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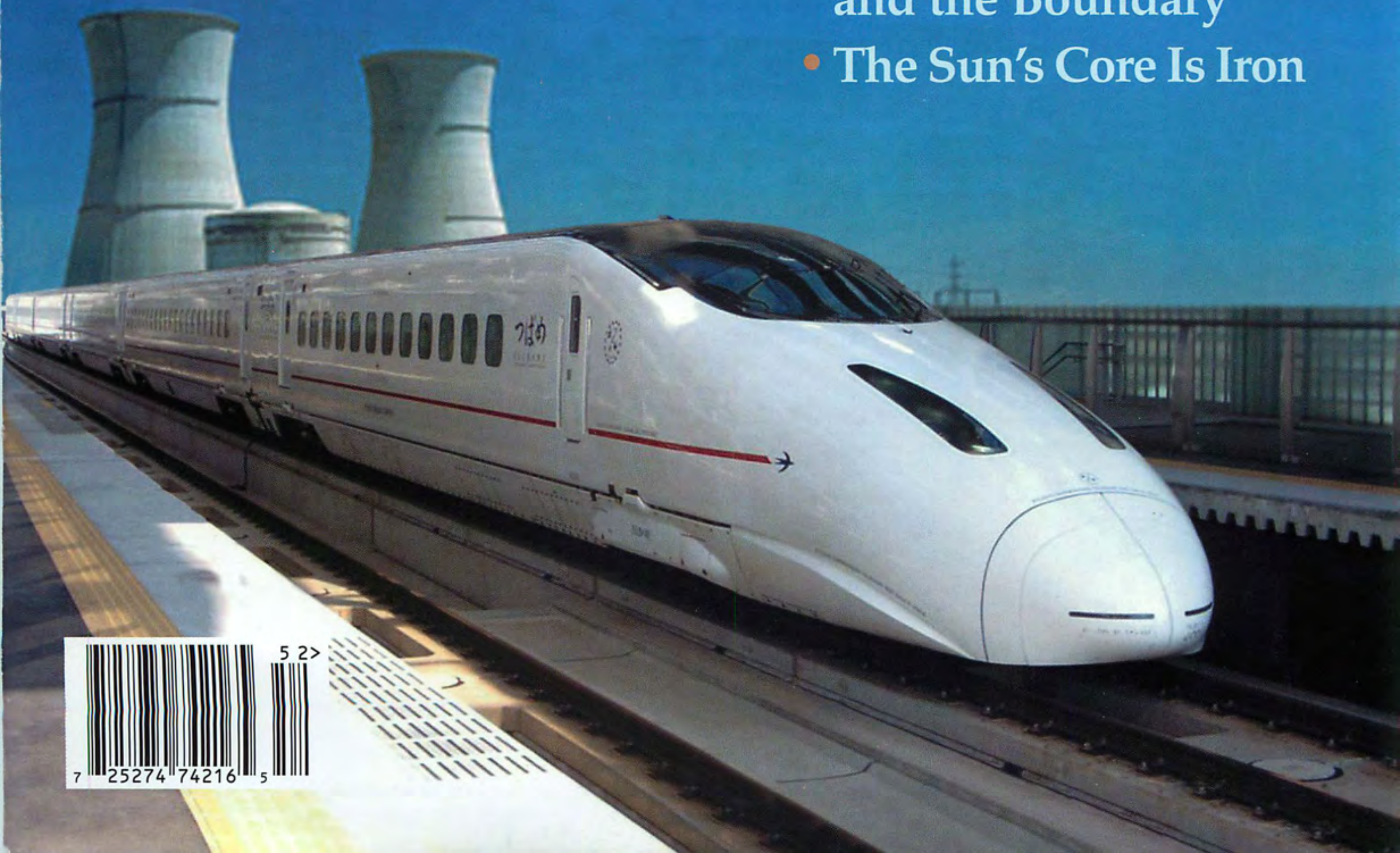

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Courtesy of Kyushu Railway Co.

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EDITORIAL

Science and the Needed Solution to the Current Global Economic Crisis

by Lyndon H. LaRouche, Jr.

July 4, 2005

This is the concluding portion of a longer piece by physical economist LaRouche. It appears in the July 15, 2005 issue of Executive Intelligence Review *under the title "LaRouche's Fourth of July Address! It Happened in Berlin Last Week."*

We may now concentrate our attention on three topical points:

- that whereas most teaching of political-economy and related subjects is based on the kind of mechanistic outlook typified by the influence of René Descartes, the science of physical economy, as founded by Gottfried Leibniz, rejects the Cartesian and related, "Enlightenment" methods of *mechanistic* analysis, and chooses, instead, the modern European revival of the Classical Greek concept of *dynamics* (Greek: *dynamis*), a conception which is typical of the major work of Leibniz in physical science generally, and economics specifically.[1] Rejection of *mechanistic* thinking, in favor of the mathematical physics of *dynamic* systems, is the basis for Leibniz's solution for the problem of defining economic value. This is also the characteristic distinction of the mathematical-physical methods employed by Carl Gauss, Bernard Riemann, and their leading associates. The leading new problems of economy worldwide today, boldly require us to adopt Vernadsky's adoption of those methods of dynamic systems used by him in defining the qualitative distinctions among the interacting domains of the abiotic domain, the Biosphere, and the Noösphere.

It is important to emphasize here, that the method which underlies Leibniz's development of the notion of power (*Kraft*) in the science of physical economy, is the same anti-Cartesian (anti-mechanistic) premise for Leibniz's exposure of the incompetence of Descartes' notion of momentum, with the notion of *vis viva,* which, in turn, underlies the more fully developed, catenary-cued concept of the infinitesimal calculus, the universal principle of physical least action which was savagely attacked by those fanatical followers of Descartes, the empiricist ideologues Voltaire, D'Alembert, Maupertuis, Euler, and Lagrange.

- The indispensable function of the concept of *dynamic,* rather than *mechanical* organization of processes, for defining the relative value among systems of respectively sovereign national-economic systems. This is crucial for the design of a global recovery program suited to the challenge represented by the onrushing collapse of the present world monetary-financial system.
- The relevant manner in which relative values of currencies of a new fixed-exchange-rate monetary system may be set for the purpose of organizing a long-term economic recovery of our planet.

Dynamics Versus Mechanics

My recent acquisition of a copy of the authorized English translation of V.I. Vernadsky's 1935 programmatic presentation of work on the Biosphere, provided me with clear and conclusive proof of what I had long guessed to have been his method, that the scientific method employed in the development of the concepts of both the Biosphere and Noösphere were reflections of his application of the concept of dynamic, rather

Wolfgang Lillge/EIRNS

LaRouche (second from right) at a closed-door EIR seminar June 28-29, 2005 in Berlin, which brought together senior representatives of 15 nations, to discuss prevention of an uncontrolled collapse of the dollar and the creation of a new world monetary system. With LaRouche are (from left) Maj. Gen. Assir Karim (ret.) of India, Dr. Sergei Glazyev of Russia, and moderator Michael Liebig.

than mechanical systems, to his principled definitions of both the Biosphere and Noösphere.[2]

As I have stated the case in various published locations, such as *Earth's Next Fifty Years*,[3] the currently increasing rate of consumption of essential raw materials, and related developments, has brought the planet to the verge of a new requirement in the practice of economics: the factor of required scientific management of the raw materials resources of the Biosphere and Noösphere. We must go beyond the mechanics of extraction and processing of extracted materials, to assume responsibility for regenerating, and expanding qualitatively, the natural mineral and other resources which we extract, chiefly, from the fossil regions of the Earth's Biosphere.

As a result of the growth of both population and the consequently accelerated need for scientific and technological progress, we face qualitatively, as much as quantitatively increased requirements for such "fossils of the Noösphere," as increasingly intensive development of basic economic infrastructure and heavier investment in more advanced technology in agro-industrial capital goods must be a built-in characteristic of what must be redefined as national public and private budgets and cost-accounting. As a result of such and related considerations, we can no longer tolerate the kinds of thinking and practice about economy associated with practice of governments and private enterprises up to the present time. The legacy of Cartesian and other expressions of mechanistic thinking must be buried with cat-like precaution, once and for all.

This pattern should compel us to change our way of thinking about national and world economies, moving away from mechanical (e.g., Cartesian) thinking, into the direction typified by Vernadsky's Riemannian approach to defining the interaction of the abiotic, biospherical, and noöspherical processes as modern, anti-mechanistic, *dynamic* systems coherent with the notion of the principle of *Sphaerics* which the Pythagoreans and Plato trace to the astrophysical origins conveyed in ancient Egyptian scientific development. This does not mean that we should not have taken this approach much earlier, but that, now, the urgency of such a change is no longer ignorable among any persons with a penchant for competence.

This means the urgent scrapping of the use of currently fashionable practices of national product and income accounting, and also of ordinary corporate financial and tax accounting. It signals the urgency of turning to new methods coherent with the reality of the dynamic characteristics which Vernadsky associated with the Biosphere and Noösphere as interacting, but distinct systems. This is the concept of dynamic systems which Leibniz presented in exposing the incompetence of Descartes' method for physical mechanics, the concept of the dynamic system underlying Leibniz's original discovery of the general principles of physical economy, as also Leibniz's original catenary-cued discoveries of the principle of universal physical least action and of natural logarithmic functions. These are systems coherent with Gauss's 1799 attack on the incompetence of D'Alembert, Euler, and Lagrange, and his notion of the general principles of curvature and of the magnetic field, as also Riemann's emphasis on Dirichlet's Principle. As the recent several years' work of the LaRouche Youth Movement (LYM) illustrates the point, these are all concepts within the reach of intelligent and dedicated young adults of university-eligible age, and are therefore concepts which should be included as benchmarks of professional competence in all professions during the lifetime of presently emerging adult generations.

This involves more than a radical change in systems and procedures. It compels us to adopt a qualitatively improved conception of the principled nature of man's situation in the universe, to the following leading effects.

Vernadsky's adopted scientific method leads him to an extremely important clarification of the practice of the experimental scientific method traced from such origins as Nicholas of Cusa's founding of modern physical science, in his *De Docta Ignorantia*. Instead of falling into the commonplace reductionists' error of defining the sensed object as such, Vernadsky divides the physically experienced universe among three general categories defined not as objects, but as subjects of the relevant, appropriate categories of methods of experimental physics: the *abiotic,* the living (*Biosphere*), and the cognitive (*Noösphere*). The abiotic is simply the domain defined by those experimental methods which make no assumption of a principle distinguishing *the products* (e.g., fossils) of living from *the products (i.e., fossils)* of specifically non-living processes. It is the existence of anomalies which do not fit the characteristics of the experimental abiotic domain, which betray the presence of the realm of living processes as the Biosphere. The Noösphere is the experimental domain of effects (e.g., fossils) which are not generated from within the bounds of products of a generality of living processes.

In other words, only life can produce life, and only the cognitive powers of the human mind can generate fossils which lie outside the capabilities of the generality of living processes (e.g., efficient discoveries of universal physical principles: creative mental activity). The latter distinction, which is, functionally, a crucial distinction of the science of physical economy, is demonstrated by the way in which discoveries of universal physical principle, in particular, are transmitted across generations, even over intervals of thousands of years. Focus for a moment on this latter phenomenon.

Take the case of the known discoveries of the Pythagorean Archytas, and of Archytas' friend Plato, which date from approximately 2,500 years ago. These discoveries are learned today by one of two methods. They are merely "learned" as from textbooks, or, actually known, not by textbook methods, but by the student's replicating the original act of discovery of a solution for the relevant statement of a paradox.

A typical example of this distinction, for purposes of illustration, is the case of the student's replication of the actual act of discovery of the principle of universal gravitation. In Aristotelean method, such as that of Claudius Ptolemy and his imitators, only repeated patterns of action in accord with a principle of circular action, are recognized. In the case of Kepler, the discovery of the existence of an efficient universal principle of gravitation, rests upon the recognition of a singularity which is associated with the fact that the orbit of Mars, for example, is elliptical, rather than circular. So, similarly, Archytas' solution for the construction of a doubling of the cube, solely by geometrical construction, appears in the experience of the 18th Century as the crucial issue of principle dividing the science of Carl Gauss et al. from the empiricist blunders of the reductionists Euler, Lagrange, et al.

By such methods of the anti-reductionists, the original act of discovery of a universal physical principle, can be the replicated act which occurs within the mind of a person living today. *Just as only life can produce life, so, only cognition can replicate the discovery of principle by one individual mind in another individual mind, even across the intervening distance of thousands of years. Such is the principle of personal immortality of the human individual, as contrasted with the mortality of the lower living species.*

It is similar with the case of life in general. No one has ever discovered a principle of life as an object of sense-perception, Rather, we experience the presence or absence of life of individual beings which have the apparent biochemical characteristics of living processes, but are lacking the continued presence of an active principle of life. The apparent paradox so posed by the experimental method of scientific work, is not paradoxical on principle. The universe is composed of three respectively distinct, but interacting known universal principles, the abiotic, the living, and the cognitive, such that, from the standpoint of the study of the relevant categories of fossils, the superior lies outside, and above the domain of the experimental subject-matter which the relevant principle commands: in which the principle of cognition is ultimately superior to that of life, as life is superior, in the domain of fossils, to that of the merely abiotic domain.

Yet, while each of the three domains is functionally distinct from the others, all three interact in shared effects. This illustrates the importance of viewing all aspects of the universe from the vantage-point of dynamic, rather than the intellectual mediocrity and relatively intellectual sterility, which is the mechanistic viewpoint of the reductionists. This fact is less obvious for the case of abiotic processes as presently defined in relevant classrooms and textbooks, but is a systemic distinction of crucial primary importance in the domains of living processes and human behavior. In the former domain, the reductionist standpoint is a barrier to otherwise potential scientific progress; in the latter two, respectively higher domains, the reductionist standpoint, as reflected in today's customary accounting and related practice, is always manifestly incompetent.

