to exist by which a circumscribed life style can persist.[2]

Actually, recognizing that roaming ranges of the order of 1000 sq. mi. characterize a settlement, that they occur without much overlap, and that a constellation of the order of 30 of them form to conduct the pattern of trade and in- and out- breeding, war, raiding, etc., then the area is about 30,000 sq. mi., representing a nominal 'diameter' of the order of 200 mile as the nominal planar domain we visualize for a standard macrosystem. While communications may have extended the range, transports, particularly heavy transports, still confine man to that class of systems' field continuum.

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[1] A. Iberall, W. McCulloch, "The Organizing Principle of Complex Living Systems, J. of Basic Eng., ASME, 290, June 1969.

[2] Note that a band of agriculturists thrust into a polar region will not make it by fixed settlements. No more will a band thrust into a particular arid region. But, as Gibbons (Nat'l. Geogr. 142, 47, July 1972, and subsequent) has suggested, it is common for man and other primates to wander till a local area is found which is less marginal. Thus we really are talking about settlements in a larger few hundred mile domain wherein more than one, e.g., 20-30 settlements, can be found to exist with at least marginal survival.

So we are imagining in-gathering into such a region, precipitation of a few handfuls of settlements, by roaming and center attractions, to form constellations. The systems' game, of forming settlements, and then constellations, we assume, will provide an ensemble of such focal settlements and constellations. The first game is the formation of focal settlements, by elites, and the second game is the formation of constellations. We are concerned first with the settlement formations at 70 year time scales, and slower, the major modifications of constellations at 500 years.

Now clearly the transformation problem is similar to the formation of rivers. A continuous sheath of 'ecological' variables (in which the climate, the humans, their bulk viscosity internal degrees of freedom hangups as both mythos and culture and epigenetic technological heritage are now regarded as part of the ecology) impinges on the two dimensional continuum earth and resolves its thermodynamic fluxes and potentials in discrete form, focal settlements (rather than line scribings). The flux paths and potential contours between settlements are also discrete forms. They are not unique. As long as generalized thermodynamic constraints including modalities are satisfied, any path is possible.

But over time, time and time again, the following institutional forms have to be resolved:

where shall we grow agricultural food
where shall we graze our domesticated livestock
where shall we live by building shelters
where shall we get water
how shall we arrange procreation (the atomic male-female association is assumed)
how shall we educate the young
how shall we take care of the old
how shall we defend ourselves
how shall we arrange trade
how shall we maintain our customs
how shall we arrange transport
how shall we acquire materials
how shall we manufacture mechanisms
how shall we care for our health
how shall we be governed
how shall we <u>characterize</u> our trans-<u>actions</u>
how shall we expend energy during idling time?

Every elite, given a group whose people-energy he must lead, has to deal with these issues in 'his' (i.e., three generation) fluctuating epoch.

As far as transportation is concerned, the convection paths develop at 'random', namely whatever accidents may have satisfied the first users. Then gradually, as overlay develops on overlay (one finds typically 300 year waves of development at outstanding focal centers) both the local patterns develop and the constellational patterns. The paths are generally low profile. Namely it is not the case that a low energy mechanical 'Hamiltonian' optimization takes place, but instead conflict considerations tend to minimize the losses to perhaps where most thermodynamic engine processes work with the same relatively low Q. The reason is simple. In all of his systems, humans(and nature) can only work at near the persistence (or subsistence) margin. His design cannot afford sustained high stress values. Very much like low endurance limit in complexly designed solid mechanisms, set, creep, degradation, stress concentration easily takes place. Thus what does persist is set on a broad shallow subsistence plane. Buildings and mechanisms and structures roughly last a generation or two. The materials of construction all tend to share the same physical molecular bonding problems that man's constituents share.[1]

And so the transport problem begins to have its modern connotation with the first two trading constellations of Armenia and Anatolia, each with near on to 30 focal centers, perhaps 8500 to 9000 years ago, or more realistically with the fully modern civilization in Sumeria (with the invention of the wheel) 5500-6000 years ago, or in Egypt (with the invention of cargo carrying boats) about the same time.

Clearly from the beginning the transport pathway of the constellation suited the convenience of the elite (or elites), and locally largely also suited the convenience of the elite. The urban planner (artisan) has nearly always been the subordinate creature of the elite. It is he who has had to furnish the systematic design (taking regard to how the plan may have initially developed). Once beyond the elite's ken, the path could then become 'rational', namely it could rationalize the thermodynamic needs of the rest of the community. In physical terms, there were differences in the 'near field' solution and the 'far field' solution. These constraints have persisted right up to the present and will continue to persist as long as man is man. The elite must have his half of the pie.

But what are the conflicting forces that must shape the urban systems' design and its relation to other focal centers?

First there is the elite's version, in his paranoia of euphoria and anxiety (bounded by mythos, culture, technological heritage, climate, ecology), of how he wishes to live. In his mind there is a priority ordering of institutional concerns, in conflict with his image ideal. His mind stretches as far as he can defend, as far as he can feel comfortable. At that point, he begins to provide defenses against agressive forces. That governs his walls, that governs his buildings. Material extensions, circulating paths, storages - these are the abstract images in which he thinks, all this since man created the notion of value-in-trade.

But he must not only be able to defend. He must be able to attack. So these inner spaces that define the urban center have that kind of easy circulating path.

But aggress and defend will not make a way of life for non photosynthecizing living species. Thus, in this era the agriculturist (harvester of the land) or the fisherman (harvester of the sea) has to be provided for. That can lie outside of the defended area in which shelter, defense, storage, manufacture can take place. Water must be nearby. And materials must be at hand. For practical

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[1] Of course the outstanding examples are the long enduring low stressed temples which face little problem except the support of their own walls against largely low static loads.

purposes, trees, metallic ore, stone, clay, cementing and binding materials have had to be available within reach, in sufficient quantity, for most of the past 10,000 years. Who got rich or who got poor among communities (i.e., gained in stored and constructed material) in the main depended on the game of aggress-defend, trade, grow, mine, harvest, manufacture, devine.

It is our contention that if the game is played out at random in a given locale, independent of the nature of the particular elites, the outcome in any three generations will not differ very markedly from the actual development path that is found. To the extent that this thesis is true is it possible to use our irreversible thermodynamic model with confidence.

So the pressure in urban centers grows outward from the elites who were the early winners in an urban center, out to the subsequent generations of elites who expanded their domain of control. By its very nature, this type of ground work diffusion provided an amorphous skein of connections rather than a rational 'minimal network' of connections.

Recall the blood flow algorithm. The pulsing constant potential source (100 mm Hg mean, 40-50 mm Hg pulse) elongates and extends the conduit to a maximum design stress (governing wall thickness to diameter, diameter, length to diameter), implying a constant mean velocity independent of size (until one gets to the very local neighborhood). Also a rational branching takes place which nets each neighborhood for all new developments. But the overall body form is also determinate, so that a rational expansion for organisms ensues - from 3 gm shrew to 100,000 kg whale.

What no one yet realizes is that the social organism must also be designed rationally so as to satisfy all of its flux requirements. This has to be done independent of the political system - e.g., capitalism, communism, socialism, feudalism, kingdom, autocracy, dictatorship, etc. It has to be done independently of the technology, although like in developmental biology, more than one phylogenetic principle of design may form developmental lines. That is what we are up to now.

## 9. Phylogenetic Development of Civilizational Systems

We suggest the following systems have evolved historically. Much of the change is dominated by the linear evolutionary rope of technological history. Even though technology is a linear rope, without breaks, the style of living has had to change.

1. Pre-vehicular mechanisms, 6000-4000 B.C. (man, bull, onager, sheep, carriage)
2. The beginnings of connected empires, 4000 B.C. - 2000 B.C.
3. The age of great empires, 2000 - 0.
4. The second wave of empires, man fills his mind space, 0 - 1900
5. The age of machines, 1900 - 4000 (?)

For a very skimpy conceptual rope, a skeleton scale for man's technological development follows: (Future findings may advance dates and add more data.)

| Yrs. before present | | Finding |
|---|---|---|
| 40,000 | | Cro-Magnon man found in Europe<br>Asian hunters may have crossed into New World<br>Abstract lunar symbol markings found |
| 30,000 | slower hunter-gatherer scale, pre-value-in-trade (but abstractions - 'values found)[1] | Man reaches Australia<br>Representational cave paintings found in France, Spain<br>Sculptured figurines found |
| 20,000 | | Sewing needle found |
| 10,000 | | Bison hunting in New World plains found<br>Bow and arrow in Europe found<br>Pottery (first) in Japan found |
| 9,000 | | Sheep domesticated in Near East found<br>Dog " in North America |
| 8,000 | | Jericho (first city) settled<br>Goat domestication in Persia<br>First crops, wheat and barley, cultivation found |
| 7,000 | | First pattern of village life in Near East found<br>Catal Huyuk, largest Neolithic city in Turkey found<br>Loom found in Near East |
| 6,000 | | Cattle domesticated in Near East<br>Agriculture replaces hunting in Europe |
| 5,000 | | Copper used in trade around Mediterranean<br>Corn cultivation in Mexico found<br>Massive stone monument in Brittany |
| 4,000 | | Sailboats in Egypt<br>First city-states in Sumer<br>Seal marks (cylinders) in Near East<br>First potatoes grown in South America<br>Wheel found in Sumer<br>Rice cultivation in Far East<br>Moth (silk) domesticated in China<br>Horse domesticated in South Russia<br>Egyptian merchant trade ships start in Mediterranean<br>Pictograph writing (first) in Near East<br>First Bronze tools in Near East |

[1] Values are the abstractions by which disparate beings or becomings can derive order or measure.

| | |
|---|---|
| 3000 | Spread of city life in Egypt<br>Plow appears in Near East<br>Accurate calender in Egypt<br>Stonehenge in England<br>Pyramids in Egypt<br>Gilgamesh and other epics in Near East (heroes and gods)<br>Cities in Indus Valley<br>Skis in Scandinavia<br>Earliest written code in Sumer<br>Minoan palace societies on Crete |
| 2000 | Use of bronze in Europe<br>Chicken and elephant domesticated in Indus Valley<br>Eskimo culture begins in Bering Straits<br>Ocean going outrigger canoes in South Pacific<br>Ceremonial bronze sculpture in China<br>Imperial government with different provinces by Hittites (1400) ←<br>Iron in use in Near East<br>First complete alphabet in Ugart people in Syria - script |
| 1000 | Hebrews introduce idea of monotheism<br>Reindeer domesticated in Europe<br>Iron begins to spread through Europe<br>First highway system, in Assyria (750) ←<br>Homer composes epics<br>Mounted nomads appear in Near East as new force<br>Rome founded (700)<br>Wheelbarrow invented in China (300)<br>Indian epics (gods, heroes) (200)<br>Water wheel invented in Near East |
| 0 | Christian era begins |

The first period (6000-4000 B.C.) was dominated more by the attractiveness of the individual urban focal center than by the circulating pattern, as long as centers lay within the general kind of connected living and trading area. Thus intercenter transport would be mainly a matter of 1-2 day trip by the transport forms available.

