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SYSTEMS MODELS FOR TRANSPORTATION PROBLEMS
Part II: The Social Physics for Modern Societies: The Role of the Cities

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16. Abstract

The objective of this research was to make use of a physically based social systems model, developed earlier, to study the determinants of city sizes and their national interactions. In particular, information on the role of a transportation systems in affecting city sizes was required.

In this second part, the relation between the urban settlements and a potential mapping that is related to the land (its population density, material and energy resources, activities, products, and consumption) is outlined. The dependence of the urban settlement distribution on long-distance international trade is discussed. The emergence of a new major social institution, the large corporation which is competitive with the urban settlement, is discussed. The socio-economic effects of transportation systems, and their modernization is described.

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PREFACE

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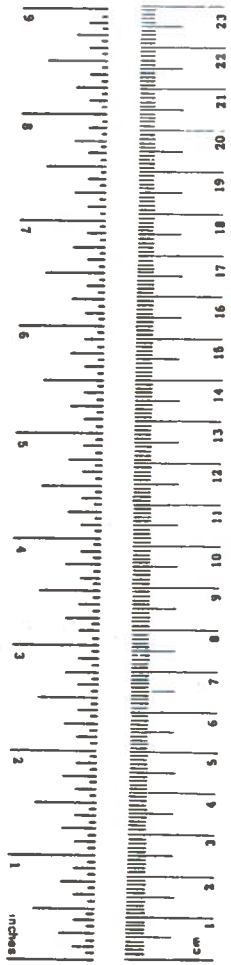
In this final part, the relation between the urban settlements and a potential mapping that is related to the land (its population density, its material and energy resources, its activities, its production, and its consumption) is outlined. The dependence of the urban settlement distribution on long-distance international trade is discussed. The emergence of a new major social institution, the large corporation which is competitive with the urban settlement, is discussed and the socio-economic effects of transportation systems, and their modernization is described.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

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1. INTRODUCTION

1.1 SYNOPSIS

A physical science based social system model was developed previously (1). The construct of physics has a hierarchical structure that permits its extension to the phenomena of the social interaction of human beings. Loosely, that hierarchy consists of mechanics, electromagnetism, quantization physics, kinetics, statistical mechanics, and thermodynamics. When used carefully, these key subjects permit a description of the laws of motion and change in an ensemble of active like entities which are free to exchange energy. State, motion, and change are defined within the construct of thermodynamics for those variables which are conserved in collisions among the entities.

When applied to human societies, the physical model requires dealing with balances among five socio-economic compartments.

a. Material Balance. The conservative flow of materials as minimally associated with levels that society is competent to deal with. (Statistical mechanical ensembles deal with their summational invariants at relatively highly organized levels. They deal with their fluxes as organized systems' entities, not as elements stripped down to a most primitive atomistic form. Thus, the living system negotiates foodstuff materials at highly organized molecular levels, e.g., proteins, carbohydrates, fats, vitamins, minerals. The human social system deals with the extension forming of technological materials as highly organized forms, e.g., ores, crushed rock, timber. In all systems' thermodynamics, one must review how the particular system "ingests," "decomposes," "resynthesizes," and "rebroadcasts" degradation products of its required fluxes in order to deal with its potentials and fluxes. In fact, one must also be conscious of many possible substitutions or equivalences that the system can deal with.)

b. Energy Balance.

c. Human Activity Balance. Elementary physics would suggest that activity is represented by a momentum balance, i.e., the sum of forces equilibrates to the change of momentum. But systems that have internal degrees of freedom that do not rapidly equi-partition energy with translational degrees of freedom have to be treated by long time-averages wherein the relaxation times of the slow internal degrees of freedom govern. The system, in increasing order of complexity, will then exhibit hysteresis, thixotropy, "genetically" coded for memory, and an "epigenetic" memory. In the human social system, the highest degree of complexity is found. In any case, thermodynamic systems that sustain their complex form and function (namely, they are not ideal gases or near-ideal gases), will exhibit a slower time-averaged motion in action modalities. Action is the product of energy and time. These systems will show a near stationary spectrum of action modes in which their activity will be patterned in space and time. These have been essentially identified for various genetrically coded systems, from bacteria to mammals to man.

d. Population Balance. Roughly, this can be identified by the law that the rate of change in population is represented by the choice function of the present generation to produce progeny, less the choice function of past generations integrated and averaged over a characteristic number of past generations. That characteristic number depends on the existing parameters of the mortality function. There are additional terms from prey-predator, immigration-emigration issues.

e. Economic Balance.

Man assigns a value-in-trade to his transactions. This extends the number of thermodynamic variables that have to be dealt with. While the Marxian notion of the labor theory of value had provided a hard physical measure for such values, that thesis has simply not held water. It must finally be recognized that value-in-trade is a construct that arises from human mind. As such, it destabilizes what would be a more elementary thermodynamic model. Instead, value-in-trade or monetary value becomes part of a complex thermo-dynamic chain.

In addition, there are five potentials which must be given considerable attention in a human social thermodynamics:

a. Environmental Temperature. The entire operational picture of a human society is largely governed by its mean temperature and range. Civilizations, as we have been concerned with for the past 10,000 years, are largely products of a temperate zone. In fact, they were likely not possible until the withdrawal of the last glacial age about 12,000 years ago.

b. Environmental Sources of Free Energy. The total ecological problem is not simply governed by temperature. The distribution of resources, water supply, meteorology, geography, ecological riches and webs for flora and fauna have a prior geological history. Thus, what is available to a social population in a region is dominated by that past history.

c. Genetic Value System. A viable system is encoded so that it persists. (This is basically a definition, not a tautology.) Living systems, which live and die as individuals but survive as a species, pass their heritage of action modalities, communications, and recognition processes - what is best referred to as motor-sensory processes - as a result of a genetic code. The systems' "values" are thereby conserved generation by generation.

d. Learned Value System. The human, because of an extensive abstractional epigenetic (learned) memory system, conserves these values generation to generation. This creates a governing social potential under which both young and old learn to operate. It is the intensive form of internal "mind" processing, for which value-in-trade becomes an extensive form.

e. Technological Potential of the Human Mind. An additional process property that develops from the abstractional ability of the human central nervous system is the use of tools and symbols to manipulate both the external and internal environment. That causes a growth of the extensional potentials of the human species. That growth has been nearly linear for the past 40,000 years. For 30,000 years it dominated man's social competence as hunter-gatherer. In the past 10,000 years of the agricultural revolution, it has

dominated man's competence as agriculturist-technologist. The process is linear because each generation can only add essentially a comparable growth segment of intellectual complexity. This does not mean that the changes these intellectual discoveries make are equal. It is only the rate of growth of intellectual complexity which remains nearly constant, and becomes, thereby, a dominant driving potential for change in human societies.

As a summary of the state of modeling in biomedical engineering at a recent NIH-sponsored panel,[1] the following one-page schematic outline was presented. It has been extended by a few line items to cover the social system.

1.2 ON A SCIENTIFIC SCHEMA FOR BIOMEDICAL ENGINEERING MODELING

Hierarchical Morphology

Molecular process definition.[2]
Cellular process definition.
Cellular ensemble definitions.

- functional units in organs (minimum unit of an organized multicellular complex).

Organ process definition

- liver, kidney, heart, brain, etc. (i.e., organized multicellular complexes).

Homeokinetic definition of the complex organism

- the complex of organ systems' interactions by which form and function are preserved.

Homeokinetic definition of social organism

- the complex of human interactions by which the form and function of the human species are preserved.

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[1] A National Institute of Health-sponsored Biomedical Engineering Workshop held at the Rand Corp. in February 1976.

[2] Definition here refers to the bringing into focus the space-time domain which is morphologically appropriate for the level.

Homeokinetic definition of the political organisms

- the complex of cultural-political-economic interactions by which the form and functions of the city-state-nation are preserved.

Homeokinetic definitions of the ecumene

- the complex of interactions by which the form and function of the civilization are preserved.

Homeokinetic definition of the ecology

- the complex of interactions by which the form and function of interdependent species are preserved.

Essential Requirements For a Scientific Modeling

Atomism (its definition - see section 1.2(a).
Ensemble (the repetitive atomisms in interactions).
Complexion (the dynamic states of the ensemble in phase-space).
Distribution function (the resultant of physical interaction).
Thermostatic state functions (the constitutive relations that emerge from the kinetic interactive fluctuations that are described by the distribution function).
Irreversible thermodynamic description (the field equations of change throughout the ensemble).
Irreversible systems thermodynamics (e.g., field hydrodynamics, or plastic-elastic field mechanics).
System's history

a. Normal course
b. Pathologies
c. Debilitations -- recoverable, or nonrecoverable
d. Death trajectories
e. Genetic change
f. Evolution.

The morphology of the living system starts from the molecular level. There are few processes (e.g., genetic mutation) in which nuclear processes are discerned. The morphology of the social

system starts from the homeokinetic definition of the social organism. There are few processes (e.g., medical disturbances of a people or its leaders) in which organ(ic) processes are discerned. The morphology of society relates to the character of the human "molecularities," in which the total human organism is the atomism.

The dynamics of the process (of survival and persistence of the social ensembles) then can be begun within that construct. However, it is useful to add two notes:

a. Any complex system whose internal dynamics persist must have a communicational basis for both internal communications and external communications. This is in addition to its basic thermodynamic chains. Namely, there must be a communicational thermodynamics that relates to the power thermodynamics of such systems. We have addressed this issue in the first part of this final report. (2)

We have shown that the rudimentary communicational dynamics is represented by a Boltzmannian distribution of the signal information, just as state energy is described in an ideal gas "perfectly elastic" collisional system by a Maxwell-Boltzmann distribution. But when the entities interact with internal time delays, we have suggested that the information flux is Zipfian - a 1/f "noise" property, which is not really noise.

b. Any complex system whose molecularities interact other than perfectly elastically (namely, they have internal losses and time delays) begins to show significant tendency toward coalition and condensation at densities removed from zero (where ideal gas-like properties may be found). This simply arises from the fact that more than one configuration has equal energy states - both the homogeneous uniform distribution and some nonhomogeneous condensed distribution have comparable energy. A critical measure is reached at which a change in phase will occur. In simple physical molecularities constrained only by mass, energy, and momentum invariances, the phases of gas, liquid, and solid are thereby determined.

In general, in more complex systems (e.g., where population number is a collisional invariant), the system[1] tends to condense toward liquid-like mobility. The typical configuration that develops is an element-substrate system, a surface active system upon which catalysis and "birth" as a more generalized notion of catalysis takes place.

The major point is that living systems on earth develop and broadcast in analogy to liquid droplets. In pre-Neolithic times such human social droplets basically interacted among each other in the form of very weak "elastic" collisions. Thus, the distribution of settlements on the land was Boltzmannian (2). This represents essentially a near-ideal gas or ideal solution kinetic binding to the earth surface. In that binding two results are achieved. First, the species, operating with its action modalities, learns how to satisfy its reversible thermodynamic constraints. Second, the species broadcasts through its available land space and works out a reticulated network of latent settlements.

Just as the liquid phase, to be noted by x-ray spectroscopy, foreshadows the potential for crystalline solid structure at higher solid density (or lower temperature), so does the roaming ranges of the pre-Neolithic hunter-gatherer society foreshadow the potential for agricultural settlements. The land is thus marked by a reticulated network of settlement foci.[2] The agricultural settlements of Neolithic times (which may vary in different areas[3]) even more directly prove out the basic network that leads to urban settlements.

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[1] We refer particularly to viable systems, whose molecularities are born, live, and die.

[2] An actual "picture" of that network in the USA may be found in (3), p. 104.

[3] An excellent example that confirms and illuminates the spreading pattern of agriculture into Europe (see (4)) is presented in (5). One can also see the extensiveness of such a developing network in prehistoric times in Europe (6). The reader is asked to transpose its maps to the modern USA map in (3), p. 104.

But that dual space-time process - of internal growth generation by generation, and waxing and waning in its growth on the land - is basically a communicational process. Each generation produces fluctuations, in number, and in mobility. That ensemble of fluctuations, developing a time series of "messages" of social man (not individual man) "speaking" to his environment,[1] fills the statistical mechanical complexion of the social system. The atomisms of a polity are its populated centers, not its people.

When the interaction is not the simple minimum coupling "elastic" interaction that leads to the Boltzmannian, but is a much more serious "communicational" interaction with value-in-trade (and warfare, and immigration and emigration and transitory states) then the distribution becomes Zipfian. That Zipfian character itself is an indicator of a communicational "language" interaction. It is the way the community communicates in order to survive. The physics of society is the interaction of its communities.

The Zipfian distribution (of signaling elements in an ensemble) states that a viable community of signaling elements will be rank-ordered according to the rule,

$$pr = p_o$$

where:

p = population (or frequency) of an element

r = its rank-order

p_o = a characteristic population of the ensemble; its first rank-ordering element.

In our current application, population p and rank-order r refer to sizes of fixed urban settlements in a social, politically bound moiety. The total population in the bound polity that is attached to fixed settlements P_1 is given very nearly by:

[1] Which is both the ecological environment without man, and also all surrounding settlement structures of man.

$$P_1 \approx P_o \left[\ln \left(\frac{2\ P_o}{'200'} + 1 \right) - 0.1 \right]$$

where:

P_1 = total population in a polity which is "permanently" associated with urban centers, as opposed to the population associated with fixed working farms or that is transitorily fixed to the land.

The number "200" is a quantum cut-off lying near the upper size of Neolithic settlements which ranged from perhaps 40-200. Thus, an a priori measure of about 200 can be selected and this can be tested for the USA during its history.

The remainder of the population of the polity is a farming population P_2, that is fixed to the land, and a "transient" population P_3. That transient population, at present in our thinking, is not well defined. These are poorly bound atomisms which have not been fully attracted to either the urban area or the farm. Likely, as drawn from an uprooted farm population, they help feed the influx to urban areas. If P_o is the total population,

$$P_o = P_1 + P_2 + P_3$$

It appears that the urban population may have been a slowly varying fraction of the total population for most of the history of interacting settlements, e.g., for the USA since 1860:

$$P_2 + P_3 \approx 0.4\ P_o$$

$$P_1 \approx 0.6\ P_o$$

[1] On the other hand, as a nominal estimate given by Braudel (7), out of a European population of 70 million in 1600, roughly 10% lived in towns. However, we cannot take such numbers as being indefinitely fixed. They relate to longer-scale civilization processes, e.g., to the rebirth of Europe in the 9th and 10th centuries following the destruction of the European Roman Empire from the 3rd to 6th centuries. (See, for example, (8, 9)). Modern Europe was not formed until the 16th and 17th centuries.

It is only since the turn of the century that a sufficiently intensive machine technology could proceed with a considerably diminishing farm population. Currently, that farm population has dropped down toward

$$P_2 \approx 0.05\ P_o$$

This is likely representative (in an extreme form) of the process of unbanization, where a number of dislocations, commonly technological - in this case, the culmination of a long-developing technological trend - creates a potential drive to urban areas. In the USA that movement has been associated with the explosion of automation, and in particular, the rapid evolution of the mobile internal combustion engine. Throughout history, one senses an ever-present transient population pool that breaks off from the more permanent population pools and transfers in time among them. We have begun to regard the dynamics of this process as being the basic forcing function for social process among living systems of all sorts. We regret that time and the specific constraints or our contract do not permit us the opportunity to develop these "network thermodynamics" issues historically except in a cursory fashion.

Table 1 illustrates the general validity of our previous relation between urban population and largest city population for the USA.

The urban population (column 4), which is total population less farm population and what is viewed as a measure of an incompletely settled - "transit" - population (in column 5), is compared with our formula estimate (column 8). We find that the urban population is accounted for by using a cut-off in the range 100-200.

We would make no claims for any special accuracy to the result, not that we don't believe it worthwhile to test more sharply for a much longer period and many more countries, but because the measurement problem is horrendous and much of it still a matter of definition and estimate - even in the USA (1900-1970) with supposedly

TABLE 1. RELATIONS BETWEEN POPULATION FOR DIFFERENT SIZE SETTLEMENTS*

Year	Urban 2500 and over	Plus 1000 - 2500 rural	Plus under 1000	Plus 'other rural'- transient	Plus farm	Peak-city	$\left(\frac{2\,p_o}{200} - \frac{2\,p_o}{100}\right)^{P_1}$
1890	22.1	24.6	26.8	40.1	62.9	2.51	25.4 - 27.2
1900	30.2	33.5	36.5	47.3	76.0	3.44	35.9 - 38.4
1910	41.4	45.6	49.5	59.8	91.9	4.77	51.3 - 54.6
1920	54.2	58.9	63.2	73.8	105.7	5.62	61.5 - 65.4
1930	69.0	73.8	78.2	92.3	122.8	6.93	77.2 - 82.0
1940	74.4	79.4	83.7	101.1	131.6	7.46	83.7 - 88.9
1950	88.9	94.3	98.5	125.6	150.7	7.89	89.0 - 94.1

*Populations in millions.

Source: (10).

"high-precision" census-taking. Ultimately, we would hope that if our reductionist social physics were taken seriously for planning and prediction purposes, some notion of what variables have to be measured might emerge , as a very directed physically based sociology.

So, very primitively at present, it appears that Zipfian rank-ordering and population cumulatives are consistent for urban interactions. We infer from the communicational (signal transport) and power and materials transport thermodynamics that we have described that the fundamental description for the social-cultural-political-economic interacting system is via an earthbound social molecularity/earth substrate network thermodynamics in terms of locally defined thermodynamic potentials. In this phase, we shall attempt to outline that "network thermodynamics."[1]

[1]At the present time, we have been invited to prepare a paper of the application of network thermodynamics to the biological system. We are appreciative of the two opportunities, because the efforts are interacting and synergistic.

It is essential to our modeling that the process scale to which it applies is made clear. While the thrust of a science for society is upon individuals, this social science does not deal with interactions among individuals, but interaction among populations of individuals. At the expense of redundancy, we would like to identify clearly scientific problems of different levels which our physics could address (see Table 2).

TABLE 2. SYSTEMS LEVELS FOR SCIENTIFIC RESEARCH

Atomistic level	Molecularity level	Systems level
fundamental particles	nuclei - electrons - photons	atom - ion - molecule ensembles
nuclei - electrons - photons	atom - ion - molecules	gas - solid - liquid forms
atoms - ions - molecules	organelles	living cells
organelles	living cells	species
living cells	organs	organisms
organs	organisms	socio - economic bonding groups
humans	bonding groups	settlements
bonding groups	settlements	polities
settlements	polities	ecumenes (civilizations)
polities	species' civilizations	ecology

Each system's level involves a "communications" language at its atomistic level, and its molecularity level, but commonly most of the atomistic-level language is regarded as "noise," even though the fluxes at the atomistic level are what provides the transport competence. It is only that the transports, as organized coefficients, are to be recognized at the molecularity level, that makes the near-equilibrium systems' physics refer to communications as largely taking place at the level of the molecularity ensemble.

When an atom enters a living cell, it does not particularly "know" it is in a living system. Thus, we can treat the relation between the cell and its overall species system in a fairly pure description. However, when the human is the atom, he finds it disturbing to consider himself only as an atomistic member of a bonding group in a settlement, or even a more insignificant member (as it were, only a nuclear particle rather than an atom) of a polity.

The problem we are asked to address is the dynamics of the polity (the USA) as a system, and thus, properly, the relation of its settlements to the polity. We are of course assuming that a reasonable physical correlation can be achieved with the underlying bonding groups in the settlements (1). On the other hand, had we been asked to address the dynamics of the settlement, our concern would have been specifically focused on the relation of the socio-economic bonding group to the settlement.

Note the interactional complexity that faces us when we arrive at those levels in the hierarchy of organization in which we can recognize our place. Thus, it is true in one sense that an atom does not know it is in a living system, but this is not the same as asserting that the atom does not "sense" that it is in a complex system. Thus, as human organisms we are conscious, below, of our organs. Above, we are conscious of our socio-economic bonding groups. We are conscious of our settlements, and we are conscious of our polities. We tend to lose focus on our ecumenes.

So, while the individual may only occasionally be forced to contemplate three, four, or five levels of organization, the administrator or leader may have to face these organizational levels in very specific order. To cite an illustration, the national leader must be concerned, today, with epidemic viruses, heart disease, individual and family welfare, the organized national efforts of truckers or teachers, the crisis of American cities, national elections and defense posture, and the Third World position on mineral and agricultural resources.

In our opinion, what a physically founded science can provide is the irreversible systems thermodynamics for each level where the local fields are each in turn at near-equilibrium. On the other hand, to mix the description of all the levels into one pot involves the application of a strategy for managing systems which relates to a much more poorly defined metascience of systems. While we have begun to make contributions to that metascience, it is not our specific current concern.

2. NATIONAL POTENTIALS

We have been asked to relate the Zipfian characteristics of the settlements in a national system with the national earth-bound potentials. We have shown that the former relate to communicational issues of the ensemble of atomisms that comprise a living system, to its command-control repertoire, where, in fact, population is part of that communicational repertoire: in the signaling switch states, urban settlement populations are involved. Now we have to embed the potentials.

Now we do not believe, in the sense that Stewart and Wilson (see (2) for references) have suggested, that there are hard physical potentials associated with earth transports of a "gravity" (or more general inverse square law) potential nature. The processes are much more like exchange forces - bondings that satisfy mutual needs when in reach of communicational exchange. We cite, to provide a mental image, the businessman with a girl friend tucked away in Copenhagen who manages to touch base regardless of spatial or temporal inconvenience.

On the other hand, it is necessary to characterize the influence process (of point 1 on point 2). The notion of influence coefficients, first introduced in bodies undergoing elastic deformation, was spread to acoustics and then to electrical engineering. One notion involves the effective "displacement" at a given point due to a generalized "force" at the point as the direct influence coefficient; a second notion involves the displacement at a given point due to a force at another point as a transfer influence coefficient. For linear networks, a principle of superposition (of forces and displacements) will exist, as well as a reciprocity theorem - the influence of point A due to B is the same as of point B due to A. More generally, in nonlinear networks, none or some of the linear theorems will be true. There are two kinds of convenient measures for influence. One is space-independent, the other is space-dependent. The measure of influence between points in a network mesh is relevant if, as with urban centers, there is a fixed

form for the network which is established and maintained by thermodynamic balances. Influence coefficients then furnish a historic metric for the "potential" of influence, and a description via the possible flux paths and flux measures between points.

Let us first consider population "influences." We would assert that in a spatially organized domain on earth, to which man is bound, within which he operates in a near-isopotential cultural-political polity[1] as a self-serving autonomous organism, consistent with thermodynamic constraints, the field is describable by linearly (but nonhomogeneously) related potentials and fluxes. The field dynamics is also likely not isotropic, but that fantastic growth in complexity of description will be avoided by assuming, as nearly as possible, the adequacy of isotropicity. The assumption is common in liquids and polycrystalline materials. It is contained in the definition of human society as a mixing pot, if not quite a melting pot.

So, a population influence coefficient would consist of the "influence" of population elements $j \neq i$ on a population element i. This might be written as,

$$V_{ij} = p_j f\,(d_{ij})$$

that is, if p_j is the population associated with the j^{th} element, and <u>if</u> we were to assume that the potential function was only dependent - at most - on the separation, then the population potential V_{ij} would be the potential created by p_j on population at element i. It would represent a measure of the "influence" of population. The sum $\sum V_{ij} = V_i$ is the total potential at i.

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[1]The systems are not uniform potential, e.g., isothermal, but the fields can be represented as deviator fields - linearly related potentials and transport fluxes. The potential barriers of mountains, cultural differences, and intrapolitical restrictions are not designed to actively shut out fluxes. Social impedances may be weird and complex, but they can "passively" control the essential flows.

Since the society is coordinated and organized into three types of elements - fixed urban elements, fixed farms, and a transient population - one would surmise that if thermodynamic potentials existed, from summational invariants, e.g., population, they would be associated with such high order elements. Namely, the more atomistic integral ought to be over social molecularities, but we ought to be able to use, as an aggregate, the population center of gravity of fixed zones. For an urban area the fixed zone would mean that contour line around a region of population concentration whose daily averaged net flux is minimal. Presumably, without a great deal of investigation, this should be close to the standard metropolitan area (SMA) region of each settlement.

When the urban areas and farm units are accounted for, the residual "transient" (or not fixed) population can be distributed by density and accounted for. Thus V_i is made up of three terms:

$$V_i = \sum \left(p_1^u f_u \left(d_{i1}\right) + p_2^u f_u \left(d_{i2}\right) + \cdots p_{m_1} f_u \left(d_i\ m_1\right)\right)$$

$$+ \sum \left(p_1^f f_f \left(d_{i1}\right) + \cdots \qquad + p_{m_2} f_f \left(d_i\ m_2\right)\right)$$

$$+ \sum \left(p_1^t f_t \left(d_{i1}\right) + \cdots \qquad + p_{m_3} f_t \left(d_i\ m_3\right)\right)$$

A priori, it is not evident what form the function f should take. There are no persuasive laws other than influence coefficients. In some sense we are forced by the same early dilemma that molecular force theorists were faced by. We appreciate that natural law provides us with two forms of inverse square force laws - for gravity and electrical forces - and we are even willing to concede that electrical forces govern human behavior. It is useful to call attention to the fact that a Laplacean field (a field which satisfies an inverse square law around a pole, which satisfies linear superposition, is Laplacean in regions away from the poles) has the essential property that the average of the

potential over any field is the average at the center. This simple geometric property permits one to assess fields for this form of force law. But just like the difficulties involved in the description of molecular force laws, the electrostatic forces were found to be highly deformed into fixed and deformable multipolar forces, angular orientation forces, and exchange forces before one could even being to attack the elementary van der Waal force description of a near-ideal gas.

We do not yet have a van der Waal force description for society. What we do have are three kinds of notions: one, that humans (as well as many other species) aggregate. Thus, there is a weak distance-related force. Two, that in some important sense Zipf was right. There is a principle, if not of least action, then of not-too-much-action. We have interpreted this in the form of an action law, or perhaps action strategy. Living systems tend to divide their daily energetics among action modes. These action modes are compatible with their nervous systems and other channels of communications, their required materials fluxes, and their energetics. These action modes are thus characteristic of the species. This is characteristic of an exchange force, which, when coupled with aggregating forces, does provide some kind of weak distance-dependent law, but with some finite range characteristics. Third, we borrow an important observation from Jean's dynamical theory of gases. If pressure (as the force among regions) arose only from intermolecular forces, he showed that the effect of remote molecules would dominate by virtue of a 1/d force law. Adding vessels would change external effects drastically. This is quite remote from an inverse square law which retains a geometric similarity.

But that kind of remote effectiveness - of outside settlements influencing the organization of the internal polity (e.g., for defense or trade) - seems to be involved in human societies with value-in-trade. Thus, a fairly long-range force relation somewhat more long-range than an inverse square law (e.g., an exchange force) is feasible.