The most notable of the implications of this investigation of life, is the way in which this view of society implicitly defines the notion of the immortality of the individual mind. From the standpoint of the principle of dynamics, the human mind is imposed upon appropriate living processes, and interacts efficiently with those processes, but it is the body which dies, a distinction which is demonstrated experimentally by the way in which the discoveries of physical scientific and Classical artistic principle are transmitted across successive generations. It is cognition, as expressed rather uniquely by discoveries in physical science and Classical artistic composition, which is the substance of the human individual's existence, a substance which lives on as the continued living imprint of the human individuality when the animal-like aspects of the body used by the creative personality have ceased to perform their assigned function. The scientist must see this distinction in that way, as the immortality of the human individual personality, and the basis for the universal principle of natural law called *agape*, as Plato presents that case for such immortality of the soul in his dialogues, as Moses Mendelssohn later.

The Dynamics of Economy

All three phase-spaces—the abiotic, the Biosphere, and the Noösphere—interact as one in any viable economy. Thus, the productivity of labor depends upon the simultaneous impact of all three, to determine the relative productivity of the labor acting upon his or her point in the larger process of society as a whole.

For example, if we might assume that the same quality of labor is operating in different locations, the level of develop-

Sam VarnHagen/Ford Photographic

Skilled Ford auto workers on an assembly line. Getting the United States and the world out of the onrushing economic collapse requires long-term credit to increase physically productive employment in capital-intensive, technologically progressive modes, most significantly in basic economic infrastructure.

ment of man-made infrastructure of production, will be a variable factor in determining the actual productivity of labor of relatively identical skill. Similarly, if the man-made infrastructure in which that labor occurs, is equal in two localities, the relative quality of the local aspect of the Biosphere will be the variable determinant of the relative productivity of labor.

Furthermore, production is not competently measurable in terms of equivalence of the quality of the object considered to be a product for consumption. The value of consumption for society, depends upon the variable quality of the place and circumstance in which the consumption occurs. In general, higher degrees of skill, as ascertainable from the standpoint of physical-scientific potentialities of the employed person, are a good, but the benefit from that good will vary with both the circumstances in which the production occurs, and with the quality of the part of the society into which that product is introduced for consumption.

It is all of these and related considerations of production *and consumption* taken into account, which interact to define a *dynamic,* rather than *mechanistic* conception of an actual economic function within society in general.

So, for example, the transfer of production from places in the U.S.A. or Europe, where the development of basic economic infrastructure and education of the population in general is relatively high, to places where labor is cheaper because of lack of development of infrastructure and of the dynamic potentials of the entire social process makes labor cheaper, as through "globalization," has caused a collapse of the level of productivity of the world as a whole. This dramatic form of actual ruin of the world economy during, emphatically, the recent quarter-century, has been motivated by a lustful expression of individual greed's indifference to the effect of its behavior on the future of the nation and planet as a whole. The result of this mechanistic disregard for the actual, dynamic costs of production, has been the principal determining factor in bringing about the presently onrushing rate of increase of the collapse of the productive powers of the human species as a whole.

The interrelationships within the process I have just summarily described, are a relationship among the functions of what Leibniz identified as the powers (dynamic, *Kraft*) represented. This is a notion as old as the famous aphorism of Heraclitus, that constant change is the primary ontological condition of the universe, of the processes of which the universe is composed. It is the introduction of either newly discovered universal physical principles, or, in the alternative, new principled kinds of applications of previously discovered principles, which are the relevant quality of action which defines the types of sets of relations to which I have just referred here.

The determining set of relations of the quality associated with those notions of discovered universal physical principles, can not be reflected competently in annual economic reports on the performance of firms, nations, or the planet as a whole. The circumstances of production of the conditions of continued life and progress of the planet depend upon long-term processes so defined, including a large portion concentrated within the bounds of a relatively long-term usefulness. Typical of this factor in the set of functional relations which I have described above, is necessary capital investments, in both basic economic infrastructure and means of production which, as improvements, have life-cycles of between a quarter- and half-century. Long-term improvements in the biosphere, have a comparable significance.

Therefore, the value of current production, and investments in improvement of the economy and labor-force, must be premised on efficiently reliable foreknowledge of the effects of current investments on potential productivity, per capita and per square kilometer of the planet's surface in the range of a quarter- to half-century ahead. Thus, the future, more or less as the past, determines the value of the economic performance of the current year of the economy's activity. This brings us to the matter of the role of credit, especially long-term credit, in determining the actual, effective value of a particular economy during any year referenced.

Accounting which does not take such long-term future impacts of current activities into account, is a manifestation of miserable incompetence typified at its relative worst.

The configuration which I have just described, albeit summarily, in the preceding fashion, conforms to the role of

Uwe Parpart/EIRNS

A shanty town on the outskirts of Mumbai, India. Transferring production from the industrialized countries to places where labor is cheaper—globalization—has caused a collapse of the level of productivity of the world as a whole.

Riemann's notion of Abelian functions, as defined in accord with Riemann's enhanced insight into the implications of what he terms Dirichlet's Principle, as I have indicated these functional configurations and their significance in my "Vernadsky & Dirichlet's Principle." Such are the principled characteristics of the global economic system of dynamics which I have identified here.

A Fixed-Exchange-Rate System

If we are to reverse the currently accelerating trend of general physical-economic collapse of the economy of our planet, we must apply discovered universal physical principles to raise the level of development, per capita and per square kilometer, of the relevant aspects of the Biosphere and Noösphere.

These applications are chiefly expressed as long-term capital improvements which have "life expectancies" of between two generations, or even longer, beyond which those investments must be either replaced or merely improved in accord with principles discovered since the original installations and their interim improvements were made. Experience indicates that the tolerable charge against the outlay of capital to provide such physical-capital investments is, usually, approximately 1-2 percent, and not more than 3 percent simple-interest charge per annum. This means that a fixed exchange-rate among relevant currencies must prevail over most of the duration of the long-term investment. The rate of profit on private investments in improvements in production capital must not be significantly higher. This must be within a system of fixed exchange-rates, since significant fluctuations in values of currencies over the life of these investments will raise the imputable interest-rate to functionally unacceptable levels.

In certain crucial respects, the setting of fixed exchange-rates is a much simpler, but also far more interesting challenge than ordinary opinion on this subject would imagine. To illustrate that vitally important point, consider the following aspects of the challenge facing a concert among leading nations at the present moment.

Currently, the nations of Europe are ostensibly bankrupt. The case for Germany merely illustrates the prevalent trend of affairs in Europe as a whole. The U.S.A. itself, under the past five years of the George W. Bush Administration, is also bankrupt, hopelessly so under a continuation of the characteristic features of the Administration's stubbornly economically suicidal policies, even far worse than Herbert Hoover's, thus far.

It would be sufficient to raise the level of productive employment through state-generated, and related forms of long-term credit. This credit must be used, in all of these cases, in particular, to increase the ration of physically productive employment in overall capital-intensive, technologically progressive modes. The most significant ration of such investments at the beginning would be in basic economic infrastructure. The initial objective would be to lower the rates of unemployment of the population as a whole, while shifting the composition of employment from so-called services, into building of basic economic infrastructure and increasing the ration of the total labor-force from non-professional services, into dedication to physical production of goods.

In general, such reforms would be sufficient to bring the indicated economies quickly above break-even levels.

However, to keep the system functioning, existing debt overhangs must be reorganized. The general objective is to shift the composition of legitimate debt (with no consideration for financial derivatives) into a generally long-term life of combined current debt and new debt launched, chiefly by governments, for recovery, expansion, and technological growth.

A relevant concert of governments has a reasonably wide latitude in choosing the relative values of a package of fixed rates. There is negotiable latitude in choosing the relevant parities for this purpose, but not much time available for making that decision. The principled question the governments must ask one another in this connection, is, "Will these values we choose today hold up for the long term of 25 to 50 coming years?"

On these accounts, the U.S.A. has great historically determined advantages. advantages derived from what I have already referenced here as the history of our constitutional system, as compared with the constitutions of Europe, for example. Moreover, the presently imperilled world monetary system is based on both the denomination of the U.S. dollar and the huge overhang of dollar-denominated debt in the international system. That debt overhang itself is not the most crucial problem to be addressed; the crucial issue is, can that debt be rolled over successfully through a process of expanded global investment? Over a period of a quarter to half century of upward development of the global economy? The primary questions are: (a) What is the nation in question prepared to pledge itself to do, as relevant long-term investments; and, (b) Is the reasonably expected performance of that nation in meeting that adopted obligation, a reasonable expectation in the considered opinion of the partners?

The necessary precondition for such long-term agreements, is an immediate shift from a "free trade," to a "fair trade" system of pricing. This means an immediate shift, away from a practice of "globalization," into the protectionist system needed to match the nested sets of commitments of sovereign governments over lapsed times of a coming generation or more, before significant adjustments might be worked into the system.

In summation, I add the following most relevant concluding observations to what I said in my relevant, previously stated outline from the referenced Berlin closed-door meeting.

The conditions for reorganization of a global return to a fixed-exchange-rate system akin to that of the original Bretton Woods agreement, are generally those which I have interwoven into the preceding pages of this report. There are certain summary conditions to be added at this point.

The principle of world economy which is implicit in my outlined perspective for reform, is not only a reflection of the American System of political-economy. It is premised on the notion of power (dynamic) presented by Leibniz in founding the branch of physical science known as physical economy, the system on which the U.S. constitutional republic was established. In crafting an acceptable agreement for global economic recovery and stability through a new, fixed-exchange-rate system, the notion of power of the long-term effort for progress of a national economy which is partner to the new system, is a notion of credible power expressed by the individual nation-state, the credibility of its stated will to perform what it would promise to do. It is this subjective factor in the realization of future intended results, on which relations of states within the new world system must depend. As the value of an investment is based on the reasonably expected performance over the medium to long term, so it is among nations.

Perceived power—perceived relative value—is the credibility of the determination and ability to perform, on what our own Cotton Mather identified as the commitment to do good. That subjective power, on which the objective power of a nation depends, is, as Leibniz rebuked John Locke, the commitment of a people "to the pursuit of happiness," to the promotion of a mortal individual's sense of immortality through a credible performance in service of the general welfare of both present generations and future generations to come. Without that commitment there could be no durably efficient government, nor relations among governments.

Notes

1. I chose Carl F. Gauss's 1799 doctoral dissertation, refuting the reductionist ideologues D'Alembert, Euler, Lagrange, et al., as the starting-point for comprehension of modern physical science among the LaRouche Youth Movement (LYM). By turning from that starting-point in their reenacting the work of Gauss, to go directly to the relevant original work of Archytas, Plato, et al., numbers of young adults participating in this program have now progressed to an actual comprehension of such matters as Leibniz's catenary-cued principle of universal physical least action, Gauss's general work on principles of curvature, and Riemann's Theory of Abelian Functions.

   Such redesigns of relevant curricula of secondary and higher education, which turn away from textbook and related modes of "learning," are essential for developing new generations of young adults capable of efficiently meeting the physical-scientific challenges of today. The same educational methods also work in the domain of Classical artistic composition, thus overcoming what Britain's C.P. Snow outlined as a "two cultures" paradox in modern higher learning. See Lyndon H. LaRouche, Jr., "Vernadsky & Dirichlet's Principle," *Executive Intelligence Review*, June 3, 2005.

   For his exposure of the incompetence permeating the mathematical physics of Descartes, as also in his introduction of the concept of power (*Kraft*) into the science of physical economy, Leibniz revived the Greek term, *dynamis*, from the writings of the Pythagoreans and of Plato. This term represented the central concept of the Egyptian, astronomy-based practice of Sphaerics central to the work of both the Pythagoreans and Plato. Leibniz's and Riemann's emphasis on *dynamics*, as opposed to the reductionist's blundering mechanics, is the basis in method for Vernadsky's rigorous definition of both the Biosphere and Noösphere.
2. Lyndon H. LaRouche, Jr., "Vernadsky & Dirichlet's Principle," *Executive Intelligence Review*, June 3, 2005.
3. *Earth's Next Fifty Years* (Leesburg, Va.: LaRouche PAC, March 2005.

Letters

A Correction by Klaus Klitzing

To the Editor:

In the article "What Was the von Klitzing Experiment?" (Fall 2004, p. 21):

In Figure 5, the plateau corresponding to the 5th Landau level, where $p = 5$ in $R_H p = 25{,}813/p$ ohm is missing, the 3rd, 4th, and 6th levels are present, and the 1st and 2nd levels are above the top of the graph. The 7th level also appears to be missing. . . .

Richard W. Burden
Leesburg, Va.

Dr. Klitzing Replies

Figure 5 shows real experiments obtained in my laboratory (and not by E. Braun at the Federal Physical Technical Laboratory, as stated in the figure caption). The plateaus originate from energy gaps in the electronic spectrum. For the material shown in Figure 5, two different types of energy gaps exist: For even values of *p*, larger gaps (cyclotron energy); and for odd *p*, smaller spin-split gaps (Zeeman energy). Only $p = 1{,}3$ are still energetically resolved. For $p = 5$, the magnetic field is already so small that no energy gaps, but only small wiggles, are visible; $p = 7$ is not resolved at all and missing.

Prof. Dr. Klaus von Klitzing
Max-Planck-Institut FKF
Stuttgart, Germany

A Manhattan Project Veteran Comments On 'Secrecy'

To the Editor:

L. Wolfe's article in the Spring *21st Century*, "The Beast-Men Behind the Dropping of the Atom Bomb," was excellent. As one who was there, I can testify that much of the article matched History-as-I-knew-it. In fact, I have only one correction to make, and a remark

Continued on page 79

ANS Pittsburgh section

Dr. Nils Diaz: We need 100 new nuclear plants in the next 20 years to meet U.S. demand for electricity, the Nuclear Regulatory Commission chairman said. Here, he addresses an American Nuclear Society meeting in Pittsburgh.

