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Key Address on Dynaculture: Progress as a Deadly Contest

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DYNACULTURE: PROGRESS AS A DEADLY CONTEST

My distinguished colleagues have discussed for us this morning several vast and vital problem areas faced by this state and this nation today. In what follows, I shall offer you a viewpoint of the current world contest and of the factors which will govern its outcome. I hope thus to provide a useful background for our further discussion of these state and national problems.

For this purpose, I must ask you to go back through some ten millennia of time. In the beginning, man was a hunting animal. He followed the wild herds as the lions do, or fished the streams and lakes. Then after a long time, some early and long-forgotten discoverers found the secrets of seed and growth, of the cultivation and harvest of plants and animals. Now an agricultural group newly established in a fertile land could make, for a long time, an increase in its food supply to keep pace with the growing population.

Thus towns, cities, states and empires grew. The old hunting cultures, overwhelmed by the force of numbers, were driven from the fair places of the earth into the barrens and the hills, there to survive in a state so weak and miserable as to be beneath the avarice of these new masters of agriculture.

But the acquisition of new knowledge, which is the very source of power, remained a hunting process. The inventor, driven by the old urge of necessity, could do no more than wander among the bewildering phenomena of nature; and for the most part, he was both scorned and feared by his fellow man who looked with suspicion upon his tampering with the proven way of doing things. So it was through most of the seven millennia since the invention of agriculture. The endless, unprogressive rotation of the seasons was central to the life of man, and from it he drew the picture of his own predicament. Bound to an ever-turning wheel of fate, he saw in his circumstances no prospect for the betterment of the lot of man on earth. True, some individuals by cleverness and strength might take from others, but this could be done only by the oppression and impoverishment of those others. During these millennia, mankind evolved the ethics, and the social institutions, that we still use today.

Then came the Renaissance, and with it the discovery of the scientific method. Now the seed of truth could be cultivated into theory and winnowed by experiment to produce an exponentially growing flow of useful knowledge. At first, the seed of knowledge was small; its increase, smaller still. Then, in gathering volume it produced in England in the 1760's the beginnings of the industrial revolution.

By 1850, the tide of that revolution was flowing across Western Europe and had spread to our own New England. That tide of revolution carried at its crest social turmoil and anguish, coupled with rising powers. In our own land it generated the Civil War.

By the turn of the century, it had reached Central Europe, where in due course it generated World War II. By 1940, it had appeared in South America, and its fringes stood roughly as shown by the boundaries on this chart. Then, through a war dominated and decided by technology, sparks of it were scattered across the world. In 1962, the main wave moves on to meet new-rising fires in India and in China. By 1980, only a narrow belt of the habitable world will still await its touch--and this last belt will dwindle to include by the turn of the twenty-first century only the most cruel of the deserts and the jungles.

In the mid-twenty-first century, the world will be approaching industrial maturity and a new factor will be emerging dominant for human destiny. But that is well beyond the forecast period of interest to us today. What is of key significance to us is the fact that this present wave of the industrial revolution: of rising hopes, of change, of conflict, and ultimately of human power, is the most certainly predictable characteristic of the human future.

We foresee a world dominated by social change and growing human powers -- a world in which progress has become a new and deadly contest -- a contest whose nature and rules are strange, demanding, and not widely understood.

Clearly, then, the present international technological contest must be scored in terms of the amounts of knowledge possessed by the various contestants and of their ability to make speedy, efficient use of knowledge to meet their needs.

Let us develop the equations for the growth of knowledge. The rate of increase of knowledge is governed by three main factors, which can be described in plain English and which will correspond to three terms in the equation. First, by virtue of the nature of the scientific method, the rate of increase of knowledge is proportional to the amount of knowledge already possessed. That is, a body of knowledge that is under cultivation by the scientific method grows geometrically; as we said above, like living things. It has a "doubling time." At the end of each such interval, there is twice as much of it as there was at the beginning of that interval. The rate of increase is, of course, also proportional to the effective research effort that is being applied to the body of knowledge. At present, the doubling time for the body of knowledge in the physical sciences is about 15 or 16 years; that is, we know about twice as much physical science in 1960 as we did at the close of the war in 1945. So, in the equations of competitive progress, we have a "research term", KI , where K measures the research effort and I represents the amount of existing information to which it is applied. The research effort K is determined by the following main factors:

- Training and experience of the research workers.
- Motivation and environment.
- Native capabilities (frustration tolerance, intelligence, vital energies).

