Master

UNIVERSAL PRIORS TO SCIENCE:

HOW THE LIBERAL ARTS COULD REVITALIZE SCIENCE

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"Mourn not the dead that in the cool earth lie--
Dust unto dust--
The calm sweet earth that mothers all who die
As all men must;

Mourn not your captured comrades who must dwell--
Too strong to strive--
Each in his steel-bound coffin of a cell, buried alive;

But rather mourn the apathetic throng--
The coward and the meek--
Who see the world's great anguish and its wrong
And dare not speak."

-- Ralph Chaplin

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ABSTRACT

James Bryant Conant's warning that the American public is likely to mistake engineering and invention for science has largely come true. Political invention of technological system concepts that lack scientific integrity is the most recent and disturbing example of how far technology strays from science.

All science depends for its existence on these Universal Priors: the human being, language, reasoning through relationships, and archival representation. These are areas that belong to the liberal arts and humanities (in partnership with the social sciences and mathematics) as subjects for scholarship.

It is time now to dispense with the tired language of "excellence" and similar epithets that do not properly externalize the merits of liberal arts and humanities in ways to which science can be critically related. The liberal arts and humanities can revitalize science, but it will take more than empty slogans and superficial rhetoric to achieve this goal, which is becoming progressively more vital to world civilization.

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The products of twentieth-century engineering, technology, and invention can be partitioned into three classes which, for ease of later reference, I will designate as Class A, Class B, and Class C.

The Class A component consists of those artifacts that are founded in physical science. Among the examples of these are radio, television, laser and maser technology, semiconductor chips, electrical motors and generators, transmission lines, and internal combustion engines.

The Class B component consists of those artifacts that have sometimes been referred to as "intellectual technology". Included in this are computer software, textbooks about computer software, computer languages, and conceptual designs of human working environments.

The Class C component consists of those artifacts and systems that include a mix of components from Classes A and B, and whose satisfactory performance depends on appropriate integration of these two classes into a synergistic unit. Included in this class would be information systems, management support systems, decision support systems, expert computer systems, space missions, hospitals, nuclear power plants, and banks.

Class A Systems

The integrity of the Class A systems rests on three primary factors:

- an elaborate and time-tested world-wide system of eternal referents, known to their users as "primary standards". They rest in vaults in such places as Paris, where they are maintained in uniform environments and protected from external disturbances. From these origins, secondary physical standards are created and located in laboratories around the world. One may calibrate laboratory instruments that are widely used in the design, development, and manufacturing of physical devices and systems against these standards.

- ethical behavior of the actors in their use of this system of eternal referents, and

- higher-level political and managerial willingness to support the ethical behavior and adherence to the system.

When some member of a Class A system is tested, if ethical behavior is presumed, it matters very little whether the test is carried out in China, the United States, the Philippines, Ecuador, Ghana, or anywhere else in the world. Those who develop, test, and manufacture such components or systems share a common language and a common system of measurement, which transcends location, native tongues, national boundaries, or the passage of time. This capacity to share such a language and system of measurement is magnificent testimony to the insight and ethics of its creators, the "natural philosophers" who built the foundations of science.

The presumption of ethical behavior is becoming less and less warranted. Those who are unfamiliar with the history of the past ten years involving large systems, their failures, and management cover-ups may be surprised to find how much has been written in detail about such subjects. One example is illustrated by remarks by Mr. Gerald W. Gordon, Chairman of the United States Activities Board of the Institute of Electrical and Electronics Engineers Ethics Committee, who described the actions of some engineers and the consequences of their actions as follows:

> "The TVA engineers eventually went public with their complaints and have been victims of intimidation and harrassment ever since. TVA had hired a consulting organization to investigate complaints but phased it out when it became evident that a large proportion of the charges were valid. The Department of Labor fined TVA $150,000 for their treatment of the so-called 'whistle-blowers'. TVA has since acknowledged some major deficiencies and has shut down all five of its nuclear reactors, at a considerable economic cost and loss of public credibility."