NRC'S DIAZ CALLS FOR 100 U.S. NUCLEAR PLANTS IN 20 YEARS

In comments to reporters in Florida on May 3, Nuclear Regulatory Commission Chairman Dr. Nils Diaz said that the United States needs to build 100 nuclear power plants over the next two decades. He proposed that building new plants on existing nuclear sites would reduce planning and construction costs, and expedite the process of obtaining permits. Companies would not have to develop costly new infrastructure, including roads, grid connections, and water supplies. Dr. Diaz reminded reporters that the United States no longer has the ability to build major equipment for nuclear reactors. "We had large fabrication facilities for pressure vessels and steam generators and major components, and most of those things no longer exist in this country." For the half-dozen nuclear plants that he expects to be ordered in the next two years, many components will have to be imported, he said. Worldwide, Diaz said, production capacity will soon be outstripped by the rising demand for new nuclear plants, so there will have to be ways found to "assure supply."

At a meeting in Paris the week of June 12, Diaz proposed that there should be a multinational mechanism for approving standardized new nuclear plant designs—to cut cost and time, and improve safety.

VERNADSKY VINDICATED: NEW FINDING SUGGESTS LIFE CAME EARLY TO EARTH

Geologists have found evidence for the existence of liquid water on the Earth's surface early in geologic time, suggesting that life had appeared within 100 million years of Earth's formation. The finding contradicts the long-prevailing doctrine that life appeared only long after the geological formation of the Earth, estimated to be 4.5 billion years ago. The new findings came during a study of more than 50,000 tiny zircon (zirconium silicate) crystals formed during the earliest period of Earth's history, known as the Hadean Eon. This describes the first 500 million years of geologic time when, it was supposed, the Earth was as hot as Hades and not capable of supporting life.

To establish their early life hypothesis, researchers T. Mark Harrison of Australian National University and E. Bruce Watson of Rensselaer Polytechnic Institute first determined the age of the zircons (crystals the width of a human hair). Of the more than 50,000 sampled, about 200 were found to be older than 4.2 billion years. The average melting point of these was only 690 degrees celsius, indicating the presence of water. "Rocks formed from meteorite impacts would be bone dry and melt at greater than 900 degrees celsius," said Harrison.

These findings suggest, as Vladimir Vernadsky intimated, that life appears much earlier in geologic time than the Huxley-Wells monkey men had led most of us to believe. (Compare Vladimir Vernadsky's 1936 statement, "The connection between the living and the inert substance of the biosphere is indissoluble and material within the geological time.") Harrison and Watson's work was published in the May 6, 2005 issue of *Science* magazine.

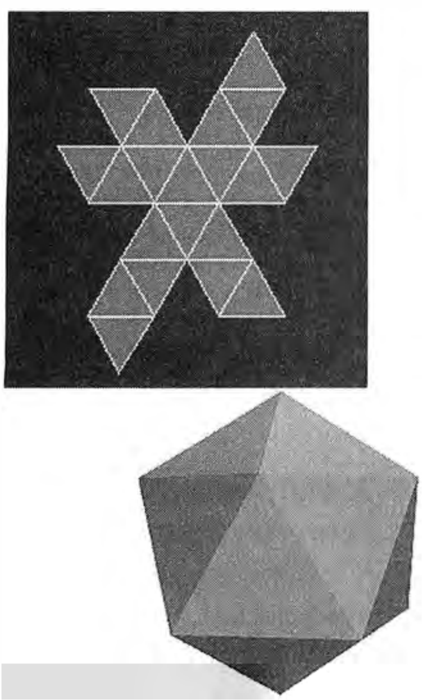


Illustration by Christine Craig

An icosahedron edge-cut and unfolded flat, with no overlaps.

15-YEAR-OLD SOLVES 500-YEAR-OLD DÜRER PROBLEM

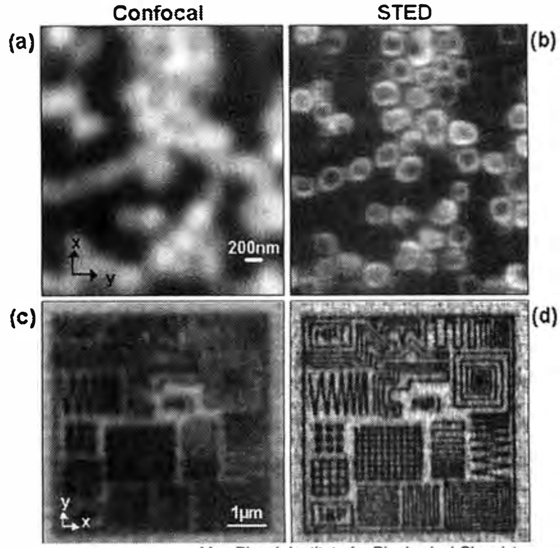
Daniel Bezdek, a 15-year-old from Calgary, Canada, recently won several prestigious awards for his geometry work on convex polyhedral unfolding. For his science fair project at St. Brigid Junior High School in Calgary, he set out to solve a problem proposed by the German artist Albrecht Dürer, 500 years ago: Does every convex polyhedron have a non-overlapping edge-unfolding?

Bezdek approaches the problem by defining a new family of polyhedra that he calls higher-order convex deltahedra. A convex deltahedron is a polyhedron made up solely of equilateral triangular faces, with each face-edge joined to only one other face. There are eight such deltahedra in 3-space. A higher-order convex deltahedron, which subsumes the regular deltahedra, allows convex faces of 3, 4, 5, or 6 sides, which are composed of equilateral triangles fully sharing sides. Bezdek then goes on to prove that every convex higher-order deltahedron can be unfolded by edge-cutting, and laid flat with no overlap. Not satisfied to stop there, Bezdek then relates this to Kepler's discrete problem of spherical packing, and applies these tools to protein-folding problems in computational biology.

NEW CONCEPT BREAKS DIFFRACTION BARRIER IN MICROSCOPY

A new technique developed by researchers at the Max Planck Institute for Biophysical Chemistry in Göttingen, Germany, side-steps light microscopy resolution limits imposed by Abbe's law, allowing unprecedented clarity at the molecular level, according to a Max Planck Society press release June 2. Ernst Abbe (1840-1905) was the first to formalize the limit of resolution between two objects under a light microscope, and relate it to diffraction characteristics of the wavelength of light entering the objective lens. Getting higher resolution with light meant using shorter wavelength light and increasing the refractive index by using media like oil between the objective lens and the object under view. Even so, the resolving limit in standard light microscopy is limited to about 200 nanometers.

Now that law, the bane of light microscopists, has been superseded by Stefan Hell and his research team, with the Stimulated Emission Depletion (STED) microscopy technique, using a new concept called Reversible Saturable Optical Fluorescent Transitions (RESOFT). The new technique uses fluorescent markers in the object under view, which are excited and then transiently and reversibly de-excited to a non-fluorescent ground state by another impinging light, which has a non-uniform intensity distribution having a zero value at some point. Only where the zero-intensity point meets the marker does fluorescence occur, and that point can be made smaller by increasing the intensity of the light source. At high-intensity saturation of the excited light by the depletion light, the zero point can be made much smaller than the diffraction limit, giving a clear view even down to a few nanometers. This technique holds great potential for molecular biology and nanotechnology.



Max Planck Institute for Biophysical Chemistry

The new STED technique (b and d) dramatically improves resolution over that of the conventional confocal fluorescence microscopy (a and c). (a) and (b) show pores in a porous membrane; (c) and (d) show fluorescent-dye-marked nanostructures produced by electron-beam lithography in a polymer.

WAS THERE AN ANCIENT CHINESE COLONY IN NOVA SCOTIA?

Paul Chiasson, an architect from Toronto, believes that he has discovered the remnants of a Chinese fort dating to the 15th Century A.D., in the hills of Cape Breton Island off the coast of Nova Scotia, complete with a stone wall, roads, and housing platforms.

Chiasson insists that the style of the stonework on the wall and the platforms, and the width of the road, point to a Chinese origin. The experts disagree, disparaging the idea of a Chinese colony in such a remote location, and saying that the site is just another abandoned farm-site from the colonial period. Chiasson is not the first person to insist that voyagers from Asia have visited or colonized various sites in the Americas. There is a growing body of evidence showing that Chinese, Egyptians, and others visited North, South, and Central America, both B.C. and A.D.

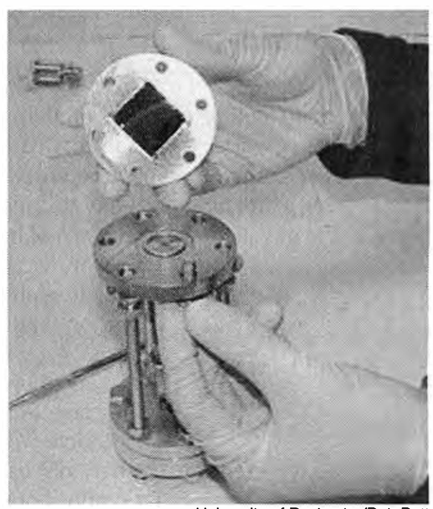
Chiasson has teamed up with Gavin Menses, who recently published an account of 15th Century voyages of discovery by the Chinese navy, including the discovery of America. They hope to get backers for an archaeological dig in the area to settle the question.

BETAVOLTAICS HARNESSES RADIOACTIVE DECAY FOR LONG-LASTING BATTERIES

A multi-university team of engineers, headed by Wei Sun of the University of Toronto, has developed a battery powered by the beta decay of tritium atoms, which could last more than a decade without replacement. By turning the flat silicon surface (upon which the emitted electrons are captured) into a porous 3-D surface of narrow pits, 1 micron wide and 40 microns deep, they succeeded in capturing a much greater percentage of the emitted electrons. This produces an efficiency that is in the range of solar batteries, without the need for solar input.

The new batteries, which use standard semiconductor technology, are hermetically sealed and very safe and reliable. Tiny ones could be implanted in the body to power surgically implanted devices, or they could be used in space applications, or for sensing equipment in remote locations.

The team's research results were published in *Advanced Materials* magazine, May 13. The technology has been licensed by BetaBatt, Inc.



University of Rochester/BetaBatt

A tritium battery that can keep going for a decade: A researcher holds the wafer test fixture that was used to test the new porous silicon diode and its interactions with tritium gas. The diode is the dark wafer in the center of the top plate.

The LaRouche Youth Movement in Los Angeles examines the "curvature" of the Rural Electrification Administration: how it changed America's history.

Ensign John Gay/U.S. Navy

Formation of a shock front: As flight speed approaches the speed of sound, the temperature and pressure of air flowing over the aircraft surface drops, producing this cloud of condensed water vapor. Even at flight speed slightly below the speed of sound, the air flowing over bumps on the surface of the plane can become supersonic: It heats up, and a shock wave develops, producing the sharp termination of the conical condensation cloud. This photo of an F/A-18 Hornet was taken from the upper deck of the USS Constellation.

Below: President Franklin Roosevelt, March 1933.

Library of Congress

Franklin Roosevelt's Economic Shock Front

by Sky Shields

The main failing of all of modern economics teaching, from free-trader to socialist, is its inability to recognize, with scientific certainty, the crucial distinction between human beings and animals. Only this recognition could possibly form the basis for a valid science of human economics. The revival of this essential concept and its elaboration by economist Lyndon LaRouche has been the basis for a long-term project embarked upon by a group of us in the Los Angeles office of the LaRouche Youth Movement (LYM). This article represents a summary discussion of approximately one year's work, spanning a number of presentations attempting to flesh out the specifics of the LaRouche-Riemann method, using Franklin Roosevelt's economic policies as a case study.

SCIENCE and the LaRouche Youth Movement

This began with an investigation of what LaRouche has called the "curvature" of an economic process, where we investigated the work of both Carl Friedrich Gauss and Bernhard Riemann on complex functions and LaRouche's application of the same to economic processes. We continued this investigation with a study of the transfinite orderings in a human economic process, using the investigation of such physical phenomena as Riemann's forecast of the acoustic shock in wave propagation—a phenomenon LaRouche has called an "economic shock wave." We next returned, at the prompting of another couple of papers by Lyndon LaRouche,[1] to the further development of Gauss's curvature concept in the form of his work on potential. All of these phenomena LaRouche has stressed as being crucial to recognize the physical-mathematic characteristics of a characteristically human economic growth process.

At first glance, a most obvious distinction is apparent between human and animal processes—so apparent that it is recognized (with a grimace) even by ecologists who would seek to deny such a distinction. This is the fact that although there has seemed to be a cap on the growth of all animal populations (including the "higher apes"), the growth of the human population has continued steadily—though with brief, but notable interruptions—throughout its entire existence (Figure 1). This, however, only serves to describe a perceived effect. One which is not *necessarily* unique to human societies—after all, wouldn't any animal population increase similarly given the proper environmental conditions? This forces us to take a second look at what is actually the underlying cause of the effect seen: Not only has there been a steady growth in the *actual* human population, but also a growth in the *potential* population, per unit land area, given certain environmental conditions. This potential population does not change for any lower animal species, although favorable changes in environmental conditions (for example, the human act of greening a desert, or terraforming Mars) may allow for such an increase in *actual* animal populations which were otherwise impossible.

The obvious, first-approximation cause for this growth in human potential is also not to be denied even by so-called free-traders and ecologists who would seek to disagree with our initial premise: the discovery, development, and application of new technologies by human minds to human processes. This application can, also in first approximation, be broadly classed into two distinct areas: one, the machine tools utilized in capital goods production; and two, basic economic infrastructure such as health care, transportation, water management, and power production and distribution. Combined, these provide the physical basis for the steady growth in what LaRouche has termed the *potential relative population density* of the human species. The following investigation has been undertaken toward the goal of consciously harnessing, directing, and accelerating this growth—in both productivity and living standards—to counter the current precipitous global collapse now being recklessly aggravated by the economic policies typified by the George Shultz-steered Bush and Schwarzenegger administrations. Hopefully, it will soon be repeated in other parts of the world.