Thus transportation as a constellational system begins more properly in the second era, 4000-2000 B.C. In the previous era, the large scale population motions that peopled Europe and Asia, that covered almost half of Africa and its coastal regions had taken place. 'Now' city-states began to come into strong existence, the ebb and flow of large empire began. War and trade of some serious significance had begun. But the paths, because of the crude technology, were restricted paths of convenience. The easier path was by sea in strict sight of land, even if the ship was still only a crude vehicle. Building technology was highly sophisticated, although limited to stone, wood, pottery, bronze, weaving. Thus the elite could indulge their living fancies.

What man and beast could make, they made.

In the third era, the great empires began. Elites had mastered the grand style of living, the grand style of conquest. Iron, and the martial arts, flourished. Each successful civilization was known for its conquering ability. Thus transport mobility for attack, for defense, for trade, for the spoils of conquest (e.g., the first road transport system in Assyria, 800 B.C.).

If we were to put together many local urban and interurban representations of transport systems from these two epochs - the urban 'start up' era 4000-2000 B.C., and the first era of great empires 2000-0 B.C., it would be clear that large scale systems' convection was not the dominant transport process. Thus the social organism was still largely a loose colonial organization. In terms of the biological developmental analog, we hadn't yet reached the stage of cortical development. But clearly in the second era, e.g., from Sumerian development onward, the need for codification - if you will vertebrate and neural tube branching - become obvious to ruling elites. The atomistic or molecular 'celular' people may bud, branch, and diffuse ideas, but it is whipped into organized form by elites.

And clearly the intellectual abstractional ability of man far outran his ability to technologically implement his visions.[1] Thus the rate governing process is catching the fancy of elites, who are then willing to back technological visions with sufficient resources.[2]

The operational command-control algorithm, roughly guiding the selection and decision process of elites, during the formative period of empires was to suit their own living fancies, to provide for a local transport system that suited them, to permit a utilitarian local transport system that suited all of their local 'domesticable' [3] subjects, and to provide a larger scale systems' transport system that would deal with aggress-defend-maintain modes (maintain includes trade).

We submit that any small group of average artisan intelligence, imbued with mythos, culture, technological and ecological comprehension, will manage to design a transport system and that the central tendency of their distribution will be a reasonable representation of the actual transport systems

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[1]This is still true. As technological innovators we can come up with more technically significant ideas in a year than any five major corporations could implement in a decade.

[2]As we have suggested, in perhaps up to 25,000 years man may exhaust his technological vision. Then the 'free' variable may itself be caught up in a thermodynamic chain.

[3]One will do better in understanding human history if one regards the situation that plants and animals 'domesticated' man (i.e., caught him up into chains that support their living, admittedly in circular form). But then the extension of that notion is the notion that elites can similarly 'domesticate' their governed societies.

among such empires.[1]

But largely it isn't until the committment to iron (1000 B.C.) as a basic extensional material[2], in the sequence of development - copper, boats, wheel, horse, copper tools, water wheel - that our modern technological era opens. Clearly - in human vision - unlimited mechanization is on the agenda.[3] What does mechanization imply? It implies the transductions and transformations of motions (i.e., motional transform systems) as an abstraction. It implies these as implementations and augmentations of human motion. To an elite, it implies that not only humans can be domesticated as motional transform systems but also materials.

But the motional transform system must be as long lived as the human (elite, and the domesticated element it replaces). And it must operate at much higher stress levels. It is such properties that iron supplied. And so in ever tighter functioning chains, mankind could be yoked together in closer acting higher density packages.

But stress (application of momentum, or in slow systems, application of action, as modalities, in time) is followed by strain (a need for force governed flow processes). Thus the ingathered social structure 1000 B.C. - 1500 A.D. called for a more rapid enabling process for the mechanistic society. Power transduction was on the agenda.

Why the 2000 year rate governing of large scale process change? We have no clear notion, except possibly to suggest that just as diffusion of detailed changes has a velocity of 20 mile/20 years, the large empire civilizational time scale is of the order of 500 years, and they each have a characteristic style that is recognized over that scale (i.e., its overall cultural scale). Thus a significant relaxation (given man's mind, which held the civilization together coherently for 500 years), will take place in 3-4 of such time constants. Thus 2000 years.

Also one might surmise, from their size, i.e., 1000 mile 'diameter' (or extent), the notion of large scale empire of a somewhat different sort can itself only diffuse with the half range of the empire (i.e., one half conflicting with the other) at empire time scale of 500 years, so that the notion of empire itself tends to diffuse at molecular generation rate (at 20 mile/20 yrs.). Thus the 2000 year time scale relates to the loss of coherence of an outlook (for conversely the gain of coherence of a new outlook) over a large empire.

While all these notions may sound purely speculative, they relate to the

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[1]This has nothing to do with the individual indiosyncratic 'genius', or even 'ineptness' of any individual ruler and any individual transaction. In three generations the specific acts and specific decisions are smeared diffusively. The 'river' paths have worn their way in to fit. The multiple conflicting transports have been resolved.

[2]As opposed to wood - still part of the natural ecology - or even copper.

[3]Just as earlier, with copper metallurgy, unlimited materials were on the agenda; and with copper tools, unlimited tools were on the agenda.

time delays in the epigenetic heritage of man. Remember in animals, the heritage is only genetic, perhaps at the 50,000 year time scale for species. That man has a 'faster' scale, of 2000 years, is thus neither to be looked at as a fantastic quickening of the biological process nor a process of such slow proportions that it doesn't relate to us at all. Any perceptive educated technical person, as he learns and expands the knowledge of his trade, has to feel the atomistic pulse that exists out to and binds him within his large epochal time scale. We will speak for our scientific-engineering profession when we say that we feel Promethean-like-bound and limited in what we are permitted to do by our 2000 year social heritage.

Thus we approach the age of machine, and of power engine, of the past 500 years. In that age, two large scale currents can be discerned. The machine became as important as man. The mechanical world shook down to a size or the order of a trading constellation (a nation) except for a few super giant larger scale constellations. These are all historical accidents, and there is little reason to believe that they will continue to exist in large scale form 500 years from now. The serious issue is one of coherence for overall natural resources. Namely, for stability, a trading constellation (or nation) must be nearly self sufficient as far as its thermodynamic processes are concerned. It is very dubious that organisms, other than those acting as viral raiders, can persist in the long run simply as export centers without developing a nearly equilibrium socially stable way of life.

This does not mean that the national moiety is highly stable, but it does mean that stability issues are governed as a turnover among near thermodynamic equilibrium spatial - temporal social organizations that can compete in up-to-date epigenetic technological aggress-defend-maintain modes. Our particular age has received an energy impulse shock which will rock the social canvas for a long time. Current 'newspaper expert' analysis is not really up to the issue.[1]

Thus with the same social cohesiveness among urban settlements that has dominated the social canvas for the past 10,000 years, but with a much greater average population concentration per center and a greater number of large sized population concentrations (maintainable by machine, engine and higher speed transport system), we must face the task of 3 generation predictions within the current technological rope.

The social drives are still dominated by the elite. So the question that must be clear is what governs their fancies today (and in the near 3 generation future, given our technological extension), and by what algorithmic (command-control) restrictions are they governed.

The upper class state of life in all our national cultures can be quickly caricatured. Their changing style by which they imprint their desires and requirements on urban centers and other ingathering areas (e.g., resorts) can also be described. Their world view - of outside areas - can also be described. But the hard - physical limited - transport facts must also govern, in order

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[1]A debate of the clear but 'unthinkable' issues cannot be conducted within the confines of this report.

to sustain the elite's view and style of life ("class before mass"). What that means is that elite views have to arise out of the populace's, but that it can then lead the changing forward diffusional view (anisotropic diffusion).

But then what are the current algorithmic constraints? Let us examine these by thinking the 'impossible' (i.e., it is similar to testing physical processes to determine the limits set by the first and second law of thermodynamics, really of thermostatics).

1. Suppose some powerful elites decided the world was too complex and thus wanted to cut down its population to a size that they would feel comfortable with and could comfortably control. Are they limited?

The Hitler or Stalin type dictatorial aggression, perhaps the British or German drives for world empire three generations ago, or the oil producing nations in the near future, may be considered representative of the threat. The aggress-defensive modalities are so strongly built in to the human species that clearly the attack cannot remain coherent enough or mobilize sufficient resources to be successful. Elites in other national moieties muster sufficient counterforce to blunt the attack. Thus clearly there are strategic rules governing successful aggress and defense coalitions. 'Morality' is simply not a governing paradigm.

But any individual nation (as the fantastic parade of the focal centers that could be named would demonstrate experimentally) is not immune to successful aggression. Thus the defense modality has been and will remain a governing modal process among national moieties.

How about the individual urban center? With artillery, the city defense was no longer possible. The entire 18th and 19th century furnished proof after proof. The 'economical' domain of defense had moved up to the small nation size (the defense of Finland, Israel, Switzerland in fact showed that small nations could remain viable because of strategic defensive regions, rather than their own power, even in this century). Thus there is a remnant modicum of survivability in small national moieties even in the nuclear age. It is, in general, based on possession of significant contribution to international thermodynamic chains (or nuisance value).

On the other hand, the loose associations of the states of the U.S.A. or provinces of Canada, etc., indicate mutual trading associations that can face interaction without significant military defense. This is not to deny recognition that each of these associations have at least paramilitary, if not military type organizations devoted to internal defense. And the distinction between internal and external defense is really only marginal.

So, constraint number one, a self defensive trading constellation which is viable, must be designed within its transport systems for defense, attack, and maintain modalities.

2. Having achieved a high degree of mechanization and power augmentation, we can raise an extreme 'unthinkable' elite issue in another form. If elite can now regard nature, plant, animal, man, and machine as all domesticable and domesticated, then why must he tie himself to the tyranny of the masses? Why can't he simply let the large part of the populace stew in its own juice

(rather than having to wipe them out by direct aggression), and simply deal with that that portion that he requires for his support, and let inanimate mechanism and power machine furnish the rest of his needs? In Lord Keynes' frame of reference, can't society operate indefinitely in a depressed state of economic operation?

Obviously to the largest extent, mankind operates at that depressed state. It behooves relatively primitive elites to use the relatively low efficiency of masses of people, operating very near the margin of subsistence, to support their style. How can it happen? Even though the yield per person is small, e.g., a few hundred kcalories per day, the amplification ratio of numbers (e.g., $10^4$ persons per elite) can provide power amplification over daily needs of the elite by a factor of a thousand. Why would the populace continue the custom? Why not? It has become part of the mythos and culture. Can it be overturned? Yes, in perhaps 1/2 to 1 civilizational epochs - 200-500 years. It can be budged in 3 generations.

But part of its self-organizing thermodynamic structure, living systems exhibit a population self-regulation. At all times they obey a law of population change near a focal center of

$$\frac{dP}{dt} = (b-d)\ P$$

b = 'birth' rate (growth) constant
d = 'death' rate (decay) constant

but

$$\left| \int_0^{N\tau} (b-d)\ dt \right| \leq \epsilon$$

$\tau$ = 'generation' (for humans, about 3 generation units, namely about 70 years)
N = a small positive integer
$\epsilon$ = a small constant

Namely given an $\epsilon$ there exists an N greater than one such that the inequity holds.[1] Namely that self-regulation is a property of the genetic heritage as it epigenetically interacts in particular ecological environments. It has been selectively bred in genetic time (i.e., geological time of perhaps 20,000-30,000 years) to so operate.

Now clearly, humans by selective breeding, have shown it is possible to select out population self-regulation in some animals. In some, an uneasy uncertainty - of either sustained reproduction or no reproduction, regardless of selection or circumstance - is found. But all this means that invariable reproduction of the breeding chain in the thermodynamic cycle is not assured.