The ethical dilemma of the engineer has been well-explored by Broome [1]. He noted, as have others such as Vickers [2] and Conant [3], that technology has historically outdistanced science in its early stages, leaving judgments to be made by intuition that can have major effects on public safety. Broome suggests that:

> "engineers and their industrial employers have already seized the reins of American history"

and that a conceivable outcome will be that

> "these elites could wield such power as to invite unprecedented visitations of technological horror upon the public. With the public out of the way, engineering elites would have license to make their own rules--empowering them to decide the acceptability of SDI, nuclear power and weaponry, etc., [and] as this sort of practice became the

norm, violations of the morality of informed consent...would become the everyday deeds of ordinary engineers. And this license would be cancerous to the moral traditions and values that Americans would hand down to their future generations."

If this sounds harsh and radical, one can only note such recent events as the shooting down of civilian aircraft in situations where huge expenditures had already gone into technology that supposedly provided protective information, and the disasters at Chernobyl and Bhopal; as well as many other less-publicized failures that involve no loss of life but involve huge expenditures for systems that demonstrably do not work, and whose cost precludes alternative uses of the funds that could have substantial human benefit.

When governments propose to allocate public resources to components or systems of this Class, evaluation can be based on many decades of archival literature which, itself, reflects high-quality scientific research whose expression depends, for its integrity, upon the eternal referents described previously. As a consequence, considerable reliance can often be placed upon the likely outcomes of the expenditures and upon the probable costs of such ventures.

<u>Class B Systems</u>

The situation with regard to the Class B components and systems is different in every respect. There are no eternal referents to impose discipline upon the language, or to help assure that the many people who may become involved with any particular member of Class B can communicate sensibly about it in any way.

There are no standards against which the performance of engineers and inventors who develop Class B components can be measured.

Class C Systems

The Class C components and systems form Jekyll-and-Hyde-like combinations. Parts of these systems enjoy the integrity that comes from the luxury of being able to refer design, development, and manufacturing decisions to high-quality scientific standards. Other parts of these systems, in the worst cases, are "jargon-based", the jargon becoming the surrogate for the eternal referents.

Selling System Development

The selling of Class C members focuses upon the history, visibility, and credibility commonly attached to the Class A components and subsystems. Thus it is possible in today's United States for politicians and industrialists to allocate and spend public funds upon Class C systems such as the Strategic Defense Initiative. All available scientific evidence indicates that the Class A subsystem conceptualized under this rubric can be created and made to work in benign environments. And similarly, all available scientific evidence indicates that the Class B subsystem conceptualized under this rubric can never be created and made to work.

It is a simple proposition that for a Class C system to work, both its Class A and Class B components must work. Yet it is quite possible to sell naive consumers on a Class C system by presenting it as though it were a Class A system.

The arguments that have been made for the Strategic Defense Initiative are not too different from those that have been made for nuclear power plants. These latter systems also have Class A and Class B components. In order to work, both components must perform satisfactorily together.

Distinguishing Between Science and Technology

Several noted authors have sought to distinguish sharply between science and technology. Among these one can mention the late Sir Geoffrey Vickers [2], the late James Bryant Conant [3], and the venerable American philosopher F. S. C. Northrup [4].

There is every indication that their efforts have not reached the vast majority of the public, including political leaders at both national and state levels. Going back a little further, one finds the thought of Charles S. Peirce, described by the German philosopher Karl-Otto Apel [5] as "America's greatest thinker", in which he devoted substantial energy to clarifying just what constitutes science. In his life, there was no large-scale technology against which science could be compared. But his legacy remains as a source of clear definition of distinctions between science and technology.

Matters of Scale

A most fascinating phenomenon from a behavioral point of view is the unwillingness of technologists to contemplate or inability to comprehend distinctions of scale. Systems are being proposed (and vast sums are being spent on them) that are so far beyond the scale of human cognition and comprehension that their continued promotion can find no justification in any science. These large systems, whether they are nuclear plants, strategic defense systems, or international banks; are perceived by their advocates as simple extrapolations of already understood systems; requiring only more people, more computers, bigger satellite systems, and taller buildings to house the management.