The Depression and the Farmer

The situation faced by Franklin Delano Roosevelt when he entered office in 1933 was daunting. Under President Calvin Coolidge—installed after President Harding's death in 1923—

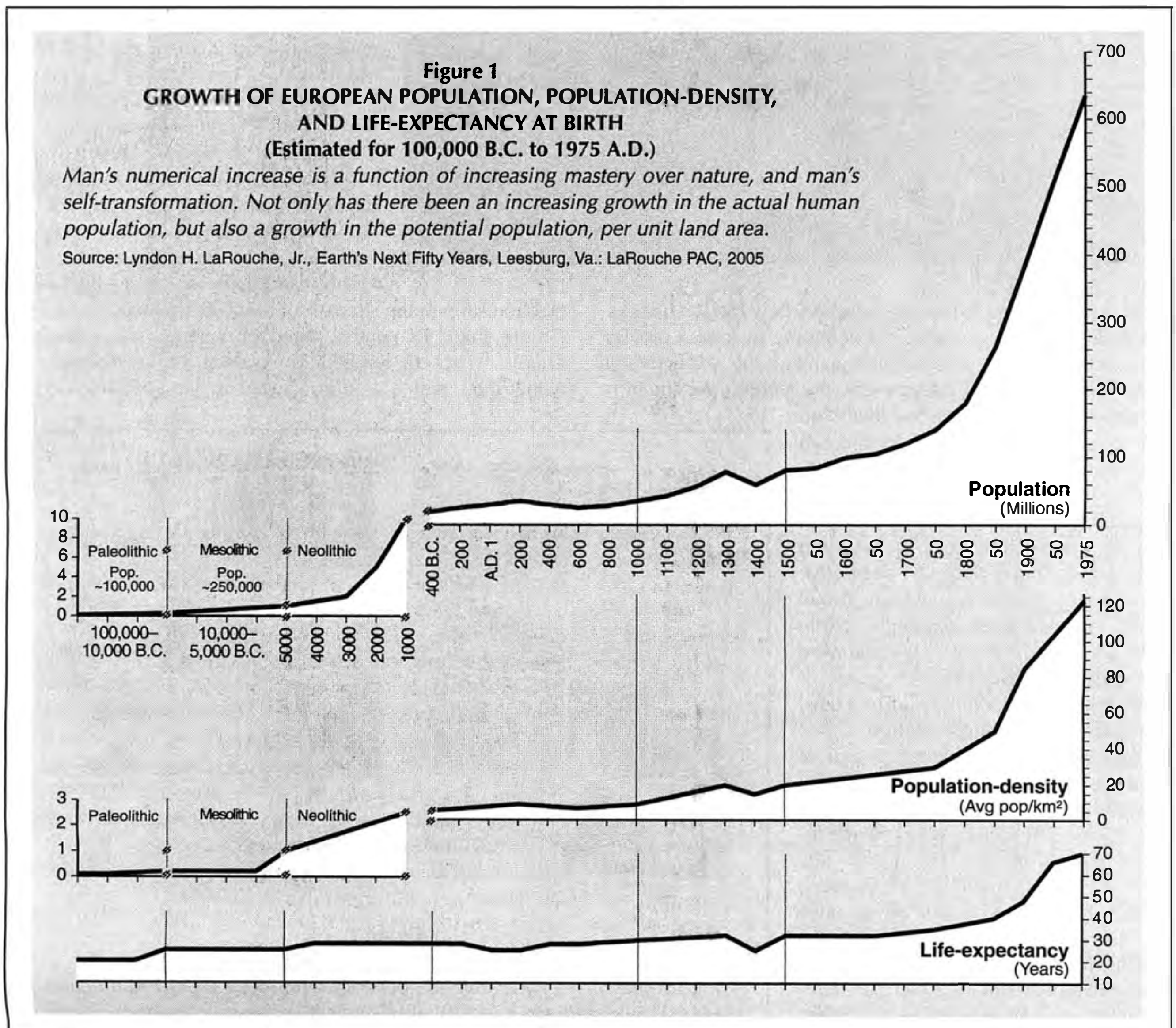


Figure 1
GROWTH OF EUROPEAN POPULATION, POPULATION-DENSITY, AND LIFE-EXPECTANCY AT BIRTH
(Estimated for 100,000 B.C. to 1975 A.D.)
Man's numerical increase is a function of increasing mastery over nature, and man's self-transformation. Not only has there been an increasing growth in the actual human population, but also a growth in the potential population, per unit land area.
Source: Lyndon H. LaRouche, Jr., Earth's Next Fifty Years, Leesburg, Va.: LaRouche PAC, 2005

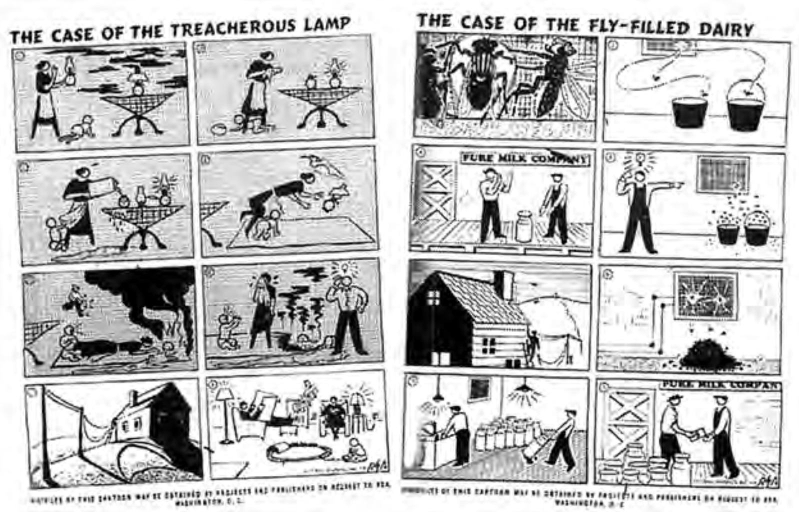
Before the Rural Electrification Administration, densely populated areas received the benefits of electricity, but rural areas were neglected by utility companies because laying the lines was considered unprofitable.

Treasury Secretary and bankers' asset Andrew Mellon had systematically starved the physical economy to feed a bloated speculative bubble. Mellon had capped the expenditures budget for the Federal government, preventing investment in the very sorts of processes we identified above as being necessary for human development—infrastructure, education, manufacturing, technological research and development, and so on—and funneled all excess money into servicing financial debt. A speculative frenzy was promoted, which drove stock market prices sky-high, while labor and the physical economy were being asphyxiated.

A post-World War I farm crisis, blamed on "over-production," but caused by this Darwinian "survival of the fittest" economic policy, was intentionally aggravated by Mellon. A bill twice passed by Congress to provide for price regulation on farm goods (by allowing farmers to dump surplus goods on the foreign market), was vetoed once by Mellon through President Coolidge, and again by Mellon through President Herbert Hoover, forcing American farmers into a trap in which the more they produced, the cheaper their goods became. *After* Mellon's speculative insanity had created the stock market crash of 1929 under the Hoover Administration, Mellon, like Bush and Schwarzenegger today, then further aggravated the situation by pushing a program of radical austerity, budget balancing, and "belt tightening," thoroughly decimating the population in an attempt to keep the financial interests afloat.[2]

Despite the introduction and incorporation of electricity into the lives of most Americans, only about 10 percent of the farms in the country had electricity at that time. Farm life was back-breaking work, which began at the crack of dawn with the first precious hours of sunlight, and ended after dark in pitch blackness. Light afforded by kerosene lanterns was dangerous and inadequate, and as a result of all of this, little or no time was left for the mental development of the youth of rural families (Figure 2).

Because of this lack of electricity, disease, parasites, and malnutrition were rampant in rural areas of the country. The contamination of the water supply by outhouses caused diseases such as typhoid and dysentery, while hookworm infection sapped the strength of much of the population (with a more than 50 percent infection rate in some southern schools).[3] Lack of refrigeration caused further diseases and malnutrition, which, in turn, caused fatigue as well as consid-



Rural Electrification News

Figure 2

BEFORE AND AFTER ELECTRIFICATION

Cartoons like these, illustrating the perils of farm life without electrification, were widely distributed in the Rural Electrification News *magazine.*

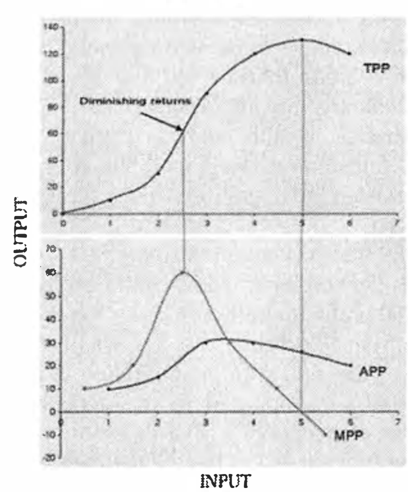


Figure 3
THE LAW OF DIMINISHING RETURNS
In a closed system, shortage of an essential input such as energy produces an apparent boundary condition. To the accountant, or victim of Econ 101 class, it may appear as an unsurpassable obstacle.

erable physiological damage to the brain development of many in rural areas.[4]

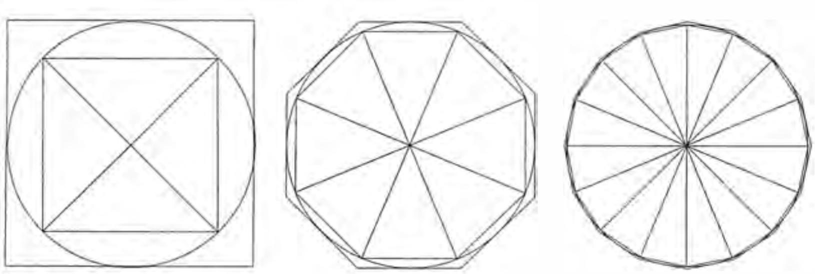
Despite these conditions, easily remediable by the introduction of basic infrastructure and conveniences, utility companies had refused to provide service to these areas. Their argument was that, unlike the densely populated urban and suburban regions, where every inch of line from the power plant to the furthest consumer was connected directly to another consumer, most of the line laid to reach the remote farms in the underpopulated South and Midwest would be essentially useless and unprofitable. The only way such a venture were even thinkable would be for the farmer to pay an initial deposit to cover the costs of building. This, of course, would be impossible for all except the most profitable farms. Moreover, the lifestyle of the farmer required so little electricity—and this mainly in the two to three peak hours just after sunset—that the rates which the utilities would have to charge during those hours would be well out of the range of any farmer.[5]

Rural rates were already far in excess of those charged in city areas. Roosevelt himself commented in 1938, regarding his 1924 stay in Georgia to treat his polio, "When the first of the month bill came in for electric light for my little cottage, I found that the charge was 18 cents a kilowatt hour—about four times what I pay at Hyde Park, New York." These circumstances formed a seemingly insurmountable boundary condition, created by the immutable laws of diminishing returns and supply and demand (as any Economics 101 student has been trained to tell you)—a product of the asymptotic infinity posited by the very nature of economics as the "science of scarcity" (Figure 3).

Embedded Infinities

"Infinity," however, is a very apt term for this sort of boundary. What, after all, is the infinite? The first images which come to mind may be the vast expanse of space, or perhaps a series of numbers growing larger and ever larger without end, or, maybe, the greatest infinite trump card of all, "God," may be invoked. These "infinities" as presented, however, never actually live up to the term. They are simply *uncountables:* quantities which are "bigger than I can imagine." The limitation in each of these cases is not objective, but rather subjective. Then, are there really no *actual* infinities?

Let us take a more rigorous case: that of Cardinal Nicholas of Cusa's squaring of the circle (Figure 4). The attempt to approximate the circumference of a circle with inscribed and circumscribed polygons leads us to the recognition that, regardless of how many times we multiply the sides of a polygon, the circle as a figure is unattainable in this manner. The circle as an actual (not imagined) existence, from the standpoint of the polygon is truly infinite.[6] However the circle—as a figure—we can recognize and create as a single, finite, idea. The infinity here is simply an indication of a discontinuous change of state: a point where the limitations of the nature of the algebraic magnitudes generating the polygon force us to



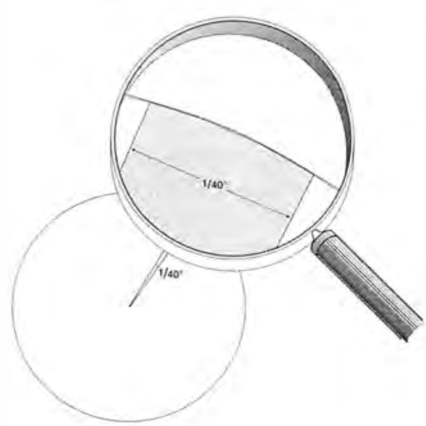
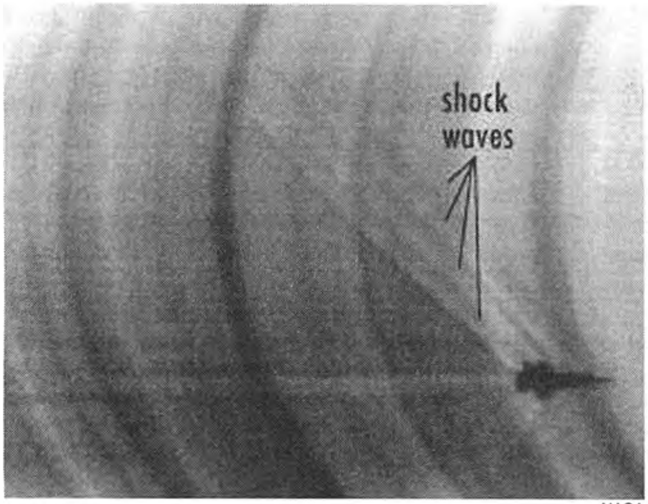


Figure 4
THE QUADRATURE OF THE CIRCLE
No matter how many times we multiply the sides of a polygon, we cannot arrive at a circle. The circle as an actual (not imagined) existence, from the standpoint of the polygon, is truly infinite.