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[1] A. Iberall "Some Thermodynamic Notes on the Regulation of Population", 1975 AAAS Annual Meeting.

Thus at present we must still assume that elites cannot control the breeding habits of human populaces. Thus the very acts they initiate themselves influence the mix of machine and man.

Machines today are acquired at the end of a long 'manufacturing' chain. Materials have to be mined or grown, harvested, refined, transformed, combined, etc. In the 50's, in the authors' circles (automatic control), it was fashionable to talk about the automatic factory. In one such frontier discussion (Gordon Research Conference, 1952) one of the authors finally saw the light. The difficulty of sustained supervisory command-control over multiple loops of automaticity required a cybernetic governing machine as complex as the human. So that, for supervisory command-control, the evolution of machines at least as complex as (if not greater than) the human's command-control was required. And the standard argument then follows - humans are made by a cheaper manufacture process than machines. And even if machines of comparable capability are developed, the life characteristics would be similar (namely training, nurture, reproduction, life span, maintenance would remain the same because of the comparable materials nature, i.e., the constants for molecular structure).

Thus - a lesson that the current generation of elites are learning perhaps for the first time - there is no high efficiency in machines, and thus all human civilizations must be run with a mix of men and machines with the requirement for a large concentration of men to machines. (Namely significant change in genetic constitution will be required before the change in mix occurs.) We are largely misled by the power augmentation ratio in the U.S.A. today (the use of approximately 10 kw per 20 watt human) as to the relative concentrations of man and machine (not manpower and machine power). It is not that more machines, more efficient machines, machines with more complex command-control systems will not be developed, will not evolve, but their application will depend on the existing thermodynamic chains. And that, again, likely comes up against the rate governing combination of materials' flux, energy flux, life span, operational environmental parameter range. (We are not judging, a priori, which will govern in any particular problem, only that one such factor will likely be rate governing.)

As far as operating at a reduced economic status is concerned, this is hardly new 'now' or 'ever'. It is only perhaps middle class America's self perception which is at stake.[1]

When times are economically bad, (i.e., a lack of distribution of scarce resources for whatever reason) it has become customary for an ingathering toward focal urban centers. Today (namely for the past 50 years), we have the novel pattern of a high concentration of mechanization and levels of distributional functions associated with urban centers. Thus the citizenry, in industrialized societies, have been increasingly divorced from its basic agriculture base of life. There is little guarantee that if economic conditions become very bad that a dispersal back to farms wouldn't take place. This has happened historically with social degradation. It represents no

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[1] A very interesting, perhaps 'first' sociological study of how centers and attitudes change is contained in R. Sennett's, Families Against the City, Vintage Books, N.Y., 1974.

thermodynamic violations. A field transport, determined by some highly non-linear systems processes can change its direction.[1] In such a biochemical field as pharmacology, the systems' field effects that may be dose dependent are quite well known and documented.

So, constraint number two, a viable trading constellation, ruled by a polity of elites must be designed to provide a broad but shallow optimal 'economic' mix of man and machine power.

And as a third constraint, not worth a tremendous debate, is that no indefinite pile-up (or depletion) of major fluxes, potentials, or focusing 'idée fixe are possible.

Given these kinds of algorithmic constraints, one is free to design the start up, the mid-game, or the end game of any civilizational pattern, say in particular, here, on concentrating on the transportation institution.

## 10. Field Topology for the Future

'Real estate' has not been the rate governing process in the land continents as a whole, until possibly in an emerging future. Thus the field algorithm for urban centers has only been associated with agricultural support areas, water supplies, land-water trading cross-roads, defense. The internal circulations have grown up to suit the governing elites - and their subsequent diffusions; the external circulations have grown up generally to suit pair binding fluxes (i.e., $V_{ab}$ and $V_{ba}$ where $V_{ab} \approx V_{ba}$, the circulation velocity).

Clearly, when a space becomes filled (i.e., the few megalopolises) wherein urban centers expand in population and land occupancy to fill their intermediate spaces, some specific kind of flux algorithm is required. Else, as found in vascular systems and transportation systems, the flux paths become counter-productive. They cannot carry the required loads.

Obviously the confluence of iron, vehicles, engine processes, stationary engine combustion process, mobile engine combustion processes - both external and internal - and the interchangeable assembly production line took place within the very recent past (70 years ago) and changed the course of the internal and external circulations. The fluxes all increased. Both mass and individual transportation was born.

The systems' designers (cities, roads, streets, mass transport systems) had no idea how focally attractive this power conversion concentration could be and could not act or react fast enough to provide algorithmic guides. So that - 70 years later - is where we stand now. A modern complex industrial society, emergent post 1900 (or 1880, or 1920 depending on measures), presents some novel integrative organismic issues than the prior looser agricultural-industrial society. The more rapid convection, reactive to many

[1] Note - thermodynamics poses limitations on local process transport coefficients; i.e., as a result of energy conservation in transformations between kinetic energy - the first law, and the degradation of the order of energy - the second law, it is necessary that transport coefficients be positive definite. See this in viscosity and conductivity coefficients. But the system can reverse the flow, as a maintained engine process.

remote markets, forces the need for organismic integration. Whereas, earlier, local supply issues were much more dominant,

The specific reason that a design algorithm must be discerned is because of the conflicting forces - conflicting 'economic' demands. The conflict is for living spaces for elite and populace, agricultural space, manufacturing space including its necessary facilities, and availability of other resources. The human, genetically, is not designed for the conflicts. He is still selected for hunting-gathering (on savannas) over 30,000 years, and more localized he is bred for agricultural, artisan, and trading, pastoralism, and raiding over the past 10,000 years. The complex urban breeding is less than a few hundred years old.

So how does it go, and how can it go, given the existing constraints?

[Note, the nominal key points in history - the first 'empire' of Sargon the Great in about 2250 B.C.; the wide spread imperial empire of the Hittites in about 1400 B.C.; iron in use in Near East and spread through Europe, 1300-800 B.C.; first highway system in the Assyrian empire, 750 B.C., (about 18 towns with populations greater than 10,000-15,000 each. They lay within a 'rectangle' 800x 1100 mi., about 100 mi. apart, on the average, with a center of gravity near Damascus); the first large scale Persian empire, 400-500 B.C.; the second large scale empire of Alexander's, 320 B.C.; the third large scale Seleucid kingdom, 300-200 B.C.; the fourth large scale Roman empire, 100 B.C. - 100 A.D. (in 150 B.C., about 40 towns with populations greater than 10,000-15,000, with 3 reaching up to 150,000 - Rome, Alexander, Antioch. They lay within a 'rectangle' 1500x3000 mi.), 100 cities from Spain to the Syrian Desert had Rome's urban characteristics.]

Clearly, the common algorithm governing urban settlements from the time that central 'constellational' authority (e.g., from the Sumerian-Akaddian cities onward) conflicted with local urban authority was that urban areas had to be fairly self-sufficient and sufficiently remote from each other (i.e., an individual family had to identify with a defense center, and its governing elite structure). This remained true up to 1920. Transportation began to change its style from 1840 on, with the combustion steam engine fired by coal.

The horse and the steam engine were complementary for the overlapping period. But on the other hand, the steam locomotive already required a new algorithm. It had to conform with the topography and it had to satisfy a long distance algorithm of serving an optimal number of urban concentrations along its path, compatible with central constellational elite requirements (at the time of construction).

But that '100' years (3-4 generations) was purely a technological era in transition. Power augmentation was on the agenda, and it was purely a short range technological race [1] that has lasted perhaps 3-4 generations. We have

[1] Note - We make a large issue about the period 1880-1960 as being the Age of Engineering, or the Age of Science, or the Age of Discovery, as if it were the dawning of a new era. But it is quite possible, now, perhaps almost in retrospect, to see it as one of a number of singular outbursts all devoted to just one issue - the mastery of a higher level of power.

developed a parallel or analogue to biological systems, with a competence to develop a speed

$$\frac{P}{VW} \approx 0.2\text{-}1$$

P - power, V - velocity, W - total weight load.

This power coefficient is effectively independent of whether the vehicle is air, water, underwater, or land borne. There is some modest differences in ultimate efficiency, depending on size and some secondary speed characteristics.

We have achieved this with out building materials - wood, metal, ceramics - independent of the material used for the vehicle. We have almost 'simultaneously' mastered external combustion, internal combustion, compressed gas, electrical conversion, chemical potential, elastic potential, rotational momentum storage, hydraulic potential, nuclear energy, thermal potential. Namely we have 'quickly' explored all atomic-molecular binding potentials and even some nuclear binding potentials. We have done it within sight of the discovery of the atomic-molecular character of matter itself.

Clearly this case is valid. Note that tracked and trackless vehicles - on land, on sea, under the water, in the air - all fluids have been explored. The sizes, like in mammals, are roughly governed by gravity stress design on the large size, and thermodynamic loss design on the small size. Nuclear power design has not yet been completely shook down.

Yet the technical path we took, rapid oxidative combustion, at elevated temperature is not so usual for natural processes. Nature uses it, but in a more degradative step. It has limited man's technological directions, namely it forces man against the same nominal materials limit (of 1000°F) that he faced when he learned to fire ceramics. Metallurgy, building, structures, vehicles, engine efficiency went hand in hand toward the same molecular structural limitations. The high melting temperature atomic configurations govern (i.e., Be, B, C, Al, Si, Ti, V, Cr, Mn, Fe, Ni, etc.). Which? Pure accident. Cu first, Fe next. After that? Make your choice, elite, we'll make it work. (Of course, it had better be available.)

What is it that man can do? In time, he can emulate anything that nature indicates is feasible. Can he 'invent' new processes? Doubtful. Can he discover more? Yes.[1]

But, just as Elliot outlined in brain development, all lines of development do not have the same reach. Some are more evolutionarily limiting. The serious question that must be raised is whether the rapid combustion engine is a limiting evolutionary line.

Frankly its limiting nature has been on the agenda for the past 70 years.

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[1]Note - the wheel is often considered a uniquely human invention. Yet, we are in process of showing that a boundary rolling molecular layer in liquids is what made the engine process of life possible.

The early conservationists already had the vision. It is implicit in the wearing out of any resource seam or well. But man's myopia won't see it. It is contained in our forthcoming paper that points out that the near homogeneity of man's reproduction requires

$$\frac{dP}{dt} = [b-d] P$$

b less than d is thermodynamically valid, but b greater than d for any appreciable number of generation times is not. Namely

$$\left| \int_0^{N\tau} [b-d] \, dt \right| < \epsilon$$

and similarly for any other process caught up in thermodynamic chains.

The concept of the ecological niche is a basic one. Namely, thermodynamic engine forms can develop in nature, but they are stable only to the degree that they enter into a short cycle chain with the major long term potential source.[1] And for life that is the sun.

But this thermodynamic character of systems does not mean an absolute determinism for each individual atomism, each fluctuation. An aggressive kinetic fluctuation can take over the start of a niche. Namely, the field inhomogeneity is not unique. Any arc length of river that meanders along steepest lines of descent can do, etc. Thus start up aggressiveness, long term survivability (i.e., evolutionary capability to develop with low global profile, while overcoming vicissitudes) and modal 'color' are conflicting considerations in fitting 'ecological' niches.