Recently the Secretary of Defense, speaking on television, compared opposition to the Strategic Defense Initiative to earlier opposition to spending money on the development of helicopters in the early stages of their development. Such a comparison is doubly-defective. First it does not show any recognition of the distinctions among Class A and Class B subsystems described earlier, and secondly it does not show any recognition of the vast differences in scale.

Surrogates for Eternal Referents

Even the most hide-bound technologist will sense intuitively that in the absence of any kind of viable physical standards of performance for Class B systems (and by extension for Class C systems), there must be some surrogate for the standards. Yet the study and identification of the human cultural subsystems in which Class B or Class C systems are promoted is a significant research challenge which seems to have gone relatively unnoticed.

Let us consider some surrogates that may or may not be suitable. Recognizing that the kind of authoritative basis for decision-making that is found in physical science (largely through the impact of its eternal referents) is needed to give any sense of integrity to the expenditure of large sums of public funds, one may strive to identify "superstars" whose behavior in the past has placed them in a special category of human being. Perhaps in their unusual wisdom their views can substitute for eternal referents in science.

The opinions of such individuals (however poorly informed they may be) can be offered as a surrogate for scientific knowledge, or even represented as scientific knowledge. We have seen such superstars emerge as key players in decision making in all of the areas where large Class C systems flourish. Possibly they are most widely known in the banking world. Some large publicly-owned banks have been led into bankruptcy. Other banks are in disarray. The World Bank, as amply described in the Washington Post in recent years, offers just one example.

In the nuclear world, the name of Edward Teller stands out as a superstar in the sense being considered here, who promotes strategic defense initiatives and nuclear plants without any discipline from a weak American scientific community that has lost its Einstein, its von Neumann, its Wiener, and its Fermi. (It cannot now even induce a president to restore the President's Science Advisory Council; or to appoint a Science Advisor immediately upon accession to office who has a record of performance that suggests ability to make wise recommendations, and who believes in fostering open debate instead of cultivating narrow cultural enclaves.)

In the Soviet Union the term "cult of personality" arose some years ago. This language seems appropriate to describe an approach to a personalized or superstar surrogate for those absent decision referents.

And in today's indifferent environment, management can also become a surrogate. The securities markets, once viewed as a means to develop a nation and to build a competitive position in the world economy, in order to help assure a better life for people, now have been allowed to become a large casino. The famous investor, Warren Buffet, has urged that the Congress enact a tax that would take 100% of the profits from security trading on securities held less than one year. One has only to look at the impact on the present securities industries to imagine the effects of such a law and the difficulty of getting it passed. The logic of management of a securities industry as a casino is a surrogate for a more solid decision-making basis that might be found in science if it were sought.

<u>Universal Priors to Science</u>

The decision has long since been made in the American culture and in others as well to extend the use of the term "science" into many areas other than the physical areas. Its use in these areas such as the study of human beings, of group behavior, of remote cultures, and of computer languages is now part of the culture. Yet it is clear that eternal referents that give physical science both its integrity and its utility are not available in these newer domains. Thus the question of surrogates arises here as well. What can form the basis for integrity of foundations, for integrity of communications, and for decision-making about these newer sciences?

To explore this issue in depth would consume more space than is appropriate in this paper. But we have engaged in studying this question very carefully. Among the conclusions reached are the following.

There exist certain Universal Priors to (all) science [6]. Prominent among these are:

- The human being
- Language
- Reasoning Through Relationships
- Archival Representations

While some will not challenge these, others insist on more than the mere assertion.

In order to establish the validity of the designation of these four, we elaborate on what they mean, and we apply what is called the Doctrine of Necessity". This doctrine asserts that if, in considering how A and B are related, one of them (say B) is withdrawn and it is perceived that the other of them (say A) cannot then exist, this establishes that one (B) is prior to the other (A) in an essential way.

Science means an organized body of knowledge that has been found acceptable for a prolonged time by an identifiable community of scholars through a process of comparing what is presented as a science with what has been observed by numerous observers at different times and places, in the spirit set forth by A. N. Whitehead ("to see what is general in what is particular, and what is permanent in what is transitory, is the aim of scientific thought").

Because there must be action to document this body of knowledge so that it becomes open to continual reappraisal through the years, decades, and centuries; the following observations about the Universal Priors that are based upon the Doctrine of Necessity are appropriate.