So we are forced to a position that recognizes spatial "force" organization, but leads to no definitive articulation. Is further effort ruled out? No. One fairly proper way to procede is to examine both distance-dependent and distance-independent relations. The simplest two forms are density distributions themselves and a 1/d potential. From such studies we can learn about the potentials that seem to govern the settlements and activities of men. But in any case, we have already recognized binding forces in our social bonding, first into extended families and then other socio-economic bonding groups, and second in the form of fixed settlements. We will say more about the character of cities and the theory of cities in a later section. First, it is useful to pursue the thread at spatial potentials.

Pursuing a joint dialectic over these issues, Hassler (11) has assembled an overview of the 1/d population potentials for the USA 1790-1970. These are further normalized to the total population. We note some of the conclusions in (11): "... the curves are all very similar. ... in the beginning of our Nation, the concentration of population on the east coast results in a ratio of east coast to west coast potentials on the order of 17 to 1. In modern times...this ratio has dropped to approximately 5 to 1."

"A second feature...is the share of the contours east of the Rocky Mountains from the period 1880 onwards. From 1880 the curves stabilized..."

"A third feature...is the emergence of a west coast peak... around 1920-1930, and still growing in magnitude relative to the east coast peak."

Let us add a little to that interpretation. First, it is clear that the relative change of settlements (as marked by population density) is quite slow. There is little change in relative distribution for periods of the order of 30 years. This bears out over the earlier contention that the nation changes its face recognizably perhaps 3 times per century, and it reflects on our note about changes being largely confined by the comparable metric

of war-to-war periods. For national planning purposes, that time scale is of considerable relevance.

Second, it is clear that the nation, in its concentration on the east coast, was not only reflecting its start-up, but also reflecting a large degree of turning toward its foreign trade component. Thus, not only did our nation start with that role to its mother country, England, but it has maintained that large degree of oritntation to foreign trade. As is pointed out in (11), it is only after 1930 that the west coast attractor becomes of some significance. Of course, it should be pointed out what has become obvious since World War II, that the southern tier of states is finally beginning to make its attractive pull evident; national planning for the next 30-60 years will have to take that into account.

On the other hand, while the mid-plains states will remain the bread basket of the nation, their continental climate prevents them from becoming a highly attractive population region. The national relaxation of population will continue in a reasonably predictable fashion (if we do not pay attention to longer-range natural catastrophes. There is a broader irreversible thermodynamics that includes the ecological factors that could say sound things about earthquakes, weather change, land productivity, and probably even man's technological gains due to progress in genetic engineering, but at this point we confine ourselves to the existing ecology. At the moment, earthquake along the west coast is the most serious and immediate threat; the water potential of our land the second most dominating threat; and materials and energy resources of our nation the third. The fourth, climatic changes, is a new factor that will require consideration in a slightly longer time scale).

3. HUMAN SETTLEMENTS, PARTICULARLY URBAN

This section, while it may be regarded, and thus disregarded, as a discursive interlude, attempts to point out the theoretical framework for relating the dynamics of settlements, which is largely localized with high spatial-density, to the polity, which is largely dispersed and scored by a large variety of potentials which are relevant to its existence, and how this framework relates to other - sociological - notions of the urban settlement.

The existence and peculiar character of fixed human settlements is largely the product of the human mind and a particular evolutionary history. From an earthbound hunting and tool-making primate of the last few million years of the Pleistocene Age, homos evolved into modern man about 40,000 years ago during the trough of the last Ice Age. With his brain and the trying experience of what appears to have been largely northern temperate and cold-dominated climates, man became a superb hunter-gatherer for 30,000 years of his existence. While there is little or no evidence for any appreciable genetic change, clearly that period applied a great deal of epigenetic selection pressure. Man became bred and fitted to most earth climates except for the limiting Arctic regions.

The poleward drift of the glaciers at the end of the last Ice Age about 12,000 years ago precipitated man, and a variety of other fauna and flora, into fixed agricultural settlement patterns, a symbiosis between man, domesticable animals and plants. That prologue has to stand for the biological and ecological background for man. As we have indicated, once settlements started, the remainder of the dynamic play latent in the human brain began. Namely, a rich diversification of activity, of type of bonding group, of material extensions, of inter- and intra-settlement activity began. We have identified these by the speculative decomposition into about a dozen kinds of socio-economic activity. Human society was no longer combined to the extended family of the hunter-gatherer. Instead one might discern:

hunter-gatherer	cog-in-the-machine
scavenger	deus ex machina (ruler)
agriculturist	artisan
trader	nurturer
raider	signifier (priest, scribe)
nomad pastoralist	

The human motor system with its abundant capability and range[1] effectively defines the approximate spatial character of human settlements.

Thus, there is a dense ingathering for common settlement. There is a spatial domain in which agricultural (or pastoral, etc.) productivity and yield can supply living essentials. There is a range at which "friends" or "foe" can be tolerated. But complete self-sufficiency for the technologically creative and value-creative mind of man is not achieved in such settlements. Such specifically defined roaming ranges may have satisfied his hunter-gatherer and earlier hominid ancestors, but they did not satisfy him. He began convective patterns among settlements. Value-in-trade, rate of technological advance, value system complexity all began. The entire panoply of abstractions that the human mind was capable of (12) came into existence, including warfare as well as trade.

This will have to suffice for what has been recognized as the social richness of the Neolithic revolution. But it must be understood that there are time delays. The learned processes must be passed from "culture" to "culture," generation by generation. This implies a diffusion velocity of the magnitude of 1 mile per year (20 miles per settlement per generation). The size domain of continental land masses puts the time scale at the thousands of years. Agriculture, pottery, metallurgy, and tool technologies have diffused at that time scale.

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[1] In a biological sense these characteristics are just associated with human size and its omnivorous habit. They can be placed within the general characteristics of hominids and are not particularly defined by the human brain.

We are not implying a unilinear diffusion. Rather one or more centers could "invent" a process more or less simultaneously and the process would diffuse. These patterns of diffusion are still in a rather primitive stage of documentation, if one wishes to trace their beginnings in the period, say, from 10,000 to 3,000 B.C. Most of that period was defined as prehistory and it has required methodological revolutions of the past two decades to begin to trace the process of social development.

Thus, while interaction, trading, and raiding among settlements are ancient processes, evidence for the notion of community, of polity, is not sharply in existence before the Sumerian-Akkadian city-states of 4000-2000 B.C., the Egyptian kingdoms of 4000-3000 B.C., the Sumerian legal codes of 2000 B.C. and the first beginning of the empire of Sargon the Great (2200 B.C.).

The fact that such notions may have had a gestation period of 2000 years (back to 4000 B.C.) or 4000 years (back to 6000 B.C.) is not at present particularly surprising. One surmises that too many details had to come together in a potential ruler's mind to make the rule of a polity a feasible thing.

One can sharpen up the time scale of urban beginning by dating it concurrent with the appearance of elaborate settlement structures (4500 B.C.). The reason would be simple. The self-mobilization of the efforts of a local community for some functional extension is not too difficult a task. The mobilization of the manpower needed for a large complex structure would seem to require slavery. At that point, not only do organized raiding and trading have to exist, but a complete pattern of social structure and its regulation. Thus, the beginning of empire, the beginning of polity, the beginning of an entire panoply of bonding groups. Thus the regular creation, birth, and death of human settlements begins. Thy rhythms of modern civilizations begin.

What problems face the polity ruler of 2000 B.C., 0, or of 2000 A.D.? We submit the same set of problems. He or his family must move in on the polity. He must gain control of its central institutional apparatus. He must look out against his external

enemies in other polities, or against other mobile raiders who are prepared to move in on him. On the other hand, he must have the allegiance of the settlements within his polity. As settlements, they (the local leadership), must fulfill obligations to the central leadership, they must assure that the necessary fluxes for persistence continue, and they must help satisfy the local fluxes and potentials for persistence. (One senses the process every national election.) Thus, in these few sentences one must sense the intrinsic conflict between central polity authority, local authority, and the structural-functional components of the local settlement. We see the minimal game played among these four levels of the hierarchy - local bonding groups, the settlement, the polity, and the ecumene.

With this prologue, it pays to enter into a dialectic with the theoreticians of the city as a well-structured human settlement, the characteristics of which have been addressed by sociological theory. We offer as a brief introductory form of their argument a rather brilliant preface by Don Martindale in (13) who begins his introduction to Weber's work with the assertion that the closest approximation to a systematic theory of the urban settlement is contained in Weber's essay and Park's paper on "The City," yet who points out that the contemporary American theory of the city is in crisis.

So, we outline salient points from that foreword that interest us. First, for a mainline of city theorists, Martindale offers Marx, de Coulanges, Maine, Maitland, Simmel, Wilcox, Spengler, Weber, Park-Burgess-McKenzie, Pirenne, Glotz, Wirth. That covers roughly three generations from 1880 to 1940. Martindale points out that the theory of the city (in his perceptions, up to 1960) cannot yet account for the notion that it is a living thing. As a life system, it acutally entwines with lower biological developmental and evolutionary issues. But why are urban books deficient? They seem to be made up of large collections of statistical assertions, but they do not create the city itself. Thus, this question, "what is the city?", still persists in American sociology. Weber's notions are highly relevant.

Martindale then presents both a brief history of the American city and its theory. Our cities are seldom older than 200 years; European cities are many centuries old. Our cities reflect both a simplified structural model of their parent model, and a terminal stage of such urban development. Our cities are simplified versions of the civic forms of English cities current at our start-up. We inverted European experience in which cities and nations grew together (e.g., post-Charlemagne, cities began a rebirth in the 11th to 13th centuries; whereas the beginnings of rise and fall of national entities does not begin until the 15th century). Pre-Revolutionary cities in the USA were chartered on an English pattern with little power granted by a colonial legislature. In 1800, only 4 percent of our population lived in cities with more than 8000 population. When cities appeared in the 19th century, they were unfashionably modelled as state government imitations with a two-chamber council. The avoidance of clear-cut responsibility (and what became manipulatory corruption) was facilitated. By 1890, the failure of American city governments was recognized.

The effect of the industrial revolution on cities, American and European, was enormous. Their populations grew while rural populations declined. The urban population in the USA was significantly foreign-born. The crowdings of population required a tremendous increase of highly specialized urban services. These requirements placed new high values on mass production, which the masses of aliens helped produce as cheap labor.

The high speed of response to be found in the urban process put pressure on the development of a theory for the city. The first efforts in the late 19th century were with regard to a theory of location of cities (e.g., Cooley in the USA, or various European authors). Cooley's theory located the city to serve a primary transportation need. A. Weber provided a series of primary economic causes, and secondary economic, political, and social causes.

At the turn of the century, academic sociology was being born. A study of the city became a natural study object. Besides a point of view of urbanizing phenomena such as its objective

location, size, and growth, and its social aspects, there was a need of both an "objective" (we would say morphological) view of cities, as well as a point of view on the data base about cities. This was begun by Park-Burgess-McKenzie (1915-1925) as a first American theory of the city of sociologists. It was basically an "ecological" theory of the city. The city was an externally organized unit in space produced by its own inner laws, an ecology of spatial and temporal relations of humans as affected by the social environment.

Their social ecology recognized four community types: Primary service communities, commercial communities that distributed materials into world markets, industrial towns, and institution-oriented towns without an economic base (e.g., recreational, political, or educational centers).

When a community reached a culmination of economic advantage that occasioned its population aggregation, it must stagnate, recycle, or disintegrate. In the course of the developmental process, the city develops from simple to complex. It centralizes and then decentralizes. Its skeletal structure is determined by its traffic routes. A characteristic form of development takes place like successional dominance in plant species. (This is a more provocative statement that the critic realizes, since we have pointed out that a Zipfian character can be associated with all "communicational" systems. Whether words in a dictionary, cities in a polity, or plant dominance in an ecology, they are all language elements in the systems' repertoire). The major processes that form the city, in order, are competition, concentration, centralization, segregation, invasion, and succession.

The formalized and standardized ecological theory of the city has dominated American sociology well into the 1950's. Yet Wirth, writing from within that tradition, casts doubt that a sociological definition of the city has been achieved, as opposed to the growth of the city as a historically recurring process. What is wrong with the ecological theory of the city? There are three major theoretical difficulties. It orients to the geophysical rather than the social life of the city, and thus ignores the human life

that produced it. The primitive character of its crucial concepts (e.g., competition,...,succession) does not differentiate human social life from any other living system, nor does it differentiate sociological theory from political or economic theory. It omits the traditional sociological concerns - groups, institutions, social structure.

(It has taken a few readings for us to finally depict the academically or discipline-oriented outlook implied, as opposed to our systems-oriented reductionist outlook. There certainly is a need to provide a sociological, political, historical, economic, anthropological, ecological, biological view of the city, but there is another sense which asks, how does the settlement work, how is it constructed, how is it regulated and controlled? These are not contradictory questions, but complementary.)

So Martindale turns to notes for a second social-psychological theory of the city. This puts forth a sociologically oriented outlook. Within the city, the human has a different outlook and operational status than outside. Urban occupations, historically, have had greater social status with specific socio-political opportunities. The peculiar conditions of urban phenomena became the province of sociologists. The first generation of non-academic thinkers includes Comte, Spencer, and Lester Ward. They created a brand-new discipline in a breezy, imaginative style.

The second generation of academically oriented sociologists begins with Simmel. As a Neo-Kantian school of social science, this generation felt the need to define and delimit its field with precision and to draw sharp distinctions between the form and the content of experience. According to Simmel, the task of the social sciences is to study the whole range of man's interactive life; and, special to sociology, to study the forms of social interaction apart from their content. Interhuman behavior does not by any means, in this view, reduce to physical action, but includes ideas, sentiments, and attitudes. (In contradistinction, in our view, interhuman behavior does reduce to physical action, and includes ideas, sentiments and attitudes.)

So, according to Simmel, it is useless to study the physical and demographic details of a city. Instead, sociology deals with the psychic forms of interhuman life in an urban environment. His psychological study of the city assumes that urban man is subject to an unusual volume of nervous stimulation, to which he must react with head instead of heart. The city's institutions conform to that outlook of its mentality. Its money economy and its intellectual dominance are intrinsically connected. Money is concerned only with what is common to all items of which it asks only exchange value, not quality or individuality, but only how much. City production becomes part of a market only of computations in the mind. This would make the idea of a money economy correspond to the ideal of the natural science, in which the world is represented by an arithmetic (digital) problem (i.e., the view of modern pure economics). Within the city, thus, life has been transformed from a struggle with nature for a livelihood into an interhuman struggle for gain.

But Simmel (1903) was not as directly influential on the ecological theory of the city as Spengler's work (1918) was. Park drew from Spengler, yet Spengler's description of urban mentality is essentially Simmel's.

Spengler's notions of the city relates to the history of German cities: their foundation as fortress cities by the Romans along the Rhine and Danube Rivers, and their history following the fall of Rome. According to Spengler, the fundamental contrast in the order of human life is between country and city, with human life always rooted in the soil. Only in civilizations, with their great cities, does man become separated from those roots. That process leads to a cyclic character for human civilizations, because that gradual detachment from the land tears down the country in time. World history always tends to be city history. And the city is intellect. Its values replace the primitive values of the land with money instead of goods. Finally, its stone edifice, its cosmopolis (metropolis) stands at the end of its life course.

(It will be evident to the reader that we share a considerable identification with the ideas of Spengler. We are involved in a group devoted to the comparative study of civilizations, stemming from Spengler, Toynbee, and Sorokin, with overtones from all of the sociologist schools which are relevantly involved. We are the only physically oriented and trained members. Our physical stability theory tends to go along lines like Spengler's - of rise and fall, of internal stability. It is only the character of the individual historical boundary value problems, e.g., Greece-Rome vs. China vs. African "civilizations" vs. civilizations in the Americas, that is a specific cause for argument. We would ask the reader who wishes to enrich the basis for his consideration of urban settlements and polities to examine the writings of both the civilizationists as well as of urbanists like L. Mumford (14). It is also interesting to examine Hardoy (15) for an introduction to a civilization other than the most common Greco-Roman "western" and "eastern" comparison. Hardoy makes reference to Childe's ten criteria to distinguish cities from earlier villages. In some significant way these criteria have to relate polity and settlement in operational ecumenes. That is, anthropological, sociological, and physical outlooks have to be reconciled in studying these very viable life forms known as urban settlements and polities and ecumens. Spengler has prepared a very specific model relating life and death among these forms.)

Wirth could not adopt this anti-urban, pro-agrarian mysticism, yet he could sense that what was modern in the world was tied to the growth of great cities. So he sought, not the physical entity, but the sociological character of the city. He took his departure from Simmel.

In the city, the large number of interacting persons made urbanites into segmental role players. This creates, on one hand, Durkheim's social anomie, and on the other hand, the need for impersonal codification and measures by a monetary (value-in-trade) nexus. Individuals, groups and interests segregate. Desirable and undersiable areas and tasks become defined. To Wirth, then, urbanism is a way of life. It may be looked upon as a physical

structure with a population base, technology and ecology; a system of social organization with structures and institutions; a set of attitudes, ideas, and personalities.

According to Simmel, Spengler and Wirth, the focal point of study is the urban mentality. Considering that Wirth was a hard-headed urbanite, his attention to either Spengler or Simmel is strange. It is only comprehensible in terms of his obvious attempt to correct the simple-minded physics of ecological theory. Yet a socio-psychological theory of the city also seems to point toward a simple-minded approach, in this case psychological. And all indications suggest that institutions tend to receive as cursory a treatment from ecology. Perhaps it is of some significance that though Wirth's brilliant statement is some twenty years old (in 1958) the reconstruction in urban theory is demanded has not been forthcoming.

(These issues are our concern. We would agree that the prior ecological theory was based on a simple-minded physics, as is the socio-psychological approach. Our basic content, philosophically founded, it that neither psychology, sociology, nor economics can put forth a set of axioms that are sufficient to define the operational dynamics of either psychological, sociological, or economic man. Lacking that closure, these sciences are only descriptive and not predictive. Thus the construction of a predictive social science is still lacking. Our contention is that a physical reductionism does provide a basis for the development of a predictive social science.)

Martindale then proceeds to discuss European developments in urban theory. European urban sociologists concerned themselves with the past of cities with a thousand-year history; Americans only look at their currently gathered knowledge as unique and unintegrated. The notion that human social forms had been developed as solutions of maximum efficiency was strange here. A good study example is the administrative form of city government.

European city government evolved gradually over centuries to the focus of a mayor and council. American cities, developed by

people of European culture, largely followed the pattern of a state (polity) government in their development during the 19th century. Looked at as an unconscious sociological experiment, this apparent search for city democracy made possible the influence of every interest in city affairs except the public interest. By the 1880's it was thought that city government was the most conspicuous political failure in America. But every American sociologist should have been excited by the development in government form that began to emerge, a move toward a traditional mayor-and-council type of European city government. Instead, this was regarded as a failure of democracy itself.

The older American system of diffused civic authority and its attendant complexity of party patronage often made mayor-and-council government possible. Another ancient form of European government was resurrected - the outsider city manager.

Again, a knowledge of city development from Greek and Roman times to the medieval cities up through the 19th- and 20th-century European history and theory is useful. The latter two centuries produced the notion that the characteristics of any unit of social life is determined by institutions, that human society is an evolutionary or historical product.

We have been challenged by our biological colleagues to produce the physical theory for these two processes. This requires a theory of origins (what is referred to as development in biology). In contrast to an ecological theory, or a fragmentary socio-psychological theory, European urban theory at the turn of the century was an institutional theory.

The seminal French historian, de Coulanges, pioneered a theory of city origins in which religion was the critical institution in its development, i.e., based on the family and the hearth. Glotz carried the issue in the Greek city to three conflicting groups - the family, the city, and the individual. Then Maine brought in a construct for comparative jurisprudence. Starting from patriarchal family life, a principle of territoriality was substituted for kinship, freeing the individual to enter into multiple contractual relationships. Thus social roles expanded. The city

developed as a legal structure based on contract and territory, rather than kinship and family. (One should note that the birth of legal codes, 2000 B.C., had that kind of association, of establishing relations in the city and in the polity.)

Explaining the city in terms of economic institutions was done by Marx and more completely by Pirenne, who traced the pre-history of cities' development as refuge from danger, as religious centers, by the constitutional foundations of the Roman municipal system, to their decay, to the 9th century episcopal "city" where the bishop resided. The latter came into prominence as the last vestige of civic life was annihilated. Then the weekly market of these centers served as stepping stones to cities. The cities then took form around the walls of these centers after an economic renaissance, effected through the activities of merchant caravans who settled at these centers and used their walls for defense. Then, under the development of trade, the old Roman cities were repopulated. The critical point for Pirenne was the development of the new class of merchants who were at odds with the country-side and its institutions. They fought for the new code of laws, property rights, and distinct command organizations. (For a more incisive historian's views, we would add M. Bloch (16).)

All this serves Martindale as an introduction to M. Weber. Weber's outlook was toward a form of social behaviorism. The task of sociology, for him, was to explain interhuman actions in terms of the meanings to the involved parties (i.e., its ethics). In his terms, all the forms of European urban theory touched on were institutional theories of the city, differing only as to the central or original institution that led to organization. Weber set aside the distinction between form and content, requiring instead a causal interpretation of social action. In Webers' view, all could comingle in the city without understanding each other. With no psychological homogeneity, city dwellers can only think effectively in groups. Thus he could grasp both the mentalities of the city and its institutions. In the city each occupation tends to become a profession.

relationship is a much clearer understanding than Zipf or Mandelbrot (a subsequent commentator) have brought to the relation.

Zipf's rule indicates that a thermodynamically constrained system, when it has to express its actions (e.g., by communications, or by disposition of its states or complexions) among a considerable number of states or complexions, where only the population of the complexions is constrained, will most probably array them near Zipfian. Actually, the more precise rule is that the population distribution will be equal in each logarithmic octave (k-nave, if some other log base is used). Thus the population distribution will be essentially the same in cities: say, in the ranges 10-5 million, 5-2.5 million, etc.

Thus from a policy or planning point of view, unless the ruler (or administration) has some very specific dynamic reasons for having to change the distribution, they should be satisfied with that equitempered rule. It may be referred to as the rule of democracy, or of blind justice. Recognizing real physical reasons for cut-offs in a logarithmic space, the policy makers should devote as much effort or attention to each equally populated logarithmic interval, whether it be in population space, or in action time.

Of course, the distribution has cut-offs in the logarithmic space. At the bottom, the cut-off still remains roughly the top of the pre-Neolithic isolate extended family. A settlement of the order of 200 barely has current survival value. Or conversely, one notes that transient populations, wandering among fixed settlements, only begin to have the latent possibility to feed the settled population by condensing or being attracted to settlements of that minimal size.

At the other end, cities in the largest sizes represent the measure of the distribution of all settlements (e.g., the first logarithmic interval starts out with the sparse number of 1 or 2 largest cities). Thus the largest centers represent a parametric

Weber starts by reviewing each concept of the city: economics, relation to agriculture, political-administrative concept, its legal concept, the city as a confederacy, the city as a body of militarily competent people. He tested these against evidence to fashion his own picture.

For example, in reviewing the economic nature of the city, he isolated it in its nonagricultural activity. A topology distinguished producer and consumer cities, commercial and industrial cities, main and satellite cities. But its economy was a necessary but not sufficient condition for the city. What was essential in his institutional theory was a theory of an urban community. Urban "communities" only appeared in the occident. They had to represent a relative predominance of trade-commerce including the following features: fortification, marketplace, court and partially autonomous law, a related form of association, and administration by authorities in whose elections the burghers participate. (See Childe's ten criteria relevant to post-Neolithic urban settlements in (15).)

All communities, including urban, were not unstructured activities, but a distinct pattern of human life. They are total systems of life forces brought into some kind of equilibrium. They are self-maintaining, regulatory.

Weber then argues that urban communities did not emerge everywhere, etc. At this point we break off from this introduction to Weber's work. We would turn the reader toward Weber's work. However, Martindale's last remarks are significant. He points out, in closing, that the modern city is losing its external and formal structure, and that internally, it is in a state of decay while the new community (15th century?) of the nation grows. The age of the city seems to be at an end. We would recommend Mumford (14) and Jacobs (17) for further reading that both continues and goes beyond Weber (also see (51)).

We wish to bring this injected chapter to an end with some observations. We are not highly impressed by the "existing" sociological theory of the city as Martindale outlined it. It relates to a morphological view of a structure known as a city.

It is not a dynamic field view. Specifically, our criticism is that territories are not simply organized as national and urban forms, for which a standard topology can be organized, in which sociologists can vote on what is to be classified as a city and what is not. There is a territory. Homogeneous population is not the stable form. Instead, clustering takes place. Dynamically, there is ingathering clustering. With agricultural fixed living, convection and value-in-trade emerge. There is a dyanmic organization within the territory. A nested sequence of spatial forms develop. All of this is indicative of a flow field theory. The field forms exhibit a history and an evolution. Thus our views will always contrast with the sociologist's. We are pleased to examine and consider his notions; in our field functional theory, we do not have to be bound to his forms.

To put forth the challenge in the sharpest way, we have to offer the social scientist the challenge of boundary value problems, as we see them. We will offer two contrasting examples of what we consider to be the power of our physical approach:

a. We can first imagine we are given a physical boundary value problem of a specific number of the following nuclear moieties - electrons, protons, oxygen nuclei - put into a thermostatted container at time t = 0. We can face the problem of tracing the history of the development of that matter field, say, for a specific length of time. We can do this with a fair extent of accuracy. We can derive, from first physical principles, some notion of its atomic and its molecular and its phase clusterings. We can characterize its distribution, its local thermodynamic equilibria states, and its systems' dynamics throughout the space of the container.

b. In the same sense, we can tackle the problem of a given territory - say, the Americas - at a given epoch - say 10,000 years ago - with a characterization of its earth potentials, and a snapshot of a distribution of population at a moment t = 0. We submit that if we are given a summary of their epigenetic state of knowledge of that time, we can then tackle the problem of

characterizing its state and its history of change, say, for the next epoch (e.g., 100 years, 500 years, 2000 years). This, we submit, neither biologist, psychologist, ethologist, anthropologist, political economist, economist can do. It is a task in "social engineering." The formalism we have been developing is the applied physics, thermodynamics if you will, for such engineering. We are more than willing to examine all the fragments that these disciplines offer, but the dynamic whole we can characterize better.

Why did we write this intermediate chapter? Because we were concerned, in May 1976 at our Civilizations meeting, to learn that there was more to the story of the control of China than the "traditional" Confucian view of intellectual-clerical control of its administrative channels; because we were concerned, in examining a number of recent books on European start-up after the Roman breakup with the Frankish invasions, to realize that a gap from the beginning of Roman decline of about 280 to perhaps 900, the urban structure virtually disappeared (how would you talk about a Zipfian character to the population of its cities?); and because the urban theory of sociology was rooted much too strongly in an abstract idealized form of the "occidental city"!