Obviously, homo sapiens sapiens is both a young species and behaviorally a highly 'colored' species. He now has geological impact on the environment. There is no evidence for cooperative wave propagative endeavor that persists much over a generation, although society attempts to project its epigenetic cultural memories of the past 500 years to its young, and there are individuals - cogitators, 'intellectuals' - who attempt to build cohesively on the basis of past learning. All that governs the diffusion rate (displacement of one cultural unit sidestep per generation). And we are still in the linear technological diffusion range. But from a variety of sources and signs, that 'high' velocity diffusion may also be approaching an end.

Specifically nuclear fission and fusion will both work. Why? It works in nature. But that again,transfers the issue a number of generation time scales. The only potential hope for man, it would seem, is to temper his modal color, and use it for two purposes - how audacious should he be, and how can he achieve long range survivability. Unless he destroys himself with his high modal color, he must ultimately accept the two conflicting objectives.

There is no way to tell a species to select that long term survivability which is least 'dead-ended'. The choices are made by the aggressive <u>and</u> ad-

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[1] Namely they become involved with renewable resource chains.

vantaged breeding.

So apply these notions to the past 500 years. After 4000 years of urban ingatherings to the beginning of empires, and 4000 years experience with empires, the technology (ships, and over-land vehicles) led to compact nations as viable governable social organizations. Empires were not ruled out. Witness the repeated effort over and over again to build them. But they only last a limited time. They cannot continue to solve the thermodynamic problem. This doesn't deter elites from continuing to try.

So what can the cogitator, a planner-diviner for the near and far future, do? He cannot plan for the random appearance of a particular wild elite. He can only plan to make the 'is' and 'ought' of a social future nearly concordant to steer future elites toward a low global relaxation, toward long term thermodynamic survivability. We do not believe that great advisors throughout history have ever been able to do otherwise.

The relaxation toward near thermodynamic equilibrium will have to take place 'soon'. 'Soon' may be one to ten generations. We cannot narrow the time scale down more. Why? Because there are many process time constants involved. Our concern is to keep our eye on the three generation time constant. Three generations ago, the rapid flux of industrial materials, the mechanical augmentation of an agricultural way of life, began. High speed mechanical production (A suitable anniversary date is Jan. 14, 1914, Ford's first interchangeable production line began - a car in 93 minutes.), mechanical refrigeration for food preservation, mass public mechanical transportation (the 1920's showed their explosion in urban and interurban form), private mechanical transportation all exploded.

Fine, it all operates. What do we learn now? First, it built up the modern level. But now it requires high cost maintenance. Too much skill, exotic materials, interacting chains, levels of manpower have to be simultaneously maintained. The man-machine link is too precarious.

Obviously all people haven't learned that (in fact most of the populace hasn't), so another generation or two has to be spent in getting that message across.

So what lesson has to be learned? How can all that we know and can learn be brought together into symbiotic integrative organization to operate for long term? As empire? No, as viable social organization. And what size is that? Again, that size which can operate near thermodynamic equilibrium, namely national and some possible supernational organization. [Specifically, we opt for some multinational corporations becoming the basis for some future national organizations. Why? Because they have developed elite managerial types to whom that kind of outbreeding apparently will occur in time. How much time? The next generation or two.]

So that brings us down to the U.S.A., or perhaps still one step away. For there still is a technical issue we wish to explore.

Clearly whatever is cyclically advantaged grows explosively till it saturates. The growth process is diffusively-wave propagatively governed. With fixed agriculture having come out of slash and burn techniques and two crop rotation, and having moved toward deep plowing and fertilizer, and further mechanization of agriculture, industry, and warfare, and with a world wide diversity of product that has sufficient potential to drive the convection of 'goods', value-in-trade became a dominant variable in creating form and function of social institutions. The control of stored and exportable goods as a basis for capital, and the exploitation of such capital became a dominant theme. (In order for this to be true, the amount of goods available for export had to be considerable as far as the city-state-nation involved, and the producing population had to be of considerable size, as compared to the import world population.)

We now have a fair idea of the technological limitations placed by agriculture and mechanical (automated) manufacture. At least, we have a reasonable notion of this for the next three generations. The 'new' technological arenas are nuclear or solar energetics, synthetic materials (more 'naturally' derived), genetics. However one can surmise, in a general way, what sort of social changes 'revolutionary' breakouts in these areas might entail. This major effect will be to increase local productivity but at unknown 'costs' (in the sense of involving more complex external chains). Generally the 'costs' have involved mainly greater through-put in materials. (Examine the difference in style of living of a 'poor', a 'middle class', an 'upper' class urban or farm family in 1970, 1900, 1830, 1760, 1690, in industrial - agricultural U.S.A. - Western Europe. Can one detect that much difference in pattern of living? The incremental changes - technologically speaking - cannot be much greater. Or else, do the comparisons among technological leader nations at 500 year intervals - U.S.A. now, 1500, 1000, 500, 0 - to sense the larger scale changes.)

So let us procede now toward the ideal design algorithm for a modern industrialized - agricultural social organism, and in particular its transportation algorithm. We start from the premise that, with a solar potential, it must be at near thermodynamic equilibrium. Namely it must be able to defend and attack at its borders and maintain within its borders. And it must achieve these by human action modalities.

Photosynthesis. Clearly its insolation periods and distribution form a primary distribution for its ability to support life. Both current agricultural engineers and scientists can estimate current and 3 generation future maximal and optimal yields of photosynthesis from the land. And also for present and future land use, it can estimate the utilization factor for the land. It, together with the entire analysis, will indicate whether intensive research in increasing photosynthetic yield or changing weather to increase growing season is productive for the period or not.

Domesticated 'support' species. From the emergent primary photosyntheic chain, there is support for a secondary domesticated species chain. Man has most often lived off this chain (flora and fauna). It is our contention that now, as extensive or more intensive than ever before in history (possibly as great significance as when the climate changed, plants and animals dispersed, and man had to become domesticated 10,000-12,000 years ago in Eurasia), man must restudy and master this chain. Herein lies his renewable species. One must realize that cultural lags can delay acceptance of change for 1-3 generations.[1] On the other hand, the highly insistent coercion of advertising has shown that it can succeed in changing styles - of food, materials, etc. - in that time scale. Not every direction of change is equally accessible, but there are really not too many restrictions.[2] Thus one can start from the current order of preferences and, by extensive R and D of a scientific and engineering nature, one can surmise what kind of changes might be achievable in 3 generations. Clearly many of these would be productive.

Non-renewable resources. Here we have come to the future bottleneck, likely in the next 1-3 generations; if not then, 4-6; if not then, 7-10; but by then. So here is where the R and D is needed. One must look at the earth as follows: as a result of natural geological processes, the earth plates move and buckle. Mountains are thrown up, earth resources are shifted around. The hydrological and meteorological cycle carry material to the ocean, and to some extent redistribute some materials. Man likely should augment that process by bringing materials back from the sea, and performing some other redistributions. He likely can no longer use up natural resources faster than he can replace them - on the average (e.g., per year or per generation). But the transition cannot be made in one generation. It likely can be achieved in 3 generations or 6. One must note that the design time for a national entity in a civilization is of the order of 3 generations. We are still involved in the 'first' mass transportation system that began 3 generations ago (more exactly about 50 years ago was the average peak wave front of development). What is at stake now is the planning either for an intermediate transition system or a full future system. We do not believe that the latter can be begun now. So we are stuck with the transition system. Perhaps a very preliminary sketch of 6 generations hence can be lightly outlined.

Of course much of the more immediate issues are metals and fuels. The limitations are the need for high stress and high temperature material. The need for high stresses can be dealt with in two ways - one, it is possible to raise the usable stress limits of natural materials; two, it is possible to reduce the peak stress requirements in vehicles and structures. It is largely military applications that pose very severe limits (e.g., in aircraft, missile 'craft'). High temperature stresses are required for combustion engines and heating devices. Again military requirements pose the most severe problems.

'People' resource They are reactive to the milieu, as we are in process of finding out. When things are bad economically, they breed to maintain a marginal subsistence number. When things get good, they reduce their breeding. Recent experiences - since the 1920's - have reduced water borne disease, largely of a self-polluting nature. 'Now', man is more subject to a few remnant dis-

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[1] Examples are so numerous not to be worth dwelling on. American Jews have departed from Kosher observance in about 3 generations; Japanese youths have changed their body size appreciably in about 3 generations, due to change in eating habits, etc.

[2] Given our statement of the preferred order of elite modalities, one might pay some vague attention to that order. A more erudite study, say of odor or taste, might judicate some preferred directions or some directions of rejection, but again, those are only modest restrictions.

eases (CV - largely due to social stress, and cancer), and an unknown future viral experience. (Aging aspects haven't changed.) It is surprising, but in recent times, it has been found that a nearly 'flat top' mortality experience (e.g., Sweden) is possible (flat out to 70) that reaches toward human 'ultimate' life expectancy (95). One surmises that a well cared for people, participating each to their abilities and socially encouraged inclinations, can achieve some fairly equitable style of living. Namely a governing elite, with self interest, some self indulgence, hard working, attending to their national interests, without too extreme a maximum to minimum style of living ratio. Whether this has stability far greater than a few hundred years is not clear.

But the conflict we will face in the U.S.A., as we can see remnants of such issues in France and England after passing the zenith of empire, is a precipitated conflict between a reactionary view of past glories and a reactive liberal-radical view of change, even radical change to find some other life mode that can achieve new peaks of achievement.[1] Meanwhile the elite will have passed on.[2] It is our belief that these will be multinational corporate structures, taking their value-in-trade resources out of the country.[3,4] Thus we have to consider a new mixed elite - remnants of the old, and a new elite that will appear to guide our future.[5] But regardless of what outlook elites may hold in the future, the industrial-agricultural way of social life will be at levels of complexity comparable to today (i.e., we are not in a revolutionary period).

So we come to the issue of unfolding a technological future from its existing state. And that now has to lean toward a lower 'global' profile, a more compact internally cohesive national entity. Do we face breakup at the 3-6 generation level in the U.S.A.? There is no particular reason. Thus we ought to be able to retain a union of states, even if many are of national unit size. The greater paradox is the role of urban-agricultural settlement - industrial settlement in the future.

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[1] Why? It becomes part of the cultural heritage, and gradually disappears into the mythic past that there was a style of life that was highly productive. Witness its past glories. Whether those past glories may or may not have reached the populace is irrelevant. They must have a world image, and their past is obviously one that fits their cultural heritage.

[2] Namely those elite who had made and ruled it big. The issue we face is where will their next great focus be directed. We opt for multinational corporate development in which they seek freedom from restrictions on their activity. Ultimately as a new outbreeder, they will be caught up in nationalistic leadership.

[3] At present they have already achieved such a seeding. Roughly they have taken the level of capital resources of the U.S.A. in 1920 out of the country. This is hardly an inconsequential seed money.

[4] The sociological study of evolution in society is seldom carried out with the depth it deserves. A ground-breaking study, albeit small and quite restricted is by Sennett. It deals with the order of developing in an urban center, Chicago.

[5] We regret that our belief is that they, being on the down side, will tend to tear down our U.S.A. civilization. This kind of planning that we are doing is the only hope for a rational long term furtherance of our civilization.