Number of research man-hours expended per year.
Laboratories and other supporting facilities.
Enlightenment and firmness in financial support.
Status of research in the community.

Management actions determine these factors and thus determine the rate of discovery.

But there is another source of scientific and technical information one may obtain it from his rivals, or his friends. For any specific foreign nation the rate at which we may obtain information from it will be roughly proportional to the amount of information it has but which we do not, and to the effort that we make to obtain their knowledge. We may measure this effort by an "intelligence coefficient," L . (Most of this information will, of course, be gotten by perfectly open and above-board methods.) If we call the difference of knowledge ΔI , then the equation will contain an "intelligence term" $L \Delta I$.

One now observes that even secret technical knowledge is like a radioactive nucleus. Once in being, such knowledge has a certain probability per unit time of decaying into the other fellow's hands. That is, secret knowledge of nature has a half-life. You may make your own estimate (from reading the newspapers) of the length of time that the secrets of either side last before "decaying" into the hands of the other side. It is certainly less than two years. Particularly, if you have an important new secret, and start to use it, this will change the pattern of activity in certain parts of your R&D laboratories and in your factories. The change is virtually impossible to conceal from an alert opponent. When he has these clues, the secret soon evaporates. Once out, that secret is gone for good. You cannot change Nature as you might change to a new code or revise the plans for a military attack.

Finally, knowledge may be forgotten, or be misfiled, or lost through the death of the individuals who held it. The rate of loss is proportional to the amount of knowledge on hand, and to some "coefficient of forgetfulness"; call it M . In a large modern nation, the problems of the storage and recall of information are very great. Some have thought that the growth of useful knowledge would finally be checked by this storage and recall problem. Examination of the real situation today yields no evidence that such a limit is at present being approached. There is reason to believe that the increase of information is itself providing adequate new technical means for the handling of information. We will subtract the loss term MI in the writing of our equations, but this will make no significant difference in the present practical results.

So, we arrive at the equations of competitive progress: If the rate of growth of knowledge is I ,

$$I = KI + L \Delta I - MI$$

One such equation can be written for each contestant.

Let us apply this equation to the real world. Suppose there are two contestants: U.S. and USSR. Assume that in 1945 the U.S. has ten times as much information as USSR. Now for the "decay" even of classified technical information, the US-to-Russia half-life is surely less than two years. So, by 1959, seven half-lives later, the U.S. discovers that the initial lead has almost disappeared. Furthermore, the original lead cannot be recovered by increasing our research effort K . Suppose we double our effort. Even if our opponent does little original work of his own, he will lag us by only about one half-life, about two years. He will enjoy some additional benefits from our accelerated program. Nor does it seem feasible to materially lengthen his lag by increased security; in our society this can hamper us as seriously as it does our rival. So, as time goes on, the U.S. - Soviet ratio of information settles not far from 1. The two powers, locked together in the strong harness of their rivalry, race up the ever steepening slope of change. Efforts to draw ahead simply increase the rate at which both contestants must meet the effects of kaleidoscopic change. We have seen in our national military and space programs the stress which that change induces.

The cold war in this model will end when the men and institutions of Russia, or of America, weaken and give way in the mounting torrent of change. The lead time ratio, and other indicators, will first give warning of the approaching end. The growth curve of the loser will then fall away from the stern, straight line of the exponential. Confusion and fear will tire into resignation; determination will fade into submission. Who will fail first?

Will we, like the hunting bands of old, meet with a new, dynamic, and alien culture of knowledge; be in our turn cast out from the fair places of the world? Will our shattered remnants be driven to the barrens and the hills, there to live on only because our wretched lot is beneath the avarice of our masters? Or is it perchance in us, in our vision and in our stamina, to be creators of this new dynamic culture: to be masters of the future? Can we escape from comfortable custom and from lethargy before these become fatal traps, yet select and carry with us those elements of true and timeless wisdom which must be the foundations of a new way of life: a way in which fundamental and kaleidoscopic change is the normal and unending situation; in which whole professions, whole industries, rise and disappear in a time short compared with a human lifetime?

Our ancestors, who turned this continent from wilderness into a near-paradise in the span of three centuries, surely could have done it. We, with the vast resources they have given us, could do it if we will. How may we apply the strong tool of scientific method to this new problem of research and development of the first intelligent human culture; that is, the first civilization designed for adaptation to a changing environment? Let us here attempt some beginnings on the problem in order to see what may be done.