So, having contrasted our field view with a sociological typological view, we can return to the potentials.

4. NATIONAL POTENTIALS - FURTHER DISCUSSION

While our concern is with the polity of the USA and the relation to its settlement structure, we cannot take the easy out of offering a specialized typology of settlements. Regardless of who or what created the settlement, what is characteristic is a distribution of settlements that serve the required potentials and fluxes of the territory. But in order to relate the distribution of settlements (e.g., the Zipfian) to the potentials, we must begin to develop a deeper applied physical theory than we have so far done. We have assembled the ingredients, so we start from the point of view of population. The assumption is that all compartments for living are filled. We wish to know what our physical theory might say about population.

4.1 POPULATION THEORY RELATED TO AN EQUATION OF STATE

It finally has dawned on us that a theory of settlement population in a territory (polity) is essentially an equation of state of those molecularities (not the human atomisms). We will review what we have learned to try to bring the real problem into perspective. It is important, for the sake of the record, to indicate that we are attempting this physics from a pre-Boyle stage, at a time (now) when the theory is still "alchemy" and not yet physics or physical chemistry. We hope we are the last of the alchemists.

Pre-Neolithic mobile hunter-gatherer roamed their territory in an ideal-gas molecular fashion. They were organized into extended families; they interacted in a Boltzmannian fashion. The entire territory in which they could roam freely might be referred to as a polity (or a primitive polity) for the following reason.

We will define a polity as that territory in which there are not extraordinary barriers to diffusion and convection. (Polity - political organization. Political - relating to government. The one generalization we have elected to pursue is that governing is an aspect of regulation and control in systems, and that the

distinction between governing by man and by mechanism is artificial. Both, in the end, are subject to natural law. We are simply attempting to restore the fragmented sciences to a whole. Thus there are rules, laws, and barriers by which a particle - whether living or not, whether an assemblage or not - traverses a field. "Polity" has the sense of the level at which the master rules for systems' behavior make themselves evident. The notion would apply also to a stand of plants, or the fauna in a territory.) We are assuming that in pre-Neolithic times the diffusion of an individual from one extended family is not more impeded at any one point in the field than another. This at least seems to be true in the case of primate bond organization.

The polity in this primitive state might be classified as the zero government - essentially no interaction state. It is not anarchy: it is simply no government, except for a small elastic propagation and diffusion among groups.

As we have made the point earlier, while this pre-Neolithic society may be near-ideal gas, its equilibrium is determined by being substrate bound. These mobile "stands" of living systems draw their livelihood from the earth, waters, and heavens. With the Neolithic revolution, with a precipitation and bonding to the soil, the equation of state has to change to a deviator state from an ideal gas configuration. "Condensations" and clusterings begin.

It seems quite reasonable that the form taken by the open collection of fixed farming communities, village agriculturists, hunter-gatherers, or nomad pastoralists is not markedly different than the prior near-ideal gas equation of state. The difference seems to be in the form of the molecularities. Previously there was perhaps more nearly one prototypic molecularity - the hunter-gatherer. Now more than one molecularity seems to be possible. While we have not done the detailed historical research, it seems clear that the changing climate (12,000 to 10,000 years ago) accentuated motional patterns toward preferred settlement patterns. Given the general world status of technology and epigenetic learning, an enriched number of molecularities could precipitate.

We believe that the number of kinds of human bonding groups that could emerge were characteristic of the human nervous system and its abstraction and language competence. What was characteristic of the period of transition from pre-Neolithic to the post-Neolithic "revolution" (the Mesolithic and Neolithic transition) was the gradual precipitation of more complex bonding groups in settlements. The face of the earth, as far as precipitation centers were concerned, had likely been marked.

Are there only cities? No. There is a broad distribution of settlements throughout various polity bounds. We do not care to count all the polities at this point, but they are not many: a few in the Americas, in Europe, and Asia, in Africa, in Australia. At the present, we are not certain of the bounds; we would have to trace diffusion patterns and try to decide what barriers impeded diffusion. While the distribution function is still likely Boltzmannian, it is the Boltzmannian tail of a distribution that will become Zipfian. Namely, this distribution is still noise, and still requires no "language" for its organization.

But clearly (in our view) that configuration is unstable. It probably can be maintained if there is a considerable disparity in the temperature of weather potential. If there is more concern with the local vicissitudes than with external convection, then the village settlement distribution can be temporarily stable.

Agriculture produces surpluses and deficits, requires programming, and requires storage. Thus time-dependent processes enter in. And also, these focussed and coordinated processes produce storable surplus, which the earlier hunting-gathering did not do.

Technological practice which grew epigenetically, plus the pressure it put upon genetic change in domesticated species, symbiotically involved with man (see (18)), put the emergence of a significant number of village agricultural settlements and dependance of fully domesticated produce in most inhabitable areas of the world by 6000 B.C. It made them potential Noelithic polities in which such settlements could then diffuse through the territory.

However, in these domains some kind of new value-in-trade could begin to couple these settlements. Why? Because surplus and deficit beyond daily need became evident.

What was characteristic of the pre-Neolithic equation of state, and likely the Neolithic equation of state, were characteristic population densities. The hunter-gatherer densities were perhaps in the magnitude of an extended family per 100 square miles, i.e., one person per 10 square miles. Such a million-square-mile "polity" might have a population of 100,000.

With change in weather, and the Neolithic farming village revolution, (see Childe (19)), the population density might have risen to 3-10 persons per 10 square miles. The change in net fertility is not great. Thus the transformation in equation of state is not great.

But by that point, a language of urban settlement, of city, could begin. Why? For any of the many reasons enumerated in (13, 14, 17). A religious center, a chief family's center, a ruler or king's center, might be organized. It is conceivable, by current records, that the first centers were religious, then leaders' centers, then a king's center.

The important notion is that the patterns of livelihood that have developed in village settlements have produced enough surpluses and deficits that convection becomes important; that convection has created enough surpluses that a storage, of whatever kind, has to be developed. The storage in general is of some kind of bonding group and its attendant materials, energies, modalities. Some kind of institutionalization or regularization of a governing command-control has to take place. We do not opt for any particular course. We submit that the dynamics of the polity itself proposes the development of this new instability, this new in-gathering of population. Very possibly it has a density base, but more likely it deals with the excess action available among all the social bonding groups involved now as atoms and molecules in the polity. Namely, the few bonding groups of the extended village settlement begin to grow toward a large, more "impersonal"

form. Soon (as Pfeiffer (20) has suggested at numbers greater than 500-1000 faces you can recognize and name) impersonal ingathering takes place. The "polar" attraction of urban life begins. A significant van de Waal attractive force begins to show itself, and like all of its force components, it is not the specific spatial form that is significant, but the range of the attraction.

Then the form of the distribution function changes. The Boltzmannian tail begins to bloom a Zipfian head. One or more communicational elements, urban settlements, begins to form in the polity. This process of start-up showed time delays, characteristically, of the order of 2000 years: the real clustering to significant urban settlements is delayed from perhaps 6000 B.C. to 4000 B.C. The full support energetics for the system was not in existence before then.

By 3000 B.C., "the high yield of about 30 bushels of cereal to 4/5ths of a bushel sown revolutionized man's diet," states a placard in the Museum of the University of Pennsylvania. In a number of areas around the earth, a contraction and condensation to real polities began. The rise and fall of urban settlements, polities, ecumenes began. The evaporation and recondensation of these phases on the face of the earth began. The nuclear structure of settlements, e.g., village settlements, which might rise and fall, was essentially fixed. This is the point at which a theory may begin. This remains a Boltzmannian tail to feed into the higher population organization. It supports the higher organization from below. The atomisms are bonding groups which condense on these nucleating centers. The atomisms remain atomisms in a considerable number of these village settlements. There is little export and import from many of these settlements. Then the molecularities are the organized urban settlements which were the subject of the literature we reviewed earlier. Their populations can condense, or evaporate, or spread.

As far as these urban molecularities are concerned, we can be satisfied with Kahn's spatial description of them (21), namely, a radial density of population ρ, which approximates,

$$\rho(r) = \rho_o e^{-kr}$$

where:

ρ_o = core density

r = radial distance from "center."

and where currently, major American cities have density values ρ_o of about 5000-25,000 residents per square mile, and a 1/k of 3-12 miles. The distribution is fairly sharply peaked around kr = 1. The effective population range is about 5/k. (The density is within the noise level.)

With some of these preliminary ideas out of the way, we can turn toward the ideas behind an equation of state formulation.

4.2 PRESSURE - MOMENTUM - ACTION FORMULATION

Consider an ensemble of colliding atoms. They very quickly feel out each other's presence, and locally form all possible molecules with higher-ordered stability by chemical bonding. They give up a heat of combination, the difference in the energy between their bound state and their independent state. Sometimes this approach toward chemical equilibrium takes place very slowly, and a catalyst is necessary to speed up the reaction rate to the same equilibrium point that would have occurred without the catalyst (a catalyst does not get "used up" in the reaction). However, if a chemical limit cycle can develop (a thermodynamic engine or chemical oscillator) by still-imperfectly understood mechanisms (that is, if gradients can be developed in a field basically by what is a combination of fast-slow processing, e.g., enzyme-substrate catalysis (see p. 313 in (22)), then the catalyst is not solely a bystander. Intermediate complexes can form as part of the cycle, and the mini-maxi reaction limits may differ from equilibrium values.

There is one additional step of complexity. If the "primary" electrical bonds are satisfied (ionic bonding or covalent bonding by quantum mechanical exchange forces), there may still be higher

forms of coalescence. Depending on weaker residual electrical forces and the symmetry of the exchange, a condensation of phase may occur. This can take place below a certain average kinetic energy (measured by temperature) of the molecules.

All this stresses that even ion-atom-molecule interaction exhibits a considerable degree of patterned complexity in its association. The issues that create complexity are what happens when external translational degrees-of-freedom are transformed via nonlinear lossy processes, into internal degrees-of-freedom. The physics of association can be followed but it takes a very detailed argument to make the case with any precision. These remarks have painted the problem scene very broadly.

So we now have to paint broadly, in a similar fashion, with regard to social condensation. The human organism has exquisite internal mechanisms for converting energy into a great variety of internal degrees-of-freedom. The human takes energy in slowly, in chemically bound form, decomposes it, sorts it out, and makes it available by both genetically governed and epigenetically governed processes, through many possible avenues. The new mechanisms that he has, different from his ancestors, are speech and abstractions, and thus the capability for the most fantastic transforms of input to output. He is not bound by hard-wired or hard-imprinted coding for immediate discharge. As a primate, he is hard-wired for group formation. Hence he forms the group, the nuclear family, the extended family as molecularities. All primate species including pre-Neolithic man show the general family characteristic that one already finds well-developed in mammalia (with specialization in each genus and even more in each species).

But as a human, with fixed settlements, man does more than any other mammal in distorting his free roaming activity. This can be seen in the difference between his actions and that of the various species he domesticates. Most of them conduct a life which can be loosely identified with what they do "in the wild." One finds new types of bond formation; but as a well-known Philadelphia ethologist pointed out on his retirement, it is surprising

how much bond formation can take place with forced familiarity and some external affection.

Man's particular distortion is that of abstractions, of the creation of artificial values. They are an artifice in that they are made up in the mind and not found in nature, but the abstractions fix chains of behavior as strong and controlling of high energy fluxes as any hard force. Some men die for "honor" regardless of the application of pain, etc.

This slow formation of bonds differs considerably from the behavior of simple molecules. It indicates why we have proposed a specific line of processes to visualize growth of complexity - from elastic collision to hysteresis, to thixotropy, to genetic memory, to epigenetic memory, back to rigidity, whence comes elastic collisions of a higher level - along which the bulk viscosity and stickiness grows. As one gets to a more complex form, the fast chemical equilibrium does not become the dominant process (except at a lower level). Thus, for example, by the chemical level of complexity of amino acids, peptide chains, and proteins, one no longer has good solution in water, and instead a much more complex set of patterned interactions is found.

So when human beings begin to act and diffuse and propagate through the polity of fixed population centers, villages and towns, their action is not exhibited via translational momentum but by human action modalities. Their bonding is not complete, but it has a sticky relaxation character. It is not the pressure-translational momentum space which is filled up, but the action space associated with social bonding molecularities, atomisms in this case, which is filled. What is characteristic of these bonding atomisms in settlements is that they institutionalize, they play roles.

It is the institutionalization that sociology stresses; it is the role playing that Mumford ((14), see Chapter 4, "The Nature of the Acient City," Section 7, "The Urban Drama") so exquisitely stresses. It is the ritual, the drama, the rites, the "professionalization" of every task that strikes the historical observer

of the settlement. All these actions seem far removed from the actions of men in the more primitive hunter-gatherer state.

Yet the individual human action modalities remain the same: they are still nearly the Iberall-McCulloch list of 20 modes. What has changed is the bonding group modalities. We have identified the dozen odd modalities that are now played out. They no longer are solely livelihood modalities as a hunter-gatherer (who lives off an ecological chain in which the sun produces photosynthesizing plants that produce plants and animals that live off those plants) or agriculturist modality. They are enriched.

Tentatively, we believe that we have exhausted a listing of the primary bonding modalities. Intense development of future social forms, or futher study may indicate a few more or a better grouping. But those details are not important. Nor is it important that sociologists gather a great deal of statistical detail about these groupings. The more important question is what determines the substitute for a pressure-momentum characterization of action space.

Clearly, the time scale for equilibrium is longer than a decade. Men bond into their life activities with time scales of the order of late adolescence, 20 years, the time to reach reproductive age. Having departed significantly from pre-Neolithic and Neolithic life expectancy (now 70 years, approaching the species' life span of about 90 years), the social patterning has changed.

The issue of pressure in settlement space relates to total population within the polity. We premise that settlement density is essentially scored on the land whenever the land space has been occupied by man for over a few thousand years. We base that on Paul Martin's estimates for diffusion of early man over the Americas; the diffusion rate of major technological advances - agriculture, pottery, metallurgy; and man's size and rate and roaming range, whose relations are physiologically cast.[1]

[1]The reader who is interested in examining details of some primates' occupancy of a roaming range can examine (23). A troop of about 40 baboons are traced in the field within a range of about 20 square miles. Note the statement (p. 202) that McNab (1963) pointed out a linear correlation in mammals between body weight and home range size, with a larger range for hunters than for croppers.

These objective factors, plus the experience of conducting or reading about the conduct of the business of life in a region (plus the ergodic hypothesis), suggests that the territory is completely explored as far as a group settlement is concerned. This is not the same as establishing population density for the territory. So our basic assumption is that all of the territory is scored by at least one viable family unit per settlement point.

One would surmise from this notion that there is an approximate critical density for the transition from pre-Neolithic to Neolithic settlement in a polity. We have suggested that pre-Neolithic population densities could exist up to, say, 100 people per 1000 square miles. That life seems to have been conducted at net reproduction rates of a few percent per century. Thus the transition to Neolithic (given the weather change and a few thousand years) might take place with populations of 300,000 for a region of the size of the USA or a total temperate-world population of perhaps 3×10^6 (assuming that there are about 10 areas of the size of the USA available around the world). This seems to be the right order of magnitude. This implies that causality must be very carefully reviewed. Did human population (with speech and technology) reach a density take-off, which exploitation in a warming region then facilitated, or did the warming and harvesting capability facilitate an increased reproduction rate of take-off? In either case, the Neolithic revolution did take place and population increased.

Then, for a second transition toward Neolithic farming settlement, can we say, loosely, that instead of a sparse population density per settlement site (or region), that the density can increase toward 2-3 persons per square mile with essentially no urban settlements? Let us explore some consequences. If we picture the USA area about 3×10^6 square miles, this is a uniform population of the order of 10×10^6 people. Assuming that group densities for bonding groups are of the order of 25-50, this represents a total number of potential settlements of the order of 200,000, namely, one settlement per 4 miles. These are all reasonable self-consistent numbers.

Thus post-Neolithic polity with urban settlements begins in sizeable territories, i.e., of 100-200-mile diameter or greater, when the density exceeds 3 persons per square mile, in a reasonable ecological domain served by one or more river valleys or river plains (since ridges or mountains, or oceans often define the limit of an accessible polity), and in which human settlement density approaches one per 15 square miles.

Then human action, at levels of the order of 2000 kcal/day, can develop the "pressure" to maintain a population livelihood. And "now" (e.g., starting between 6000-4500 B.C., coalescing to a number of well-defined areas by 3000 B.C.) the total range of human atomistic bonding groups can begin to grow. Above the limiting density, the major factor that counts is what has become the artificial, man-made polity, and what is the status of technology. We are not concerned with specific start-up issues - that is the concern of the historian - but the characteristic process.

At critical density, in a region, one or more centers increase in goods, one or more centers decrease in goods. A circulation pattern, with value-in-trade, develops. These gradient differerences attract others. In the economy of effort, is it easier to gain sustenance, surplus and wealth by one's own effort or by raiding a neighbor? (A modern example of a primitive society's social game may be found in (24).)

Thus, as appears clear quite early, urban areas are organized around defense, around trade, around artisan grouped functions, and other services, around rituals, around rulership. It is premised that what made the region a settlement in the first place were distinctive or useful ecological features. So we do not care to enter into controversy, which will require acquisition of a great deal of data, as to what were the first likely causes of instability. As one reads the story of start-up various cities (see, for example, The Centers of Civilization series of the University of Oklahoma Press, which treats the start-up of various cities that have had a radiating influence within the time of their civilization), it is clear that some elite group generally had a reason for starting up an urban settlement. But that reason,

itself, was responding to the pressure of a regional instability. For one apparent reason or another the region had to be organized toward what would then become a more restricted polity. So the natural polity, the settlement and bonding group, the density of settlements, the instability of urban settlement among those settlements (the density of current salient urban settlements is a distribution with about 200-mile separation, i.e., perhaps 75 such major centers in the USA), the coalescence toward polity, the polities, the ecumene, then the rise and fall of urban settlements, polities, and ecumenes is roughly the order of development. What constitutes "pressure" is the formation of these atomisms and molecularities that form and develop upon the solvent earth's ecological film. Pressure is measured by the distribution of action among these various levels of the human social sphere. Men begin the battle for power, the ingathering and broadcast of persons and groups that establish elite leadership over urban settlements and polities. Above the critical density, where there is sufficient surplus - in materials, energies, manpower, extensions, technological potential - then the urban settlements are broadcast and maintained according to a Zipfian relation, or as we have shown, in the integrative form of a logarithm distribution.

For the urban settlements to be supported, the agricultural settlement is the essential requirement. Its needs may change with technology, but then the balance has to be sufficient to cover both the agriculture and the material resources for the technology. It is these balances achieved over the polity that determines the level of urban settlements that can be maintained. Otherwise, the population of those settlements is broadcast into a wider milieu. The immigrant leaves Europe for the USA

In each age, the elite ruler examines the same question: "Is it easier to maintain my existing polity (or settlement) by my own efforts or is it easier to raid my neighbor?" That question arms his neighbor and produces a near parity in position of neighboring polities. Once in each generation, someone in the ecumene has to test the near balance.

Thus we have approximately characterized pressure, not as momentum, but as excess action to create and maintain urban settlement and polity. Action now is generalized, not only as kcal/day for the human, but all of the materials per day (or year, or decade, whatever is the best equilibrium period) and energies and value-in-trade required to maintain the society at its operating technological level.

4.3 POPULATION DENSITY

Thus we find, very much like the ideal gas issue, that population density itself is a major factor in establishing the equation of state regimes. At extremely low densities there is no need for administrative-legal polity. A people have to live off the land. The condensation of people-power, of material resource, of technology to organize greater complexity, is not there. But above critical density, in a reasonable ecology, population density can lead to organization. A precipitation of elites can determine ways to organize polities.

One may surmise that the thrust toward complex organization (e.g., urbanization) begins with a Neolithic revolution in which initial critical density is established within a region. In lieu of any other information, we have suggested that, given a reasonable temperate economy, that density level may be of the order of 100 persons per 100 square miles. Countdown toward civilizational organization then may be conducted in increments of 500 years. That is, when some such critical density is exceeded, then either an attractive ingathering of population may take place, or the population density may begin to increase sufficiently, per 25 generations, that a more complete village agriculture will fill up the polity region.[1] While in the former case, of the first

[1] As Childe suggests (19), the Neolithic revolution showed an increase in population. The Neolithic village communities were larger than the earlier human groupings but their expansion in number and state of living has implications. Each village kept budding off daughter villages: that is how the space tended to become filled. But at the same time conflict with other states of living took place. All of the process rhythms of civilization thus began.

critical density, the delays may be up to 10 units of 500 years, at this second critical density, take-off toward civilization begins more promptly.

At this point, the historical development of specific boundary value problems begin. The population thrust to civilization is measured by,

$$(\rho-\rho_a)\ A = P_o e$$

$$\rho_a\ A = P_a$$

where:

ρ_a = a critical density at which the region is comfortably capable of conducting a village agriculture

ρ = actual regional density

A = area of the polity (region with no special impediment to individual motion)

$P_o e$ = population excess

P_o = total population

P_a = agricultural population.

What is undefined is the polity area. Namely, what defines the polity, now, is the emergence of an elite leadership who create a coherence structure, an institutionalization of the population, and also a barrier to motion. That artificial barrier is what creates the polity. It exists by virtue of some latent force that a polity leadership can exert to prevent its unfettered crossing. It is a characteristic of the peculiar command-control development of the human primate's nervous system that permits him to be domesticated by his own kind, and in fact encourage some of his own kind to do that domestication.

So for whatever the local reason, and whatever the specific local enculturation which ecology and the earlier history of the region has encouraged, a local elite structure develops. It feeds off the production that the population can produce as excess.

With convection and value-in-trade, the populace permits that elite population to store and control the excess produce. The process of urbanization has begun. The cycle of ecumenical civilization has begun, in which village agriculture, etc. are transformed into metal and stone, aperiodically pulling down the civilization, and requiring its subsequent build-up from the pieces. While there is a transfer of technology and "objective" learning, there is little evidence that either the people or the elite learn from earlier civilizations what controls must be placed on their own human conduct. Instead, similar to the range reported by Aristotle, command-control covers the rule of the one, the few, or the many, and extends from rigid authoritarian role to anarchy of the mob. Self-interest of the elite at particular start-up periods is particularly influential, and the cultural framework within which it develops lends coherence for some period in the range of 1-25 generations.

While this may not seem to be a highly constrained system, it is the total degree of constraint that the external science can place upon the game of urban socialized life. Satisfying the summational invariants leaves a large degree of the system's patterning undetermined. They are basically systems thixotropic processes.

Nevertheless, regardless of the political form, the population in a region lives on. Its excess population provides pressure for urbanization, roughly in accordance with Zipf's law, but the polity area is not so easily determined.

In any era, given population density, ecology and technology, the size of one or more ecumenes is likely determinable. It is possible that from rules of military strategy, some notion of the many polities may be derived, but the actual count and demarcation will be determined by cultural-historical processes involving interaction with energetic elite individuals. There likely is a distribution function for turnover of polities. That number (say, the half turnover time) is likely under 10-15 generations. Why? The excess richness of the polity provides each generation with "reasons" for elite adventure. It is essentially a threshold

number of generations which is involved before a polity turnover will take place, particularly in an ecumene where the perception of more advantaged and less advantaged arises with sharp distinction.

Clearly the pursuit of all of these issues requires a fantastic richness of maps. These are not currently available in the form and number one would require to examine all of the detailed issues required in history. Instead, one has to work with pieces. For example, it is only a small notion of the relation of city development to the dominant polities of history that is provided by Mumford (14) in 600 pages.

Since we cannot tarry at many of the relevant historical questions, we can only assume that what we have proposed may be useful orienting hypotheses. Hopefully our project officer will be trying to provide the documentation for one polity, the USA, from its founding days circa 1790 to present.

However, in moving forward toward picturing what a polity can do in its development, it is useful to abstract one note from Mumford. In comparing what might be found in the development of the later Hellenistic city as compared to the earlier Hellenic city (a few hundred years different), Mumford points out that, "No city of the fifth century (B.C.), not even Periclean Athens, was able to spend as lavishly on public works as these rapacious and highly organized kingdoms and empires, drawing on a far ampler economic base." So the development of a polity depends on the total resource potential it can draw upon, material as well as personnel.

So we imagine a polity of area A, and population density ρ (these may be averaged, or local densities) with a total population,

$$P = \rho A$$

and a critical population P_a required for agriculture,

$$P_a = \rho_o A.$$

where:

ρ_o = agricultural density.

We imagine that the agricultural population can operate at a level, within the technology, so that it can produce enough food (or equivalent value-in-trade) for the entire population. If the effective daily heat of individual consumption H (e.g., 2000 Kcal/day, or some moderate multiplier of that number of make up for losses) then the product inequality gives:

$$\rho_a \, HNA\ell = \rho HA$$

$$\frac{\rho}{\rho_a} \leq N\ell$$

where:

ρ = total population density

ρ_a = in agriculture

N = the gain in food power production

ℓ = the modest (less than unity) loss factor.

What is to be done with the residual population $(\rho - \rho_a)$ A? This is the issue facing the ruling elite. A significant portion of it is enticed into urban settlements,[1] some are transiently settled. But the important question, for viability, is the fraction that is occupied usefully and productively in the maintenance of a healthy society.

There is a fraction of the population that makes up the elite. This is a few percent (i.e., 0.02 ρA).[2] There is a population

[1]Mumford (14) points out that at its height the Roman Empire had about 5600 civic bodies within its jurisdiction. In population and size the empire was similar to the USA at the turn of this century.

[2]Mumford points out that perhaps 1800 patrician families lived well in Rome. Assessing this as a population of about 10,000 it is representative of an elite concentration.

that makes up the mining, manufacturing, artisan, service, and maintenance components of the polity. There is a long list of occupations, current and ancient, that are required in any polity. The minimum requirements for all of these occupations can be estimated. Then the polity has need of an internal and external defense group. It has need for many administrative functions. These grow with the complexity age of the polity. There are social criminals, who live by raiding the society. The finally, there is a population excess - that pool of labor that is identified as unskilled, poor, low-cost labor.