Source: *Fidelio*, Summer 2001



NASA

The shock waves are visible as this plane breaks the sound barrier.

leave them behind, in favor of a transcendental mode of representation.[7]

This discontinuity is of the same quality as that recognized by Bernhard Riemann in his 1856 paper, "On The Propagation of Plane Air Waves of Finite Magnitude."[8] There, Riemann takes a phenomenon which had been recognized by mathematicians before him—the fact that the differential equations for fluid flow all approach insurmountable infinities once velocities approach the limit for the propagation of a wave in that medium—and demonstrates that this infinite discontinuity is really a part of a higher-order, continuous function. This mathematical infinity is later encountered, physically, during the 1940s, as the so-called "sound barrier."

Many at that time declared this "wall of sound" to be unbridgeable: instrumentation failed; the laws of lift seemed to reverse themselves, forcing planes into a steep dive; and maneuverability disappeared almost completely, hurling those unfortunate enough to encounter this barrier into a helpless trajectory, straight into the ground. The laws of physics themselves seemed to dictate a barrier beyond which man was not allowed to penetrate. However, Riemann had already demonstrated that this "barrier" was no such thing *almost a century prior!* This phenomenon of seeming infinities fascinated Riemann, and formed the basis for many of his physical investigations. These "transfinite" orderings proved to be characteristic of physical processes in general, and as such, it should not be surprising to see them make their appearance in the science of physical economy.

Like the breaking of the "sound barrier," rural electrification, as directed by the Roosevelt Administration, transformed the geometry (or field) in which the physical phenomena observed by the utility companies was taking place. And, just as the incorporation by Adolf Busemann and Ludwig Prandtl of Riemann's higher-order conception into the construction of planes during the late 1940s proved the existing mathematics to be obsolete in the case of supersonic flight, the incorporation of a new physical principle of social organization into the economic processes of the 1930s, demonstrated the financial accounting methods of the utilities to be incompetent. The act of electrifying the rural areas transformed the productive potential of the entire country, thus increasing the amount of production of real, physical wealth such as capital goods and—most important—functioning, developed human minds. That, in such a way that even the operations in city areas were transformed in their efficiency.

Thus, the geometric transformation of increased *power* (physical economics as defined here) redefines the expression of mere *energy* (financial profit), thereby absorbing the embedded "infinites" of a physical process into a higher-ordered whole. This is the only sane, anti-entropic definition of *profit* which the true economist (as opposed to the accountant) should allow. The rules of accounting, like those of mathematics, are meant to be broken, as has been illustrated by the entire history of human development until the present day.

The real reason for the hesitancy of the utilities, and for their high rates, however, was another form of speculative insanity which had been promoted under Mellon. Massive parasitical financial structures called Holding Companies had attached themselves to the utility companies. Buying up assets in the form of entire businesses, these companies fed off the inflated stock values of the utilities, servicing this debt by sucking from the physical economy in the form of increased rates and lack of infrastructural development, a phenomenon similar to that which Lyndon LaRouche has illustrated with his Triple Curve collapse function (Figures 5 and 6.) Roosevelt attacked this insanity with his 1935 Public Utilities Holding Company Act (PUHCA) and 1935 Federal Power Act, but the problem of finally bringing electricity to these rural areas remained.

The REA As Curvature

The Rural Electrification Administration (REA) emerged from a team functioning under the direction of Franklin Delano Roosevelt, through a series of decisions beginning with its creation on May 11, 1935. The August 1935 transfer of funding from crisis-relief funds turned the REA into a self-liquidating loan agency, and the 1936 REA act solidified the REA into a permanent supervisory and loan institution. Its loans were issued both for the construction of lines and for the purchasing of appliances by REA borrowers. These loans were issued at a 2 percent interest rate over an extended period of time, to facilitate the physical development of the areas involved. Of the three avenues possible for a loan program—loans to private companies, loans to municipalities, or loans to collaborative farm groupings called cooperatives—the last quickly emerged as the preferable route. A similar task of long-term low-interest credit generation and distribution for productive investment is being proposed today by Lyndon LaRouche (Figure 7).

A first look at the initial, local effects of Roosevelt's rural electrification program is revealing in itself. The forecasts of the utility companies and their accountants were proven to be stunningly inaccurate (wherever they were not also blatantly dishonest). Not only did farmers manage to find ways to utilize electricity, but in order to make their electricity use profitable *they had to devise as many ways as humanly possible to*

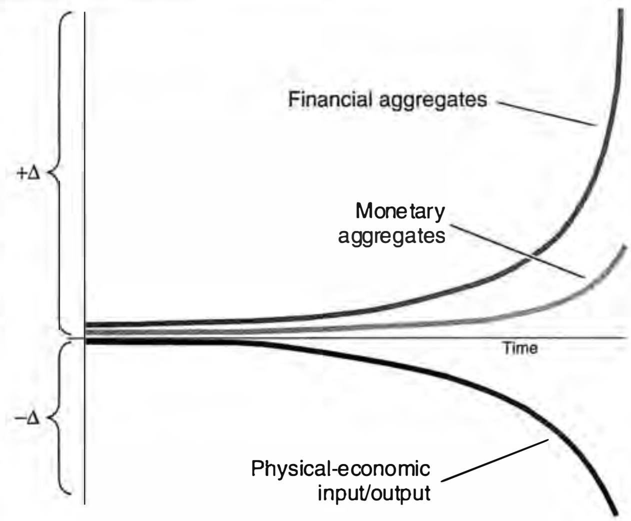


Figure 5 (a)
A TYPICAL COLLAPSE FUNCTION

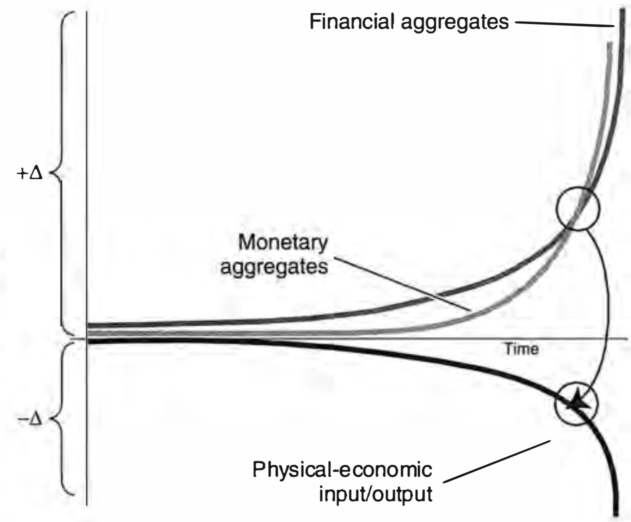


Figure 5 (b)
THE COLLAPSE REACHES A CRITICAL POINT OF INSTABILITY

The recent decade's jump in financial speculation represents a cancerous growth which has been steadily killing the global physical economy. As more and more of the world's resources (financial and otherwise) are funneled into maintaining "the markets," the possibility for the development of real wealth is destroyed.

Source: EIRNS

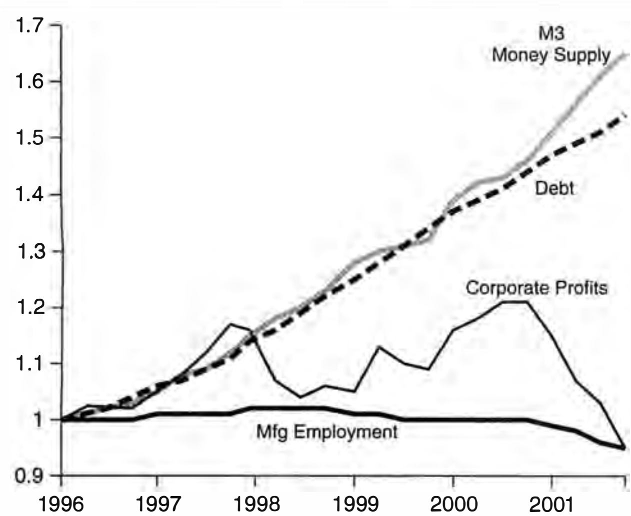


Figure 6 (a)
THE U.S. ECONOMY'S COLLAPSE FUNCTION SINCE 1996

Source: EIRNS

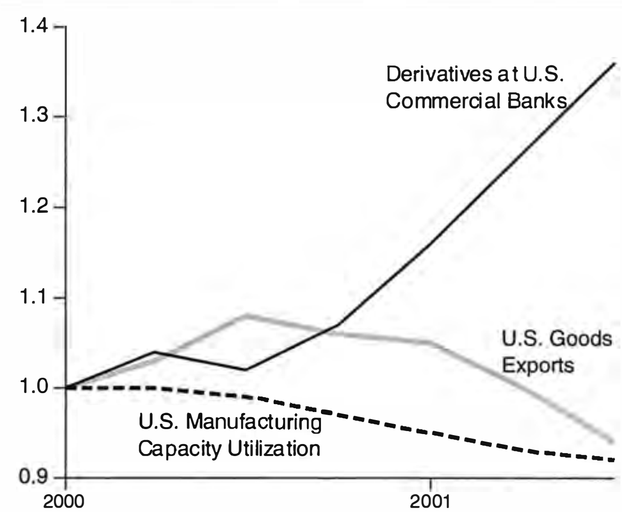


Figure 6 (b)
DERIVATIVES SOAR, MANUFACTURING FALLS IN 2001

Sources: FDIC, U.S. Department of Commerce, Federal Reserve

utilize electricity in their daily labor, and then some. A simple, first-order financial analysis showed that the costs paid by farmers for electricity did indeed shoot up dramatically—however, so did the returns as a result of increased *physical* productivity on the farms. So necessary was this rapid application of technology, that the REA began hosting what were called "circuses" (officially known as Farm Demonstration Tours) in which the multitude of uses for electricity in farm life were demonstrated—from cooking, washing, and lighting, to grinding feed, brooding chicks, and drying hay (Figure 8).

Most important, however, was the creation of free energy in the form of the creation of more *time*. For instance, the introduction of an electrically pumped water system, to replace the pumping and hauling of buckets of water by hand, *created, in*

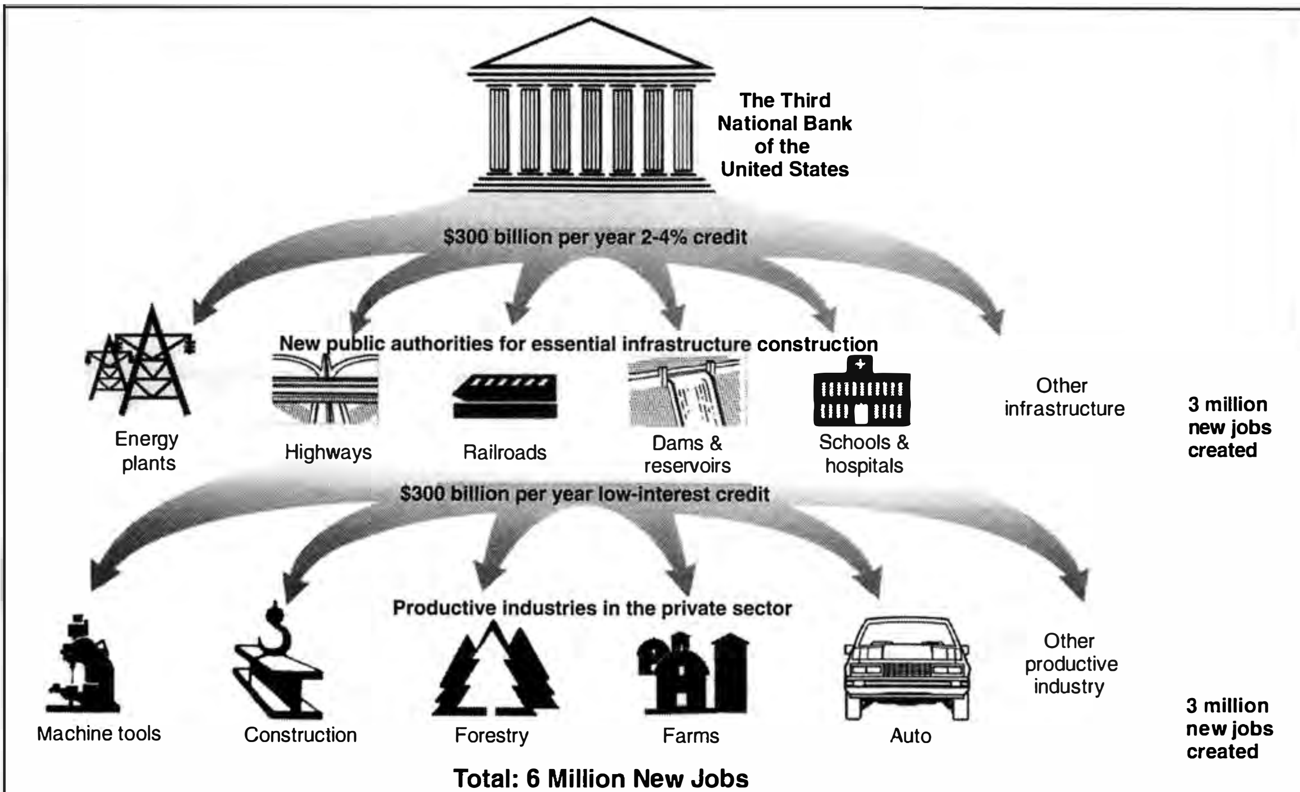


Figure 7

LAROUCHE'S THIRD NATIONAL BANK CREDIT STRUCTURE FOR FINANCING PHYSICAL-ECONOMIC GROWTH

In 1992, LaRouche proposed bankruptcy reorganization and massive investment in infrastructure and industry to create 6 million new jobs in the United States. He estimates that the comparable, scaled-up program required today would yield 10 million new jobs.