The design of a new, dynamic culture may be divided into four major areas, as follows: First; the individual -- his philosophy and his training for an ever-changing way of life. Secondly; the principles of organization, that is, of men working together in a situation where whole industries rise, have their use, and decay in a decade or two.' Third; the economics of change, the vital question of how to make progress at a profit. And lastly; the vast and ominous problems of politics and statecraft in an era when men live in the presence of titanic powers, not all of which will be in friendly hands.

First, for the individual, the dynamic man: Every culture has a set of beliefs so deeply held that if a man in following these beliefs, meets with disaster or death, it seems to him that the fault must be his and not that of these principles. Such a set of principles is called by the anthropologists the social myth of the society. For a dynamic culture, what must be these principles? I suggest the following: First, knowledge is power. The infant in his cradle must look up to see his parents, happily engaged in acquiring and using new knowledge. He must come to realize that his power to help himself and to help those around him depends on his learning, and learning to use, the information made available to him. Secondly, "The joy is in the becoming" -- not in the being, nor the doing, nor the having. The ecstasy of new insight is so strong a thing that research men become addicted to it; pursue it for its own sake throughout their lives. By teaching and example, the whole population of a dynamic society must be made to share and to value that joy of growth. In our society, the knowledge that a trade or profession will shortly disappear may inspire dread on the part of those engaged in it. The dynamic man will view with excitement and pleasure the opportunity to leave the old occupation and to engage in some new and emerging one for which he is now training himself. One result will be that the intellectual stimulus of college years will be extended on through life, so that men and women will still be going to school in preparation for yet another career at age 50 or 60. Third, "As you serve, so shall you be served." In a complex society, the individual is dependent for nearly all that he has or does upon the services of others. If he serves others well, then he will be well served. In the future society a free man will be one whom others are eager to serve, so that his wishes are fulfilled as soon as they are known. It can also be demonstrated in the mathematical theory of social relations that a substantial amount of altruism, of desire on the part of the individual to serve the general social good, is essential to a healthy society. Finally, in a society where change is the leading characteristic, social mobility will be essential. The specialist, in some obscure and abstract topic of today, may be the leader in the solution of tomorrow's vital problems. It will be essential that the individual move quickly from his present position in society to a different role and status as changing needs require. There can be no privilege of birth, such as the "divine right of kings." A basic principle must be equal rights and opportunities for all.

For the individual in a dynamic society, creativity will come to have a new importance. Creativity is not only essential for arriving at new, powerful solutions to engineering problems; its techniques are also essential to the individual in maintaining his personal orientation, even his sanity, as

he encounters an endless sequence of novel situations in which he has little or no previous experience. His work, his organization, even the machinery, the buildings around him, will change almost kaleidoscopically. A confident skill in the technique of creativity enables the individual to meet this situation. Creativity involves the following operational sequence: First, the creative individual must have native ability -- sticks and stones are not creative. Second, he must be prepared by education and experience. Then, there must be an encounter with a novel problem, and this encounter must involve frustration, that is, the routine solutions must be inadequate. This is followed by repeated trials and by maturation, that is, some time may pass before the solution is apparent. At last comes insight -- a flash of genius -- involving excitement and satisfaction. Not all flashes of genius yield correct answers. Verification is the role of the scientific method.

This is a rather different picture from that presented by some of our young professionals, who believe that creativity is enhanced by relaxation and luxurious surroundings. Necessity is still the mother of invention. It is true that Archimedes discovered his principle while floating in a warm bath, so that in the shock of insight he ran dripping through the streets of Alexandria shouting at the top of his voice. But there is a beginning to that story, less often told. The ruler of Alexandria had demanded that Archimedes solve the problem of non-destructive assay of the gold in the royal crown, by a certain date, or else he would be executed. The road to creativity, as often as not, lies along the rim of Hell. The dynamic man must learn to walk with confidence along that road.

We shall now turn from the individual to the matter of individuals working together to the organization of a dynamic society. Let us examine the traditional pattern of organization in the light of modern concepts. Any organization is a cooperative effort toward some objective, that is, an organization is a goal-seeking entity. In modern technology, goal-seeking devices are called servomechanisms, and a powerful theory of this subject has developed. Let us view the topic of organization in servomechanical terms. The nearly universal pattern of current organization is the hierarchy, and its familiar diagram is shown on this slide. In servomechanical terms, it is an open loop, multi-stage power amplifier. Its transfer function is the SOP. It is capable of repeated performance of a set of diversified operations. For example, if it is an automobile company and the big chief says "Make Ferd's," his will is enormously amplified so that a stream of almost identical Ferd's pours out of the factory doors. But such a servomechanism is potentially unstable. In a changing situation it displays a form of institutional hysteria. Let us examine hierarchial hysteria, that is, the change syndrome in hierarchies. One of the essential design features of a hierarchy is that the missions of the various organizational segments are almost independent, and that such interrelations as exist are simple and very constant. This minimizes the requirements for communication between segments on the same level. Technical change upsets this orthogonalization of the missions of the hierarchial segments. For example, in the old days the Army Technical Services were well-orthogonalized. The Signal Corps could wigwag to its heart's content without paying much attention to the cannoneers in the Ordnance Corps. Then came the vacuum tube and a technical