Are the needs of the polity and the needs of the social bonding groups well matched? The answer is no. There are often strong immediate reasons that attract population excess to an urban settlement. At a slow, few-generation rate, those who become poor in a polity turn over and adapt. At the start-up of ecumenes and newly forming polities, population tends to be rooted to the earth, but during its later history an increasing population is rootless. They are attracted to the cities, they become migrant, they begin to develop culturally, a poverty bonding group. One need only study the urban slums and the migrants in any culture in any historical period to recognize the great disparities of their characteristics and reasons for their existence. Yet they show no compelling dissatisfaction with their role.[1] As long as no new

[1]Tabulated results of happiness and rank happiness in the United States are given in (27). Over the study period 1946-1970 more than 90 percent of the people polled reported themselves fairly or very happy (about a 50-50 split). The highest degree of great happiness had a broad peak in the 1955-1965 period. (It has been our private estimate - sensed and intermittently studied since 1947, that the American system reached its peak in about 1950. Loosely, this study is consistent with that observation.) In a study reported in 1974, in which happiness is ranked with income, for annual income above $4500, the fairly or very happy segment climbs above 90 percent. While the fairly happy group remains constant at the level of about 50 percent of the population, at the poorest level of under $1,000 income, the not very happy rises to 25 percent. On the other hand, there is also a shift to the very happy category - for the high income. Thus the poor show a modest but not complete dissatisfaction. One might assume that the drive to move away from poverty comes from that 20-25 percent of the poor who are dissatisfied. Consistent with these findings, at income levels under a few hundred dollars per year, all people in the world become very unhappy (36).

currents are swept into the society (e.g., by wars), the poor remain as a pool within society. Even their role is professionalized. (See Matthew (25) for a Victorian picture, or S. Terkel's writings for more modern examples.)

The approximate law of population change remains:

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

where:

b = current birth rate

b_o = an average effective birth rate, which essentially relates to a past epoch (in humans, approximately the life expectancy).

Thus the basic thrust for increase in population is the choice function of having children today as compared to the choice function about one span of life expectancy in the past. Of course, this relation (an assumed constancy in b_o) is less exact when life expectancy is changing quickly (e.g., due to improved medical care, epidemics, climate changes affecting land productivity, extended wars) and it is less exact when considerable cause for migration exists relative to the polity (there are significant attraction or repulsion forces from the one to other polities).

Why should there be any basic difference in choice function (or summed choice function)? In other living species, we can see reasons in predator-prey coupling, in coupling to the total ecology including weather (see for example (28)). Beyond these factors, which are attenuated in humans, we can only see the major effect of the change of technological potential. Clearly, ecumenical interactions over the past 6000 years have governed the rise and fall of civilizations, of polities, of the growth and decline of cities. In the large, population has grown. Technology, regardless of how primitive we may regard it in more advanced nations, and the expansion of arable land has simply provided enough goods and materials for a growing population. Famine has always kept the death rate sufficiently high that no untoward explosion has taken place.

But a relatively high explosion in population has taken place in the past 200 years (a population doubling approximately each hundred years). That is the result of a growth in machine power, with all of the technological arts that it has fostered - new farming technology, building, materials, and transportation. That phase is drawing to an end: potential exhaustion of nonrenewable resources faces man today. There is an epoch of adjustment (up to a few hundred years, up to 10 generations?) in progress. A deceleration of population growth is taking place. Elites and the people are beginning to find all kinds of "reasons" to reduce the current birth rate.

This period in human history is unique. Such a world-wide leveling off of population process has never been in existence. Thus one must expect it to be somewhat stormy. We are seeing the storms in many forms - the sexual revolution, the changing outlook toward the nuclear family (the outlook toward the extended family has already changed), the awareness of the differences between have and have not polities. Thus while the countdown (toward a population leveling) will take place somewhat smoothly at ecumene size (the whole world now being one ecumene), the crisis among polities will certainly not abate.

Note the modern polities, the organization into coherent nations, is relatively new - only one 500-year epoch old; it has been marked by strong conflict since its start-up. Historically we have watched the process in Europe, more recently in North America, South America, Asia, and still more recently in Africa. We would be foolish to decide that our polity, the USA is indefinitely immune to political-military rearrangement. Yet like practically all elites and elite-oriented people (most of our citizenry, including ourselves, are still oriented toward our organized form of polity, but it must be admitted that we hang on by the skin of our teeth), we favor the centrist stability of our own form. Is it self-regulatory, viable; must it be shored up to survive; is it on a path toward self-destruction? These are the ultimate questions that are tied to the question of our population laws,

$$P = \rho A$$

$$P_a = \rho_a A$$

$$\frac{dP}{dt} = \{b - b_o\} P$$

$$A = ?$$

The conduct of a lifestyle at any age, but in particular at middle age, to maintain a long life requires careful design of operational modalities. We cannot maintain a large useless rootless population; we cannot maintain a large parasite population: it is both the nonproductive idle rich and the idle poor that are detriments.

And yet what we can and must support depends on how we manipulate and use our molecularities, namely, our urban settlements. So the story of a polity is always tied to its cultural start-up, its resources, its ecological experience, its technology, the role it plays in the ecumene, but internally it is tied up to how it manipulates its urban population excess.

It is very probable that in middle age, a very regular program of internal maintenance and repair is desirable with a minimum of external adventure. At least that is the premise that we will adopt. Our science suggests that we are at the age at which there is some choice possible of a more or less precipitous approach to old age. In indicating the parametric form of our social laws of motion, we adopt the premises that fit those possible trajectories. Too great a dissonance with regard to that outlook simply indicates that we are further along toward decline than sweet reason would have us believe.

One need only recall Dudley's (The Romans) question: "Could the late Roman Empire past Constantine, 337 A.D., have saved itself?" A lack of coherent policy in the polity, when it reaches a critical stage, will not help its further existence (a reminder to our extreme ideologues).

So the dynamic phase with which we must concern outselves (in population) is, given a decelerating population, a decelerating growth in urban population, a diffusion toward suburban life with increased cost of services, a declining availability of internal nonrenewable natural resources, what polity can influence our most benign survivorship? As far as territorial-bound potentials are concerned, now must we look forward to some modest relaxations of of the former processes? Certainly, as is clear in (11), there is a shift in population density distribution in progress.

The trouble with the growth process, differing from the decay process, is that elites find good self-serving reasons for attracting and bringing in a large urban population. But when the initial wave has passed and a middle life process in which a population growth still is useful has also passed, when the growth continues and there is not sufficient reason to bud off new centers, then some sort of decay process has to take place. But that takes place slowly: a number of generations are involved.[1]

We suddenly (much more suddenly than England) face a welfare state. Mumford's Section 4 in Chapter 8, "Death in the Afternoon" (14) spells out the welfare process that overtook the Roman Empire. It is not a blind repetition of history that we appeal to. It is only that a very related dynamic process is in progress. We have piled up a large not-easily evaporable pool of unemployables in our urban settlements. They will not go away.

Our outlook is not that of a reactionary bent. We do not cynically advocate war, pestilence, cruelty, or indifference to our large welfare population, but we also do not advocate passive compliance. We have a population that is getting older in its relative distribution; we maintain - through health care - an increasing population served by more expensive medical care. The

[1]As an appropriate introduction to later sections, a recent article in Science (26) presents an economist's view of some relations governing city size.

problem we face in the USA is: do we move toward the older Paleolithic path of being indifferent to and encouraging the death of the less fit, or do we explore paths toward a system where socially useful and supportive roles are found for all?

In modern thermostatics, it is said that the path evolves toward that which requires the minimum irreversible production of entropy. Thus the rate at which our population diminishes, how its age-specific characteristics change, how the population distribution among our urban settlements changes, will depend on the interaction with the other potential and flux processes. More specifically, it is the balancing perceptions of our emergent elites who will decide what form our overall internal-external economic-military process patterning will take, and thus the form of our future society. The social game does not thereby become idealistic-vitalistic. It is this polity's culture in this ecumene that casts up elites and their outlook. Their decision making should be determinable from the current state vector, and thus the war-to-war one-generation and the near-equilibrium three-generation processes should be estimable. Our remarks have been intended to delimit the kinematic space-time cone of the future.

4.4 TECHNOLOGICAL EVOLUTION - THE ELITES CHOOSE

The elite exists from the surplus it can accrue. That notion implies value-in-trade. That notion also implies abstraction. Thus what is being exchanged no longer has a one-to-one correspondence to other "real" thermodynamic variables. Somehow the elite can produce, cheaply (namely, at little cost in scarce resource materials or energies), substance or pattern that he can trade on what is otherwise unequal. Both sides are satisfied in the trade, but there is an inequality in number, material, or energetic resources. Thus a flow of such goods takes place to the elite. It can then enter into more normal exchanges of goods with that surplus. Childe (19), for example, indicates how the nearly "magical" skill of the metallurgist, in providing copper tools, was a significant item in breaking up the self-sufficiency of the Neolithic village.

Thus it has long been so, that "magical" competence - artisan skills, magico-religious invocation of natural favor, leadership skills, perceptions of such new "magic" - has furnished a basic for elite advantage. Some vague notion of the human process that provides such advantaged segregation is furnished by Rashevsky (29).

If there are positive definite choice preferences (e.g., eat rather than not to eat; to be entrained with sensory-exciting novelty, rather than tiresome motor routine), there is a modal motion toward those preferences. However, if there are neutral choices, and it is possible to entrain a definite imitative preference on one side, then that "potential" can serve as a source to drive a positive flux toward the entrainer. The essence of the matter is that the neutrality of the market place - the symmetry of outlook of the buyer and seller - is not the case. Both the real thermodynamic needs and the needs imagined in the mind - those which can be epigenetically created and endowed with value, as an intensive variable - can be translated into extensive variables of value-in-trade.

So with this introduction, we can look out at American vistas as the elite might see them. In our view, they would see no loss in future opportunity. Compare the current view with a view of 70 years ago. Elites then could see primary industrialization as being still the major goal (as compared, say, to 70 years earlier, where equality of production with world markets was a more primary goal. That goal led to American mechanization and American technical ingenuity). A well-fed prosperous farm community was ready for exploitation. One could only build and industrialize. Thus the age of the large corporation began.

Today a large corporate structure exists. They are four-tier-oriented in their relation to the large world market. First, there is still the spread of industrialization that they see; second, it is the spread of a consumer goods market that they see; third, there is the hardly tapped service market that they see; and fourth, it is the finance market itself as a basis for control that they see. The tightening of the noose of a growing scarcity

of nonrenewable resources is not seen by them as an impenetrable barrier, but as one more opportunity that can itself be explored and made use of in decision-making options. As a whole, this represents a view in which the entire earth's ecology is an interlocked system of coupled subsystems.[1] A so-called systems management science and management-specialist class has been developed to serve the elite.

Some have seen that management science as portent of a new social revolution, and in fact, one segment of a post-industrial revolution, (e.g., Galbraith, Bell, Drucker). We incline to believe (with Lundberg) that no particularly new process has developed. The current management form is one more layer of specialization, a "new" form of molecularity, one more overseer function that elites have encouraged to simplify the task of running the more complexly interacting social systems. The magico-religious schema has moved from forecast by the patterns of sheep's entrails to the geometric-arithmetic threads of mathematical modelling. But these "objective" bureaucratic institutionalized results do not essentially change the outlook of elites who concern themselves only with the manipulation of power for their own purposes. This management layer, with an increased abstractional capability, simply makes the decision process more impersonal, more insulated. Witness the fact that the same religious ardor for the process exists in the ideological extremes of the USA and the USSR, with little less drive in the other smaller industrial polities.

The point to this discussion is that the elite have adopted a new form of atomism that again crowds the form of the molecularity. Instead of the more nearly "horizontal" economic bonding group, society has become more organized by the corporate structure and corporate field. Giant "informational macromolecules"

[1]Some flavor of future trends can be garnered from (30).

are beginning to emerge. These are known, loosely, as total delivery systems. They now are approximately identified within:

a. Automotive and stationary power systems

b. Utility supply

c. Food production

d. Plant and building construction

e. Utility construction

f. Primary materials

g. Distribution

h. Fiscal management.

If, 70 years ago, these elements - all components of the technological potential which is used to link the essential thermodynamic variables - were either nonexistent, functionally supplied by individual initiative, or the basis for some local small business unit in a community, that state of affairs is no longer true. Major monopolizing corporations have taken over many, if not most of these links. Their outlook is toward national and transnational markets. As small business competitors, we no longer find it possible to compete with the giants. The problem is not the lack of ideas, of skills in individual elements of business. It is the total problem of being swamped in the market place.

We were cognizant of a similar problem with regard to the small "grocery" store family business just prior to and after World War II. It seemed clear that the large distributor (e.g., A & P, etc.) would sweep over them, but the process did not take a day. It took a generation and it stimulated the formation of a particular form of response - the supermarket - where almost a generation of competition gradually shook down the giants.

In the same way, the issue is not which particular year or decade or which particular form of small business will fold, but that, give or take a generation or two, the further primacy of large-scale corporations will be established. Now clearly their

status transcends local settlements. There is still a conflict in status with national polities. The ability of such corporations as Lockheed to manipulate the American Congress as well as many other national political leaderships seems hardly abated, regardless of how "scandalous" the process is regarded by the press.

It seems clear that a conflict between multinational or transnational corporation and polity is in the offing. Nationalism, ethnicity, various perceptions by which otherwise rootless people might bond together in their domestication, are still basic factors.[1]

Assuming that money and organizational skills of the elite will flow wherever international markets suggest there is a spot for exploitation, does this mean that the people are just casually pushed around as cattle? No. The history of the past 70 years has shown the form of big unionization to provide a counterthrust to big business.

And there still remains a number of other counterthrusts. The Soviet Union and China present other ideologies, so that the large corporation has to both confront its "parent" polity as well as that of foreign antagonists' or adversaries' polity.

At the present, the unsettled issue is the availability of sufficient manpower and machine power to the large corporation to provide it with military equality with the polity. Scenarios of development of new political form are sufficiently easy. We still await the specific historical form that may occur.

Historically, we have seen the following: excesses of the robber baron organizing state of American corporations led to organized

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[1] To illustrate what we would hope is an extreme form of that outlook toward people as a domesticated species, we would refer the reader to (31). We can lick inflation at a "natural" rate of unemployment of 6 percent, the author says, without much hardship. Couple such notions with an additional sign of the times, wherein women in the labor force now exceed 40 percent, and one can draw some conclusions as to transformations that may be involved in human social life in the future, in particular in the USA.

labor. That organization was partly riddled by big business by calling upon a penetration by organized crime. On the other hand, Communist ideology attempted penetrations of the unions with limited success, and even less success into the political organization of the polity. But organized crime has very successfully taken over a large degree of control of urban settlements.

These are all facts, erring at most in the precise degree of control that might be inferred from these statements. Is this the view of the future? Not necessarily, or rather, not exactly. The corporation has gained a great deal of organizational experience. Even the Communists have learned a great deal. The manipulation of the mass media is much more highly knowledgeable. The symbiosis between big business and labor, and big government is more highly perfected. High-speed mobility (only two generations old) has come into its own. The concentration of nuclear-powered warfare is only a generation old. On all of these scores, plus the new challenge of resource scarcity, the future organizational status the new challenge of resource scarcity, the future organizational status of society is a different ball game from the old, in a social context.

Thus, now, in examining the potentials associated with human action on the earth, it is not only an abstract linear rope of technological evolution that is to be faced, but one must examine the national and transnational status of these potentials and imagine their future diffusion and propagation on the basis of how both the conflicting outlooks of polity and transnational corporation examine the future opportunities. The social organization on the face of the earth is no longer to be confined to the conflict between polity systems externally and polity and urban settlements internally. A new precipitated form, the transnational corporation, must be specified. How they manipulate technology will be the main thrust in the future.[1]

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[1]The remarks of a reviewer of Science (32) are quite relevant to these problems. While the specific issue is the interaction of culture and information processing, the thoughtful reader will face the dilemma with regard to all technological advances. Yet the kind of analyses of both the book reviewer and the reviewer can not deal with the problems they raise.

Recall that it is the components of the thermostatic state, of the equation of state, that we are attempting to define. The elites create a second pool, a condensed highly energetic phase (a new liquid phase if you will). In a large field with materials, resources, and technology, they are highly competent to put the system into complex motion. One need only read the news taking place in the polity any time during the past 9000 years to sense that.

All this is not necessarily much different from any similar lower ordered physical process, including the not yet fully explained evolutionary process. But one still may question why is there so rapid a change in social form. It would be foolhardy for us to deny that the pace of historical change has been rapid. To illustrate: written language 250 generations ago, empire 200, feudalism prior to 150 generations ago, enlightenment 125, world empire 100, dissolution 80, reawakening - cultural quickening and polity - 50, mercantile explosion 25, mechanistic explosion 15, transnational explosion 1 (?). To the engineer, these large-scale changes at a scale of perhaps 20 generations, 20 relaxation oscillations, is a rather fantastic change. He could only conclude that the system was highly unstable.

The physicist, perhaps, could furnish a better example. The pinwheel of the galaxy turns slowly. It is amazing how many star lives are spent in one such revolution. What this illustrates is that if the field material is rather rich in low-energy differentiated materials, processes, and states, and there are no impediments to mobility, the local field is "unstable," and sweeps through many historical-evolutionary states. One hardly can take them seriously (except when they are your size).

So human history, past the abstractions of speech, and the last glacial era, has still not fully stabilized. The drive resulting from value-in-trade is a fantastic unstabilizer of social forms. We can perhaps epitomize one basic characteristic, which might apparently seem related to the more modern view of the free market, but likely was relevant from the post-Neolithic start-up of New Obsidian (17).

One may note that he who calls for a free market place is one who has an advantage there, whereas one who calls for some regulation (e.g., us) has a disadvantage. The underlying notion behind this dysymmetry of outlook must be factored into our descriptions, mathematical or otherwise.

Let us illustrate some of the possible formal statements of the issue. If one buys a car, it "immediately" has diminished in value by the order of $500. This value-in-exchange is not symmetric between traders in the market, or perhaps otherwise put, value-in-the-mind and value-in-trade are not equivalent. There is a thrust that pushes one side of the exchange (the demander) into the market place whether he wills it or not. The elite provides the counterthrust that creates the momentum pressure that fills up the market. But a one-sided incremental gain partitions the value-in-exchange in favor of the elite.

That process is at the underlying "nuclear" level. We are not concerned with morality but physical consequence. Somehow that act, individually achieved in the person market place, integrates through all levels and drives the higher levels of order into much larger form, much larger space instability.

Apparently social forms continue to develop and evolve in an attempt to find forms in which an equality of exchange can take place. But each new form that evolves seems to require a number of generations to explore its consequences (e.g., 5-10 generations), namely, humans tend to act as followers of what they have seen, rather than as originators each generation. The epigenetic storage of memory in the brain creates an effective inertia in human social processes. Then, given a social continuum and the time scale (3 generations) for relaxation to near-continuum conditions, it is possible for the elite at the 10-generation level to visualize and begin a new vortex or phase condensation. Vortical wave follows vortical wave until it seems necessary for a new phase condensation to take place.

Thus city-states as polities were ultimately replaced by nations. The transnational corporation is easily the settlement's

equal and is vying for equality with nations. The conflict in momentum space is - at this moment - perched there. Social pressure is thereby in process of undergoing a redefinition.

4.5 SOCIAL ACTION - THE MODES OF SOCIETY

One senses, from the descriptions we have provided, that population aggregation and clumping and diffusion on the earth's surface within a large polity are driven by the first- and second-order delay processes initiated by elites and their interactions. Thus the slow motions of land-referenced potentials follow these elite actions. However, the problem we have to resolve is the level of aggregation at which society currently works.

Some physics behind the problem is in order. It deals with the issue of historicity and evolution and thermodynamics and perhaps parts of the issue of what stands in the way of a reductionist science for all systems' phenomena, in this case social phenomena.

Because of the questions raised in these projects, we are also involved separately (e.g., Iberall, Soodak) in a physical foundation for systems. One basic physical notion is that an ensemble of like active atomisms, at sufficiently free space and time scale, will act as a continuum subject to a specific form of physical law, that is called irreversible thermodynamic.

One apparent objection is that if one knew the laws of physics that governed the motion of these atomisms (e.g., Newton's law of motion), one could then prove the theorem.

Now in the case that the atomisms equipartitioned their energy into internal degrees of freedom, and obeyed laws of motion, the proof is easy. But what if the system is a group of cells, or humans, how can the same kinds of demonstrations have any merit? The answer is roughly as follows. At the lowest level of reductionism (33), it is not asserted that the actual motions contradict the laws of physical motion of bodies. The difficulty seems to be in the internal motions. If I kick you, you may kick me back.

Namely, what seems to be characteristic of living systems is a stimulus-response character.

But this doesn't differ from physical force. At the most primitive level, a force "causes" acceleration. But then Newton showed how forces aggregate in rigid body motion; Hooke enunciated elastic body forces; Stokes enunciated viscous drag force; Maxwell enunciated the consequence of elastic force dynamics and electromagnetic force as another field force. Thus the "pecularities" of stimulus-response may be specialized in life systems, but their internalized nature as forces is not new.

The essence of the matter is as follows: if form is preserved (an essential requirement) as well as activity and interchangeability, then the measure of internal activity is the bulk viscosity. The bulk viscosity become a measure of all internal cyclic processes - cyclic so that form is preserved. The important thing to note is that the gateway to the internal processes still has to remain the translational degrees of freedom. Namely, mass, energy, momentum, and change must enter through translational momentum.

Now the laws of translational momentum, never violating the law of physics, "ultimately" (although there are lossy thermodynamic collisions to conserve physical determinism) must therefore be compatible with those laws of motion. Thus the motions one finds are "collisions," with mean free paths and relaxation times, a stationary distribution of such collision processes, and diffusion as a consequence. The translational measure is a shear viscosity.

The fact that ultimately the internal cycles, regardless of how slow, have to be commensurate with or nearly commensurate with the translational cycles, states that the ratio of bulk to shear viscosity, the ratio of respective action internal and translational, must be essentially a constant, regardless of how large. Then a continuum thermodynamics will hold at the bulk viscosity time scale, e.g., 1-3 generations for humans.

How is this condition violated? We will provide an example. What is the chemical thermodynamics to be associated with a newly spread paint layer (or asphaltic road composition)? When freshly

laid, the bulk viscosity is relatively low. As the paint ages, it hardens, becomes brittle, and some materials crystallize or flake. The bulk viscosity approaches infinity. Does this vitiate the ability to write a chemical thermodynamics? No, it certainly changes it. First the process, being aperiodic, has to be treated by a kinetics. Generally we are not far removed from equilibrium, so that we only have to moderately open the equations of description. Aging and evolution have to be included.

To illustrate the complexity, one stage further, imagine describing geochemical processes. Our scale becomes geologic. Our problem is that we can describe history piecewise for epochs until a number of competitive branching processes of comparable energetic arise. Then we have to do some aspect of stability or catastrope theory to estimate which single or conglomerate of branchings will take place. This is the current character facing us in human social history. Once the city-state was the polity. It was swept over by the nation-empire.

A number of centuries ago, the legally incorporated corporation - legally "equal" to a person - was invented. Less than 50 years ago, it had the force and strength of a bonding group. And in fact, in many ways, most Americans have gradually swung into a dual cognition and loyalty - of their corporation form (whatever, industry, government, or academic) and their trade of guild form. The transition took place in one generation, 1930-1950, measurable by the confused fight between vertical and horizontal unionism (in the circles we were involved with) and in comparable transition in industry starting from the Ford interchangeable mass-production line (1918).

But in a rapid one- to two-generation shift, the corporation quickly developed the power of the urban settlement (a major corporation can control almost any city). And it has even more quickly moved into equal power to most polities. So the social bulk viscosity is changing. We must comprehend that our thermodynamics has to be done as one-generation kinetics. In each generation, there is a social aging and evolution of its structure.

This must serve as an introduction to examining the modes of society. The presence and existence of developing world shortages, the contrast between the have and have-not nations do not lessen the opportunities for elite corporations. It heightens it.

In order that the physics of future social processes be comprehensible (an issue which is not different in the past or present, but now being highlighted for the future), the investigator must be conscious of the nuclear pool of domesticable human beings and its characteristics. Because of the abstractionist competence of the human brain which makes it so easily entrained through sensory channels, particularly arising via interpersonal exchange, the human has always been easily swept into social whirlwinds. As illustrations: the past - the Romans had little difficulty overpowering the Celts. As soon as the Romans comprehended the ethnological style of the Celts there was little difficulty in defeating them, whenever the Romans chose to. Whereas the Romans had a much more difficult problem with the Germanic tribes. In the present - can one seriously say that religious fratricide among the Irish makes sense today? Or that those tens of thousands of American youth can be swept into the incomprehensible crusade of Reverend Moon?

An interesting commentary on hypnosis, and the underlying notion of human suggestibility is given in (34).

Even more pernicious than individual is mass hypnosis (as far as human "freedom" is concerned). Will the investigator sense the power of modern high speed visual-audio "communications," in which any elite power group, in proportion to its manpower potential or value-in-trade power potential, has access to these communications channels, and the audiences are measured in the millions and tens of millions? It was instructive to watch the communists in the 1920's and then the Nazi's in the 1930's begin to develop the modern art of agit-prop. While we in the USA prided ourselves as being the center (if not <u>the</u> center) for individual liberty and freedom for independent thought, speech, and action, can this thesis be maintained with the power of current TV advertising and

and the capture of an average viewing time approaching 6 hours per day? The press sources mightily defend a freedom of press, but one should note that it is a freedom for their potent corporate organizations. It is not the freedom of the individual to have access to their channels. And all of these subtle changes have only taken place in the past decade or so.

Our concern is not to attack or defend institutional forms, only to note their evolutionary emergence and history. Elites arise from the nuclear level, they see a way to entrain into existing atomistic and molecular levels, and these institutional forms play their role out. These institutional forms call up counter-institutional forms. An epoch ends when these forms have nearly played out. New epochs start when elites find means to create or take little-known institutional forms and bring them to dominance. The issue remains, over and over again, whether the process avenues - energy, materials, population, technology, value-in-trade - will permit the new emergent process to take over.

The nation as dominant polity became the systems form perhaps 500 years ago. It was 500 years in conception from the time of Charlemagne. The world ecumene began its process of closing perhaps 500 years ago, although (western) historians regard the period as the rise of the west, the age of world exploration. While world empires have formed and been overturned, during this entire latter period no one polity could form a total world empire. It has been impossible to control all of the process avenues with sufficient coherence. Instead, some other group of polities could mount effective force. Thus the historical notion of balance of power became the historian's and politician's major strategic descriptive element and operational tool. But as far as the national polity is concerned, as is currently evident in the U.N., the national polity has been reduced to an absurdity. The world has its real estate partitioned into too many small pieces that have no future viability. Thus nations, or at least fixed patterns of nations, have no stability. The status of national condensation, coalition, revolution, upheaval, counterrevolution has been achieved. We have reached the stage of a dynamic near-equilibrium among such upheavals and their countermovements.

At the other end, the individual today, as in some past periods, has a complete feeling of isolation from his ruling polity. The individual senses that he cannot control his destiny. He has yet to explore all of the countermovements of this epoch.

Our concern is to offer a convincing theory of social molecularities above the atomistic bonding group. Our major thesis is that the bonding group was thermodynamically stable, "economically" viable (economic because it could have all of its required scarce resources) for all of man's history. But higher organization began then, post-Neolithically, with value-in-trade.