A rational balance for this future requires a transport system that truly satisfies the conflicting transport requirements of this system as an integrated system. And the increased industrial product through put required ever since the 40's has to be efficiently served. For the first time an efficient national distribution system must be designed to serve a high internal convection. This is required as a substitute for the focal centered local circulation of urban centers.

So what algorithm will serve total large national transport and also serve local convective transports. It was a prominent member of the Congress who called to our attention some time ago when we tried to interest him in our proposed ecological study, that the entire north central part of the country had been operating a long time as an extractive economy. Our point is that we cannot run and denude our country as an extractive economy. Thus the 3 generation future of national transport has to be based on those centers and areas that can supply a more replaceable and reusable materials. Namely one has to lay out those regions which are most nearly self sufficient in thermodynamic resources at a projectable future technology. Note that two full scale computations are required. One has to work out a viable thermodynamic chain for the future projected technology (at least in major details). Second, one must work out how the local system is in near thermodynamic equilibrium.[1]

But independent of the details of those computations, the network requirements can be laid out. In what we propose here, a near equilibrium design algorithm is derived. Others, equivalent in function, are possible, but it is contended that little difference in design will result.

1. Design an agricultural supply system for the future. The requirements are a tolerable mix of 2500 Kcal/day per person (plus whatever losses are estimated). A sufficient surplus may be projected that helps represent part of a balance of trade. (Remember, all that can be shipped out in the future is whatever is renewable, e.g., air, water, some salts obtainable from bordering oceans, the finishing of raw materials which are to be shipped in and out.)

2. Design the required inputs for that agricultural system, e.g., fertilizer.

3. Design a domesticated plant-animal system that is integrated with the agricultural supply system. (This means that conspicuous consumption and wasteful consumption is no longer tolerable - at least for more than 1/2 decade to shake the notion down. It means that some 'traditional' notions, e.g., corn-hog ratios, beef cattle, etc. will have to be shook down to re-examine what mixes of meat versus fish versus plant foods provide near optimal supplies. In

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[1] Namely, it is always local - in space and time - issues which are most pressing. Thus a critical part of such computations is a plausible path from now to the future. If man were ever to achieve the same social viability as the biological organismic viability, some smoother transition at the 3 generation level is needed in materials for systems' replacement and turnover, rather than the closer 300 year civilizational centers replacement. This program presents exactly that kind of design challenge.

other words the 'free' competitive system will simply have to be narrowed down. The likely optimal solution will be to provide the American public and foreign supply with a mix wherein the 'winner' of internal supply is rewarded a little higher than the residual 'winner' of external supply, e.g., by the difference in shipping economy, so that some measure of competition can exist without it being wasteful. If that 'freedom' algorithm is not suited, one can choose some other. But totally free markets can no longer meet future social needs. The supply solution sought is not 'good enough' slop for man and beast, but a quality product commensurate with available supplies. These are difficult computations, but technical people applying the 'would I and my family be satisfied by such materials for long term use' test can easily lead to satisfactory product selections.)

Note that these systems are largely seasonal, namely governed by the earth's cycle. A large degree of 'engineering' know-how exists among farmers, lumber men, fishermen, meat and poultry ranchers, synthetic food manufacturers. Clearly their interests have been largely value-in-trade, market oriented. But beyond that their technical know-how, their scientists and engineers technical know-how, can characterize how such a system can work efficiently. Obviously, they will be extravagant in the use of high productivity, likely wasteful materials. But by scaling their responses at various levels, both in present and future technology, one can gather an idea of what class of fairly economic solutions exist. They will be high productivity solutions, but they must be at the margin of small use of nonrenewable resources (future generations can design even stricter requirements, if needed).

An economical transport system can be designed for those needs. What that sentence means, among other things, is that certain 'utilities', e.g., transportation is no longer a free market commodity. The solution must be conceived as an orchestration of an optimal combination of various transport means. It is still the case that water transport is likely the cheapest means of transport and rail transport next. The 'more final' design modification of a water ways system that fulfills clean transport, water supply, hydroelectric power, and recreational use, is one order of business. Pipe line transport is a second required system. An adjunct low loss (in energy and materials) guide-rail system is another requirement. It is most plausible that an electrified power system be used in which utilization is distributed in off hours, as seasonal transport.

There are two conflicting notions contained in this recommendation. If we are truly in the decline state of our civilization and it is no longer possible to reconstitute a common faith, common purpose, common goal outlook to bind together our diverse regional, cultural, ethnic, occupational molecularities, then a large degree of socially tolerated vandalism will take place. How can such an expensive, vulnerable, system be proposed? The question is whether we have any alternative? At the present time, without adequate experience in the 'design' of 500 year 'civilizations',[1] we can only surmise that if one

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[1] Note that every chief executive faces this kind of problem, although in a smaller way. He has had no experience in this executive task - for life is truly an aperiodic relaxation - so he does the best he can with his experimental preparation up to that point. His 'best' information is some case study of how the process chain was handled and fouled up by others in the past. But there is no guarantee that his stewardship can control the dynamic destiny.

can wave propagate and diffuse a coherent thesis into a society, it, at least will, with the longest time constant, relax to the state that large scale potential gradients are driving it. The alternate is the Fanon philosophy - vandalize and breakup the system as quickly as possible. All engines have a utilization schedule. We see no reason to discard a system so early, or still so useful in its life phase. But the utter sustained mindless statements that defendants of our current status make, e.g., "The free enterprise free market system has worked so superbly, and is the only system that can deliver" is most surely going to sink us almost as fast as the wildest revolutionary. It simply lacks understanding of how short lived that free market expansionist system has been. (Like most Malthusian - Gompertzian explosions

$$\frac{dP}{dt} = aP$$

whatever material entity P is. Namely thermodynamics always recognizes a b-d component to a, wherein the difference, is strictly bounded.)

'Youth' in systems always 'feels' unbounded. It isn't until a large numner of collisions that the system becomes 'aware' of its bounds.[1] Systems that have any self regulatory competence to preserve its life span against breakup deterioration, in middle-age, are fewer.[2]

But, of course, to provide coherence in our societies requires a coherent philosophy (read outlook) of design for materials, defense, industry, transportation, education, procreation, health, recreation, governance, technology, communication. Else you wind up with a shiny new interplanetary space vehicle in an early neolithic village settlement.

So we can only proceed on the notion that U.S.A. society will recognize (by cognition) its socially needed design in 3 to 6 generations.[3]

The advantage of a distributed power transportation system rather than a

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[1]Obviously many will object to the anthropomorphization, but it is used with the same intent as Elliot. It is not that all matter has the outlook of man, it is that man has the same outlook as nature. In an organized ensemble, every atomism 'senses' the presence of every other atomism. Consider, if you will, phase change in which only limited number of molecules precipitate into liquid or solid phase; or consider ionization and recombination of atomic - ionic - molecular species concentrations. There is a systems' coherence developed whether centralized by a central nervous system or not, or whether by chemo combination, is a small matter.

[2]E.g., stars can cascade up a cresendo of interesting temperature processes before blowing up in a nova-like explosion. Perhaps life took on a second look with oxidation processes replacing the earlier reducing processes. We, thus, already ride on a rising cresendo.

[3]Does a man or woman become middle aged prudent by 35, or by 55? In the main, with 70 year life spans, these seem to be the lower and upper limits. Thus we are putting the same kind of limit estimate for the discovery of prudence nationally.

self powered distribution system (i.e., independent prime mover engines per vehicle) is that losses can be minimized, optimal efficiency of scale can take place, and the generating source can be modified as technology progresses. But electricity seems to be the main transmission source certainly for the next 3, probably 6 generations.

But that means (in the transportation system) copper and aluminum and iron, a dependence on non renewable metal resources. Not completely. In the first place the losses do not have to be large, except for the high stressed wearing material iron. In the second place, these losses, by careful engineering-scientific design, can be significantly reduced. In the third place, in a longer time scale, the technological issue of dependence on high electrical potential ohmic thermal design can be reassessed. Living systems have selected the low potential chemoelectric path. We would consider metallo-organic or ceramic-organic catalytic processes as a technological path worth the exploration. For operation in 3 generations? No, more possibly 3-6 generations.

How is such a system to be designed? It is designed by a series of rounds of approximation. One must first select the focal regions as centers that have key contributions to make. The rivers follow the land. Roughly, agriculture is related to water supplies. As we said some future rounds can indicate key water supply changes that are worth considering if and when they become technologically feasible and viable. The same is true then with regard to weather modification.[1] If one wonders how such 'practical' rounds of computation are made, the answer is that there must be planning ongoing at various time scales, i.e., 3 generation planners; 1 generation planners; political scale - half decade - planners; seasonal planning operators.[2]

The orchestration of the seasonal movement of materials among focal regions - first to achieve agricultural needs and then to achieve related needs - is essential. Note in our model, we count on a significant reduction of one way extractive processes. For example, we are very serious in believing that forest and other growth products will have to provide the largest substitute for structural materials.

The latter remark requires comment. We believe, technologically, that high strength naturally derived materials can be developed. The only two losses are reduction in modulus (from $30x10^6$ psi to $10^6$ psi - namely more flexible structures), and reduction in temperature range. The former tends to eliminate high structures. But in a very significant sense high structures must go. A few story open structural design has to become a more dominant style, as a society which is more solar oriented is created. You can say "never", nevertheless conflicting needs will knock the large urban monuments down.[3]

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[1] E.g., at some time the issue will arise whether 1/3rd of a nation in desert is tolerable, or whether some mountain modification could change that climate.

[2] The scheme is not new. It is used in the biological system. It was Sloan's contribution to G.M. management to divorce planners from operating responsibilities. For those who say this will take the 'fun' out of seat-of-the-pants management, this is the same revolution that took place in operating an airplane between 1910-1930 start up and 1950-1970 'maturing'.

[3] They started with the Sumerian urbanization of 4500 B.C. Their life-span has been reached. They have peaked.

Obviously the conflict will make the ephemeral demand for the daily newspaper obsolete. The product is too valuable for such trivial use of the material (10 years of growth for 1 day of use).

It is only the need for high temperature 'engine' parts that grown materials cannot easily satisfy, but we would not regard that so pressing for 3 generations. Technology has time to advance arts here.

Thus the materials fluxes are from primary producing and secondary producing centers out to functional population centers, and out to borders. The transportation system has to be designed as a least loss system.[1]

But that system can only survive if it has an internal and external defense (sub)system. There is a required algorithmic study whether the transport system thus designed is optimally defensible.

Not all systems are defensible. You must fit into the 'ecological' niche (here of nations and technologies and political systems). But you cannot spend all your energies in defense. An excessive cost in defense pulls a system down, in time.[2] But some national, as well as individual, tragedies have to be played out.

And so, the system - now and in the future - must be examined for its defense posture. One must count, on the average, for about 1 major quarrel per generation, or three in three generations, with the understanding that major rhythmic gains are made in technology per war. Also one must understand that about 3 generations (i.e., three major wartime spurts) tends to blur the technological vision of scientist and engineering practitioner. He is welded to his past 500 years and his vision has some discernment out 3 generations, but by then it becomes faulty and full of noise. It is the high temperature freedom from 'normal' constraints that permits the explosive impulses of wartime. This doesn't necessarily result in notions that are absolutely 'new', but it releases all those bulk viscosity tie-ups and repressions that might have been hanging around. The collective 'mind' is cleared and brought impulsively toward equilibrium.