revolution which transformed and intermingled the activities of the Signal and Ordnance Corps.

The next step is "Mission Maginotism." The chief of each great office entrenches himself behind paper-filled filing cases and engages in what he sees as the defense of his established mission and budget. This kind of warfare does not lead to the solution of the technical problems involved, and the crisis continues to develop. Then the general staff, feeling that it has a duty to coordinate things, steps in and tries to end the conflict by issuing directives to the combatants. This requires a sudden radical increase in the number of staff officials. The result is what I call cancer of the staff. But everybody tells the staff that staffs aren't supposed to operate. This both inhibits the initiative of the staff and reduces the responsiveness of those to whom the directives are sent. The crisis now develops into an emergency, and there is a cry from the spectators that a "czar" is needed. So higher authority prepares an elaborate cloak of authority and places it around the shoulders of some individual who is supposed to be neutral and, therefore, probably knows very little about the situation. Now everybody knows that the czar is an artificial creature, and many of the participants probably knew him well in his less glorious days, so people don't pay too much attention to him. This usually leads to a very rapid succession of czars, and the situation gets worse. Finally, there comes to the czardom an individual who is genuinely both an autocrat and a genius. Such a man will arrange to maximize the tensions in the organizations concerned, and then either await or manufacture an acute crisis. The czar uses this crisis like a hammer to break the bonds of the old organizational patterns. The highly stressed structure comes apart in a way reminiscent of brittle fracture. Then follows a period of cannibalism, during which, under the guidance of the czar, the larger or more powerful fragments eat up the smaller or weaker ones. The czar thus attains his objective of reorthogonalization. For instance, in the missile case, there may emerge a hierarchy well-organized for missile development. But in today's world of swift moving change, that moment of good adjustment soon passes as technology moves on, and the cycle of hierarchial hysteria begins again.

Clearly the long-lived and classic type of hierarchial institution is not suited to a dynamic culture. Yet, in most men's minds, the hierarchy seems to be the only conceivable pattern of organization. We must seek a new way of looking at the principles of organization, and thus escape from the mental prison of our preoccupation with the hierarchial form. I propose the following viewpoint: Let us adopt a model of society in which the small squadsize group represents the social molecule or fundamental unit of organization. The social individual then is defined by his memberships in a set of these small groups. In general, an individual can have membership in something like 8 to 12 of these groups. The larger structure of society is in this model defined by the interlocking memberships of individuals in these small groups. Now it becomes easy in this broader pattern of thought to identify the hierarchy as a very simple and a very special case. The individual hierarch is defined by 2 belongings. He belongs to the group containing his colleagues and his supervisor. He also belongs to the group which he supervises.

The personnel of a hierarchy thus provide the intergroup interactions (a physicist would call them the exchange forces) which correspond to the pattern of a hierarchy. Using this small group model, we are now free to construct a great variety of other organizational structures defined by varying intergroup memberships and roles of the individuals. These relations can vary in an orderly way with time, and they can be extended to the relation between men and machines. An example of a time varying relation, in which the same men on signal, assume varying organizational patterns, can be found on the football field, or on a larger scale aboard warships, where the crew rapidly assumes changing stations and functions at the call of the captain.

We see that much research in the theory of organization for change must be done before we have a satisfactory capability for the design of dynamic institutions. But today's problems cannot await the outcome of this process. What can be done now? This slide provides some suggestions.

There is no substitute for entrepreneurship. The individual creative hierarchs must get themselves together regardless of hierarchial structure, and perform their innovative function on their personal responsibility in the fashion of free enterprise.