Human beings develop and produce the science. Without them it cannot be developed and produced.

The body of knowledge is conceptualized and formulated in language. Without language it could not be expressed.

The human mind reasons about what it has perceived, and it reasons through relationships. It is relationships that lend the organization to the knowledge. Without the relationships and the reasoning that goes on involving them, there could be no organized body of knowledge.

Science is not what a single mind accepts. On the contrary, it becomes science only after extensive scrutiny and broad acceptance. But this requires a means of archival representation of what otherwise might only be verbal or might exist only in the mind. Without such representation organized and presented in a way that permits and encourages widespread study and scrutiny, there can be no science.

Science as Design

The British philosopher S. Glynn [7] has noted that the process of developing science bears great similarity to the generic process of designing. His arguments need not be repeated here, but if one assumes that he is right it becomes clear that the two-culture views of C. P. Snow have left out of consideration an entire field of study, namely design in its broad sense [8].

The relation of design to the Universal Priors can readily be envisaged. Whatever human beings do to create new concepts and new phenomena, or to modify existing concepts or phenomena, can be called design; at least as soon as the behavior that is involved becomes articulated and is shown to follow a pattern that has constructive outcomes.

All human conceptualization involves language, which is necessary in design to create patterns of relationship that are articulated through the language. Whenever the designs are large in scale, many people become involved other than the designer; and it is only the language and the patterns of relationship that are available to communicate to others who are involved, how their own contributions and behavior relate to the achievement of the final outcome of design.

Because of the intricacy of communication, and the precision with which it must be carried out in order to allow replication of what one mind conceived in the mind of another (as the language of sheet music amply illustrates, carrying messages across cultures, across national boundaries, and across the centuries), archival representation of outstanding quality is needed. Such precision may be needed just to enable one mind even to appreciate fully the product of another mind.

Science Must be Revitalized

The vitality of science depends upon its support structure. Recently it was noted in the Chronicle of Higher Education that at the very time when a major new discovery had been made in the field of superconductivity involving room-temperature superconductors, the support being extended to the leaders in this field by the National Science Foundation was reduced. In this same period, vast sums of public money were being expended in areas of systems that go beyond human scale, and to pay for other things that simply are not scientific, but rather are technological.

But in general the problem is this. The American public, the Congress, the Governors, and leadership in general, with a few exceptions, simply don't understand what science is. Partly as a result of this, monies being expended in the name of science are mostly not being spent on science. The implications of this for the long-term health of the United States are very bad. In the field of space studies alone, where billions of dollars are allocated ostensibly for scientific studies, much less than one billion is actually being spent by the U. S. on space science. Full exposure of the alternatives has not been adequately presented and represented to the public before decisions are made that have far-reaching consequences.

Nuclear plants have been built without the needed scientific basis for their design, construction, and (especially) waste disposal and retirement.

Vast computer systems are being planned with no scientific basis for software development. It would be helpful to the cause of good government and good science if, for example, every taxpayer could read a recent report to the Department of Defense concerning the military software situation [9]. Five uncoordinated programs are presently funded to try to cope with a track record of poor performance, in an area projected to cost $30 billion by 1990, and on which many other systems depend in order to perform satisfactorily. And the development and production of this same report by a group of people who were chosen for their knowledge of the field, did not appear to public view until well over two years had elapsed from the time the assignment was accepted! Yes, this report was requested in order to seek improved productivity in the defense software business.

The country is gradually taking on the image of a welfare state for technologists operating in what is almost a managerial vacuum without scientific basis for what they do, driven by a political system that does not perceive superior alternatives.

Revitalizing Science

What would it take to revitalize science?

Applications furnish the critical test for science. In the areas that involve large systems, it is becoming critical to establish and maintain with high visibility the closest possible connections between science and applications. But how can this be done when these systems are invariably Class C systems, and when there are no eternal referents available with the quality and standing in the scientific community to enable quality control to be properly carried out?

One answer may lie in returning to the Universal Priors and giving them high priority, visibility, and the most meticulous attention in open design processes through which such large systems take their structure and detail.