But noting that warfare is conducted with no holds barred, one must consider a future strategy for defense. Defense has always been profligately wasteful of resources (even while encouraging their development). Can one conduct warfare with 70 year old materials? Almost. Note that warfares 'today'

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[1] Most systems are designed by Hamiltonian optimization laws, e.g., any minimal path problems in the calculus of variations. We have developed an alternate but parallel strategy. Systems are really designed according to the 'Q' of the processes. Local energies have to be designed to overcome losses. Then the system is quasi optimized by a pseudo-Hamiltonian program. Namely all sorts of local deus ex machinas are required to make the system work.

[2] As with organismic defenses against external attack, there is a complex life shortening theory that may relate to how various organs or institutionalized lines are deteriorated. This is not a well developed science.

are conducted with a mix of 1900, 1920, 1940, 1960, and 1970 equipments. The same dispersion was true in 1940, etc. So the answer is 'yes'. An extremely careful and perceptive military does not have to wait for the last moment before it gives up a highly aggressive posture (e.g., ancient Rome) and selects and settles for a long term survival posture. In the 18th century, the preservation of an army was more important than engaging in fights.[1] In the 21st century, the preservation of nation and its 'spiritual', natural and material resources may be more important than engaging in fights. At least to the extent that this outlook is achievable in the U.S.A. the dissolution of our national portion of civilization can be prolonged.[2] Nuclear warfare has to be counted on. At most it can be delayed 1-10 generations. It has already been delayed 1 1/2 generations.

But then industry, tied seasonally to the primary materials production, must be specified. Are their focal centers? Possibly, but somewhat weaker. Note that usually their location and use of nonrenewable resources is what governs their location, and to the extent that we are still using nonrenewable resources, this may still be true. Namely other resources are still the focal attraction, e.g., clean water, transport availability, power availability, a production chain.

How to design if the focal centers are not so strong? One basic systems way is to do a Monte Carlo or Markov chain technique. Design 'at random'[3] a number of focal systems' layouts, and game them particularly for stability. Use some optimization criteria, e.g., lowest materials' nonrenewable cost, or what you will, to select some design that lies near the probability maxima. This means it will have maximum survivability. If in fact there are critical narrow valleys, these are the regions in which considerable technological research is warranted to try to broaden the gap. Some gaps may not be broadenable (Example of today's genre, the possible fragility of the ozone layer, or the $CO_2$ concentration, or mean surface temperature). These must be walked around gingerly. To illustrate, the spectral confluence of great floods is estimateable. The cost of human resettlements every periodic epoch must be carefully estimated against a modified land use, against modifying the water system.

The extension of the transport system to fulfill these secondary seasonal needs must be considered.

The design of tertiary goods and services which are needed must then be designed for their focal centers. At this point the thermodynamic completeness of local regions must be considered. A difficult division into equally 'have' regions must be arrived at, for if this cannot be done, then an indefinite reason for conflict will have been created. Best are nearly equal domains of near self sufficiency. Next best are regions each lacking one major

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[1] A. Beaufre, An Introduction to Strategy, Praeger, N.Y., 1965.

[2] The authors are not arguing against significant useful combats that contribute to long range survival, but against stupid adventures that sap the natural life.

[3] One might as well use a number of perceptive 'random' humans' design. This is cheaper than using an idiot machine which does not, yet, have human programming capability.

material which balance out in a cyclic circular chain. Next best are two or more lackings that balance, etc. Even better than the best is when there is a seasonal reason for moderate change in transports from region to region.

The ordinary notion has been of a melting pot. We submit that this has no stability. Heterogenous molecularities precipitate out. Thus the best design is for a designed diffusional mobility in which molecularities are in a suitable motion. The jet set mobility of 10,000 miles per year is too fast. The post-neolithic scale of 1 mile per year is too slow. An artificial engine process that speeds it up is not bad. Thus, for example, the USSR's notion of paid vacations is a good one. It gets people, who wouldn't go, to resort areas.

Of course, the statement would be made that American automobile mobility did this. No. The resort areas did this more - a Coney Island, an Asbury Park, an Atlantic City (a British Brighton, etc) - was an American solution. We clearly understand the desire for elite exclusivity, but we insist that the future will have to provide regular diffusional mobility of an entire populace - poor, middle, rich. It must be provided at good quality and at moderate cost. The temporal magnitude of such diffusion can be estimated. It should be of the order of 300 miles per year (give or take a factor of 10). The 'reasons' for such diffusion can be invented. They may be recreational (sun and sand, or snow. Remember there is a priority order of excitation hungers, if physiological survival is not at stake.[1]) They may be for health (e.g., travel to health centers for yearly checkup). They may be for education (e.g., students now are accustomed to travel away from home for education. In fact two cultures have already shown its feasibility past age 6-8, and perhaps its post-adolescent necessity.) They may be occupational (namely, many mobile near elite and near indigent have already gotten aboard such travel routes). The only need for such movement is secure egos. With some intelligent planning of living quarters, intermittent (holidays), seasonal, or slow sustained convective patterns of living can take place.[2]

It is our contention that some such sort of slow convective diffusion is necessary to hold this nation together. It is not the case of trying to melt ethnic and other molecular groupings. The 20th century has been quite clear in its message (as one could read from ethnic formations all around Europe after a 6000 B.C. Indo-European diffusion), groups do not dissolve. They precipitate. Aimlessness creates weak 'bureaucratic' formations, which any slight convection organizes into 'hard' bureaucratic lines. These principles are sufficient to form all kinds of systems. Systems of customs, habits, occupations, laws, etc. form by them. The order of precipitation is clear - 'forms' develop around rotational momentum, internal chemical or physical phase change, nuclear, or fundamental 'particles' energetics. Thus inhomogeneous irreversible thermodynamics always remains the order of the day and night (a most felicitous phrase).

Our basic point is that if there is a need to lower the global profile

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[1]We have identified these earlier.

[2]Mildly high mobile persons have begun to make a move per 3 years. This may be too fast. But cultural shock is not great at 2 moves per generation.

(e.g., to use fewer nonrenewable resources[1]), then a more regular plastic-solid thermodynamic array is required, and the more carefully the alloying and heat treatment is developed to extend its domain organization and the domain organization binding, the better chance that that chunk of nationalistic alloy has to persist. All that a stone can do (or a living species) is to survive its weathering while its atomisms and molecularities stay in sympathetic association.

So 'finally' we come to the populace. Have we designed a 'fake' system for them? No, we have designed a background system into which they can fit. And this may require more than one round of design. Let's illustrate.

The system we have designed may have a certain human carrying capability. But we haven't put humans in the system. So we can either start by superimposing an optimal concentration of humans onto that system (which we haven't defined yet), or any of the near optimal systems that are so designed to nearly satisfy the same restrictions, or we can design for a 'half' (e.g., 20, 40, 60, 80%) population. Now starts the deformation, back and forth, until an optimal fit between system carrying capacity and population is achieved. We can and ought to test the self regulatory characteristics of the system. Namely, does the system have evolving characteristics to move toward that solution in 3 generations, given some policy decisions and commitments?[2]

So now we turn to the optimal conflicting design for people and for their operative system, particularly from a transportation point of view.

Clearly the dominant human process is the day-night cycle. Human systems' needs are seasonal. Human individual needs are daily. The problem we are posing is that by having recognized the need for a low global profile in the operation of our social system, and by recognizing the large component of a yearly repetitive cycle, we could design a public utility system (water transport, pipe transport, tracked transport) that largely took care of that complex cycle, in a largely self-regulatory way. Now, to a considerable extent one can begin to design a use of the same system for shorter interurban daily transports to fill up the duty cycle. (The time scale for regular transports still always remain 10% of work time, e.g., 1-2 hours. In Neolithic times, this was in a 25-mile diameter, so speeds of 2-3 mph would do. Post-Neolithic, with regular transports between neighboring 25 mile regions, one requires 10 fold - 20-40 mph - transports.)

All this planning gets away from the current frenetic impulse action, the 'absolute' freedom to do what one wants when one wants to. The whole point is that complex systems tend to limit that freedom, and it becomes highly expen-

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[1] Remember, if man were to be wiped out, by himself or naturally, this hardly represents much concern to other species, biochemical or geochemical. Even if man were to wipe out biochemical chains, the geochemical chains would persist with existing resources. The driving potentials are still there.

[2] At this time, we don't want to stop to discuss the significant issue of outbreeding versus inbreeding. There is some need for population interdiffusion and immigration and emigration, but we will leave the problem for some other time. (But see (24)).

sive energetically. We propose to lower the global profile by providing many more self-regulatory chains than these feedback chains (e.g., telephone for a reservation and immediately, by feedback, learn whether one is available. The net effect, over a long period of such travel experience, indicates a rather high cost - in time, cost, facility, delay - that is not commensurate with the apparent ease of receiving the service when it is a class item.) Thus a slower pacing with a lower cost more certain system, one which is pieced out to meet the major contingencies, is the essentially required system 3 to 6 generations from now.

So we approach urban foci. How is transport to be arrayed for an urban center by some algorithmic construct. Because now a transportation algorithm is needed. One must remember two American visions (they are peculiarly American because we were a large sparsely settled country) - one, the vision of the right and the wrong side of the railroad tracks (at least partly governed so because the railroad was dirty); and a second, more recent, the vision of the linear city.

Both for a change in pace, and a question as to future styles of living, we inject a piece from Harrison Salisbury (<u>To Peking - and Beyond</u>, Quadrangle Books, N.Y., 1973):

"Journey to Another Century

I caught my first glimpse of China through the slit of an observation post atop the barbed-wire-nested guardhouse at Lo Wu station, terminus of the 27-mile railroad that runs from Kowloon through the Leased Territories to the Chinese frontier... The year was 1966, and China was tense with the exploding Cultural Revolution...

"I had two other snapshots of China from afar. One was from Macao, the 400-year-old Portuguese trading center...

"My third glimpse came from a Russian TU-104, tossed like a chip by a thunderstorm over the Ussuri River...

"Three images of China, each menacing and dangerous; each stern, chilling, forbidding. Approach China with caution - this was the message. And there was, too, an implicit contrast in discipline, the ragged individualism of the marginal western world on one side, and the strict law and order and neat landscape of China on the other.

"I thought I had a good idea of what China would be like, partly formed from these furtive glimpses, and partly from remembered fragments of a hundred crossings of Communist frontiers...

"Which is by way of saying that when I walked across the bridge at Lo Wu, typewriter in one hand, briefcase in the other, camera around my neck, I was prepared for a grim encounter. I was not expecting the shy grin that appeared on the faces of the two PLA men with their back-slung Tommy guns at the China side of the bridge...

"First impressions are important. My first impression of China stood in stark contrast to my expectation of China, and to my experience with Communist countries in general and the Soviet Union in particular.

"But I thought, of course, the Chinese may simply be putting their best foot forward. This may not really be their style at all. Think again of the Cultural Revolution...

"The waitresses were clean, neat, friendly. They did not seem to think that it was an indignity that I had interrupted their leisure by sitting down at a table - as Russian waitresses usually seemed to do...

"I didn't know why, but I felt at home. And it was a feeling that never left me. Not even in the depths of the countryside; not even on that curious midnight ride through Peking. Not in Yenan. Not in the great cities - Shanghai, Wuhan or Canton. Wherever I went, China felt like China. There is no other way of putting it. It was Chinese, recognizably Chinese...