Our second thesis (now emerging fully) is the structure above that level is not fully stable. True that it takes the form of real estate, of dense concentrations of people. But the form is not clear.

It has finally dawned on us that in a physical sense the bulk viscosity problem which is represented by that form is very much the same problem represented by the living system (35). The bulk viscosity may be associated either with energy-delayed fluctuations (associated with temperature) or volume-delayed fluctuation. These are the two components of internal delays associated with momentum because of the equation of state of simple atomisms. In complex systems, it is not the energy fluctuations which count but the volume fluctuations. It has occurred to us that both life and society begin at this level. Namely, they begin at the level of associated "liquids," really "liquid-plastic" structures.

Life forms, having had billions of years to play out their role, have approached near equilibrium. Most of the fluctuation forms that could emerge have emerged. Certainly there is a continuing evolution, but note that it hardly takes place at the kingdom level. Mostly we see very small shifts in phyla, basically small shifts at the species level.

Social organization has simply not had any time to complete all of its evolution. That evolution for this species is finished in perhaps 10,000-15,000 years. Thus our story is halfway through;

we can still expect many changes, even if the ancient themes do not change their form.

So as a third thesis, we see new social forms that envelop the bonding group. We see these being developed by elites to satisfy their desires. However we see counterstructural organizations emerge by which the populace tends to keep its position up with the elite. Thus blob is followed by counterblob. The problem is not to visualize the thrust for a blob or counterblob. That seems easy, based on man's neurological-ethological characteristics. The difficult problem is which of equally plausible alternates and when will the first response take place. It is some such precision that would be required to make a believer of the historian, say.

Thus if we drop back just 1000 years, we can note the following changes taking place in the hierarchical ordering above bonding groups. We have concentrated on a European-western half of the history of the Roman Empire.

Growth of towns
Feudal manor system - ecclesiastic organization
Mercantile revolution (guilds)
National organization
International conflict (technology, war, exploration)
Colonial empire
People's revolution:
British revolution - American revolution - French resolution
Property counterrevolution - corporate system
Unionization
Social revolution:
Socialist - communist - social democrat
International colonial conflict
State capitalism counterrevolution
Transnational corporations
National revolutions
Have-not revolutions: ethnic - national
Agricultural counterrevolution .

We believe that a little more detail on the transition of social forms, particularly as it affects urban centers, is in order. We have drawn our material from Pirenne (37), which fills out the story of the development of urban centers in the west better than (8, 9, 13, 14, 17). It starts from a period 1000 years ago, what we would identify as the period which provides us with an archaic view of our civilization. Our intent is not to fill out a detailed story of history, but to provide a time frame for significant shifts in elite patterns of governance and dominance.

300 A.D. - The dominant Roman Empire, essentially a Mediterranean commonwealth. (The Empire had already peaked, particularly in the west. But a considerable trade continued, particularly maritime. Inland trade had become apathetic. The eastern part far surpassed the west, in both civilization and economic development. By this time there were no longer any really great cities except in the east. Trade was centered in Syria and Asia Minor. The Syrians were the traders and their ships the carriers.)

(Note the regional box. To the far west the Atlantic was unconquered because of sailing technology. To the north, the Celts, the Scandinavians, and other Germanic tribes were warlike enough, and hardy enough, and the ecology unproductive enough to prevent any permanent victory over their early post-Neolithic way of life. The Celts, most completely, were pushed to the northwest. To the south, the African deserts and tropical jungles prevented penetration beyond the coastline regions. To the east, the Mongols ruled the steppes and posed a potential threat to the Greco-Roman era for the entire 1000 years earlier.)

300-450 A.D. - The Northern challenge occurs. Germanic tribes - Goths, Vandals, Franks, loosely pressured by the eastern Mongols - move in on the Romans. The western half of the Empire begins its transition. They exhaust the Romans and transform western provinces into Germanic kingdoms. Inland cities and trade in the west diminish.

(It has been only a matter of time before unconquered outlanders - "barbarians" as far as civilized Empire was concerned - would make a countermove to grasp the "goodies" of civilization. The only issue is precisely when and where. Obviously, in some important sense the defender would have to be declining and the attacker rising. And that process is measured in some handful of generations.)

450-650 A.D. - In particular (among Germanic tribes), the Franks moved down to the Mediterranean. Their aim was not to destroy the Roman Empire but to occupy and enjoy it. But this forced the political orbit of Rome to the east, and destroyed the religious aspect of its ecumene in which its border defined both the political and religious frontiers, at this time, of Christianity.

The arrival of these Germanic tribes did not put an end to trade and urban life in the west. Instead, most towns survived the invasions. However, it increased the importance of Mediterranean transportation and commerce as the Romans fought back (500-550) to maintain the west. The Church survived the invasions, and in fact contributed very largely to safeguarding the continued existence of Roman cities.

The Church had patterned religious districts on administrative districts of the Empire. Each diocese corresponded to a civitas. From 550 on, civitas took on the meaning of "episcopal city," the center of the diocese. (One sees how the spatial form of the population network continues beyond political change.) These cities were centers of economic activity surviving the preceding civilization. Of course, the state of development was basically in proportion to its nearness to the Mediterranean.

All this commercial activity continued after the disappearance of the Empire, and depended on the continuation of Mediterranean trade. It likely did not change much from 400 to 700. But it had changed its character from an east-west Roman trade to a Merovingian-Byzantine trade, on the Mediterranean, a trade from Spain and

Gaul to Syria and Asia Minor carried on largely by Syrians. At the same time there existed indigenous merchants.

The commerce of Merovingian Gual also extended to the other Germanic kingdoms of the Mediterranean - Ostrogoths of Italy, Vandals of Africa, Visigoths of Spain. But the great inland sea no longer belonged to a single state. The west remained dominated by the Mediterranean (as it would again in the 15th and 16th centuries). "At the beginning of the 7th century, anyone who sought to look into the future would have been unable to discern any reason for not believing in the continuance of the old tradition." (37)

650-730 A.D. - The protracted wars that the eastern Romans (the Byzantine Empire) fought with the Persians and the Balkan barbarians (who had been fed by the second pincer half of the Mongol invations[1]) weakened them to where the sudden eruption of Islam took over the Mediterranean and chunks of the Byzantine Empire (Syria, Africa, Egypt, half of Spain). The Mediterranean became a Moslem lake. Trade to the west was dead. For the first time since the Celts, western Europe had to live by its own resources. The Roman towns declined.

650-750 A.D. - With the European west severed from eastern civilization, the minor Frankish Empire was to become the arbiter of Europe's destiny. The rise of the Amulfings (580-770), later legitimatized as the Carolingians (770-1000), and their defeat of Saracenic Islam (Charles Martel - 730) causally connected the Carolingian Empire (from Charlemagne - 800) to the foundations of Europe of the Middle Ages.

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[1]As McNeill (38) points out, "The sudden irruption of the Huns into Europe was immediately preceded by a not dissimilar irruption of the Ephthalites (the Turko-Mongols) into the eastern marches of the Sassanid (Persian) state ...371 A.D. ... The remarkable chronological coincidence suggests that displacements of people within the central steppe...pushed both Huns and Ephthalites from their accustomed pasture lands." Also see Grousset, The Empire of the Steppes.

750-1000 A.D. - We turn to the Carolingian Empire. It was important to protect the Mediterranean coast from Saracen raiders. It was important to oppose the invasions of the Norsemen in the north and west. Thus no extensive long-distance commerce existed. Yet Jews managed to conduct some itinerant internal trade via the river pathways - in the cloths of Flanders, wines of Rhenish Germany, even spices from Spain, salt, and slaves. But it was a reduced commerce, not worthy of the name of an economy of exchange. Instead, there were small local market places, instituted for weekly provisioning of food from the country.

Charlemagne did not reinstitute a political economy. He unified an empire for competence to conduct wars. For that he also formed alliance with the Church. His lack of economic planning is made clear by how he got his resources. They were by tribute and as booty, not from taxes on a market place or market transport. Instead of recruiting functionaries who would administer an economy, he selected and created an aristocracy. This led to the dissolution of his empire.

This contradictory notion provided the embryo for the feudal system, instead of the system of the Byzantine Empire, or the Islamic Caliphate of tax collection, a treasury, tax-maintained public works, and army and navy. Instead, the economic base of the state and of society was the landed proprietor: an inland static agricultural state.

As a remnant from the last days of the western Roman Empire, more and more land became hereditary, and the old free farmer became bound to the soil. Further, the bond between the Church and king hastened the same process. Thus a considerable continuity in the organization of ecclesiastic and lay demenses existed from Roman Gaul to Frankish Gaul. All lands - cultivated, woods, heaths, and waste lands - fell into ownership. The Germanic tribes had no motive for changing the organization. Land fell into the hands of the proprietor, and under deeds of tenure to the peasants.

But after the Merovingian era, when trade, the merchant class, and the municipal population nearly disappeared, the great land estates fell into the same trouble as the Frankish Empire. Their markets disappeared. The economy became one of consumption, rather than one of trade. The ninth century became a closed domestic economy, an economy of no markets.

As Pirenne points out, this was not a natural phenomena, but a result of the historical evolutionary changes that had taken place. Great proprietors did not give up selling because they did not want to sell, but because they could not sell: there were no markets.

It is interesting to note that at this time, say 800-1000, the Russians (as a broad strip along the eastern edge of Europe) began an extensive south trade, trading both with Byzantium and Islam. The trade originated in Kiev and went south.

This lasted until about 1000 when the Pechenegs - barbarians along the Caspian and Black Seas - brought an end to the trade. Obolensky points out (39), every few centuries a bewildering procession of tribes swept out of the steppes and put considerable pressure on Europe, as a northern, central and southern pincer - Cimmerians (starting in ancient Greece 800 B.C.), Scythians, Sarmatians, Goths, Huns, Avars, Bulgars, Khazars, Magyars, Pechenegs, Cumans, and Tartars (until the 15th century). Thus the contrast: Islam shuts off European trade; Russian trade persists as long as routes to Constantinople and Baghdad remain open.

With the disappearance of European trade in the 9th century and the last vestige of a city life and a municiple population, the influence of the bishops became supreme in the matter of a different kind of town. Instead of the Roman-Merovingian town, the bishop maintained a municipal system. This was not based on trade, but on the ecclesiastic organization. The town was the bishop's residence. Each diocese was the territory around the city which contained its cathedral, and the civitas (about 800) became the bishopric and the episcopal city. Its inhabitants depended more or less directly upon the Church. It consisted of

clerics, monks, teachers and students of the Church schools, and of servitors and artisans. Generally, a weekly market was held where the neighboring peasants brought their produce. At the gates, a market toll was levied. There were storehouses where the harvest from the demesne was brought in by the tenant-farmers. The lay court was conducted by the castallan or advocate, vassals of the bishop. This system did not share the municipal spirit which became part of the communal movement of the 11th and 12th centuries.

The evolution of these towns - as fortresses as well as episcopal residences, with suburbs beyond the wall, as real defense centers against attackers, both local and foreign - began from about 800. Technically, they were burgs. Above all, they were military establishments, not urban settlements. They were not cities in a social, economic or legal sense.

The Carolingian empire reached its watershed at the beginning of the 9th century. The Frankish kings had succeeded in superseding the Roman empire. Their battles now were with Saracen pirates in the Mediterranean, Vikings to the north, Danes and Slavs, the Caliphate, Byzantium, the Church, and the Lombards. The Carolingian Empire falls, but in its place a political Europe was born.

But the invasions - of Vikings, Danes, Slavs, Magyars - obliterated a free peasantry, and created the feudal system, wherein protection provided by a noble was trade for personal freedom.

The 10th century, while not an age of economic recovery, was an era of relative peace. It was also a period in which local governments were reorganized.

1000-1100 A.D. - This century begins an awakening. The area in culitvated land had not increased perceptibly. But an increase in population permitted a reclamation of woods, heaths, and marshes to usable land. The great forests of Europe began to be cleared (the great clearing took place in the 13th century). "It is easy to see that the increase in population and the burst of

renewed general activity of which it was both cause and effect, (unfortunately, no dynamic connectivity is offered) operated from the very first to the benefit of an agricultural economy." (37) (Note: it is unfortunate that internal dynamic processes, as opposed to external events, are not well studied by historians. One is left only with hypotheses. Through the 9th century, the horse was not a working animal, but a war animal. The development of the iron shoe was an important innovation. From the 9th to 12th centuries, farmers began to develop oats, an important crop to feed horses. Beginning in the 9th to 10th centuries, the horse, mule, and donkey became more important in the agricultural work picture. Milk cattle were beginning to be bred in some regions. The ox, of course, was the chief work animal. Was it in fact a successful manorial system, in which the lord or his administrators encouraged better feeding of his peasant serfs, and their technological creativity to innovate which increased production, and encouraged increase of population? Reynolds (40) points out that with an increase in production as manors came to flourish, there was a steady increase in the wealth and population of those parts of Europe where the manorial system had first established itself; that by the 11th and 12 centuries there was a larger population density in northwestern Europe than elsewhere in Europe. This kind of encouragement of population, first detected here, in which the living standards went from very low to less low, was also likely the process by which the new factory owner of the 18th century encouraged the fantastic explosion of population that we still face today.)

A commercial revival begins in the 11th century. Who were the tradesmen? Likely they were long-distance peddlers from Venice. Venice had been founded in the 5th and 6th centuries by refugees from the Huns, Goths, and Lombards. At that time all Italy was part of the Byzantine Empire. Venice remained so. Thus she developed and maintained trade in the orbit of Constantinople, which even in the 11th century was the greatest city of the Mediterranean (the eastern Empire center to 1453.)

In the 10th and 11th centuries, part of Venice had become extremely wealthy with trade (she also inspired Lombardy to such commercial life), not only with Byzantium but also Islam. Venice was a major naval power.

With the arrival of the Normans, and the Crusades against Islam, the sea empire of Islam came to an end (not the land empire). And so by 1100, the maritime commerce reached out to the shores of France and Spain. The old ports were revived. Soon routes were opened over the Alps, and via the rivers. By 1100, Italian merchants are found in Paris and on the Flemish coast.

An important element in that northern story was that, beginning in the 10th century, the Scandinavians turned from raiding to trade. They began to take on the character of the seamen of the north, as the Italians became the seamen of the south. Flanders became the western focus for sea commerce.

1100-1200 A.D. - In this century, western Europe was transformed. No longer a consumption comunity, it developed into a commercial community.

Under the influence of trade, the old Roman cities were reborn and repopulated, around the military burgs, the seacoasts, river banks and confluences at communications junctions. Each became a market, attaching its surrounding country. They were located, on the average, one to each 25 square leagues of land. (Apparently approximately 200 square miles. Thus cities were located, on the average, about 15 miles apart.)

We believe that we have taken a sufficient side excursion to learn more about city structures and demonstrate what we believe we have learned. The remainder of the story, of how the long-distance outside trader settled and catalyzed the local town into a municipal organization, organized around the requirements of commerce, are better read in Pirenne (37)[1] and Bloch (16).

[1]Modern modifications of Pirenne's arguments are found in (48).

a. Suffice it to say that what governed the existence of European cities was long-distance trade, dominated by sea (or river) transportation. This same process could be traced along the first civilizations of the Tigris-Euphrates, Egypt, China, and Greece. So Rome and the barbaric aftermath (Hun, Goth, Viking, Frank) that leads to modern Europe - Charlemagne and afterward - just furnishes more examples. And the USA in its history would only furnish an additional example.

Trade is a long-distance exchange that takes place throughout the entire ecumene, regardless of what are its polities.

b. The trade supports the settlements.

c. Trade dries up when outsiders at the periphery of the ecumene sense their have-not status and want part of the action. Likely at the beginning they do not have the power to enforce their role and the elite inside see no reason for sharing their "goodies" or bringing in the "barbarian" peacefully. Thus in time a conflict for spatial dominance takes place. The history of civilized man suggests that the time scale is a few hundred years.

d. In addition to intra-ecumenical wars every generation, perhaps every 10 generations a violent fluctuation takes place and the ecumenical patterning changes from "outside barbarians." These become a new elite. The story does not differ for the north, east, south, or west in temperate climates.

In the case we have traced, Islam's control of the Mediterranean severed trade and led to the decline of European cities, roughly from 650-1100. But the depth and breadth of that "long sleep" was perhaps more basically due to waves of eastern Asiatic nomads, sporadically (each few hundred years) penetrating the European border. In some crude sense that penetration represented a few millennia-long diffusion back to the seacoasts.

All of this is a field process, roughly a field instability process, that - given a knowledge of the boundary facts, ecology, and man's epigenetic memory - should be describable by military considerations involving technology and considerations of human behavior. However, as we know, the bets of war are not made on a

daily or seasonal basis. They await a generation or so of festering and choosing of energetic elites.

Then, as we see, when the tides of trade and settlement and optimistic population growth diminish, and instead the issue simply of internal living returns, there can be a stasis, an age of dispersion to the soil (or to external dispersion). Troubled times can exist. Gradually, strong local elite leaders arise, who can protect. They charge for the service (Stalin, Hitler, Mao charged considerably).

Man's innate skills begin to make the soil productive. The elite leader encourages the human productivity. He ingathers, encourages technology, encourages fecundity. The field is again ripe for broadcast of urban settlements. An internal pressure builds for external trade. For whatever reason, it breaks out and reestablishes a larger-scale trading ecumene. That process too takes a few hundred years.

What we have provided is not an absolute typology, but the fragments of the hydrodynamics of social field instability. They represent process fragments by which momentum or action diffusivity is broadcast over the regions of the earth. Bonding groups and earthbound communities do not disappear, only polities shift their changing borders, as they also rise and fall.

What does this have to do with social action and the action of elites? It is the "independent" action of elites which one may note differs in different parts of the social field and in different phases.

It is not possible to tell such stories in any social age of innocence. They tend to be filled with myth and fable. It is interesting to read some of the history of a theory of elites in a "neutral" political theorist like Mosca (41). We can expect little more attention to our physical model now, but it is part of the advance that man makes in understanding. It has no effect on short-run change, but it affects the long-term course of man's conduct of society.

Elites take turns, in phase, of looking out and of looking in within their polity. They are now in process of looking out, particularly when it becomes difficult to look in.

Thus world trade will be expanded. Elite competition will take place for that. So the best that the administrative aide to the elite can do, either in or out of polity government (and that includes us and our project officers), is to encourage a good internal communications system. Whether our current cities tend to decline or not, a carefully drawn algorithm of development can make a reasonable future for our populace. And this can be true regardless of whether the molecular power passes from settlement to large corporation or multinational corporation. There is no way, within the present millennium, to straighten out the transfer of power by any rational scheme.

As Mosca points out "...obvious... to the most casual eye. In all societies...two classes of people appear - a class that rules and a class that is ruled."

We can summarize the problem of emergent social organization in the following simplified line; while it may even be oversimplified, it will indicate some of the characteristic stability problem of society. The Neolithic agricultural settlement was followed by the trading confederation. The trading confederation provided power for small internal tribal "kingdoms." These encouraged condensation to the first empires. These encouraged stronger local kingdoms that pulled these empires down. These strong local kingdoms crystallized as strong city-states. The city-states confederated and were taken over by a strong city-state. The strong city-state became a "world" empire. Tribal "kingdoms" outside and inside pulled the world empire down. These developed strong commercial city-state, small kingdom, and commercial nation. These encouraged formation of some empires. The corporation began to emerge as an internal organization as competent as the commercial city-state. Nations got stronger and pulled empires down. Supernations came into existence. Nations and global corporations now have comparable power. Underlying the entire history of change is the character of the existing state of technology.

Roughly, this is where we stand now. We deal with a complex of various incomplete stages of molecular organization precipitated onto the world platform. The underlying problem remains one of thermodynamic equilibrium, of finding states of social "matter," social phases in which the aspirations of the elite class and a popular class can be satisfied. Stability issues continue to raise social blob against social counterblob.

The increasing complexity arises from technological advances, the large amount of extensional material which has to be brought into the chain, the large continental and global scale at which the problems are addressed (namely, the fact that it is a world market for goods). The human compartment has basically not changed.

Two humdred years ago, modern machine technology began. It could begin to sustain a global scale for process. At that time only national polity was patient enough to sustain that scale of process. Two hundred years earlier, it was city-states that had strengths comparable to small nations who could sustain the threads of a large-scale commercial revolution. That was based on the technical evolution of ship transportation.

The modern machine technology only comes of age perhaps three generations ago. All that means is that global control of process has fallen on the highly industrialized nations and the large corporations within their bounds. The current crisis among their cities and among the have-not nations are two sides of the same conflict.

Thus formal countermoves will have to take place. We have not resolved the issue. We are simply pointing out that equipollence now exists between small nations, large corporations, large urban settlements. The only organization that stands above them are a few superpowers, and it is no longer clear how they will retain their position.

If one examines recent issues of Fortune (listings of top 500 American corporations in industry, banking and utilities) one senses that some large-scale social power (equivalent to large-scale urban settlement power) exists for industrial corporations

doing over $300 million business and having more than 5,000 employees. As one goes up the scale in size, one senses, for example, as much power in a company with 10,000 or 25,000 employees as settlements with perhaps 100-250 thousand people. Thus, beyond the number of employees and scales, the important issue is how far their markets and their exercise of political power extends.

More specifically, it appears that just as a map of the United States population in 1970 (11) shows about 70 settlement clusters as dominating the organization of activities of people, so about 50-100 major corporation clusters dominate the activity chains of both people and the polity. The top 100 corporations employ about 15 million people. Their immediate families represent about one-third of the population. If we consider their influence about twice as great (i.e., our nominal rule of a tenfold sphere of influence), this conservatively represents a control coloration of one-half to two-thirds of the American population.

To add one more dimensional range to our description, it is useful to note the fields in which corporate power is exhibited. It includes:

Insurance
Banking
Oil supply (for machine power and petrochemicals)
Automotive equipment
Chemicals
Electric power
Other utilities
Communications
Steel
Nonferrous materials
Business machines
Electronics
Food
Rubber
Machinery
Aircraft

Shipping
Containers
Building materials
Household goods
Drugs.

If one were to examine the leading guild structure of Florence in its heyday, one would not find an exact correspondence with these areas of interest. Thus it is not specific extensions that create the elite. Rather it is the existing state of technology. The elite then operate through those social modalities in which they can control power. That may serve as an introduction to the materials compartment.

But, we can first summarize the social actions that might be expected from our elite in the future. If our elite would be willing to expect a modest growth in their wealth and power in the future, then we could see a rational growth toward a more balanced, near-equilibrium economy. We would move toward a conservation of nonrenewable resources. We would move toward a mixed planned society like the Swedish, with a standard of living that could exceed ours now as their does. We could see a more equitempered distribution of income and wealth.[1] We could see a leveling off

[1] We are hardly a social success when, as recently reported, there is found among the urban population 26 million people living below a poverty level of subsistence. There is a very interesting political commentary that should be made. The Washington Post of September 27, 1976 (p. A-1) reports on an "Elites in America" post-Harvard survey on political attitudes among our two major parties. Republican Party workers believe, by a majority ratio of 4 to 1, that poor people are almost always to blame for their poverty; Democratic Party workers, by 5 to 1, believe the opposite. These ideological extremes are not as great among the party members. We are not attempting to emphasize partisan differences, having noted that we expect to find a broad spectrum of ideological belief on almost any issue. But with such a distortion of the difference between the dynamics of an individual atomism and of a bound ensemble from our ideological extremes, it is difficult to be sanguine about what directions our elite are willing to attempt to move use.

and reduction in population. We could see an intensive R&D effort to watch population, consumption level, and production. We could see a rebalance of vested interests. We could see the very careful definition and pursuit of national interests abroad in both trade and defense. In some very important ways this represents a balance of both "the best" of conservative and liberal ideas. As we have found, and as Sweden has shown (among other documents, examine Gallop (36)), work devoted to personal and social ends, and some compassion and empathy for one's own, make a livable community.

But these goals are not enough. Whether it be due to an aggressive selection process, or what, our elite still feel the need of playing out a manifest destiny. They still cannot settle for modest goals. One need only read the monthly profiles of "Businessmen in the News" in Fortune, over any period of time, to detect the character of the managers that the elite select to run their trade establishments. So we are a number of generations away from such a possible phase. Meanwhile, of course, international events can and have intruded themselves to change the course of history. The American elite cannot avoid the challenge that the world markets hold for them. They are the latest version of the Phoenician, Syrian, Venetian, or Viking seamen. But it is our peasant future which is being decided.

Thus it should be noted that we presently recommend describing the internal structure of the polity by two discrete distributions - one, the 70-odd population center distribution (11), and two, the comparable strength major corporations (e.g., on the basis of employees, assigning them a 10-1 strength). The remainder of the population, and the remainder of business activity can both be distributed. Then we can begin to visualize input-output tables for these major corporate entities. The value-in-trade and character of that which is in trade represents the outlet by which elites express their control at existing technological levels.

4.6 THE MATERIAL NEEDS OF SOCIETY

The material needs of society are served by the agricultural and trade needs of the polity at the existing technology and ecology.

Economics has elected to describe this by input-output tables, as far as manufacture is concerned. To summarize the existing state of technology, such input-output tables are not bad. But one must also have an idea of how that table can change in the future. That is a task requiring closure for the system. One must be able to run a total round of relaxation among all the compartments in order to estimate the change in input-output tables. And that closure must be made on the basis of knowledgeable engineering scientific technicians who can forecast the change in technology for the next generation.

It is our suggestion that once the earth potentials in both production and consumption are available for the polity, in particular for the nation by generations as one approaches the present (e.g., 1790, 1830, 1870, 1910, 1930, 1959, 1970), and correlated input-output tables, then a rather knowledgeable estimate can be made for a next period or two (e.g., 1990, 2010). We are suggesting not simple linear extrapolation of materials, but scientific and engineering estimates of what technologies will change and what resulting change in materials will be involved.

In the light of our comments on the changing molecular organization, we surmise requiring aggregation for perhaps 75 population centers and 100 major corporations as well as the more distributed field form (or perhaps distribution only of the deviators from these major centers). Clearly, we have not yet been able to resolve how one integrates both the settlement and the corporate results, since they overlap. But that arises because they are becoming equipollent structures. Perhaps a mixed accounting is required in which centers whose population is dominated by a few large corporations are used as one scorekeeping component, and other centers which are still well-diversified and mixed in corporate structure are another compartment. Then the third component is the residual distributed population, the societal "background noise" of the USA.

At least the population centers have already been identified.

4.7 THE VALUE-IN-TRADE COMPARTMENT

Neither our current support level nor our charge will permit us to go into quantitative detail on the operation of this compartment. Thus our remarks will have to be directed generally at its dynamics. They are subject to revision in the future as greater depth of understanding and detailing is achieved and permitted.