REA

Government created a boom in private production where private production, left to its own devices, would have suffocated itself, much like the sow, who, prior to the development of the pig brooder, "naturally" would tend to crush to death at least one piglet per litter under her own body weight. The interventions of human reason, whether represented by man's intervention into Darwinian "nature," or by Federal government's regulatory role in the development of economies (as opposed to Darwinian "free enterprise") is crucial to mankind's development.

effect, 30 extra 8-hour days of a single operative's activity per year. That is, prior to electrification, 240 hours were spent per year pumping and carrying water from its source. An equivalent amount of time was spent hand-separating cream, and again as much in cleaning and maintaining lights run on kerosene fuel.[9]

Thus, with these three technological injections alone, three months were added to the year for a farmer—months that were spent on increased physical production as well as newly discovered leisure time for various forms of intellectual development.[10] In particular, once electric lights had freed the farmer from dependence on daylight hours (including adding more time for nighttime pursuits such as reading, which did not otherwise exist), the deeper significance of the phrase *transformed potential* begins to become clear in discussing the life of the farmers.

Transforming Potential

In a number of his recent papers,[10] economist Lyndon LaRouche has stated that the idea of potential most applicable to the current discussion, is that laid down by Carl Gauss, in his essay on attractive and repulsive forces which act according to the inverse square of their distance,[11] as well as his work on Earth magnetism.[12] To understand the point made there, try this experiment: Take two strong magnets, and attempt to bring

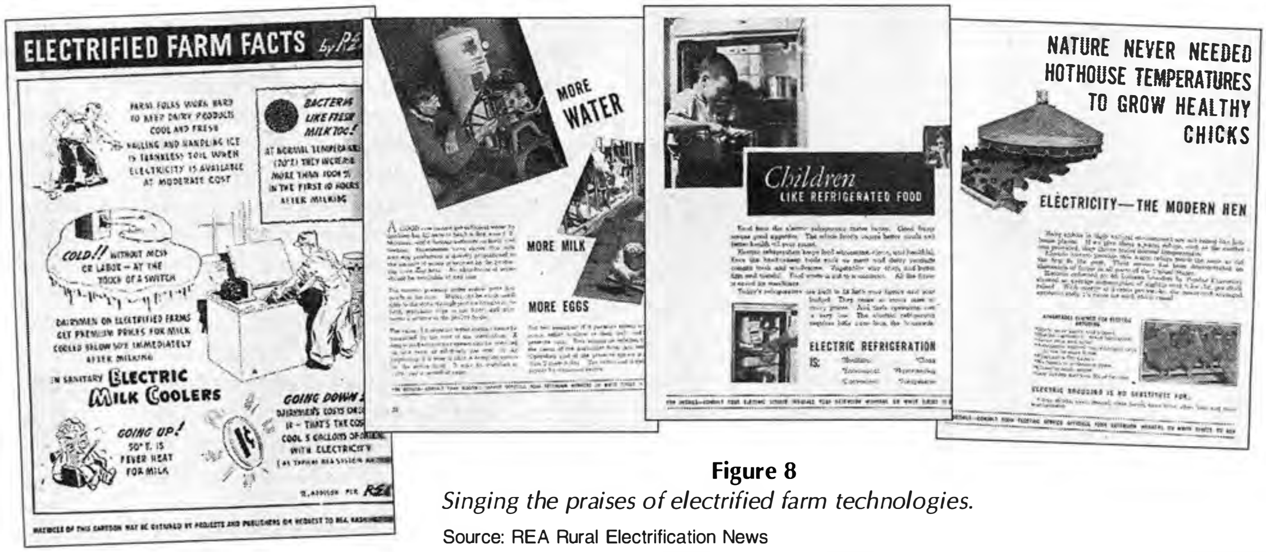


Figure 8

Singing the praises of electrified farm technologies.

Source: REA Rural Electrification News

them closer and closer to one another without allowing them to touch one another. What do you feel? It would seem that there is clearly some force acting to pull these two magnets closer together (or to keep them apart, depending on which direction you have them facing). Further examination of the strength of this apparent force would reveal that it lessens with distance. Moreover, this same dependency on distance exists for the observed gravitational and electrical forces as well. Specifically, they vary in proportion to the inverse square of their respective distances ($1/r^2$ if we set the distance equal to r). Take a second longer to play with the two magnets, and then reflect upon the force which holds you securely to the planet Earth.

Now, to understand the requisite idea of potential, simply understand this straightforward observation of Gauss: *There is no force acting to pull the two magnets you are holding together.* There is, in fact, *nothing* pulling on either magnet. No force. The "pull" you are experiencing is merely an effect observed by sense perception, and the "force" between the two magnets therefore has no existence in and of itself, but rather is merely the shadow of some other, actual phenomenon.

Think about this further: In the case of gravitation, what is it that causes two masses (you and the Earth, for instance) to attract one another? Gravity? What is that? Most people, when asked, would reply with the tautology that it is the force which causes two masses to experience a mutual acceleration. How do we know that this force exists? Because the masses present are undergoing an acceleration, and Newton's celebrated equation states that $F = ma$ (force equals mass times acceleration). Therefore, what is the force which causes two bodies to attract? Well, the force which causes two bodies to attract. . . . This circular reasoning is no game, but rather is a product of attempting to explain the properties of shadows by the shadows themselves (like a physicist attempting to explain the clearly observed effect of the shadow of a bat on the shadow of a baseball)[13] (Figure 9).

Rather than be caught in this trap, Gauss took the discoveries he had made transforming the sense-perceptual concept of curvature into an actual principle[14] of the transformation of a set of relationships defining a potential for action, and applied them to the phenomena of gravitation, electricity, and magnetism in order to develop a concept of a *potential field.*[15] To describe the effects of the transformation of such a potential field, Gauss's student Riemann elaborated Gauss's own original work on functions of a complex variable. Gauss had recognized that the doubly extended nature of complex num-

Brendon Barnett

Figure 9

HOW DOES ONE SHADOW MOVE THE OTHER?

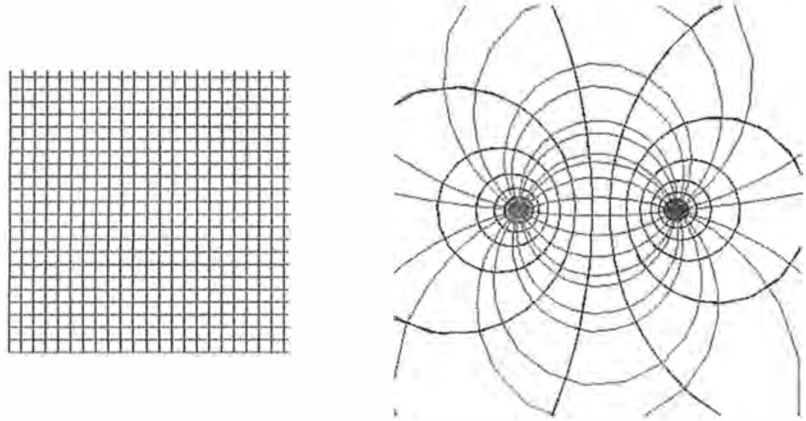
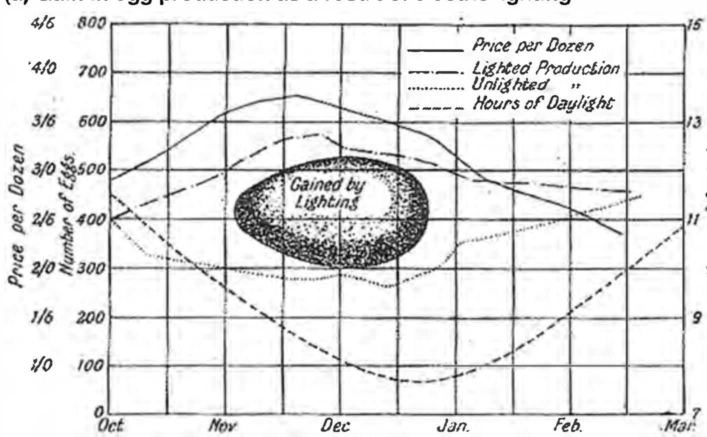


Figure 10
THE COMPLEX SINE
Gauss recognized that the doubly extended nature of complex numbers allowed them to be represented, in their entirety, on any surface. Any transformation of the relative positions of these numbers, therefore, as in the case of applying a mathematical transformation, corresponded to a transformation of the least-action lines of one surface to those of another. Here, the complex sine function.
Source: Bruce Director

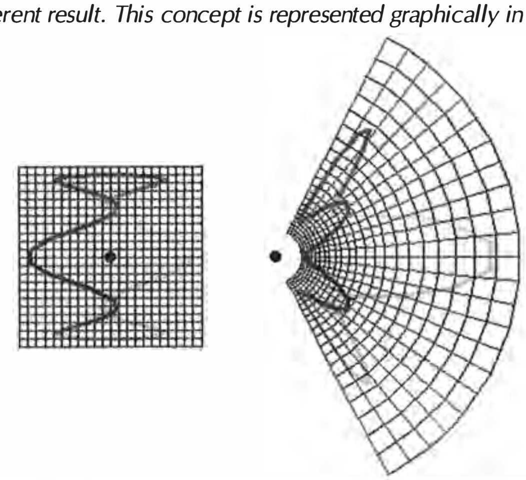
(a) Gain in egg production as a result of electric lighting



Source: Red Wing Report

Figure 11
EGG PRODUCTION WITH AND WITHOUT ELECTRICITY
Under normal conditions, chickens lay considerably fewer eggs in winter and at night. Without changing this built-in property of the chicken (by, perhaps, building a new chicken), we can simply transform the physical space-time manifold in which the chicken operates (a). The chicken, now, by performing exactly the same action, though in a different manifold, produces an entirely different result. This concept is represented graphically in (b).

(b)



bers—numbers utilizing the quantity $\sqrt{-1}$—allowed them to be represented, in their entirety, on any surface. The only difference in each case would be the relative positions of the complex numbers. Any transformation of the relative positions of these numbers, therefore, as in the case of applying a mathematical transformation, corresponded to a transformation of the least action (or geodesic) lines of one surface to those of another (Figure 10).

Now, take this idea of *potential,* as that "curvature," or set of relationships, which defines the possibility for action, and apply it to our initial discussion. What is it exactly that causes the transformations of the scalar magnitudes of time, productivity, and the more complicated but superficially scalar quantity of standard of living? Might these observable effects be but the shadows of an underlying, transformed set of relationships? Or, more interesting for our present-day purposes, what sorts of action on that underlying *field* could produce the desired effect on magnitudes such as the above-mentioned *potential relative population density* of the human species? We will take this question, already alien to modern day, university-trained "economists" (really just glorified accountants, and shoddy ones at that) such as Alan Greenspan, and return to our earlier discussion of the Roosevelt-era Rural Electrification program.

Dirichlet's Principle and Physical-Economic Potential

To discover what it is that defines the economic *field* in the case of the productivity increase felt by the FDR economy, we'll take our cue from what Riemann named "Dirichlet's Principle," and identify what constitute the singularities and boundary conditions which define the potential for action in that case. For this, remember the role of physical-economic infrastructure and machine tools as the physical medium by which the introduction of a new scientific principle into human activity is effected. These things define the boundary condition of an entirely new phase space, in which even activity in the non-rural areas of the economy is transformed by virtue of its new relative position (*analysis situs*).

The appliances demonstrated in the REA farm circuses, as well as those demonstrated at co-op meetings, were entirely the products of private enterprise. Thus, contrary to the simplistic fantasies which Shultz's Arnold Schwarzenegger would like to transfer straight from his movies to economics, government created a boom in private production where private production, left to its own devices, would have suffocated itself.

The new technology produced to effect rural electrification (particularly when viewed in connection with the full effect of Roosevelt's other infrastructure-development projects), produced an explosion in the manufacturing sectors of the economy which were otherwise far removed from the drastic transformations taking place in rural America. By the time of the mobilization for World War II, the Nazis, fortunately for humanity, were facing a transformed United States as a result of this transformed potential. Roosevelt had created the possibility for the United States to shoulder *more than half* of the productive burden of the war.[16]

Roosevelt's Secretary of Agriculture, Henry A. Wallace, called for a 25 percent increase in crop and livestock production: 13 billion pounds of hogs, 128 billion pounds of milk, 4 billion pounds of chickens, 52 million acres of wheat, 88 million acres of corn, 23 million acres of cotton.[17] This burden, impressive enough on the face of it, was aggravated by the fact that the farmers, in most cases, had already sacrificed much of their able-bodied workers to the war effort. It was only because of the prior internal transformation experienced under Roosevelt's REA, that this increase in scalar output was possible. Just as it is the internal (geometric) reorganization of a machine, which allows a higher density of its output in the form of energy flux density, without necessarily requiring an increase in the actual energy brought to bear (Figure 11, a and b).

It is precisely this method of directed credit generation and massive investment in high-technology infrastructure production that is needed for the United States today. For the modelling of the desired processes, we must look to the further development of Gauss's concept of a potential field, by the work of Bernhard Riemann on multiply extended magnitudes as well as his work on Abelian functions.[18] The possibility of real-time modelling of these sorts of processes, using actual economic data, represents a characteristic phase shift in the science of physical economy. This involves projecting and analyzing seeming infinities in order to effect a transfinite shift in the expression of various scalar economic magnitudes, by acting on the multiply connected relationships which constitute an economic "field."