"I had come expecting to find tensions, to find harsh lines of worry curving the lips of officials, to see worn and sullen looks. But as I stood on the balcony of the reception building at Shumchun and looked across the hot courtyard to the street, no one even glanced my way. It was obvious that this was simply an ordinary village street in an ordinary Chinese village, yet it was right at the Leased Territories line, the frontier. A hundred yards away lay Capitalism, the outside world, the enemy. Where was the vigilance, the surveillance, the electrified barbed wire, the watchtowers, the trained police dogs?

"It was difficult to believe that I was plunging into a nation on guard, a nation pregnant with xenophobia and fear. What was the scene? Ordinary Chinese coming and going, coming to the station to wait for the train to Canton, strolling down the street to buy in the shops...

"An ambulance slowly halted outside the station. Two young medical attendants with white smocks and nose masks opened the back and helped out an elderly man, probably a patient going to Canton for treatment...

"First impressions...I leaned back against the lace antimacassar, neatly pinned to the blue upholstery of the train seat. It was a clean train, decorated in blue and gray, lace curtains at the window, many excited Japanese tourists taking pictures of each other, and at one end, a rather poor painting of the famous new bridge across the Yangtze at Nanking.

"I turned my eyes to the window and watched China...emerald-green countryside, the emerald of rice paddies (I thought of the Emerald City in the land of Oz), terraces in the red earth climbing every hillside; gray water buffalo in the ponds and paddies, knee-high corn, women in conical straw hats transplanting the rice; new orchards on the hillsides, new pine stands, and in some places people setting out the trees; fields of cabbage, beans, peas, squash, melon and cucumbers; walled gray-brick villages, each with a two- or three-story tower. Grain elevators? Or watchtowers?

"I lost track of time as field succeeded endless field, then looked at my watch with a start. We had traveled for an hour and a half through the countryside and I had yet to see a car or a truck or a tractor or any kind of farm machinery more complex than a shovel. I had not even seen a road, only narrow paths wandering through the fields, curving around the paddies, linking village to village. The countryside lay quiet, verdant, planted to the last inch; the villages seeming to grow out of the very fields, the people moving slowly across the horizon at their traditional tasks, backs bent as they set out the rice, backs bent as they set out the new young trees, backs bent as they pulled their barrows along the narrow paths.

"As I watched a man trundle his barrow through the field, I realized that I had done more than simply walk across the plank boards of the little bridge over Shumchun River, passing from one country to another, I had walked across an invisible line that took me from one century to another. On the Lo Wu side I was in the 20th century, the 20th century of industrialism, of tin cans, of paper wrappings, of gasoline engines, of urgent motors, of blazing billboards, of crashing sounds - the world of waste and garbage and litter and junk, the land of machines and hurry and hustle.

"Now from the window of a 19th-century railroad car I looked out at the 17th century. There was nothing in this cavalcade of villages, this checker-board of rice paddies, this world of men and women and animals and simple tools, hand made, hand wielded, that would startle the eye of a traveler to China in 1672 or even 1572. The people wore the same conical hats, the same simple blue trousers and formless jackets that march across those willow pattern dishes of grandmother's day that introduced most of us to the land of China. The rice grew in the same way, its green as brilliant as ever. The water buffalo had not changed. The meticulous orchards and precise terraces had been transferred from some ancient scroll.

"There were no archers on the village walls but, perhaps, they still stood guard within the watchtowers. I knew the great iron-bound gates in the village walls still clanged shut at sundown. This was not a journey into nostalgia. It was a genuine journey backward in time, a backward leap of centuries into a coherent and compatible way of life in which the land and the people, their animals, their rice and their millet lived and grew in harmony, all things falling into the place that nature and nature's bondsman, man, had intended them to fall.

"Well, perhaps, I exaggerate a little. It is true that I saw striding across the countryside, heedless of fields, heedless of villages, the conventional stilts of an electric line, starting somewhere behind and extending as far as my eye could see. But there was only this single standing line. It is true that the train's presence, moving easily across the fields, quiet, no sound from its whistle, smooth on the well-balasted rails, was a 19th century anachronism. But there were no other signs my eye could detect that I had not suddenly and improbably been propelled backward into a century that was coterminous with the one in which one of my ancestors set out in a small sailing vessel from Bristol, hoping, in a matter of months, to make landfall somewhere in the New World, a hope fulfilled, providentially, in Rhode Island in 1640.

"The implications of this discovery I did not attempt immediately to fathom, but they were obviously profound. I had come on a journey to the Future. But I was first plunging deep into the Past.

"Could it be that the path to the Future led backward in time to the 17th century, rather than forward across the industrial battlements of the 19th centurn? Could it possibly be that the Industrial Revolution in grimy Birmingham and Manchester, that cataclysmic event that Marx saw, analyzed and then employed as the launch-point for his vision of a new society and a new man, arising out of the factory-created proletariat, could it be that this outward thrust of humanity, idealized in the west, carried to almost mythological perfection in computerized America - could this be in reality a cul-de-sac with no opening to the future, a cul-de-sac that China with its ancient roots so firmly imbedded in the soil had already discovered led only to disaster?

"Or was this Chinese landscape the simple product of austerity? Perhaps the Chinese, lacking machinery, lacking modern tools and instruments of production, had simply settled for an interim solution - to put their traditional agriculture into order, to practice the art of farming as it had always been practiced, without introducing the machine age, imposing only on the simple landscape certain basic new patterns - better organization of labor; lifting the yoke of landlord oppression and debt; an end to starvation, undernourishment and epidemic disease; and, for the soil itself, better seed, better fertilizer, herbicides and pesticides.

"For any judgment on this, a train window was hardly sufficient. It would require first-hand knowledge, visits to the communes, talks with the peasants, a close-up look at what well might prove to be a blend of China's oldest folkways with some of the new weapons in the 20th century's armory of technology.

"This question remained for later resolution. But there was another - equally pressing. Was China, in fact, the land of "blue ants" as so many writers had insisted, a nation of 800 million human robots, dressed in blue denim, emotionless, faceless, automatonistic creations bent to the inscrutable will of unseen masters pushing buttons in the depths of some secret retreat in the inner recesses of the Forbidden City?

"That was a concept toward which I myself had been drawn more than ten years earlier, when I had my first glimpse of Chinese workers in Outer Mongolia. There were then in Mongolia some 40,000 Chinese - sent there as a contribution to mutual aid. I saw them everywhere - in Ulan Bator, building apartment houses; outside the city, throwing bridges across the Tola River, installing water conservancy systems in the dry steppes, building roads, doing the thousand-and-one tasks that an underdeveloped country urgently needs to have done. As they went about their work, they fitted perfectly the "blue-ant" tag. They wore identical dark blue trousers and dark blue tunics (both men and women, although most of the workers were men); blue caps of identical cut. They rode bicycles in almost military formation (no one else in Mongolia rode bicycles). At 6 A.M., I saw them on the stony banks of the Tola River doing their calisthenics - hundreds of them, bending, twisting, jumping, turning, like a mechanistic ballet. I saw them march in the Nadam parade, a blue clockwork brigade, their clothes baggy but their pace machine-like amid the turbulent outpouring of Mongols, arms swinging and legs uplifted with almost Prussian rhythm. Blue ants. It was easy to believe their minds and thoughts were as disciplined as their arms and legs.

"It was but one short step from the concept of "blue ants" to the concept of the Chinese colossus - the titanic China, 800 million strong; the world's greatest mass of humanity, trained, obedient, ritualistically ready to do the bidding of their mythic leaders. It was, of course, out of this construct that the Russians had fashioned their terrifying image of China as the new Mongol horde. The question was simple: Were the Chinese, in fact, "blue ants" or was this just one more of the pejorative epithets that foreigners had applied to China over the years? Was it, in fact, merely a color shift from "yellow peril" to "blue ant"? Were these concepts, in fact, merely two sides of a common coin?

"Here the evidence was swift and persuasive. It took no time to see that the Chinese did not look like blue ants. True, they dressed more or less uniformly, but the uniformity of dress did not stifle diversity in personality and temperment. After my first glimpse of the waitresses in the restaurant at Schumchun, I could no longer believe in the "blue ants". These girls - pretty, jolly, not the slightest sign of stress or self-consciousness - kept up a constant stream of jokes and chatter as they waited on the foreigners. There was nothing rude or inattentive about that. It was simply the mark of warm and easy relations among themselves. They went about their tasks not like automatons, not like soldiers obeying orders, but like simple youngsters, enjoying their work and enjoying each other. I could not think of these pretty girls as "blue ants".

"But in Canton, and then in Peking, in one Chinese city after the other, I saw how the concept had taken shape. Many Chinese do dress in baggy cottons or synthetics, and the predominant color is blue. But it is not one standard shade of blue (as had been the case with the labor battalions in Mongolia). The blue ranged from horizon to midnight. Some were fresh and some were faded. Some were new and some were shabby. And the color monotony was broken by the blouses of the girls and women. Though simple, they embraced a range of colors and combinations. If they were not yet what we would call bright, they were not monotonous or uniform. And the children were a delight. Their clothes came in every shade and style, the gayer the better; and it quickly transpired that a quiet effort was being made by the government and, I suppose, the party, to persuade both men and women to express greater individuality in clothing. A visit to any department store confirmed it. Dress goods counters were a riot of colors and patterns - patterns being bought, and obviously not entirely for children.

"But the "blue ant" image didn't apply simply to uniformity of dress. It was intended to describe uniformity of conduct, uniformity of thought, uniformity of habit, perfect obedience, submissiveness to orders, subordination of personality to some higher scheme. If this concept were valid, the New Man (and New Woman) of China would emerge as a kind of stamped-out product of the modern ideological factory - labor cadres, cannon fodder, disciplined soldiers in civilian dress.

"One warm night in Peking I was riding from the Chien Men Hotel toward the Central Telegraph Office on the Tien-an Men. It was sweltering, and all of Peking seemed to be on the street. As we approached the broad boulevard where the new Peking subway is being built, I saw two youngsters, nine or ten years old, on a pedestal in the center of the intersection where the traffic officer normally stood. The officer had gone off duty and the two youngsters stood in his place, wildly flinging their arms about, directing traffic to their hearts' content. The performance upset no one. There were no hasty calls for the police; only chuckles from passing truck drivers. I tried to visualize a similar scene on Gorky Street in Moscow, bur my imagination broke down. In the first place, the traffic officers <u>never</u> go off duty in Moscow, not even at 4 A.M. In the second place, not the boldest street urchin would dare offer what would be understood in Russia as a challenge to constituted authority. In Peking it was seen for what it was - a small boy's innocent joke.

"That same evening a bit further down the street, my way was almost barred. Some youngsters had opened a street hydrant in the time-honored fashion of the old Lower East Side of New York. The water was gushing halfway across the street, and a hundred joyous boys and girls were splattering themselves. Once again there was no call for higher authority. No cops came and turned the hydrant off. No youngsters were scolded. No one was arrested. On my way back from the telegraph office I stopped three times under street arcs to see what had caused a crowd to collect. In one case it was two young men seriously pondering a chessboard. In the other two, it was games of cards. I don't know what the game was but I don't think it was Old Maid - unless in China they play Old Maid for money. One day at the Ming tombs in the lovely western hills of Peking, we walked through a shady park where sightseers were having their lunch and a quiet drink. At three tables I saw card games in progress - nothing furtive about any of them. Just people enjoying themselves.