For economic detail, beyond our current capability, one could start from the Wharton School model (or examine the earlier Brookings Institute model) which has received and may receive even a greater amount of national attention in the future. Ecomonic models are equilibrium models, although there is growing emphasis on introducing lag processes in their chains.

Walras, Marshall, then to Keynes and Kuznets, represent a main line of stating and formalizing a system's closure for a macroeconomic model. Wharton models the economy with three accounts - the national income account, a flow-of-funds account, and input-output tables. Leontief developed the input-output tables. The Brookings Institute coupled the national incomes account to input-output tables. A coupling of the third account is in progress.

By virtue of an underlying principle of choice optimality (an optimization principle) on the part of the consumer, Wharton School can provide an economic relaxation computation from any change in input conditions. It is not a dynamic model. It is a relaxation (to equilibrium) model from changing input conditions, or from alternate scenario conditions. It operates by making such estimates by quarter year computation rounds.

But in a causal model, we have to ask whence does causality begin? Clearly, the changes seen in the value-in-trade compartment are changes in investment policy of elites, changes in policy of the government, put and take, e.g., investment or confiscation, from comparable strength agencies. We have indicated that the system as a whole is a circularly causal system. Thus elites are causally urged to their decisions. Are we at an impasse? Not if we have a causal model for what governs elite decisions.

If one is not available, a usual strategy is to invent an operations research policy model, or to invent an optimization principle which has some sense of "explanation." But the novel idea we have offered is that in systems of high internal delay and energy tie-up (bulk viscosity), one may only operate over the relaxation time dynamics of the internal degrees-of-freedom, and that such internal dynamics expresses itself in externalized modal behavior. Thus we have offered a spectrum of time scales at which behavior (in the present case elite behavior), can or will make itself evident. At the expense of being too detailed, but as an illustration of the specification problem, we offer the following list:

Physiological Modes

0.1 sec. - Reaction time (nervous impluse)
1 sec. - Reaction complex
6 sec. - Behavioral fragment (some unidentified brain segment)
2 min. - Relaxation time for physical activity (e.g., oxygen equilibrum)
10 min. - Settling time for autonomic system (e.g., blood flow equilibrium)
20 min. - Fragment of total attention (e.g., CO_2 equilibrium)
1 hour - Modal time scale (e.g., reticular core fluctuation)
4 hours - Total boyd relaxation time (e.g., cortisol fluctuation)
24 hours - Scale for total modal range (e.g., circadian equilibrium)
3½ days - Local environmental adaption (e.g., water equilibrium)
60 days - Mood fragment (e.g., body turnover)
1 year - Total environment adaption (seasonal equilibrium)
5 years - Coherent life activity
20 years - Major live fragment
70 years - Life span.

Related to these physiological modes, elites societal modes emerge:

Societal modes

4 hours - At this high-speed end, we can see fragmented daily jitter, e.g., the jitter of stock market activity.

1 day - This is the reaction time for business.

3 days - There is a coupled time scale from the day's decisions to a reaction time of other people.

30-60-90 days - Significant activity commitment is made in business at this scale.

1 year - In fact, man's tie to yearly agricultural cycles makes this a salient market in major business activity.

3-4-5 years - Again, there is a coupling from the organized yearly decision to a reaction time of other organizations.

20 years - The major life fragment of the generation enters and governs major change in command-control of organizations.

70 years - A social relaxation time toward equilibrium occurs.

The Wharton School model, operating at changes-per-few months level does not find high detailed coherence. There is a considerable degree of randomness in the changing inputs. We would suggest that while forecasters (crystal ball gazers?) generally want fast answers, the greatest coherence has to be at the nearer-to-equilibrium period of 20 years.

While a whole detailed style of dealing with daily, weekly, monthly, and yearly vicissitudes develops on the part of the individual, it is the more long-range expectations of the ensemble that tend to govern coherency.

Thus in our opinion, whereas high frequency econometric modelling can be left to such economic groups as Wharton School, Brookings Institute, or various economic groups within government, based perhaps only on "pure" economic closure, there is another larger-scale grosser dynamic modelling that suits the entire polity for policy purposes, e.g., for planning long-term transportation

policy, education policy, etc.). The task is not easy to start. It is a systems' task. And perhaps the Systems Center deserves commendation for beginning it.

It is clear that many other departments have related perceptions of the problem (such as an institute for defense analysis). Thus it is quite likely that a generation of development of various types of national plans will be seen. In that context, our planning type may be one of many. It goes without saying that in a reductionist sense we believe ours is most fundamental, deriving its base from physical law, and being cast dynamorphically with the real system. But that point is obviously open to dispute. Competitive games are an American style of play.

To provide a little more detail on pure economic modelling, the macroanalytic national incomes account system deals with four sectors - households, business firms, government, and a foreign account. Banks are treated separately from nonfinancial businesses. The accounts that make up the model are kept as a double-entry accounting scheme. How the national income account is linked to input-output tables may be found in Duesenberg (42).

The flow-of-funds account (43) deals with financial assets and liabilities, in a framework of balance sheets. The first differences of a time sequence of balance sheets provide a flow-of-funds statement of change of assets and liabilities in each sector of the economy.

A recent model by Bosworth and Duesenberg indicates how the national incomes account and flow-of-funds account systems may be treated simultaneously. As Klein has pointed out (in a talk at Eastern Economics Association Meeting, October 1974), work is still in progress to develop complete national financial systems. The expectation will be a large detailed macrosystem, but with a great deal of sector, market, and industry detail. It may be constructed of considerably more than 1000 simultaneous equations. That amount of detail is believed necessary to follow "exogenous" changes in particular input-output sectors, for example, food and fuel issues. On the other hand, for what may be criticism of the

nonisomorphic character of this modelling, see Brainard and Tobin (44).

Clearly, at present, we are in no position to adjudicate or comment on current controversies at the frontier of economic modelling. However, we expect to find it very interesting when Tinbergen's current portion of world modelling is released under Club of Rome sponsorship.

A very small sample of the critical discussion following Klein's presentation of the present and future of macromodelling is the following: there is a context and political environment to a model. That is, there must be political feedback in models. Monetary and fiscal variables are endogenous, not exogenous. Policy makers within the system affect purpose by monetary variables. Thus they are involved in feedback. If polity variables are treated as exogenous, the equations are mistaken (i.e., open loop, at best), and thus lead to a wrong idea of system operation. So one must build in feedback loops to recognize the endogenous nature of policy, and the policy influence of class structure on government. Political economics will have to be taken seriously. (Note that in our systems' scheme, we have ideological feedback built into a policy loop.)

Note that this one criticism points out that the economic compartment is at least coupled to a political segment, that the system is a political economy. "Pure" economists have not indicated a satisfactory way to couple that component except in open-loop fashion. And as far as outstanding critics, the Marxists are concerned, Heilbroner pointed out (at the same Eastern Economics Association meeting) that while they were valid in indicating need for a political compartment, their arguments have been naive.

Let us characterize the problem quite specifically. While the notion of democracy could have flowered in ancient Greece at the scale of city-state polities, it was dead until the American Revolution. Instead, hereditary rule, rule by conquest, or rule be divine right became the political organization under the thrust

of organized military power than an Iron Age made possible. But with the rebirth of political power to a citizenry, or the rise of limited monarchies, no universal brotherhood of man, no withering away of a state organization took place. Instead, a new elite developed and showed new ways to express its control. With the concept of socialism, on through Marxist inspired socialism and communism, after 1848, once again a withering away of the state could be envisaged. After the American and French Revolutions, there was no opportunity to test these schemes until after World War I. We have now had three generations of experimentation. The socialist, mixed, communist schemes show no withering away of a state. Instead, new elite forms develop and show their specific ways to control the policy. The most ambitious attempt to develop another scheme, Mao's schema for continuing revolution, has just entered a new phase; Mao is dead; we predict the development of an elite. Mao's scheme, other than a possible excuse for elite to replace elite at some suitable time scale, is dead. The populace do not have the energetics to continue the process a few times per decade.

Thus again and again it is only the internally "hot" elite molecules who have the energy to seek to sustain a role of leadership in every society.

Note that in our modelling there are two different distributions - the populace and the elite, and that the political "arm" is simply a feedback policy loop in which a great variety of couplings are permitted by the elite. As far as the "laws" of movement are concerned, we do not deal with momentum, but with action modes. And those for both elite and populace are quite limited. An ergodic history of man, with value-in-trade, indicates a repetition of similar modalities again and again.

With this introduction, we turn toward a specification of a relaxation round computation in a modern polity, e.g., ours. Clearly, we can detect the problem posed by the economic compartment. At the scale of months, the investment elite has behavioral

freedom to operate with his wealth. One can hardly detect the physiological mood changes of the individual at that scale. Thus as Klein has indicated (in debate with Forrester at MIT in 1975) he cannot find any economic predictability. While there is less personal freedom at the yearly level (e.g., a corporation may take losses for one or several years), he dependence on yearly vicissitudes of climate have a considerable influence on the economic business cycle. Many industries are seasonal.

One approaches a more mechanistic character at the generation, i.e., war-to-war, scale. At that scale, the investor must invest. (He approximates "doubling" his wealth.) Even sun spot activity (possibly related to weather) has had two full cycles. But most important, both the generation and the extensional (e.g., industrial household) material has had an appreciable turnover. The players change (just as in the body, over the period of a few months, the atomic players in the body cells have turned over).

So we can sketch out a round of systems modelling.

4.8 ONE RELAXATION PROCESS IN SOCIETY

We can start with boundary conditions at the end of a war.

a. There has been a considerable disturbance in the civilian economy. There has been a considerable change, generally speed-up, in technological processes and knowledge.

b. While there may be a delay in explicating its future expectations, there is a complex of expectations which the populace can hold. Namely, even though the populace is left with the disillusionment with war that Richardson has pointed out ends the war cycle, there are latent expectations which culture, ecology, and technology imply. The elite will attempt to capture those implications.

c. In our opinion - it is only a matter of opinion until a number of such computation rounds are attempted and the more rapidly convergent first computational step is proved - the best

a priori step is to estimate what a generation of the populace can produce and what it needs, given its culture, resources, ecology, climate, and technology. (As an item of the day, see (45), which provides a tentative but quite authoritative estimate of food production and consumption for the next 25 years.)

For retrospective practice, one has all of the modern nations of the world to practice on, say, past the American Revolution. Such national experience as Germany, England, Japan, and Sweden have had after World War II could be very instructive.

d. Within that estimate, it is then possible to make an estimate of what roles the elite will play in attempting to realize those social aspirations. They will manipulate evolving technology, the resources, foreign relations, the populace within growing social forms that the existing boundary conditions will tolerate. In one era it might be the nobles; in this era it is the corporate structures in the industrial capitalistic nations; it is the development of the productive means in the socialist/communist nations; it is the selection of instrumentation of power in the dictatorially dominated nations.

e. That level of economic activity which the elite generate, and its dynamic cause, distributed through the generation, including both internal and external trade, will affect the distribution of population among settlements, the rate of growth of population, and the rate of positive or negative emigration of population.

f. The regulatory scheme by which control is exercised by the elite is the political arm of the polity. The character of control and its sophistication has varied in various historical epochs.

g. The open-ended character of the epoch is shown by the fact that in a generation or so, the internal and external political process has likely reached another crisis and the next war-phase emerges in the ecumene.

As we have pointed out, the perceived threat provides a dominant cue to elite command-control in the political feedback loop. Yet the social process is more determinate after a number of generations. The outcomes of individual wars are not sharply known, but the underlying causality, the resource balance, and the direction of movement in the ecumene can be estimated. But these processes are, at this time, outside of our scope. If pure economics offers formal relaxation processes a few times per year, we now offer a physical relaxation process per generation.

We can loosely sketch out a potential "computational" scheme for such a relaxation. The scheme, or ones quite similar to it, is computationally implementable by a modest-size planning group. It fits in with our Ziebolz modelling for this polity. While we offer too many steps in a computation round, with some practise and experience the closure can be completed more rapidly. The major purpose is to outline the chain.

We will discuss it for a computational epoch, which the reader may picture as a year or a quarter in a high-speed computation, but he should sense that the period is wrong. In our view, the computational epoch is of the order of 4-5 years, namely as a "quarter" of a generation. We sense it would serve the same purpose as quarter-year computations: by drawing a bead 4 or 5 times on a generation plan, we manage to keep closure quite tight.

So we ask that a balance be struck for the last epoch (e.g., generation), and the epoch before. Then we ask that a simple extrapolation be done from these past two epochs for the next epoch. Since the various compartments have some real constraints, the simple extrapolations are subject to these constraints and thus require some methodology, e.g., linear programming, to optimize the extrapolations. This round of "computation" is pure mathematical extrapolation - what is past is prologue (i.e., mathematical continuity). Now some science is brought in.

First, knowledgeable earth scientists should make an estimate of the validity of the extrapolation for climate, hydrology, geophysical, geochemical, and biochemical processes. (Note this is better today than ancient readings of the portents of the gods.) This includes availability and degradation of resources. A round of computation based on this input modification is useful to suggest the sensitivity of the resulting balance to these "ecological" factors.

Second, knowledgeable scientific/techological people should make an estimate of the validity of any extrapolations for science and technology. They should forecast scientific/technological change and what effect this would have throughout the system, e.g., on input-output tables. A round of computation based on this structural potential change should be made. Again, it will be useful to indicate the sensitivity of social balance and change to these technological factors.

Third, knowledgeable elites should examine the system, as modified by technological change and as unmodified by that factor. They will have to select the technology changes they approve of. It is their investment in such change, and their investment as new elites, that will select the likely technical changes. Technical man proposes, but the elite dispose. A round of computation based on the action of the elites should be made. Sensitivity of elite action is useful information.

Fourth, knowledgeable functionary political/administrative people should examine the system to determine whether it has served everyone's needs, i.e., the elites, the populaces, and the purely technical needs of the polity. Depending on the system and the epoch, the elites exercise greater or lesser control of this compartment. They propose changes in the extrapolated roles for these factors based on their rules of operation. That is, they too perceive constraints and permissibles, the "do's" and "don'ts" of their society. They offer some modifying corrective action. A round of computation based on political/administrative action should be made. Its sensitivity may thus be determined.

Fifth, the action role of the populace should then be knowledgeably corrected, instead of their extrapolated role. This affects their reproductive rate, their mobility, their value systems. A round of computation based on their action modifications should be made.

This likely returns us to the beginning. Perhaps one or more rounds of iteration modification through these five perception classes are required for convergence to a prediction. Our proposal is that such predictions should be made each "quarter," namely, the prediction rounds become the equivalent of five-year plans.

Who or what is done with this model? Clearly, only one compartment outlook "immediately" has the public interest, and that is the political/administrative. So it is appropriate for that link to perfect that model and use it to guide its intrusion into the social chain. This model is not really different from our earlier, more formal, policy model.

One notes that the political/administrative system node does not control the other nodes. By its action, it can try to influence the other nodes. It may in fact have no such power, but at least the model is indicated.

On the other hand, the model can be operated by the elites to determine their effective control of the system, or it can be used by "outsiders" who impact the system through trade and defense, if not yet quite through climatic control. As an appropriate example, there is little reason that the political/adminstrative nodes may not program out friend or enemy polities, or the major polities in the ecumene, to determine what interfering actions it may take in support of its own national interest.

As introduction, this is as much as we wish to say about a system's model. It is understood that political/administrative decisions made for a generation are of considerable import and cost. Thus a "quarter" review scheme is not a bad one. This is true for a capitalistic country as well as a socialistic one

So for a last section, we turn to one final direct commentary on the issues mentioned in the task sections of our contract schedule. Before turning to that section, it is worthwhile to introduce a few comments on one of our neglected system's potentials, the value system.

4.9 VALUE SYSTEMS

We have indicated in earlier government studies of the relation between management, elites, and research and dvelopment that the conduct of men is not rationally governed. Consistency, if it is to be found, lies in internal biochemical chains. As we have studied a deeper reductionist basis for a brain science and a social science, we have become increasingly struck by the large degree of logical inconsistency that people expose - presumably scientifically oriented and trained people who claim objective outlooks - when the topic is man and society. One finds a surprising degree of "vitalism," a belief in the special character of life and society that suggests that any effort to deal with it by deterministic inanimate laws is almost a taboo. Thus whether we wished it or not, the topic of value systems, particularly organized value systems, has been forced on us.

Historically, societies have always had organized institutions to govern the content of their value systems. An institution and commonly prominent extensions including buildings (e.g., the ziggurats of ancient Sumer, markers of the first urban explosion) have marked essentially all societies. However, the form by which the elite have utilized this institution for their own purposes has varied. Sometimes the king represented a god figure, sometimes he ruled by divine right. Sometimes a president (erroneously - he is not yet that fully an elite figure) has represented the moral force of the nation. In the Soviet Union, with no official religion, the Communist Party rules via an oligarchy theocracy. The Party is the source of all moral values. While it is reputed that current American foreign policy has demonstrated that Communism

is not a religion, we would counter from a greater sense of how its believers act and react. And the current attacks being made by internal dissidents in the USSR have clearly indicated that these values transcend written law.

What you cannot do is introduce a value system solely on the basis of its rationality or its superior rationality to what came before. Examples are Menes' futile attempt to introduce a monotheistic deity (Ptah) in Egypt; futile interdominational arguments, say in the USA during the first quarter of this century, to introduce an ecumenical unity over the common acceptance of a monotheistic God; the futility of insisting on the strict scientific assignment of a rationally conceived God as a first cause among scientists, as Newton accepted, with no subsequent intervention; or if one denies the existence of a divinity, the futility of observing a strict neutrality with regard to one's rights as compared to anyone else's.[1] It is always the long-term outlook of the culture which is served in an evolutionary but bounded sense. Religious systems never die. Intermittently they may be impulsively shifted in long term.

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[1]The content of a religious outlook is not devoted to the subject "How I shall make my living from day to day?" but with questions like: "Why was I born? Who was my Maker? What shall I believe? What should govern my relations with my fellow man?" We would submit that all societies have to operate from some kind of value system, even a society in breakup such as the Ik. In atheistic USSR, these beliefs are provided by a central "political" party which asserts the supremacy of the state in both daily affairs and affairs of the "spirit." Politics and religion are combined in one face. This is not new in history. However, we would assert, in recognition of their intrinsic religiosity, that such beliefs tend to raise the greatest hostility among those who possess a fundamentalist belief about a personal interventionist monotheistic deity.

An interesting review article on some modern aspects of religion (46) - evangelism and fundamentalism - offers some significant commentary on the problem of value systems in the USA. It points out that evangelism was the main tendency of American Protestantism in the 19th century, and that its renascence since 1950 has been spectacular and is one of the most important and least understood of social phenomena; that fundamentalism was not the most important doctrine of Protestantism here in the 19th century; that while a modern ecumenical doctrine would seem to have emerged from fierce denominational struggles during the 1920's, a disappearance of the fundamentalists as victims of their own ignorance and unwillingness to evolve was premature. Instead, they too have emerged as a second strongest arm of Protestantism in the USA.

Yet the manipulation of a value system is not purely the creation of an elite. Rather the "new" elite of the past attempt to modify the value system to fit their ends. The social game, playing itself out generation by generation, leads the populace to select those forms that permit them to rationalize their position, and a new elite who are precipitated from the populace help shape the system into its current form. These new elite who come from outside can either quickly grasp and conform to the existing system (e.g., outsiders who took over rule in China) or attempt to destroy it and set up new systems. But even though the value systems go through many changes, the spectrum of choices can be fairly well outlined, and one can estimate what changes will fit at any time.

The ergodic character even of value systems, as opposed to, say, a singular convergence, by "revelation" or by human "progress," to a unique asymptotic value system, or a universal religion itself probes at the physical or thermodynamic foundation of a scientific reductionism. We can take a telling case from the current frontiers of this subject (47). See in particular the chapters by Sir John Eccles and Karl Popper. They share a sense that a complete reduction is not possible. They are in

fact in the process of writing a book whic will extend the positions they have indicated in (47). Representing a combination of one of the world's greatest figures in neurophysiology and in scientific philosophy, they must be attended to, particularly since alternate efforts are directed to a complete epistemological reductionism in natural systems, <u>including</u> life, mind, and society. However, we wish only to make one brief central point relevant to value systems.

Popper and Eccles identify three worlds. World 1 is the world of physical matter, fields of force. World 2 is the world of conscious and "perhaps" subconscious experience. World 3 is the world of language, written or printed. These worlds, in Popper's view, are autonomous. Reductionists, he states, only accept World 1 as existing and thus autonomous. World 2 they replace by behavior, and World 3 by verbal behavior. Popper, on the other hand, believes World 2 can not be reduced. The rest of Popper's position can best be read.

However, in reading and listening to their positions, one is struck by the following essential note: there is a sense in Popper's exposition that the dimensionality of World 2 (and World 3) is not constrained. The mind can continue to invent or develop new variables nondenumerably without limit or order.

It is interesting that first, starting with a neuro-physiologist, Warren McCulloch, and now with one of Sir John Eccles' students, Rudolpho Llinas, we are proposing a very specific limitation to what is to be expected from mind, and that in fact both the formal structure and functional structure runs quite parallel to what we ascertain from the physics of World 1. Namely, that Popper's characterization of the mind-brain-body problem represents one more effort to avoid "getting on with the problem." One must note that our efforts have been involved with a cybernetic view. We have tried to link mind and brain through function and mechanism. First we have attempted to enrich the construct of

thermodynamics for complex systems. Then we have spent a number of decades in acquiring some physiological facility. Ultimately through McCulloch, we were forced to start in on brain mechanisms, the command-control system. And then, in order, in our reductionist model, we have begun on social orders.

It is surprising to us, in our modelling, that we have had to reach the subject of values. As we have indicated, stemming from the limitations of our brains we can indicate the limitations in value systems. Their ergodic nature past a few thousand years of start-up issues seems to be clearly foreshowded. Intermediate to stimulus and response is the organism, but six millenia of human history indicates a limited repertoire of valued responses. Themes tend to repeat again and again to fit the social circumstance. Only technology continues to change "linearly" - so far. It too will likely become ergodically entrained.

5. TRANSFORMING COMPARTMENT BALANCES INTO NATIONAL POTENTIAL FIELDS

At the present time, pure economic models, e.g., Brookings, Wharton School, provide a growing competence to deal with the near-equilibrium balance in the value-in-trade (money) compartment. However, they perform their balance at too high a frequency. Instead, as we have suggested, a much more lagged version has to be cast, on about the national-election time scale, which would fit in well with our political scheme.

Since the polity in which our culture operates is money-measure oriented, this compartment balance may be used as one of the basic "balance sheets" that have to and will be examined in assessing the evolving national dynamic history.

As a first approximation, we suggest that existing forecast methods be used for projecting segment into segment. It is obvious that such forecasts are largely free of dynamic theory and largely represent mathematical continuity issues. Given policy inputs, they indicate equilibrium responses.

However, we ask that the initiatives and fortunes of the elite be separated from the populace. And we ask that an overview be taken (and modified per time segment) of what basic thrust the policy will take from a war-to-war epoch perhaps a generation apart. This will continue to be modified during the epoch. We ask that earth scientists, meteorological, hydrological, agricultural, geographic, geological, provide predications about changes in the earth potentials they expect during the epoch, and more narrowly, during the next few segments. This should not only include expected mean changes but also catastrophe probabilities (e.g., floods, earthquakes). This characterizes the environmental potentials. (In lieu of any other scientific data, the past can be extrapolated. That is a zeroth approximation.).

We ask that knowledgeable scientists and technologists examine the technological potential and indicate the character of changes that they perceive in the next epoch or segment. That should be reflectable in the input-output tables.

Those changes have to be first examined within the material potentials, both within the polity and abroad, to note what changes this would make in predictive transformations of the potentials in the future.

The potential to meet mind-conceived-of goals of the elite must now be examined. An "objective" value function could be proposed for capitalistic countries, for mixed economy countries, for socialist countries. Actually these strategy functions could be stereotypes or they could take into account specific "national-cultural" differences. To a considerable extent each nation's war-to-war outlook tends to modify the value function. Perhaps one time a rapacious profit maximization may have been a capitalistic value function, and may perhaps still remain a stereotype held by many political radicals. However, as even Klein and Forrester have pointed out, now many new elements have to be factored into such a value function. We are not involved in issues of good or evil when we state that the ongoing elite's perceptions must be applied to the data at hand to surmise and predict the elite's course, investment, cooperation, competition, or chaotic inaction.[1] Those choices by the elite influence what actual changes will take place in input-output tables and in the fluctuations in material and energy potentials on the supply side.

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[1] At the time of writing, a most telling article was discovered. As part of a Washington Post-Harvard inquiry into attitudes, group leaders were asked their perceptions of the equity status they assign to economic elites (49). Except for a reduction of the renumeration of elites by a factor of two-thirds, they accept their own status and a status tenfold higher for elites. It appears to us that it is that acceptance which makes the system possible.

On the consumer side, a response has to be made by the populace. The populace will not automatically take up what is to be supplied. A small gradient must be developed so that the potentials can create flow. The elite have to act as catalysts to speed up and impede the flows. They must catalyze the transports. They must match the flow of people and materials. Heretofore, understanding of this catalytic matching has been an intuitive process; we are trying to get the process out into intellectual consciousness.

We suspect that control of population increase has commonly been exercised by increasing the food supply to the populace. We suspect that the agricultural explosion in Europe in the 13th century, and the large industrial population in Europe in the 18th century were so controlled. We suspect that an alternate strategy is in progress now to reduce population. While these remarks seem to be directed at problems at the scale of the centuries, if not millenia, we would like to suggest that they are problems really related to the wars of a few generations. If so, then the localized fluctuations deal with perceptions of war to war.

Those of us whose lifespan includes the depression, World War II and beyond, can sense the social pressures that change each decade or half decade as to our family size. We are aware that the recent "sexual revolution" and the current abortion conflicts are cut from this cloth. The control of materials, e.g., our acceptance of synthetic foods, our acceptance of changing views of quality merchandise, quality service and a "quality" of life itself, are being influenced at the time scales we have in mind.

Note that we, as consumers, have little long-range choice of what we will accept. Instead, corporate, political, and advertising forces control the rate at which these changes diffuse into our lives. Thus we find a manipulation of their powers to control the transport processes. It is a tribute to his persistence

and the mystery associated with the issue that M. Friedman has only just received a Nobel Prize for elucidating the large degree of social regulation that the supply of money and its velocity affords.

Thus there is a large degree of technical (through transport competence) and political manipulation possible for the transport competence within a polity. We have defined a polity by the region in which the transport diffusions do not change, e.g., by being impeded at frontiers. Rulers have known for millenia that defense transports are not to be internally impeded, and our national transportation systems still reflects that knowledge.