Every science, including physical science, depends on these Universal Priors. Physical science incorporates a way to buffer or shield its knowledge from the ambiguities and idiosyncracies of human beings and language, by developing and maintaining eternal referents, the physical standards. These standards discipline the human being, control the integrity of the language, enforce reasoning through well-established relationships in the domains where applicable, and offer the archival representations needed to allow continuous re-evaluation and amendment.

There appears to be nothing in sight in the areas outside of physical science, or in areas that involve a mix of physical science and other knowledge, that is now effective as a surrogate for the eternal referents, i.e., that insulates or buffers the knowledge from negative impacts of the Universal Priors.

Unless something can be found, the stress must revert to the Universal Priors themselves. A way must be found whereby human beings, language, reasoning through relationships, and archival representations themselves approach (collectively) the status of agents of integrity achieved by the eternal referents in physical science.

To Whom Must the Challenge be Given?

The challenge of revitalizing science must be given to people who (a) are in a unique position to carry it out, (b) possess the fundamental knowledge to do so, and (c) have the will to do what is necessary to make it happen.

Only one group of people can easily meet parts (a) and (b) of this description. It is the faculty of the liberal arts colleges, including their colleagues in mathematics and the social sciences. They collectively maintain and sustain the knowledge of the human being, of the language, of reasoning through representations, and of appropriate archival representations. With appropriate interaction with their colleagues in mathematics and the social sciences, the liberal arts faculties have the resources to bring to the situation the necessary awareness, sensitivity, a newly-based set of ethical principles, and the sense of the importance of ingraining in the behavior of the scientists and technologists of tomorrow what is required to revitalize American science.

If we do not begin now to conceive in detail how to do this, and start to do it soon, this nation will suffer greatly. We have already become the world's largest debtor nation in a period of vast spending on unworkable military systems, and we have been drawing down our capital built up over many decades. As we decline, other nations may ascend but still others will decline with us.

Still, one must recognize that in professional education, such as that practiced in engineering colleges, there is a long history of requiring humanities and social science in the curricula; and that such requirements have not produced the benefits sought. On the contrary, engineering students (like their counterparts in business, law and economics), are given almost no education in design, and are not taught to connect philosophy, psychology, and related subjects with design. Nor is the often promoted "breadth" of the study of liberal arts demonstrated in any significant way in the behavior of professionals who manage or carry out the total design, partial design, or incremental redesign of large systems.

Instead, the society can be excused if it expresses a view that it is becoming intellectually numb on the rhetorical diet emanating from institutions of higher education, that substitutes the word "excellence" for a systematically worked-out and rigorously justified description of what can be done with education in the liberal arts and humanities, when integrated with sound philosophy and social science.

Systematic and detailed planning is not inconsistent with open and liberal thinking. The myth that treats mere exposure to liberal thought as equivalent to learning, internalization, and assembly in the individual intellectual repertoire, peaks in the fuzzy perceptions of those dogmatic promoters and defenders of liberal education who exemplify its weaknesses in their rhetoric.

Liberal education has become too willing to hide behind rhetoric such as "we promote excellence", and seems to have managed to hide any articulate expression of its mission that is more than skin-deep from the consciousness even of its own students. It is time to study seriously the value of liberal arts and humanities in context: not the context of the subjects and not the context of the university, but in the context of the world and its needs; and it is time to begin to use feedback from that world about all forms of unsocial behavior as guidelines to how to re-conceptualize the purpose, content, and practices of and in such liberal education. Standards for the long run need to be set and met, not stored and ignored.

Guidelines and Initiatives

Suppose the challenge that this manuscript strives to articulate actually was taken up, and the comment was made that guidelines or proposed specific initiatives should be offered.

Or suppose, alternatively, that it was argued that the issues described in the foregoing have not been lost on the technological community and they they can be expected to provide the corrective measures.

Either way, one can benefit from pondering a recent article in the Chronicle of Higher Education, in which there was discussed proposed philosophical directions for one of the better-known institutions of higher education in technology in the United States: the Georgia Institute of Technology [10].

In this article, the President of that institution leaves little doubt about his stand on research. According to the author of this article, "industry-sponsored research, especially in high-technology areas, is 'where the action is'."