Along with a much-needed policy shift, we would also have created the possibility of harnessing a phenomenon once experienced only intermittently in human history—this capacity for surpassing the physical boundaries on human development—and transforming it into the sole, consciously directed element of human economics. This return to the practice of economics as a true science, as opposed to the lunatic casino approach being applied today, will be a crucial accomplishment of the LaRouche Youth Movement in the period immediately ahead, and must become a critical area of our focus.

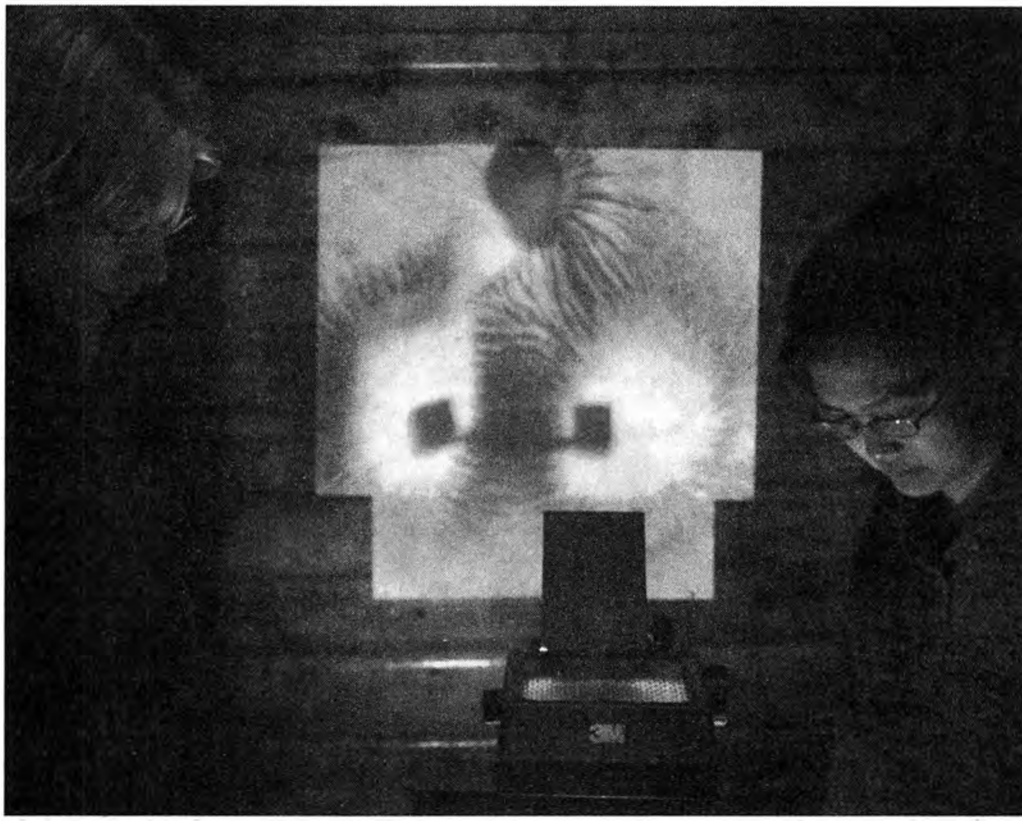
Sky Shields is a leader of the LaRouche Youth Movement from Los Angeles.

Notes

1. Lyndon H. LaRouche, Jr., "Cauchy's Infamous Fraud," and "How Most Economists Became Illiterate," *Executive Intelligence Review*, April 1, 2005.
2. A more thorough discussion of this period can be found in the book-length report *Economics: End of a Delusion*, which features a theoretical essay of the same name by Lyndon LaRouche, as well as a study of the Franklin Roosevelt recovery measures, written by Richard Freeman. Copies of this study may be obtained by contacting *Executive Intelligence Review* magazine through its website http://www.larouchepub.com.
3. Deward Clayton Brown, *Electricity for Rural America: The Fight for the REA* (Westport, Conn.: Greenwood Publishing Group, 1980).
4. This phenomenon is seen today in impoverished parts of the world (including the United States), and is often attributed by the ignorant, or those in wishful denial, to either "laziness," or worse, to some sort of Nazi-eugenics-inspired concept of racial inferiority.
5. This should remind readers of the current arguments against development of so-called "Third World" areas of the world today.
6. The reader is also encouraged to further research the work of Nicholas of Cusa (1401-1464) to obtain a rigorous, non-fundamentalist concept of an infinite God.
7. This recognition forms the basis of Cusa's discovery of the transcendental nature of *pi*.
8. Bernhard Riemann, "On The Propagation of Plane Air Waves of Finite Magnitude," *International Journal of Fusion Energy*, Vol. 2, No. 3 (1980).
9. A similar free-energy effect would be experienced with the introduction of an integrated mass transit system for areas such as Los Angeles. However, the opposite, disastrous slowing-down effect is to be expected from the Bush Administration's current planned elimination of Amtrak, our national rail system.
10. See "Cauchy's Infamous Fraud" (*Executive Intelligence Review*, April 1, 2005). "The Power to Prosper" (*Executive Intelligence Review*, April 29, 2005), "The Revolutionary Aspect of LaRouche's Method" (*Executive Intelligence Review*, May 13, 2005).
11. Carl Gauss, "General Propositions Relating to Attractive and Repulsive Forces Acting in the Inverse Square of the Distance," available on the LYM website at http://www.wlym.com/›jross/curvature/.
12. Carl Gauss, "The Intensity of the Earth's Magnetic Force Reduced to Absolute Measurement," translated from the German by Susan P. Johnson, available on the *21st Century* website at http://www.21stcenturysciencetech.com/Translations/gaussMagnetic.pdf.
13. The scalar quantity of energy is another such shadow magnitude. Although true in all parts of the physical sciences, this fact is most obvious in the field of physical economy. The attempt to manage an economy by simple accounting measures of energy input and output will tell you next to nothing of real significance about actual economics. Rather, the true economist (as opposed to the mere accountant) will concern himself with the geometric properties of a piece of machinery (or economy as a whole) which transforms the amount of energy brought to bear per unit of area.
For this reason, Lyndon LaRouche developed the geometric concept of *energy flux density* as a measure with true ontological significance, unlike "energy," which is simply its observed effect. Other such effects are the shadow quantities called "mass," "velocity," "acceleration," and "momentum."
14. See note 11.
15. This is not to be mistaken for Maxwell's concept of the field, as taught in universities today.
16. Thus, contrary to mythology, it was Roosevelt's economy created *first* which won us the war, and not vice-versa.
17. Marquis Childs, *The Farmer Takes a Hand: The Electric Power Revolution in Rural America* (Garden City, N.Y.: Doubleday, 1952).
18. Further discussion of the work of Gauss and Riemann will be taken up in an ongoing pedagogical article series, "Riemann For Anti-Dummies," written by LaRouche colleague Bruce Director. The entire series can be found at http://www.wlym.com/ under the section header "pedagogicals."

On the Re-Discovery of A Principle to Communicate The Relationship of Principles

by Cody Jones



Field lines formed by iron filings around a magnet are projected onto a screen. Pictured are Wes Van Der Schaaf (l.) and Liona Fan-Chiang.

Our development of an appropriate model to communicate the principle of change of potential for action (that is, a change in the potential-field), as a function of the introduction of a newly discovered universal principle (singularity), first required the re-discovery of a particular universal principle on our part.

An investigation into Hans Christian Oersted's 1820 discovery of the perpendicularly oriented relationship (characteristic of a least-action manifold, and the basis of our electricity-driven modern economy), between two already known phenomena, electricity and magnetism, yielding the hypothesis of electromagnetism as a single phenomenon, and associated experimental proofs of this relationship, became the basis for generating the technology to be used in our model.

SCIENCE and the LaRouche Youth Movement

We started with the construction of several solenoids. We used 3-inch X 1/2-inch steel bolts, wrapped up and down numerous times (the more the better) with very thin insulated copper wire, leaving two ends of the wrapped wire free, to be connected to the positive and negative poles of a battery. The circular movement of current around the bolt produces a magnetic effect perpendicular to the flow of current, with poles occurring at the ends of the bolt. (See how this is affected by changing the direction of current flow).

Three of these solenoids were thus mounted, in the vertical position, 6 inches apart in triangle formation, on a solid wood platform, with a clear piece of Plexiglas held slightly above the solenoids by wooden pillars. The two ends of the wire of each of the solenoids were separately run through their own commutators (switches for changing the direction of current), meeting back together at a single on/off button connected to the DC battery. The switches allow for changing the number of magnets activated at any one time, as well as which pole (north or south), sits under the Plexiglas.

On the Plexiglas was sprinkled a thin layer of iron filings. (We gathered these from a sandbox at the local park, by a process of moving a magnet, wrapped in a plastic bag, through the sand, attracting the iron filings that had been naturally dispersed through this fossil of living matter, and then we further distilled them out through a simple refining process).

Upon activation of one of the solenoids, the iron filings will align themselves in radial spokes emanating from the magnetic pole, in conformity with the potential field generated by that singularity (that is, the magnetic pole). Demonstration of the introduction of a new singularity can then be achieved by activating a second solenoid, whose poles are reversed, in relation to the first solenoid. When the Plexiglas is gently tapped, a kind of stop-action transformation (animation) is achieved, as the iron filings realign themselves according to the new action potential that has been created by the introduction of this second singularity. The introduction of the third pole provides yet another transformation. (Notice the effect of the relationship created between like poles).

It is important to realize that the "field lines" (as named by the evil James Clerk Maxwell) shown by the formation of the filings, are not fixed. Each run of the model will provide a new set of lines. What is constant is the particular "shape" of the pathway of action that can be taken, as determined by the type, and relationship of the singularities. In other words, what's determined is the quality of action that can occur in the field.

(Notice that the animations generated by this model are of the same form as those generated by Bruce Director, in such locations as "Riemann for Anti-Dummies," Part 58[1] on "Dirichlet's Principle," to demonstrate complex transformations of a Gauss-Riemann type.)

Demonstrating 'Potential'

This universal-inspired model served us to demonstrate pedagogically, in first approximation, the idea of "potential," as most thoroughly developed by Lyndon LaRouche in his paper "The Power to Prosper,"[2] and further elaborated in a series of classes on LaRouchian economics presented by the LaRouche Youth Movement.

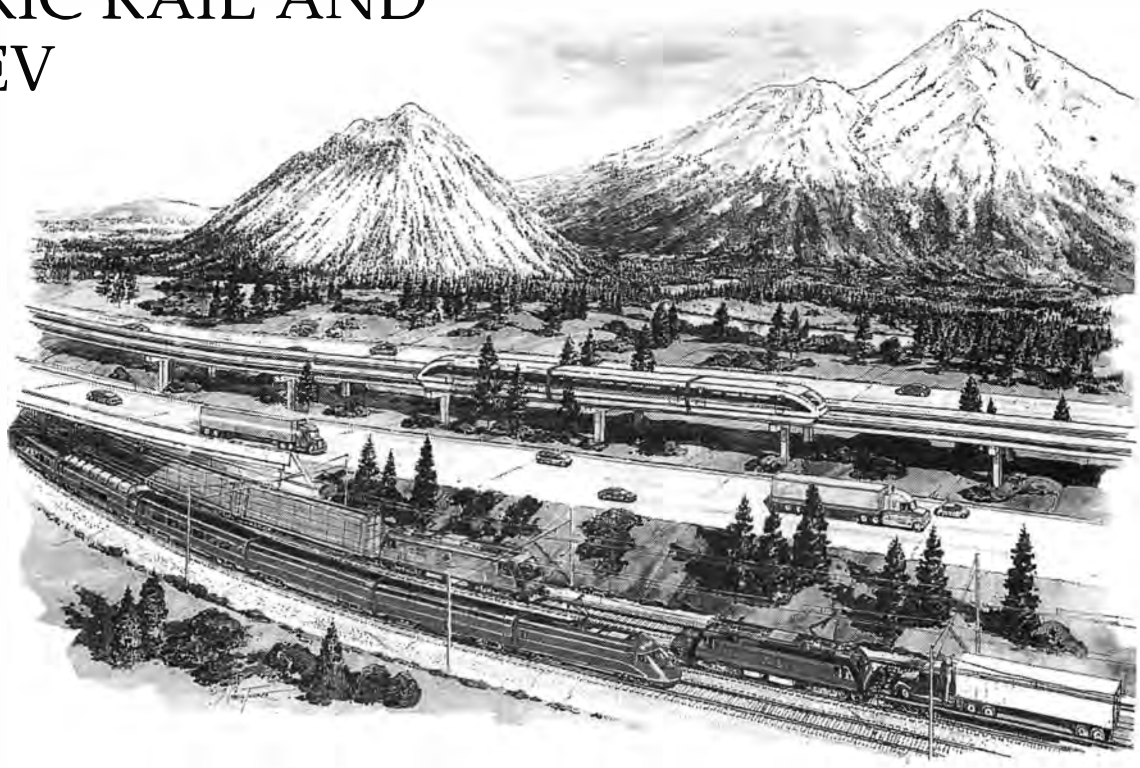
SCIENCE and the LaRouche Youth Movement

I find it most appropriate that the model developed to demonstrate the nature of change produced by Franklin D. Roosevelt's Rural Electrification Projects, would be premised on our own re-discovery of the principle of electromagnetism. It was the re-discovery of that principle (*power*), which gave us the new power to communicate the principle of change in potential, as occurs when a new *power* (principle) is introduced to the domain of Physical Economy.

Notes

1. This series of pedagogicals is available at www.wlym.com.
2. Lyndon H. LaRouche, Jr., "The Power to Prosper," *Executive Intelligence Review*, April 29, 2005.

42,000 MILES OF ELECTRIC RAIL AND MAGLEV



An end to gridlock: The West Coast high-speed ground transportation corridor would use electrified railroad and magnetic levitation lines. Envisioned here is the Interstate 5 freeway route in Northern California near Mount Shasta, where a new maglev route would cross the existing north-south railroad.