"I don't want to make a big point out of a few games of fan-tan. But I don't want to dismiss the card-playing either. China is just emerging from the Great Proletarian Cultural Revolution, the turbulent and traumatic upheaval which, it is said, has transformed her society. And I am prepared to believe that this is so. But I think it is also apparent that the Great Proletarian Cultural Revolution has not created a generation of "blue ants". As always, Chinese society is a diversified whole. Perhaps it has more discipline than in the past. Perhaps not. China has always been a disciplined and cultured nation, and if it seemed to old China hands that it was not, it is likely that it was the disturbing influence of western materialism and amorality that corrupted the personality of the Chinese who were in contact with it, and who thus became, in essence, its victims.

"There are certain main lines of contemporary Chinese character. There is even, as we shall see, important evidence that something like a New Man (and New Woman) has been created, at least, in part, in China. But the image of the "blue ant" - this is a caricature that never had more than a vague authenticity.

"To be sure, China is a homogeneous nation. Her population is more than 90 percent Han, that is, ethnic Chinese. Less than ten percent of China's residents have other ethnic origins - Mongol, Kazakh, Uighur, Manchu (if that can be still distinguished) and many small fragments of ethnic groups like the Hakka and the Wei people. Both of these are probably basically Han, maybe even the building blocks from which the Han people arose. This does not mean that the Han stock is pure. Far from it. Again and again outside races have swept into China and conquered her. But each of them has been numerically small compared to the Han mass and each has been culturally inferior to the Hans. As a result, the Huns, the Mongols, the Manchus, and all the others who fought their way to the Dragon Throne became, after one or two hundred years, indistinguishable from the Hans, the world's oldest and strongest people.

"When the integral nature of China is perceived (and Americans coming from the most diverse of populations, find it extremely difficult to adjust to the idea of a nation made up of the same people, possessing the same racial stock and the same culture, with infinitesimal variations north and south, east and west) then the small core of truth that is encrusted by the "blue ant" fallacy becomes plain.

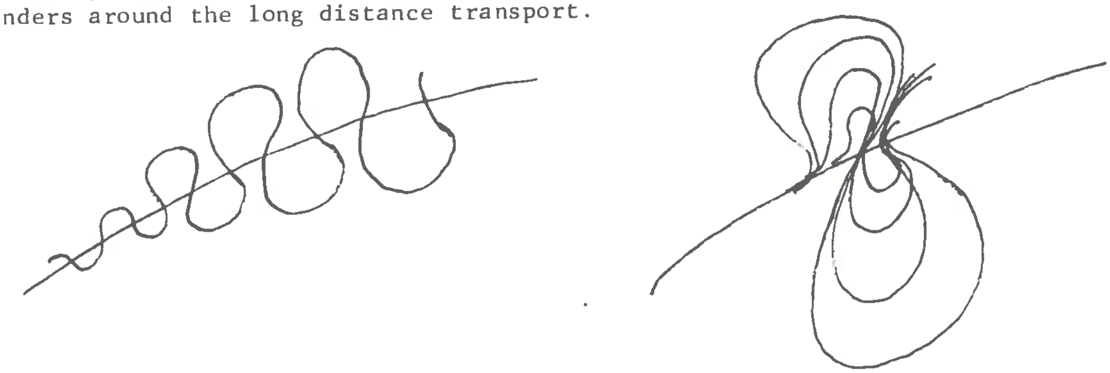
"For instance, in the days of the Empire, the common people, the ordinary people, the peasantry, were forbidden to dress in the gay and luxurious silks and satins and velvets and cloths of gold that were the mark of the Empire and the ruling class. It was not, thus, necessary for any Communist regime to insist by edit. indoctrination or egalitarian principle that all people dress more or less alike. The fact was that the people in China had <u>always</u> dressed alike as far as the memory of history goes, and that is close to 5,000 years. No Chinese looking out on the hurrying throngs in the shopping streets just off the Tien-an Men sees anything new or strange about the fact that everyone dresses very much the same. His eyes would be offended if people appeared suddenly in the galaxy of colors, shapes and sizes that characterize the crowds thronging into Rockefeller Center of a summer day.

"The same is true of Peking itself. To many visitors, Peking streets seem gray and drab, lined as they are by endless blocks and squares of Peking courtyard houses, all one story tall, all with nothing distinguishing on the outside, all enclosed within gray or tan walls that give no hint of what is inside, most of them with access through narrow streets or hutungs, blind alleys between enroaching, barren walls. And no other building more than one story high, except a few put up by foreigners before 1949, and, here and there, a hotel or a ministry built by the present government. (I am not counting the big new quarters of four-, six- and eight-story apartment houses that have been built in the city's outskirts under the new regime, largely to house the hundreds of thousands of new residents, many of them workers in new suburban industries.)

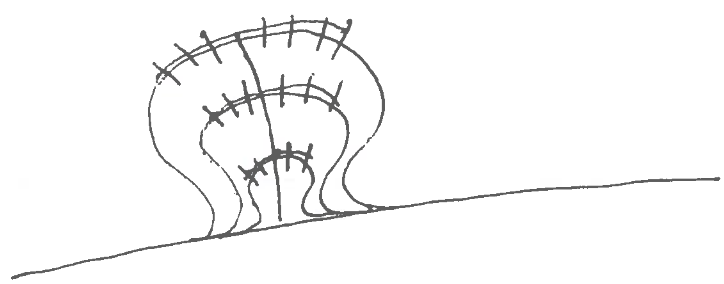
"The facade of Peking, its inward-looking drabness, grayness, monotony (which quickly turns out to have its own attractiveness) is not, as the thoughtless visitor may think, a product of the stern puritanism of the new regime, but rather the cultural heritage of the great Empire, which remorselessly refused to the very end to permit anyone to build in Peking any structure that would in any way, by height or design, detract from that most dramatic of all creations, the Imperial City."

There is nothing wrong with the long distance algorithm for transport to be the 'geodesic' paths (by whatever optimization is chosen). The issue is the local settlement algorithm. In the blood system, it is the vascular channel that develops for new developmental areas, and then it grows and fills out locally to feed the subscribers. A genetic form is cast, because it fits the animal, but then the animal grows up to flesh out that territory. The same issues face us in urban centers.

A keynote for stability purposes, is that urban centers must develop, like meanders around the long distance transport.



The meander has the competence to grow outward without challenging the basic validity of the long distance transport system. It then satisfies the possibility of transverse local transports.



And thus, conceptually, space filling branching can take place.

But the transport fill is not necessarily of the same type as the, say, fixed rail (or pipe) long distance transport.

In the first place, this system has to be largely geared to a daily transport cycle. Its major splines may be electrical and may be mass transportive. Its further out splines may no longer be machine powered, but man powered (except for a limited number of special cases).

The design of these urban blocks are likely size limited, but it is only such study that will determine the limits of economical urban size.

We trust that the advantage of this system is clear, namely that in an industrial - agricultural civilization it becomes possible to yoke together disparate producing and consuming entities so as to satisfy their major requirements in a daily and yearly sense, by means of a long range 'arterial' and local 'capillary' system.

What if you don't 'buy' this system? Well, as the Chinese have shown there is a labor intensive agricultural system. As Salisbury said in his 1972 China trip, "This was China. The villages spaced across the plain, each village within sight of three more villages, and village succeeding village, until the last was lost against the landscape. And everywhere the color of earth." It is a different 20th century solution.

We hold no brief for that solution for our country, certainly not for its political system; even more certainly not for the Russian political or socio-economic system. We would like to hold a brief for the future of our own.

So - for the moment interrupting the flow of our modelling description - what can we do with this model of our potential future? Directly nothing, it is a 3-6 generation from now model.

But, we as technologists, scientists-engineers, can feel and sense the technological aspects that such a plan requires. It is not cast as a utopian plan. It is one of the few that can satisfy large scale thermodynamic equilibrium at a 'high-potential' operating level. At this point we are playing like Mother Nature. We are inventing a living (social) species that have some chance of survival. Whether future generations - 10, 30, 100, 300, 1000, 3000, 10,000 generations from now - can invent other thermodynamic schemes, we can't say. We can only fit our constraints.

But by intellectually taking a stance toward such a future, in our R and D, in our recommendations, in our body English, then gradually we can provide an emergent technological package that will steer the present, near present, and future selections of our elite. There is nothing subversive about that activity. It is the only planning choice we have.

Thus the problem becomes more immediate to select and emphasize those steps that will lead toward that future. Namely we can get there by the lowest global profile if we plan our generation, half generation, even shorter generation steps most carefully.

Let us list some of the conversions that have to be made.

1. Transportation, in the large, must be changed from a private to a public utility. It can no longer be competitive, it must instead be measured by efficiency yardsticks.

2. Transportation, at the daily, weekly, seasonal, yearly level, must be planned activity, as far as its use of public resources.

3. The long distance seasonal requirements of transport must be developed carefully into a coordinated net.

4. A conversion from dependence on independent portable power source to stationary distributed power sources must take place.

5. Seasonal, weekly, and daily transports must be scheduled and routinized, so that a moderate amount of random freedom exists for all sorts of 'accidental' requirements.

6. Socially depressed or crises states should be seized as opportunities to make changes and build toward a future system. To the extent that they are able, we now submit that technical experts have got to pool their past and potential future knowledge toward something that represents common rational[1] planning. We do not believe they have the competence to be doers, but they do have deomonstrated competence to work together technically at times. It is that character we wish to stress. And we wish to stress that likely the way to do it is to plan in good times and execute in bad times.

7. The priority of energy transformation is the current reduction of hydrocarbon fuel; the increase of coal and oil bearing shales; the increase of fission sources; research in fusion; in solar energy; other earth processes - geothermal, wind, wave; other electric converters, e.g., fuel cells

But the basic problem we face is not to emulate China (except in one respect), but to increase our political efficiency, such as local and overall government (which is what China did, even if we don't care for her system). In the depression, our avante garde learned that cities weren't manageable. Post World War II - 1950-1965, the politicians (who had blamed the cities' problems on the depression) learned that they weren't manageable. The people (who still blame the politicians) haven't learned that cities are unmanageable.[2] That the city and its surround has to be treated as a viable economic base is simply not there in their heads yet. So

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[1] i.e., to make things - of disparate nature - fit together.

[2] Nor have the newspapers. One may note, say by looking from day to day at papers in Boston, New York, Philadelphia, Washington, daily editorials that castigate local politicians as if their fault was specific to their town, without the slightest notion that it is the same in each of these towns. And one notes rising politicians who try to spend the minimum time at municipal problems so that they can quickly escape and make it up the chain.

8. The need, beyond transportation is to adapt the various compartments and institutions of our social system toward a harmonized technological whole. We can preserve freedoms for people but at some cost. The general activist cost is likely one for me, one for society. In that respect we and China have to be alike. But then the question is by what means?

## Summary

In this introductory portion of a system' science for transportation planning, which is based on the statistical physics of ensembles, a foundation is laid on how statistical mechanics, equilibrium thermodynamics and near equilibrium thermodynamics can be used for systems other than the atoms and molecules of its Standard application. Its relevance to living systems is indicated. To provide some insight to its application, three example systems are briefly discussed - rivers, the vascular system in mammals, and the development of the nervous system and the evolution of intelligence in the living system. The study then quickly turns toward social nets. The likely problems in that social net, particularly as they bear on transportation and transportation R and D are discussed.

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