But now we are up to a more sophisticated understanding. (We hope. As Pirenne indicated (37), an emperor like Charlemagne did not understand the need for encouraging a useful tax system. Our current debates do not indicate a clear understanding of the need to encourage our urban settlement structure, small business, and likely a highly cooperative industrial complex. Instead, in our opinion, ideologues of both the left and right take positions that will tend to destroy our fantastic national competence.) The sophistication that some nations are beginning to bring to high-speed international intercourse based on their own internal competences presents new challenges in understanding the system.

How we build and maintain internal transportation systems - both urban and national - and the freedom with which people and material can move, very significantly will determine our national future. In any case, in this loosely prescribed way, the compartment balances and potential fields are dynamically inter-related.

6. RELATING ZIPF'S LAW AND NATIONAL POTENTIALS

Our reports have grown in their understanding of the relation of power thermodynamics and communications thermodynamics. The latter contains the essence of Zipf's law; the former contains the essence of the national potentials. So we will summarize what we believe to be our latest perception of the problem.

Interactions and stability theory determine the thermostatics of a system, and its thermodynamics under gradients and other sources of stress. The laws of physics are directly applicable to the mechanistic interactions (mechanical, electromagnetic, gravitational) to cast both the local and field form of association.

However, in the evolution of such systems, complexity levels are quickly reached at which branches of local forms characterized as states have comparable probabilities of occurrences and energetics. The direct application of physical laws cannot decide the relative state forms. All of these comparable states may likely exist.

If we know that the complex system persists and thrives, then instead of hunting for a very detailed higher-ordered theory (whose existence we cannot guarantee even today), we find it possible to use the body of physics as a strategy to determine the character of a higher-ordered complex to this level. The strategy can be referred to as the "truth, the whole truth, and nothing but the truth" strategy. Without going into detail, the prototypic example is a distribution which is determined by what seems to be a priori true, then modified by restrictions that somehow also are known, and which include nothing else.

So we now imagine systems in which hard bonding laws have determined some primary physical associations (e.g., chemical bonds in molecules, organelles in cells), but we find many common associational states that emerge not as hard form, but as functional form. In some basic sense we detect an "institutionalization"

of process. The effect of the process seems to take one through all of the likely equipollent states. There is no strong power thermodynamics associated with the changing state.

Those changing patterns, in our opinion, are representative of a communications system, a language, and it is that patterned process with which Zipf's law is associated. We have indicated that when the associational patterns are made up of independent entities which only collide elastically (to which only an energy conservation holds), then the distribution of states seems to be Boltzmannian. However, when there is a sharing of all resources, and even significant reformation of the states, then a Zipfian principle of least effort seems to apply. The coding of states seems to be near Zipfian.

The notion, loosely, is that there is a flux of almost hidden variable quanta, small energetic elements, that are in sustained motion. They count for very little in the thermodynamic energy balance. But they can be used to form the phonemes of communication. Among atoms, they are the stream of emission and absorption quanta. In the living organism, they are segments of system set that are formed in the nervous system that result in fragments of behavior. In a human society, they are the individuals that are free to move around in the polity, very much like free electrons in a metal. It is these elements that can be used for an institutional communications system, a system that controls the formation of switch modes.

These segments, ordinarily, are part of the "thermal noise" of the system. It is not clear - being a matter of evolution - how the command-control system manages to perceive and seize on these elements to control the switch state of the system as a communicational element. In some sense the element is "key" and located in a loop where it can serve as a useful modulator.

Thus a complex system embedded in its milieu begins when its underlying atomisms have a considerable number of degrees of freedom, and the ensemble has a considerable number of degrees of cooperative freedom and the system has to switch modes of comparable energetics among its degrees of freedom for system's survival. That complex of requirements necessitates an internal communications system and an algorithm for switching modes. Some element at hand, convenient to the command-control center, and requiring little energetics, is used for the language element. In human speech, it is motor control of a vocable pharynx and 20-odd modulating positions of a mouth cavity which can be used for language fragments. Or it is motor control of hundreds of small muscles in a versatile hand as a tool that can be used to form writing elements. Note that the communciations rate can take place at the nervous channel rate: the channel has evolved to reach the same rates as the sensory channels.

In human societies, the communication takes place by the formation of coherent bonding associations. Note that it took the coincidence of the primate bonding character, the human brain, and the domestication by agriculture to produce the language elements of settlements.

The elements of language are always nearly noise, and any stranger to the language is fairly impressed by that notion initially. But that noise character is indicative of its basic "thermal" nature. One surmises that if the system did not have a continuing thrust for survivorship, arising both from the coding that drives both the atomisms and the system's cooperative modes, the language would tend to decay toward a Maxwellian-Gaussian thermal noise, or perhaps even white noise. Thus language is maintained and transformed by a vigorous history and evolution.

But the system develops language via a physical strategy, and the most common strategy is Zipfian. From one side, the selected fragments of language themselves form the switch language, and their higher associations of those fragments are used to continue to extend the language. Thus the frequency or size of the language ensemble becomes Zipfian, and trails out to a noisy tail.

We can get some further notion of the character of language by building it up from one word to many. If the language had only one word, in our case of interest, say, all extended families are hunters in their own domain, but at each time epoch, a family may settle. One senses a Boltzmannian character to this process because it has been free of any interaction. One must grasp some sense of polity to see why a "language" has to develop.

It has been content arising out of the intensive value system potential that furnishes reason for interaction. The combination of an intensive religious value system, the extensive value-in-trade system, and values of cooperation for aggression and defense has been highly pursuasive in developing the language of settlement. However, once we are given a thrust for interaction, it would then seem clear that the richness of language develops in proportion to the number of different modes needed for survivorship.

Continue the pursuit of a language concept by means of a two-mode state (e.g., switch the system to "on," from a system that is "off"). We may regard this as requiring a vocabulary of one or two words, for example one, if the switch-on state has a fixed life epoch. For example, we can imagine a field of hunters (or hunter families) who each epoch can decide whether to hunt or to settle. That is, settlements are one-word settlements. They are either occupied by a fixed group, or they are empty. (One could use the mouth as another example. Each epoch either a voiced sound would be emitted, or none.)

Each generation (of leadership) a switch state is made. Since we have postulated only one word, then the only choice is to hunt or to settle. Considering the richness of the internal potential value system, this "vocabulary" is not rich enough. Instead, a complex of phonemes are developed. These are the complex of bonding groups that can form in the society. Each generation they voice their decisions. Thereby the language of settlements is developed.

The language that develops is the complex of urban settlements of various sizes. What we believe essential is not the rank-order relations of the settlements by size, but the distribution of settlements among various sizes. Roughly, the total population per population octave is about the same. To illustrate, for urban settlements:

TABLE 3. URBAN POPULATION IN MILLIONS PER SIZE OCTAVE - USA*

Year	Population Range in Thousands											Average	+ Dev.
	8000 -4000	4000 -2000	2000 -1000	1000 -500	500 -250	250 -100	100 -50	50 -25	25 -10	10 -5	5 -2.5		
1880			1.2	1.9	1.3	1.8	0.9	1.4	2.2	1.7	1.6	1.7	.3
1900		3.4	3.0	1.5	2.9	3.3	2.7	2.8	4.3	3.2	2.9	3.0	.4
1920		5.6	4.5	6.2	4.5	6.5	5.3	5.1	7.0	4.9	4.4	5.4	.7
1950	7.9	5.7	3.9	9.2	8.2	9.5	8.9	8.8	11.9	8.1	6.5	8.1	1.5

*Source: Fortune, June, July 1976.

The average mean deviation is about 16 percent of the indicated years. If we examine corporate employment, we find the following approximate figures:

TABLE 4. CORPORATE EMPLOYMENT PER SIZE OCTAVE - USA (1975)*

Employee Range Thousands	Total Employees Millions
800 - 400	2.0
400 - 200	1.8
200 - 100	2.6
100 - 50	4.5
50 - 25	6.3
25 - 12.5	5.0

*Source: Fortune, June, July 1976

These data, representing about 22 million employees, cover industrial, utilities, transportation, retailing, financial, banking, and life insurance companies. We may assume, roughly, that the lower octaves (companies employing less than 12,500 employees) will average approximately 5 million employees per octave. Thus in employment, we might say that the largest corporations (above 100,000 employees) are perhaps still undersized. While at this time, still quite speculative, this would tend to be in accordance with our conjecture - that corporate structures are rising to achieve equipollence with urban settlements. It would help account for the fact that such equipollence has not become apparent until quite recent times. It would suggest that the dominance of corporate structure in the polity is still in an adolescent stage.

Whether true or not, we can return to our description of this Zipfian-like distribution character. Basically, we see a property similar to the Weber-Fechner law of sensory discrimination. The system has to meet a complex of conservations, and potential constraints. Both kinematic and kinetic relations have to be satisfied. The variable range is large, extending from some small quantized element. Some sort of scale independence has to exist. Namely, it cannot be the same perception to distinguish 1 from 2 or as 10,000 to 10,001. Thus, instead, a logarithmic sensitivity is achieved.

The Zipfian-like or logarithmic distribution (e.g., whether the rank-ordered population sizes p, p/2. ... , or p, p/2, p/2, p/4, p/4, p/4, p/4 ... , both sum to log resultants[1]) is supported from below by the minimal elements that have some competence to form, exist, break up and be abolished in the complex irreversible field, and above by the largest size unit that can form and cohere as a localized structure within that same extended field. In the case of language, it is the phoneme structure that can be encoded for within the neural network (it will be identified with vocable structures for humans, and some such short elements will become the most common rank-ordered symbols), to the most complex word structure that can be held in mind. (We will not bore the reader with the supercalifragalistic play of English children, but one notes how few polysyllabic words are required for even quite complex speech. Of course compactness is achieved because of the vicenary phoneme code, rather than a binary code.)

In the case of urban settlements (as we showed), a settlement of a few hundred is a "phoneme." Beyond it is the mobile family structure that can pick up and move (or be moved) almost at social will. The small enclaves that form, as a village, in suburbia, can turn over their form with very modest economic disturbances. At the other end, the enormous apparatus required to support large cities makes their fluctuational size and relative position mobile, but the generation-level time scale is

[1]The Zipfian to ln (2n+1), the octave to ln (n+1)/ln 2.

clearly more apparent. Their size is limited below the polity, because they require too complex a governing structure for their total supply structure to be able to enforce their control. They can only act as a size-limited liquid droplet.

At one time, the corporation was even more limited. Automation, transport competence, and technological miniaturization in mechanism, material, and power supply have made corporations much more mobile. That together with their economic-political power makes them an emergent element within the polity. Whether their long-term Zipfian-like support will be possible is still not certain.

In any case, it should be much clearer how these coalitional "communicational" elements in a system (e.g., concentrations of thermodynamic variables - such as people, materials, energy sources) with their characteristics "polar" spatial distributions are related to the national potential fields. These concentration centers serve as energetic sources by which the thermodynamic system's game is conducted.

7. POTENTIAL-LIKE INTERACTION FORMS

The question was raised as to the significance of 1/r potentials as a measure of the strength of interaction between centers. The very notion of a statistical mechanical field with many of its intrinsic forces being inverse square forces (total fluxes independent of distance from a center) and a mean free path and relaxation time motion would suggest the likelihood of weak inverse square law relations holding at macrosize. On the other hand, the electrodynamic quantum exchange force would suggest the formation of a more complex clustering than a simple homogeneous Laplacean field. Thus, while one would expect to find center clustering and potential-like influence coefficients, one would not expect to find a rigorous 1/r potential field. As various of the TSC studies made in 1976 have indicated, there are transport relations that are more or less costly than 1/r transportation. Similar properties were discussed with regard to Mandelbrot's modification of Zipf's rank-order law in which a nonunity inverse exponent represented the variety in the language (49). The great variety of thermodynamic goods transported in society possesses a large amount of "variety." Thus, in spatial form, one expects a rich vocabulary in distance-dependent properties.

At any epoch, the considerable number of interactions have sorted out the balances among distance-dependent transports. Much of the issue is the relative value of the materials transported, their bulk, and the added cost of transportation. The important issue is the change of conditions that results in a slow change in the distance dependence of these potentials.

8. RELATING TRANSPORTATION PLANNING AND NATIONAL DISTRIBUTION FUNCTIONS

Since the modern trading society is highly dependent on its transportation modes, its internal structure and its transportation systems are highly interrelated.

Suppose a society is running along a certain course. One can examine generation by generation how it makes use of its national potentials, one can determine its fluxes and its population changes, and some extrapolational idea of what it might do in next few generations. But part of that problem is the changes that will take place with technological improvements in its transportation system.

Note that to a large extent, one must make estimates of where the society's national transports are going, with considerable concentration on long-distance transport. It would appear that history clearly indicates that long-range transport is governed by the competition and conflict among remote polities. Thus it is not sufficient to, say, plan building an international fleet. Competition among a great number of factors determines its economic viability, its defense utility, whether it can be usefully subsidized or screened from attack to where one's own nationals attempt to support or circumvent the effort of developing the fleet. However, such decisions are not "solely" political decisions made within the nation. They are the decisions which are made by the elite portion of a nation, acting only partly through the political chains.

The question turns on what our role can be in a matter like this. ("We", in this case, means not only the authors of this report, but our project officers, and in fact all those involved in both staff and line functions in planning transportation.) Our role, in the main, can only be a technical one. In the light of current social and technological evolution, and our understanding of the history of its current status, all we can do is point

out the richness of implication in what we comprehend.

We are asserting two things that we have learned from our studies - of both the physics of the historical process, and history itself. A large-scale polity is highly dependent on its long-distance transport planning for the maintenance of its internal settlement concentrations. There is evidence that we have not given that subject the full attention it might deserve since World War II. (For example, the merit of a concerted maritime R&D program as compared to certain high-cost defense systems could be an interesting comparison.) Second, we have learned that to keep our internal social "language" in the pink of health, a good internal transportation system is required. This means both intraurban and interurban. The automobile served in the second and third quarter of this century with increasing competence to provide a common mass transportation. The epoch is coming to an end. It would behoove policy planning within DOT to work out transportation plans for the nation.

Clearly, the dependence on automobiles cannot be halted instantaneously. Thus progress in reduced fuel consumption, in multiple ridership, in trip reductions, etc., are all programs to the good. But at the same time, some totally new ideas have to be phased in. One major one, for example, is a public awareness of the importance of treating its public utilities with respect. Perhaps in the middle age of a civilization such notions are difficult to instill, but it is necessary. The respect for public facilities upon which our future rests has to be encouraged.

In many urban areas public transportation has been allowed to lapse. This is not the case in such cities as New York, Philadelphia, and Boston, but many of the cities with suburban spread have simply not kept up their public transportation. The total thermodynamic economics of a polity requires population concentration, not population sprawl. There is an optimal number of population centers, which we believe are approximately spacewise

determined. We are willing to accept at a first approximation 60 centers per area of 3000 by 1000 miles, namely, one large population concentration per 5000 square miles (i.e., one per 70 mile diameter).

If one accepts a Zipfian-like, or an equal-population-per-size-octave thesis rather than or in addition to local political self interest - namely cooperation rather than competition and chaos - then a loose kind of transportation planning can be achieved. In some reasonable priority order, the specific requirements of each local population concentration can be met in turn. One would surmise that the richest social implications for transportation planning could be thus achieved by understanding that these population concentrations which emerge "naturally" as the language of each region, each with their own specialized problems, are in fact the composite "temporary" boundary conditions of the summational invariants. ("Temporary" may be quite a few generations. Each such number of generations, the urban area has to be renewed.)

To go beyond this general theme at this point would require attention to the problems of each particular area, e.g., Los Angeles, Dallas, St. Louis, Minneapolis. This is beyond our scope, but in each area, there are general and particular problems that will have to be faced for the next generation or two.

9. OPTIMIZATION IN THE NATIONAL POTENTIAL FIELD

As we have indicated, there is a "linguistic" optimization in the national potential field. The very notion of a settlement, a population concentration that is not complete in all of its material requirements, implies that it will be served partly by convection from other settlements and partly by its own local coherent processes. It implies that a metric value-in-trade will have to exist. One finds the point clearly made in the start-up of Sumerian cities, and no less so for all succeeding periods of history.

The optimization is contained in the notion that if one scans the polity at all microscopic scale ranges down to the minimum quantum level (for that epoch) up to the maximum macrocity size, one finds an approximate homogeneity. A map of the American colonies in pre-Revolutionary days shows the same characteristic as a satellite scan of the lights of settlements today. It is like a mapping of star densities. Each region (this is on the earth, where the resources are not perfectly homogeneously distributed) is exploited by human settlements according to its earth potentials. Thus, subject to those constraints, the population concentrations occur.

Given a technology, a climate, a geomorphology, an average resource potential, and a large-scale trading need for balance, one can sketch out national potential fields, and population distribution. While various estimates so made may differ in details, we suggest that they will have the same distribution characteristics.

10. NATIONAL POTENTIALS AND TRANSPORTATION

An existing society has a population and population growth rate. One can estimate, by extrapolation or by further refinement by our proposed notion of a round of thermodynamic estimates, what the population and growth rate might be a generation or two in the future. If there are uncertainties in such estimates - as yet, in the application of such a primitive stage of a new science - then the notion of mean and extreme likely estimates can be made. Those increments of population can be distributed among the population centers in accordance with our Zipfian-like or octave-like distribution function.

While this process can be done by mathematical indifference, one may then review the redistribution to see whether it is compatible both with present local conditions, and those envisioned for the future. If there has been a runaway of traditional industries in a region, and there is no technological change that can be visualized as needed or emergent from that region, there is little reason to expect population growth in that region, rather than population escape to more favorable regions.

One ought to be able to sense, at that point, whether any national policy of an R&D nature can possible alleviate those regions that may appear to be badly hit for the future. At least, as technical people, we would view such a challenge, with a 20-40-year lead time, as being a worthwhile risk that we could get our teeth into. On the other hand, as experienced technical R&D people, we know that it is exactly such long-term notions that we cannot sell elites on. Thus one must modify our technical perception by what "foot-dragging" elites will buy (50).

As each succeeding facet (i.e., summational invariant) is examined, one continues to redistribute the population excesses. For example, one has to run the balance of food production to see if it can fit the changed population and the possible requirements of international trade. One must examine the industrial production and consumption requirements to see how they match the population changes. And so forth.

As one completes these rounds of computation and near balances, one is aware, at each round stage, of a need for transportation - of the people and the materials - and energy requirements for the operational system. It is possible to design transportation systems, as change, as extension, or de novo. But one must note that such computations have to be of rather grandiose scale. For example, one must sense what such a computation might have entailed in 1850 or in 1910. What one cast in 1850 was relevant to 1910. What one cast in 1910 has been relevant to 1970. What one casts now has to be relevant to 2040.

One must sense that a high degree of automation will have to be involved; that dependence on renewable resources for materials and energy may have to be involved; and that industry may have to be labor-intensive. All of these might seem contradictory today, yet one can sense that there are technological solutions by which all these things could be true. What we can guarantee is that the solutions for the future will not be Utopian.

In any case, the possibility that more than one type of transport system will fit each region certainly exists. However, the future needs should be estimable from balances among the various national potentials, and one should be able to estimate the thermodynamic costs - dollars, materials, energy, people - required in the balance, and see what seem to be the best options to encourage. They likely will go that way, because the processes we are discussing are ones that skilled people have some intuitive

sense of. Our objective is perhaps to save some thermodynamic wear and tear. Is it better to run through middle-age aware of the best nearly conservative path, or do you prefer each day to be an uncertain adventure? That, man, remains the forecast issues for all time.

11. CITIES AND NATIONAL POTENTIALS

We have managed to touch on the relation of cities and potentials. We will attempt to be more explicit. Gross homogeneity per octave of size from a minimum quantum to a maximum quantum is the apparent rule for complex thermodynamic associations. Nominally, growth is near population equilibrim, but every so often there are changes in the near-isopotential environment (after all, it too has a history and evolution). Then the stability of the field changes and one sees "relaxations" to a new equilibrium state. That relaxation is a first-order process, i.e.:

$$\frac{dx}{dt} = kx$$

That arises becuase of the homogeneity of the process. But that gives rise to the Malthusian paradoxes - infinite growth, or death (depending on the sign of k). The paradox is removed when it is recognized that k is not a unitary measure, but a measure of state in the past and now:

$$\frac{dx}{dt} = (a - b)\, x$$

For definiteness, we use living systems which are born and die. (We didn't have to refer to birth and death of individuals. It might just as well have referred to concentration of charge, or chemical state, or momentum.) Thus we see a birth rate (a) and a death rate (b).

As we have indicated, the death rate now really refers to a birth rate some effective time ago. The above relation relates to how a positive state-producing process in the past compares to a state-producing process in the present. The thermodynamic closure relates to what determines "a" and "b," which can be complex as well as real positive.

But by its very nature this thermodynamic relation for homogeneous systems has different applicability in different epochs and time scales. Thus, for example, during the period of hominid development, man's ancestors grew slowly in population. The population grew with modern man. Why? Likely due to man's technological mastery of an increasingly benign climatic opportunity.

Ten thousand years ago, man became domesticated by plants and animals. That ingathering and precipitation of population in place led to a greater increase in population growth. It also began to fix the potentials of earth for the human population to a spatially immobile time "stationarity" rather than its earlier fluctuational mobile form. But then specific processes began to emerge which would determine how population and population centers would begin to fluctuate.

Certainly, ecological factors were the major source of population fluctuation. Pestilence or disease could flash through a population and knock out half of it in a short time, any time until recently, and it would still be foolhardy for man to deny such effectivenesses, even today. While sensational motion pictures may not present reality, headlines of national disasters "somewhere else" have sufficient frequency not to rule them out. Floods, earthquakes, epidemics, all have their temporal spectra.

On the other hand, man has clearly made some progress. The growth of the life expectancy and the squaring up of the mortality curve till we tend to fall apart, like the one horse shay, closer to a biological lifespan of 90 years or so, indicates that progress. Genetic change, and possibly only genetic change (whose age of feasibility only begins now) may increase that span. But nominally, the moving frontier of the deathspan can only be marginally improved, and immunity to death from a great number of possible causes cannot all be eliminated. A residual fluctuation level is to be expected. Knock heart-disease mortality and cancer mortality down: there remain various residues.

In addition, humans have both standard biological techniques and their specialized biological-sociological techniques for control of population. Killing the young, starvation, contraception, and warfare are some of the better known.

On the other hand, whenever economic conditions, particularly when beneficially perceived so by the elite, or when defensively perceived so by the populace, require a growth of population, such growth would occur within a few generations. If the population could not be achieved biologically, then immigration (or emigration) could be encouraged. A scale for national or international movements of significant magnitude could always be mounted at the time of a generation. One easily finds such significant movements in post-World War II Europe and in the USA. And roughly, as we said, these changes would be distributed in all size octaves.

But then if catastrophe does not govern, and wars do not govern, what remains is largely the effect of evolving technology. The balance between the farm and the manufacturing, trading, etc. urban area changes with technology, end changes as regional technologies redistribute the populace. In each region, however, the nominal homogeneity among sizes remains.

12. THE EFFECTS OF A NEW TRANSPORTATION SYSTEM

Open up long-distance ship transport, the ecumene expands into new lands. Open up transcontinental railroads, the nation fills up between the ends. Open up auto transportation, the entire canvas fills out. Open up air transport, and international intercourse becomes easily possible. Note that these were all long-distance transports (longer than the 10-20 miles of local form).

The problem in the USA is not a new transportation per se. The automobile and truck and a national roads system has made fantastic inroads into every other form of transportation. One problem we have is what to do after the automobile, assuming that it has a limited lifespan in its present energy-wasting form?

It would seem that the automatic guideway (whether hard-railed or not is irrelevant. Technologically, we would believe that a non-hard-railed system will emerge, but that depends on a number of technical horseraces involving principally conservation of nonrenewable material resources) will become a way of the future. This will involve a possible mix of multipassengers and freight, and central power supply. We are quite confident that this system will take over, but we have no certainty as to when it will be proposed as a basis for national policy. We will await the appropriate establishment of technologists to put the scheme forth before the elite.

What will be the effect of such a long-distance, presumably higher-speed system? We believe it will make it possible for us to continue a high technology, highly industrialized society, regardless of how our industrialized basis shifts. In our opinion, it will shift to more sophisticated dependence on renewable resources. That will not lessen the need for transport in any great amount. Nor is there any great need, in our

perception, for any large degree of increase in speed. A slow, few-generation increase in average transport speed seems all that is required, and may be as much as we can maintain.

The second requirement of a new transportation system is the local mass transportation needs of the population centers. One will have to pay careful attention to the findings of the TSC 1976 reports which seem to show a significant potential drive associated with the radial distribution of population, of income, and of transportation potential. If these gradients help to create rather than to stabilize urban instability, then the development of an urban transportation system will have to be carefully studied experimentally. We believe they do; thus a considerable amount of risk may exist in the form of such future systems. It is very possible that informed selection by local option may be required to project us into the future: the growth or shrinkage of urban systems may depend on the mass transportation systems they elect to develop.

But in the development of that system, one will have to keep the following new social thrust in time. Classically, the economic pie produced by the populace is split among food, shelter, and "personals" elites. Now there seems a thrust to split a full share to health elites. Is there now to be a thrust for a full share among transportation-energy elites, and if so what sort of societal pressure will this develop?

13. SUMMARY

We have attempted to develop a first-round-description reductionist theory of the physics of modern societies, emphasizing the role of the city and corporation in supporting the political structure. Alternate views are described in (13), (14), (17), and (51).

That task is an awesome task. Most people, including both physical and social scientists, are wedded to the notions that life and social phenomena are too complex to describe by physical law, and that man is endowed by a free will to escape the net of determinism that a universe of physical law might imply. Yet clearly, the primitive substances, of particles, nuclei, atoms, molecules; the apparent continuum matter of the planetary atmosphere, hydrosphere, and lithosphere, the stellar atomosphere; the interacting constellations of stars and planets that are part of the complex whirling motions of the galaxies, and the cosmos itself are all subject and generally explicable by deterministic physical law. Is it only life and societal life forms on an obscure planet that can escape that web of law, or is it just that one must cast the net cautiously?

The fundamental debate between those who would present a reduction of view of human behavior and those who deny the basic validity of this approach misses the truth and diverts the attention of highly motivated professionals on both sides. Those who oppose the reductionist view consider the complexities of the human organism and his environment to be so vast as to be intractable to reductionist techniques. Indeed, the human <u>may</u> be more than a finite material combination of inanimate building blocks. The point is, however, that physical reasoning extending the frontiers of explored physical domains into living systems can produce impressive results. There are many important classes

of human response that can be accurately described by physical reasoning. The concepts of the physics of living systems provide an enriched methodology that need not be at odds with other views so long as they all submit to the empirical tests of reality. Humans contain undreamed of potentials and complexities. They also contain unimagined physical responses that reflect simple scientific truths.