The President is quoted as saying "Forget about all this talk about 'SCIENCE'." Somebody should tell him to read Muriel Rukeyser's biography of Willard Gibbs [11], where Lord Kelvin's views on Gibbs' work and this President's views of science are uncomfortably equally uninformed.

An example of what is being promoted at Georgia Tech is a "three-dimensional computer graphics model that could be turned and tilted on the computer screen to show the city [of Atlanta] from all sides". This would be used to get support for bringing the Olympic Games to Atlanta. The President has read Thomas Kuhn's views and believes that "a good, rich problem is the greatest stimulus for scientific progress."

Researchers who shun targeted research in favor of "pure" research are described as "intellectual snobs and foolish to boot." This man needs badly to read Gibbs' biography.

What he is saying is a smorgasbord of intellectual pap. Of course it is fine to work on good, rich problems; but given the current state of American technology, is the 3-D computer presentation of Atlanta a top priority item? And given the large scale of today's technology (spoken of approvingly in the reference), what evidence is there that any genuine science has evolved out of today's giant projects? As the former president of the American Telephone and Telegraph Company and his close associate Karl Darrow have testified, the industrial impact of Gibbs' research (understood at the time mainly by Clerk Maxwell and other distinguished Europeans, but not Lord Kelvin) was massive because it was fundamental. And several university presidents in the U. S. failed to recognize its importance in Gibbs' day, even when informed by knowledgeable Europeans.

Whatever scientific benefits are coming from the space program, they may be insignificant in comparison with that developed by people who approached science not as an either-or proposition, involving the dichotomy of pure science and applied problems; but rather as a systematic mode of investigation involving a mix of theoretical and applied study, motivated by a need to know rather than a need to put on a medicine show.

In the chain of deep logic that evolves as genuine scientific exploration is carried out, there is superficiality, depth, and the intermediate concepts that link them. The Universal Priors lie well toward the deep side. It is hard to imagine problem-solving faculty discovering accidentally on the way to a 3-D portrayal of Atlanta that they need to know more about the Universal Priors and how to relate them to human accomplishment, if they cannot be persuaded of this by an introduction to the history of scientific achievement, as portrayed by Vickers, Conant, and others.

Yes, initiatives will be taken, but there is little assurance that they will do more than perpetuate a stagnant level of technological development, accompanied by catastrophes.

The guideline that is most needed is one that will place system design on a sound intellectual footing. A beginning has been made to develop such a guideline in a forthcoming book [12], where the Universal Priors are coupled to a model of a science that offers some discipline to protect those who might be equally disturbed by the side effects of bad science in potentially good applications and by bad applications unsupported by good science.

In the final analysis, we are talking about how we apply our capital to help assure the future of the earth and its people. But we are not simply talking about national currencies.

The Use of Capital

Moral capital and intellectual capital are the greatest forms of capital. With them, economic capital can be produced, and investment in people becomes more and more possible. But if the moral and intellectual capital is drained away and not restored, no amount of technology can be brought to bear to produce respectable economic capital, nor can we make the investments in people that are needed to replenish and sustain our intellectual capital for the future.

Conclusion

Liberal arts education for scientists and engineers is moribund, undirected, and (perhaps) motivated only by interests of faculty in their own professional pursuits. But at the same time there is a great need for liberal arts education to be planned carefully in order to revitalize science and, through science, its applications in technology. Forces are in motion that threaten to bankrupt our society through application of huge sums of money for ineffective and dangerous technology, which lacks adequate scientific foundations and theory.

It is especially dangerous that such activities have been promoted under the guise of being applications of science, lacking the critical distinctions that management and the general public have been unable to make for lack of technological and scientific insight.

One workable approach to correct this situation is to initiate and build up in higher education for scientists and technologists the study of generic design, founded in upgraded Universal Priors that can be authoritatively taught from sources in the liberal arts community, with help from social scientists and mathematicians. The potential benefits of such an approach are large for the society as a whole. It will be futile to wait for the technological community to correct its own shortcomings, for it is these very shortcomings that are responsible for the current difficulties.

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