We now turn to the third major area of our study: The economics of innovation. We have noted that new, useful information is a key to progress. Information is the sole product of our national research program. For it we pay many billions of dollars every year. Let us examine the characteristics of information as an economic good. We shall find that information is a remarkable, indeed a unique, kind of merchandise. First, it has unlimited shelf-life. Second, it never gets used up. Third, it is unique in the sense that it is replaceable only by other goods of the same kind. It is a mold in which all who labor and all natural resources are poured, and the quality of that mold determines the value of all work and of all products. It is the only good that I know of which has a divergent marginal utility, that is, the value of a new piece of information is proportional to the amount of information you already have. The economic science required for the evaluation of any specific piece of information does not yet exist, but some general statements can be made about it. For example, the total value of a piece of information must be proportional to the sum of the marginal values attained from each use, integrated over all time. This sometimes leads to difficulties, because if the price to be paid for a piece of new information is to be comparable to the value of that information, there could be no purchases. For instance, consider what the King of England should have paid Isaac Newton for the invention of the Law of Gravity. Clearly, the total value to humanity of the use to date of that law would far exceed the total value of the British Isles in Newton's time. Yet, it is useful in evaluating research proposals to estimate the number of occasions on which scientists in the affected fields will change their research plans as a result of this work.

Another vital area in the economics of change is cost estimation. The consequences of an innovation are ramified: Its total cost may not be

at all obvious. A change set in progress by a few million dollars' worth of R&D may cost hundreds of millions, take decades to complete, and generate a great deal of human stress.

A topic of particular importance to this audience is the correct estimation of space systems development costs. When an overrun occurs in the program of one contractor, the whole community of space industry contractors has to pay for it in terms of diverted funds and stretched-out schedules. The advanced research and technology projects, which are widely distributed among the space industrial companies and upon which their future capabilities depend, are often the hardest hit. This situation, in which the future prospects of many companies, and of the nation, are mortgaged to pay for the miscalculations of a few, seems undesirable.

An effective remedy requires improved techniques in the economics and administration of change.

Economics is closely related to our final major area, Statecraft, and provides a convenient introduction to it. Let us compare the economic situations of the Soviet and the Western worlds. In the dual of gross national products, the Russian's thrust into the future lies at a steeper angle than our own. But he has been using his whole strength, and cannot lift his blade higher. We hold our blade at a more relaxed angle, thus. As things go, we will be overtaken about 1990. If our grip weakens (as the pessimistic economists believe it will), and if the Russian purpose holds, we will be passed in 1980. But we can, by economic skill and discipline, raise our blade thus, or even higher. We have the power to choose whether we will be overtaken, or not. The outcome depends to no small degree upon the cost effectiveness of the national space program, and upon the ability of that program to create new sources of productivity.

Economics is one major factor among others in the matrix of statecraft. The language on this slide symbolizes one aspect of the great, and decidedly dangerous, deficiency of the techniques of statecraft today. There is a need for brilliant minds of the scientific type to structure the field; produce a symbolism and a calculus to span it. Only then can we expect the rapid progress of techniques for the use of human powers which can keep pace with the growth of those powers in a dynamic culture.

In closing, I present to you the picture of America as a typical case of a backward and under-developed country. Consider these problems said to be characteristic of the "under-developed" societies. Such societies have an acute problem of capital growth. So do we, and the Government is making unusual efforts to ameliorate it. In emerging societies, a sudden drop in infant mortality, plus a continuing high birth rate, leads to economic distress. We, too, face a population explosion, with the threat of Malthusian disaster to our present standard of living. Then, there is the matter of "hidden" under-employment -- of "Uncle Bum" who lounges in the shade of the Banyan tree and produces nothing. The Communists have a pragmatic cure for this one. An armed patrol collects Uncle Bum, shoves him into a freight car full of similar citizens, and they all go off to work for the State. But how about hidden under-employment in the

USA? Did you ever hear tell of the 40 hour week? The 36 hour week? And on down? This decrease in time on the job is good in that it provides the individual with more freedom; more time at his own disposal. If he invests it in education, and in activities to increase the wealth of the community, all will be well. If he wastes it or uses it solely to increase his personal consumptive powers, then sooner or later he will lose his freedom.

Educational deficiencies are a hallmark of backward countries. We have this morning heard a discussion of our own problems in this area. In particular; we are deficient in the numbers of men who have taken the vigorous advanced training needed for success at senior levels -- a situation exactly parallel to that of the newest African nations.

And we are indeed in the greatest need of a "great leap forward" along the strange, new path of progress. Unlike the other "backward" nations, we have the strength. I have just pointed out the way. If we fail in this, it will be through lack of will.

So, I leave you with this thought: When all is said and done, the future of America depends upon what Americans do with their Saturday mornings.