If we quickly turn our focus in the hierarchy of systems on the ecumene, the polity, and its structural atomisms - the concentrated organized settlements of people who themselves are organized by bonding groups - then we can identify the physical science relevant to cities and to transportation.

First, we deal with the thermostatics of the polity and settlement system. The polity maintains a population of people; this includes moderate growth and decline, also immigration and emigration. That population is distributed among fixed settlements down to a minimum quantum size, as well as a maximum quantum size. In addition, there is a fraction of the population transiently in flux.

Because of the life characteristics of the living entity, the first time scale for thermodynamic near-equilibrium in the polity is the generation time, approximately 25 years for people. On the other hand, because of the life-giving potential, the sun, a large number of processes have relaxed at the daily scale. Thus there are a great number of almost complete relaxations to be found in that range (1 day to 25 years).

For maintenance of the form and function of the polity, there must be balances in materials and energies, and these must be achieved by action-momentum modalities. These complex systems have a large degree of internal complexity, and so they have evolv a command-control system which controls how momentum impulses are used to initiate action rates (action is the product of energy and time). What emerges, in a homeokinetic sense, is a Markov

chain of linkages in a matrix of action modalities. One eats, sleeps, works, etc., in characteristic patterns.

The large spatial range, population range, temporal range, and complex of internal process leads to the expectation of logarithmic distributions. Thus population is basically distributed equally among settlement sizes in octaves, e.g., nearly equal populations for all cities ranging in size between each factor of two in population. At the present time, we cannot distinguish among a number of such logarithmic laws, such as an exact harmonic series of relative city sizes 1, 1/2, 1/3, etc. (Zipf's law), or a series like 1, 1/2, 1/2,1/4,1/4,1/4,1/4, etc. We will consider all of these distributions Zipfian.

The thermodynamics of living systems is based primarily on the sun as a potential source, and the earth as a second source of a variety of potentials. A complex species like man enters into an ecological web with many other thermodynamic living and nonliving engine systems. However, the special characteristic of man is his extensive tool-making and tool-using capability, his capability for the abstraction of speech, and the epigenetic character of continuing evolution of the content of his abstractions - technical and scientific evolution of how things work and how to make them work in new ways.

When, as a result of climatic change, man changed his character from that of a primate hunter-gatherer to a settled agriculturist, these competences took on a fantastic "linear" growth. That is, each generation-increment of time had the same competence to add new technical complexity to that which had been learned before and to transmit it.

A characteristic style of human existence then emerged. Depending on technology, a fraction of the population was tied to the earth in agriculture; much of the remainder was tied up in urban settlements; these settlements - while filling up the earth space with an appreciable density related to man's daily walking range - generally precipitated for reasons that favor resolution of conflicting considerations. A convective process then provided

assurance that a thermostatic balance would take place: the necessary materials and energies and people were circulated to maintain the function of the social system. Thus, for a variety of local reasons, a certain fragment of the population continued in transit.

Such internally complex systems do not maintain their processes solely out of simple collisional interaction. Condensation and the emergence of order parameters lead to the development of a command-control system and a chain of authority. In man this emerged in his new brain, which is capable of dealing with abstractions and values. In the social system, this emerged by the development of an elite class structure. This was already foreshadowed in mammalian and more particularly primate ancestors. Through all time, there have emerged two classes - those who rule, and those who are ruled. This is not a function of ideology, although the forms that the ruling classes adopt may vary with ideology.

In any case, a rule of law and a polity emerges. There are rules for the conduct of the bonding group, the settlement, and the polity. Out of the value systems in the human mind, the notion of a new thermodynamic variable, value-in-trade, emerges. Its unstabilizing effect is to change society from a single class distribution (e.g., a Neolithic hunter-gatherer extended family with a primate leadership) to a dual class distribution - the many who are ruled, and the few who rule. The growth and segregation of social "wealth" and "power" occur.

Given a people, a technological epoch, an ecology, and a land, various elite rulers can (and do) arise and govern that society. It is a cooperative endeavor. The settlements professionalize and bureaucratize all division-of-labor efforts. In terms of these five classes of variables - materials, energies, action modalities, population, value-in-trade - any number of leaders, past or present, believe they can run a society for their generation, given a modestly benign land. What we have done, perhaps different from other more intuitional approaches, is to formally

identify the minimal variables required in system's balances, and to provide some assurance that these are in fact physically determined and not pulled ad hoc out of some magician's or even philosopher's bag. Abstract computability of the command-control operation of such systems is thereby advanced.

But in running such systems, there are a few systems' notions that we have to add. First, since we are dealing with near-equilibrium operation, (at the generation or few-generation level), we are not confronted by determinism-versus-free-will arguments. At this time scale, the individual freedom has largely disappeared. Even the perception of the great man has largely disappeared. We confront near-equilibirum computations that take us from time 1 to time 2. Second, within the polity, there are two large-scale processes that persist in every epoch - trade of the polity within the ecumene, and thus trade among population centers, which matches requirements and intermittent warfare among polities in the ecumene approximately every generation.

Idealistic persons might like to develop peace in the ecumene. We have argued that war is part of the same abstractionist construct that creates language, and values, and value-in-trade: there is a mismatched perception among polities for each new generation of players, and the agressive hostility of war attempts to redress the perception. Within that construct, then, leaders can function to develop fluctuational balances around the mean balance required for the society. Further, these same processes - of trade and war - develop very strong forces that govern the relative rise and fall of urban settlements.

But then how the ensemble of centers - urban settlements, farms - persists instead of collapsing relates to the fluxes and potentials in the large polity field. This is no casual sentence or cliché. It appears, for example, that to maintain a healthy ensemble of urban settlements requires a goodly flux of trade external to the polity.

Then the relation between the urban settlements and the land is dominated by how they deal with the basic potentials that can

be indexed by earth coordinates. The potentials of population, of production and of consumption are slowly varying space and time functions. They only change modestly in time; they change more with the evolution of technology.

The effect of transportation systems within the polity is loosely as follows: given technological changes, both new and old elites see opportunities to exploit those changes. That exploitation, by investment and mobilizing the number x power product of people and machines, increases the action rate going on within the polity. More resources and energies flow out of the ground. More food is produced. The population of the society changes in proportion to its changing perception of a satisfactory lifestyle. Each (generation) epoch then produces new technology and the life cycle goes on.

The effect of transportation systems is impressed at two different points in the system. These are identified with the local problem, and the inter-settlement or polity problem. We have stated that the maintenance of settlements is dependent on the polity and ecumene, and transportation system. Long-distance transport by sea and its slowly increasing rate of speed has been highly influential in determining the maintenance of the status of large polities. The explosion of the modern age of the west in the past four centuries has been highly dependent on that technological development. It behooves the USA to attempt to keep a competitive position in some long-distance transport. We have stopped innovating and have left that achievement to others. A future dependent, in one component, on air or space travel may not be possible much longer because of fuel costs (except for defense), but whether by water, air, or space, a continued process of involvement in thermodynamically efficient (in materials, energy, people) long-distance transport is essential for the health of our internal settlements.

The same conclusion is true for transport (materials, energy, poeple) within the polity. An adequate system of high thermodynamic efficiency is essential.

A superadvanced transportation system, or one that is too costly, that is not geared approximately to the real needs of the future, is of no more use than an inadequate system. We have pledged our system for the past hundred years or so to coal, and the past 50 years or so to oil and gas. Except for a specific data, the time scale of these currently nonrenewable resources is running out. It is timely that national planning for a next form of power and transportation system be begun. While we believe that we know the form that such planning has to take, more to the point is that such planning be begun and the technological commitment to produce it be begun. The R&D phase of some of the requirements may extend over a long time.

The effect of a new long-distance transportation system, or an optimal mix of systems, is to help determine what opportunities both present and future elites will see for exploiting our national potentials. That will determine how rich a future the American people can have. We have indicated what constraints we believe exist on such future transportation planning. Others may see different constraints.

Finally there is the problem of local transportation. In perhaps two generations, a transition has been made from animal power to mass transportation by engine power converters using central combustion fuel or auto combustion fuel. That permitted the growth of urban settlements and their populations. However, the mix became more heavily dominated by the automobile. It has posed serious congestion and saturation limitations. This is becoming more seriously exacerbated by potential future shortages of fossil fuel. The large populations that technology has made possible (e.g., via increased food-production capability and via knowledgeable health practice) require large population concentrations. It is simply not thermodynamically efficient, not possible, to create a homogeneous spread. The approximate cutoff in small-sized settlements is of the order of a few hundred people. While one can visualize a thermodynamic relaxation to a tremendous number of such villages, little or none of the scale for efficiency required to maintain a high industrial and advanced modern society

would be possible. Clearly, a small fraction of the population has no objection to returning to such a pastoral existence, but the influx generation by generation of people with some taste of a lesser degree of labor-intensiveness and the attractions that large-city trade can provide, does not make this the alternate of the future. Thus the transportation problem of adequate daily speed for the population distribution within a radius of 5, 10, and 20 or more miles has to be faced.

The transport and communications systems of a polity serve two functions. In the large scale of the polity they speed up fluxes to prevent the system from breaking up. This is not an idle notion. At the present time, transportation costs have reduced the competence of our system in serving the more remote, sparsely settled portions of our country. As that population can attest, it has produced some state of crisis in the viability of such communities. The issue is not these communities, but the ability to hold a nation and its internal organization together.

In the smaller scale of the polity, at settlement sizes, the transport system controls the ability for the settlement to serve its productive function. But this is particularly related to the poorer urban segment of the population. A polity cannot survive if the pool of its poor are on welfare rather than productively involved. One might very well define the mission of the elite to see to it that all of the members of society are socially involved. If they do that, then it does not matter what they take as their share of the pot. If they do not do that, then the elite are not worth one minimum measure of value-in-exchange.

In the past, the populace was basically charged equal shares of their income for food, shelter, and personal expenses. One notes a tendency for the health component to begin to demand a full share (not there yet, but getting there). It would be a very great transformation in the system to begin to demand a full share for energy and transportation. Can the urban poor function in this case? Policy makers for future transportation, both local and national, will have to keep that in mind.

We note that the large corporation has moved into a power status where it competes with and may supersede the urban settlement as an institutional form. It is not the case that the phenomenon is new, but the character of a formal competition among these entities is changing. It is quite conceivable that social systems' design, e.g., transportation systems, may have to take this new social phenomena into account. Cities must be treated, within the nation, as a cooperative ensemble, an ecological net which supports the life of a nation. To let the role fall to the large corporation may or may not be desirable, but one would surmise that public policy consideration be given to the issue.

13.1 MORE DETAILED RECAPITULATION

In a previous contract, we had developed a physical-science-based social system model. This model indicated that the autonomous variables, both steady-state and time-varying, of a human society were to be found in the following:

a. A materials balance

b. An energy balance

c. A balance among human activities

d. A population balance

e. An economic balance among value-in-exchange parameters.

The underlying physics relates to the fact that, in interactional exchanges among people (to which statistical mechanics is applicable, since the interactions present a physical system), the following quantities are the only ones that are always guaranteed to be conserved:

a. Matter can neither be created nor destroyed, only transformed.

b. Energy can neither be created nor destroyed, only transformed.

c. Momemtum cannot be destroyed, it can only be transformed into physical action (physical action is the product of energy and time locked in a specific mode).

d. A biological species neither creates nor destroys itself - each generation it is encoded to reproduce its form.

e. In modern times (since the Neolithic revolution), man has assigned the notion of value-in-exchange to his transactions - in each transaction, value-in-exchange is conserved.

For the active processes, that are found in a human society to go on, there must be five major potentials available to fuel or drive the social system. These are:

a. The environmental potential of temperature (as part of the entire presentation of weather)

b. The environmental sources of free energy

c. The genetic value system

d. The epigenetic (or learned) value system

e. The technological potential of the human mind.

The underlying physics relates to the environment of potentials upon which people feed in order for its society to be conserved, namely:

a. The life process depends on the radiation temperature environment for photosynthesis, particularly related to water, and the gel-like materials of protein, fats, and carbohydrates.

b. The advanced life processes have to exist in a complex ecological web, since they cannot live just off a photosynthetic process.

c. The action spectrum of a living system derives from its genetic encoding.

d. Humans, with their competence to abstract, speak, learn, remember, and transmit, develop a culturally inheritable system.

e. An essential character of that abstracting ability of human mind is the ability to develop tools and other mechanisms and processes out of whatever is at hand, and add new technical potential each succeeding generation.

We were asked to use that new social science base to consider determinants of settlements and settlement sizes, and the effect of transportation systems on settlement sizes, and to consider the physical basis for demographic potential theory, all as it could be related to national transportation planning.

13.2 THE DETERMINANTS OF SETTLEMENTS

The application of the first four potential compartments to humans, prior to fixed agricultural settlements and thus a subsequent need to invent value-in-trade, led to the development of an extended family of the order of 25-50 people roaming in a potential home range of daily walking range as a hunter-gatherer "molecular" society, essentially isolated from other settlements. Their distribution function - the distribution of such extended family sizes - could be described as a Boltzmannian distribution, exp (-aP).

The distribution of isolated extended hunter-gatherer families is exponential with their sizes. That size distribution has been found to exist among all of the small isolate cultures reported in Murdock's Ethnographic Atlas. There is a finite cut-off at minimum size for family viability and one for the maximum size at which such hunting-gathering can still be stable.

But when we turn to fixed agricultural (post-Neolithic) settlements, there now is interaction among settlements via the variable of value-in-trade. The instability introduced by this new autonomous variable transforms the form of the distribution function. First, as both the sociologist Sorokin and we ourselves have argued, the sociological unit of organization, which we have referred to as the social molecularity, persists at essentially pre-Neolithic isolate size. That size is more characteristic of the primate mammalian brain with its genetic coding, as represented

in the primate troop, than is something new in men. One can bond with a limited group. The new post-Neolithic society is th represented by all of the bonding groups that people enter into, now richer than the prior single hunter-gatherer group. We have identified about a dozen such groups. They include the basic "occupations," such as farming, nurturing, trading, bossing, raiding, "signifying" (abstract functions of reading signs, such as priest, scribe, intellectual), being a cog-in-the-machine, scavenging. These bonding groups are essentially life commitments. They are developed as hard bonding forms that are not easily broken up. They are literally "chemically" bound, part of human body chemistry.

On the other hand, the inborn attraction to interacting population centers and the forming of their distribution function is a much weaker constraint. The population rule, loosely identified by Zipf's rule,

$$P_o = P_r^r$$

where:

r = rank-order of population center (e.g., 1, 2, 3, ...)

p = population of the rth-ranked center

p_o = a characteristic number, e.g., the population of the largest center.

on the other hand, we have identified as a "communicational" language of thermodynamic systems that are constrained by its physical compartments. Between our physical contributions to the theory and the very specific result that our project officer, Dr. Hassler, was able to derive, we now are certain that Zipf's law is only a kinematic constrained law of thermodynamic systems, a "language" that they use, and not an intrinsically bound physica constraint. Since this was one of the major results we had to achieve, we must indicate its significance for transportation policy and planning. The status we have achieved for this

relationship is a much clearer understanding than Zipf or Mandelbrot (a subsequent commentator) have brought to the relation.

Zipf's rule indicates that a thermodynamically constrained system, when it has to express its actions (e.g., by communications or by disposition of its states or complexions) among a considerable number of states or complexions, where only the population of the complexions is constrained, will most probably array them near Zipfian. Actually, the more precise rule is that the population distribution will be equal in each logarithmic octave (k-nave, if some other log base is used). Thus the population distribution will be essentially the same in cities: say, in the ranges 10-5 million, 5-2.5 million, etc.

Thus from a policy or planning point of view, unless the ruler (or administration) has some very specific dynamic reasons for having to change the distribution, they should be satisfied with that equitempered rule. It may be referred to as the rule of democracy, or of blind justice. Recognizing real physical reasons for cut-offs in a logarithmic space, the policy makers should devote as much effort or attention to each equally populated logarithmic interval, whether it be in population space, or in action time.

Of course, the distribution has cut-offs in the logarithmic space. At the bottom, the cut-off still remains roughly the top of the pre-Neolithic isolate extended family. A settlement of the order of 200 barely has current survival value. Or conversely, one notes that transient populations, wandering among fixed settlements, only begin to have the latent possibility to feed the settled population by condensing or being attracted to settlements of that minimal size.

At the other end, cities in the largest sizes represent the measure of distribution of all settlements (e.g., the first logarithmic interval starts out with the sparse number of 1 or 2 largest cities). Thus the largest centers represent a parametric

measure, in a logarithmic sense, of the fraction of the population that are not occupied in more nearly isolate farming families they represent the urban population. There is a modest problem to determine the transient population, but that is related to opportunity or lack of opportunity in the society and to the need to feed the population centers among all logarithmic intervals. If a political leadership wishes to shift the population distribution, and it had better have compelling reasons, (example - man wishes to bring the species of horse as a draft animal to the western hemisphere or polity leaders wish to diversify industry for defense) then additional constraints are required to put clustering into the distribution.

There is a characteristic dynamic pattern (e.g., 500 years) along which civilizations tend to force their distributions, so that both rise and fall of their civilizations will take place, but that would be considered speculative within the scope of our contract. Thus we stand with our and Sorokin's notion: that in any technological era, it is an equitempered preservation of the bonding groups rather than the population centers which is the essential function of a useful government interested in its own survival and well-being. Since this affects government and industry rather than the institution of transportation directly, we must now address a second topic - the spatial character of settlements, and the potentials bound to earth. Transports, in a technical physical sense, deal with how those physical variables which we characterized as autonomous because they are conserved in local interactions, are in fact changed by movements into or out of the local atomistic region. Transportation, in the DOT sense, is the extension of that underlying concept where it is in fact large masses of people and materials, that are moved between regions at various spatial and temporal scales.

13.3 SPATIAL CHARACTER OF SETTLEMENTS

The pre-Neolithic settlement was isolated at daily walking distances. Thus a few hundred miles represented absolute isolation, and say 70 miles (derived from continental data) represented very minimal contact between adjacent "tribes."

In post-Neolithic society, with agricultural settlements and trade, the separations dropped down to less than daily walking range. But the important point is that - whether pre-Neolithic or post-Neolithic - man felt out the potentials of the earth. Thus water, topography, resource, and defense possibilities, etc. have been loosely known for many millenia.

In an a piori sense, thus, one finds a similar homogeneity in centers for American settlements in 1790 and 1970, similar also for a star field. That spatial picture depicts the rough uniformity of population in each logarithmic interval. Of course, that overlooks the detailed topographic/topologic factors which the many generations of humans have felt out earlier. Deserts and mountains, arctic regions, etc. create very specific local deformations. Physical descriptions always suggest that you learn the general picture as an idealized problem, and then attend to the reasons for detailed local deviations.

If one examines the local population settlement, one would expect a characteristic distributed form. D. Kahn, of the Systems Center, has in fact examined a considerable amount of experimental data and verified a particular exponential model. Again, in a physical sense, we are not asserting that all cities have a particular hard radial distribution - after all this contradicts the human's abilities to feel out the potentials of the land - but that as an approximate idealized physical rule there are certain kinds of local ingathering forces that produce an urban center distribution of population.

Thus, from the instability produced by requiring fixed agriculture and movable trading, urban centers nucleate and grow with a characteristic spatial distribution; in summation they produce a characteristic equal logarithmic distribution of population sizes. Now, the actual total population or population density of the polity and its transportation requirements depend both on its national resource potential and the kind of trading or raiding processes that it maintains within the bounds of its ecumene.

13.4 GENERAL PROCESSES IN THE POLITY

For simpler pre-Neolithic settlements and other biological species, most often it is the so-called carrying capacity of the land that governs total population limitations. With humans and growing technology it is possible to increase that capability, but we were highly surprised to learn, in this study, that the viability of cities since the Neolithic period depends very largely on long-distance trade, trade in the entire ecumene. That is a very unstabilizing physics. It dominates the history of man, from Anatolia-Armenia of 6000 B.C., from the first empires of 2000 B.C., the Roman Empire, the new formation of nations in the 15th century, the expansion to the western world, the industrial revolution of the 19th century, the rise and fall of 19th-20th century empires, the modern rise of the multi-national corporation.

A major reason for ever-increasing trade has been the linearly increasing process of technological complexity, which keeps finding new ways to use and increase the number and amount of materials and energies. On the other hand, the competence of people does not change. They continue to do the same things.

The consequence is that if the utilizations of materials and resources are distributed over the land area so as to be represented by consumer and producer potentials per unit population density, one finds that these potentials are very slowly varying functions of time.

In our collaboration with Dr. Hassler, he has begun to gather and develop the data base by which the actual form that these potentials take can be seen and can be queried. The results are interesting: they reveal, basically, that very slow effects of change as a trading nation, concentrated on the east coast, has gradually spread to the west coast. The value of these potential representations - for the production and consumption of the important classes of materials, their transportation potentials, for energy production and utilization, for population concentration, for economic value - is that one can soon begin to query this representational system above the performance of its various autonomous processes. One can begin to see how government policy, in particular transportational policy, begins to affect the system. We are at the point, at the end of this contract, of developing the dynamic interdependent relations that determines the socio-political-economic-technological operation of our American society. Policy that does not understand how it affects the real dynamic relations can easily be counterproductive.

13.5 TEMPORAL PROCESSES IN THE POLITY

In particular, when we speak of dynamic interdependent relations, we have a very specific spectrum scale of operating processes in mind. These operate via a cascade wherein the longer time-scale processes press on the shorter-scale processes, down to the fastest of social concerns. We visualize these scales as:

a. Daily repetitive processes
b. Weekly processes (a fact of social organization)
c. Seasonal processes
d. Yearly processes
e. 3-4-year processes - basically political
f. 20-25-year generational processes.

A major social signal which dominates the last process is the epoch between wars. People attempt to retain their positions of influence or association in the social chain for their generation. The major techological explosions connected with wars, and the wear of people and of materials tend to dominate that time scale. Decision- and policy-making tends to be coherent at that scale. The polity holds its face for that length of time. Our large-scale systems (plans, factories, transportations systems, technological changes or advances) tend to have to be designed for that scale.

Even without detailed formal dynamic relations, on the basis of these ideas one can sense the effect of existing and new transportation systems on the nation.

a. Its role is to permit its citizens the free motion that is required to keep the compartment balances operationally full. This is presumably a most elementary statement.

b. Coupling this with the "blind justice" nature of equal populations in each logarithmic interval, we can understand better what a complete transportation system has to do. It has to serve each population segment equally. If, for example, the farm population has now dropped to f percent of the total because of technological change, its needs for public transportation has dropped to that level. If there is a 25 percent transient low-paid labor force in this country, it is necessary that they have a satisfactory public transportation system for their needs (e.g., bus, train). This component cannot be neglected. DOT may not have to deal with the elimination of poverty, but they must deal with the access of the unemployed or poorly employed to transportation. The mobility of population, and the ability of the nation to respond to trade needs and defense needs remain key ingredients in commercial societies. Then the problem is how to serve the rest of the population, the urban segment (i.e., 70 percent) by public means.

There is an answer that has served quite well for 50 years - the compact self-powered engine system, the automobile. Thus the public answer was to serve equal access roads to all segments of the populace. That is part of what is known as a dilute concentration, noninteracting solution. The compartments were not so tightly coupled. Energy (e.g., as fossil fuel) was known until 10 years ago as almost a free or unlimited commodity, but now the compartments have become fully interacting, no longer dilute concentrations. In economic language, we are faced by scarce resources. Thus the problem is to arrive at a better mix of what constitutes equal public service to all of the population.

These ideas, as a report summary, do not solve the problem, but suggest the kind of answer that technical people working in these coupled process problems are familiar with. That is, pursuing our coupling ideas, assigning materials, energies, activities, population, and dollar costs to various mixes of solution, one can arrive at an estimate of the optimal mix and kinds of new transportation that are needed. The major optimizing constraint that has to be provided is that it has to serve all segments of the population equally, all time frames for which it has been planned equally; and it has to be equitempered across all productive segments of the technological economy.

We are prepared to offer continued detailing of the dynamic relations governing society and the best form of policy to administer the operation of such a complex society for any of the major complex institutions in the nation. We are appreciative of the opportunity to have learned in the beginnings of this physical science art in Army and DOT contracts.

14. POSTSCRIPT

Our project officer, Dr. Hassler, has taken the content of the arguments we have offered and has reduced the development to its truly minimal form. He has shown that Zipf's law emerges from the bare bones of distributing population number in equiprobable class intervals:

$$P = \sum_{1}^{k} P_i = \sum_{i}^{k} i\, n_i$$

$$N = \sum n_i$$

Then Zipf's law emerges from exremizing the number of complexions (W):

$$W = \frac{P!}{\prod_{k} P_i!}$$

when only population intervals are constrained.

Namely, $\delta \ln W + A\delta P = 0$

then $P_i = i\, n_i = \text{constant}$

emerges.

Note that this does not conserve the number of settlements N, only population P. Its most significant implication, as we have surmised in that in any logarithmic interval, e.g., for cities with specific populations between 2500-5000, 5000-10,000, 10,000-20,000, etc., the cumulative population is constant. Zipf's law then really only states that any individual has no more reason to be attracted to one available interval than another. Thus it is a very weak, essentially nonphysical constraint. Physical constraints, as we have shown, attract and condense population in accordance with the highest moment equation, e.g., a Maxwellian distribution for kinetic energy, or the Boltzmannian.

We properly have referred to the Zipfian distribution (where it arises as a selection process used by thermodynamic systems) as a "near-noise-like" thermodynamic language. First, there must exist a thermodynamically constrained system. Second, it has to require a language of many complexions. Then the thermodynamic system constructs the language out of materials or energies at hand in a "natural" process that fits the system.

But then these results lend greatest support to the notion that the most important social entity is the social molecularity, the social bonding group. Its properties really govern the thermodynamics of the polity. We would tend to believe that this was the sociologist Sorokin's major thesis in characterizing the canvas and course of the social process. We would therefore believe that the conservation of social molecularities, in full thermodynamic sense, becomes the major tool for sociopolitical planning. This modifies our conclusion in section 1.2(b). On the other hand, it proves our conclusion in the same section about equal octave distributions. Thus, for policy or planning purposes, one can use that weak conclusion unless there are stronger thermodynamic reasons for clustering. The emergence of bonding groups has to come from the cultural-economic-technological processes in society; government regulation must come equitempered. When adminstrations favor particular groups at the expense of others, except for major crises, counterproductive results often occur. The social health of a polity requires a harmony of all its parts. And that is independent of ideology.

APPENDIX - REPORT OF INVENTIONS

The work performed under this contract, while leading to no invention, has led to several innovative concepts on the use of near-equilibrium thermodynamics for living social systems. Compartmental balance of food materials, energetics, manpower, productive function, economic balance, and technology were introduced as concepts for social systems modeling, as well as the idea of summational invariants for social systems.

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