Illustration by J. Craig Thorpe, commissioned by Cooper Consulting Co.

A Plan To Revolutionize America's Transport

by Hal Cooper

An experienced railway consultant lays out the requirements and timetable for how to get from here to prosperity, via electrified rail.

The United States, and indeed the world, is now at a critical juncture, with two starkly different pathways for its economic and energy future. One is to continue to degenerate into fiscal austerity, as the result of 40 years of world financial deterioration, which began with the introduction of free-market, free-trade policies in the 1960s. The other option is to rise to a new height of growth and prosperity by returning to the American system of economics, as advocated by economist Lyndon LaRouche.

It is proposed here to construct a 42,000-mile-long route network of conventional speed electrified intercity railroad lines for the transport of freight and passengers, which will be largely built on the trackage or rights-of-way of the already existing railroad network (Figure 1). There are also smaller route networks of 10,000 and 26,000 route-miles proposed as partial alternatives. In addition, there will be a 42,000-mile-long magnetic levitation network constructed generally along the existing interstate highway network, which will operate at very high speeds (Figure 2). There will also be 10,000- and 25,000-mile-long magnetic levitation networks.

The proposed national railroad electrification network will be designed to move large quantities of freight between cities, plus the passenger traffic which now goes by rail, as well as the traffic that will go by rail in the future. The proposed national electrified railroad network would be expanded from a starting point at almost zero today, to 10,000 route-miles by 2015, to 26,000 miles by 2020, and to 42,000 route-miles by 2030.

The operating characteristics of this intercity electrified railroad system would be as follows: The freight trains operating on these tracks would be designed to run at speeds of 90 to 110 miles per hour, carrying trucks and containers, and from 70 to 90 miles per hour for most other freight trains. The large, heavily loaded unit trains carrying coal would be the exception, as they would generally operate at speeds of 35 to 45 miles per hour, for safety reasons. Passenger trains would be designed to operate at maximum speeds of 125 to 150 miles per hour. The track configuration would be one of double tracks throughout, with crossover tracks and passing sidings at periodic intervals. There would be triple tracks or even four tracks along certain very heavily travelled railroad lines.

The construction of this national magnetic levitation network would be planned so that 5,000 route-miles would be in operation by 2020, with 10,000 route-miles by 2025, 25,000 route-miles by 2030, and 42,000 route-miles in operation at full capacity by 2040.The magnetic levitation system would be built as an elevated, double-guideway track system throughout, using some crossovers at periodic intervals. The system would be built primarily along the existing interstate highway medians, for ease of right-of-way acquisition as well as for safety and operational reasons. It would be designed to operate at speeds of 350 miles per hour, or even higher, in some locations between the major end-point cities.

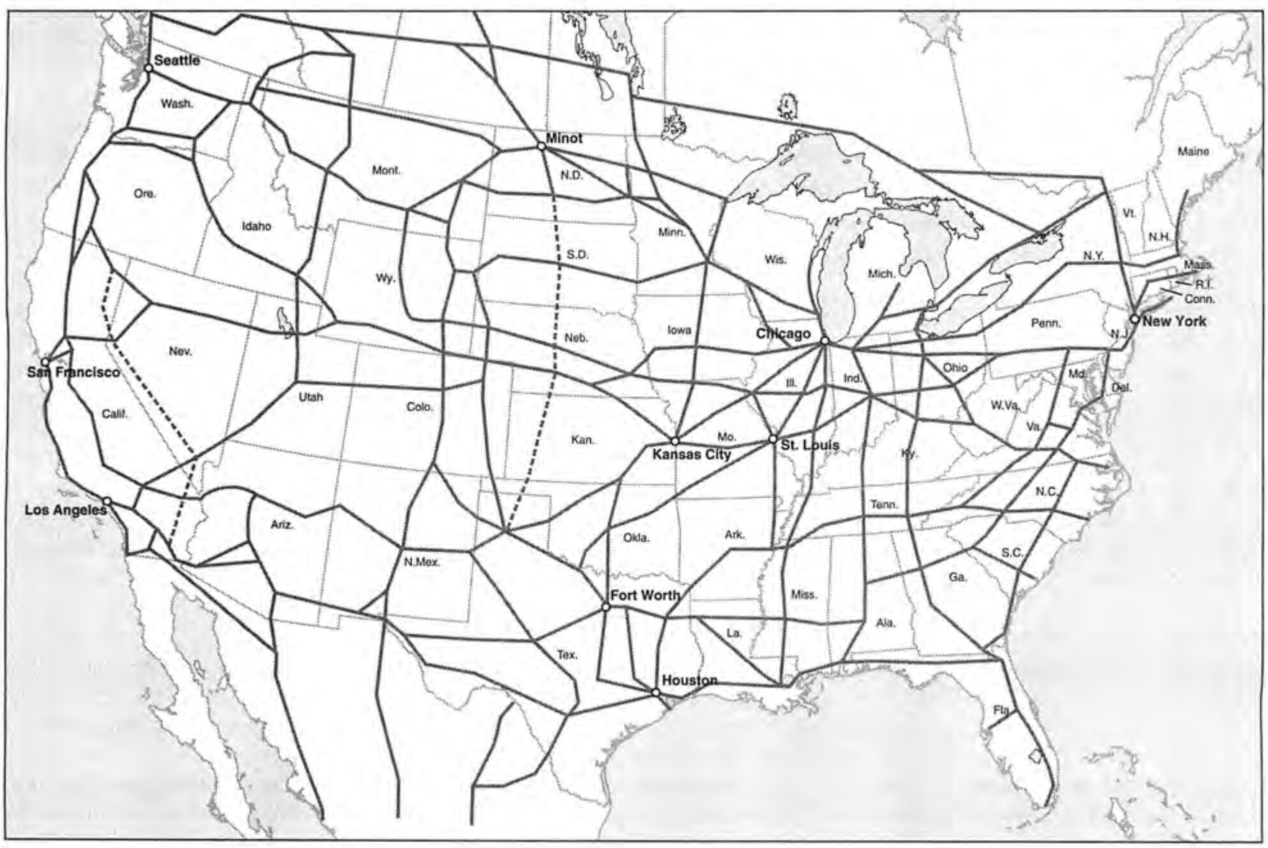


Figure 1
THE PROPOSED 42,000-MILE-LONG NETWORK OF NATIONAL ELECTRIFIED RAIL
This route network of electrified intercity rail would transport freight and passengers, largely on existing (upgraded) rail lines.

Figure 2
THE PROPOSED 42,000-MILE-LONG NETWORK OF MAGNETICALLY LEVITATED TRAINS
This new high-speed maglev network will be constructed along the existing interstate highway system.

The national railroad electrification system operating on the existing railroad lines would be designed to carry primarily freight, as well as passengers for the shorter trips. The electrified railroad would carry not only the existing railroad freight traffic-base, but also increasing volumes of trucks and truck-trailer combinations, as well as the box containers in intermodal combinations on flat cars. Drivers would accompany their truck freight in their own separate passenger cars, as a part of the intermodal freight train, so that they could then drive off to their destinations from the terminals.

Intermodal truck-rail transfer terminals would be located at periodic intervals throughout the entire national electrified railroad system, including at small towns in rural areas. Passenger stations, as well as intermodal freight terminals, would be located in a large number of communities throughout the entire rail network, in order to provide a maximum level of staffed station coverage for the public, and not only at end-point cities.

This would be designed to replace, at least in part, the need for automobile trips and some plane trips of less than 300 to 400 miles, and would have as its primary mission the intermodal diversion of truck traffic from road to rail for anything longer than local pickups and deliveries.

The proposed magnetic levitation system would have stops only at the major end-point cities and in the larger intermediate inland cities. Magnetic levitation, at 350 miles per hour or higher, would be designed to replace airplanes for those trips longer than 300 to 400 miles, but less than 1,000 to 1,200 miles for passengers. Airplane travel would then only be required for those cross-continent and long-distance trips greater than 1,200 to 1,500 miles, or for shorter trips to remote locations. An extensive feeder-bus network would serve both the magnetic levitation system, as well as the passenger trains of the electrified conventional railroad system. The magnetic levitation system would also be able to carry the majority of the high-value parcel traffic, with special cars on the existing trains for use by package carrier companies, and distribution and sorting centers in the major cities.

The proposed schedule for the construction of the respective 42,000 route-mile national electrified-railroad network and the parallel 42,000 route-mile magnetic-levitation networks are illustrated in Figure 3. The national electrified railroad network would be completed and in full-scale operation by 2030, with service starting in 2010; while the magnetic levitation would begin service in 2016 and be completed by 2040.

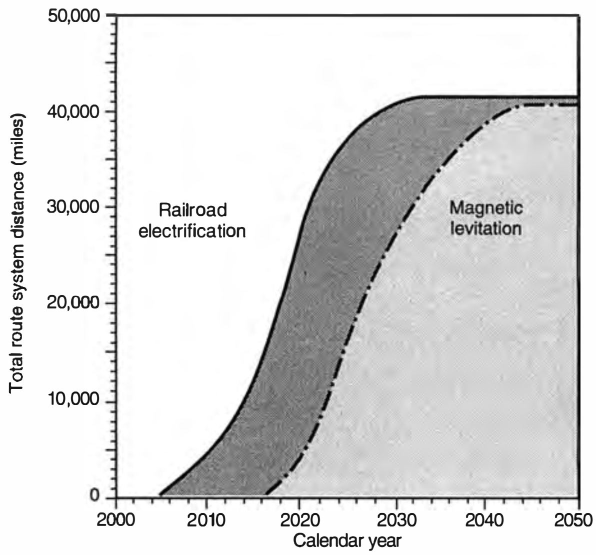


Figure 3
THE 45-YEAR TIMETABLE FOR REVOLUTIONIZING AMERICA'S TRANSPORT SYSTEM
The intercity railroad electrification would start immediately. Maglev would be phased in starting in 2016.

There are some locations where both the electrified railroad and the magnetic levitation systems would operate on common rights-of-way, at locations where interstate highways and major railroad lines would be in close proximity to each other. One such location is along the Interstate 5 freeway in southern California, south of Bakersfield, where a new railroad line would connect through a major new 32-mile-long tunnel under the Grapevine Grade, along with a magnetic levitation line along the freeway going up the mountain, as shown in Figure 4. The second location is along the Interstate 5 freeway route in Northern California near Mount Shasta, where a magnetic levitation route crosses the main existing north-south railroad line, as illustrated on page 22. (Both illustrations were painted by the noted railroad artist J. Craig Thorpe, and were commissioned by the author for the Schiller Institute to illustrate the present concept.)

Intercity Freight and Passenger Traffic

There has been a considerable increase in intercity freight traffic volumes in the United States in the past 20 to 25 years. The overall freight traffic volume in net ton-miles per year has increased from 1,492 billion net ton-miles per year in 2000, at an annual rate of 2.8 percent per year. The percentage of this freight carried by truck has increased from 37.2 percent in

(Continued on page 30)

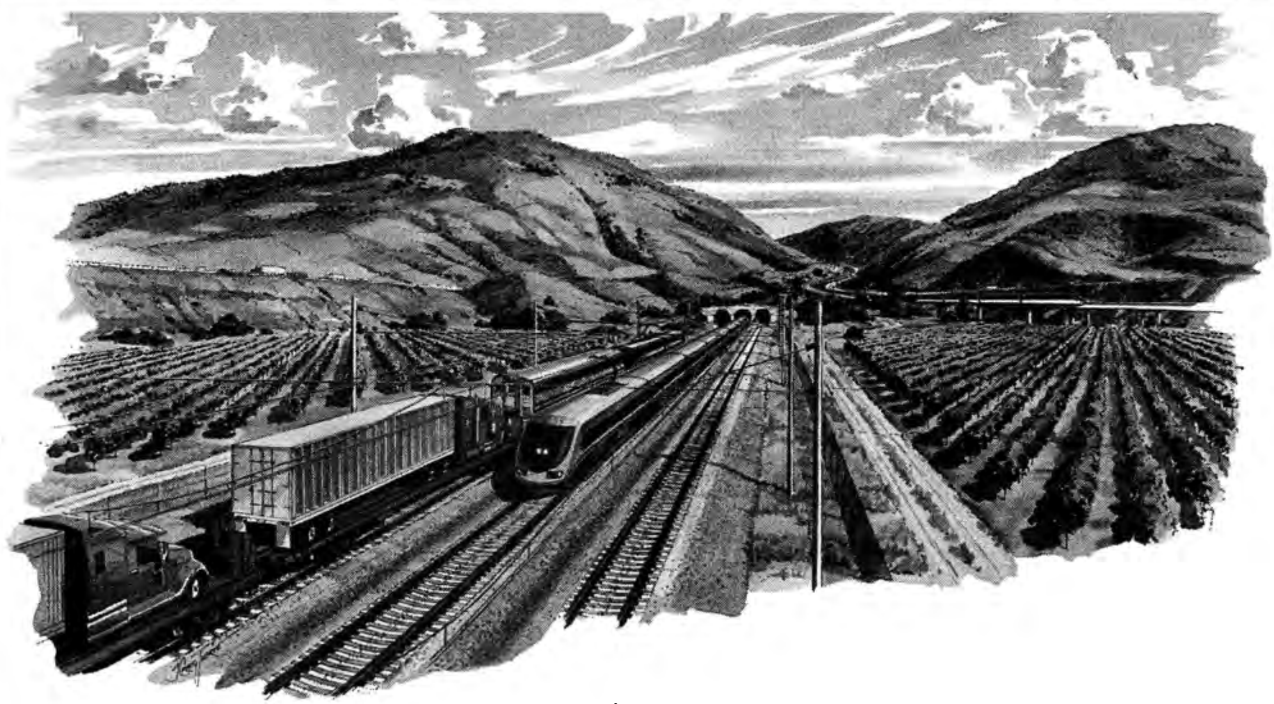
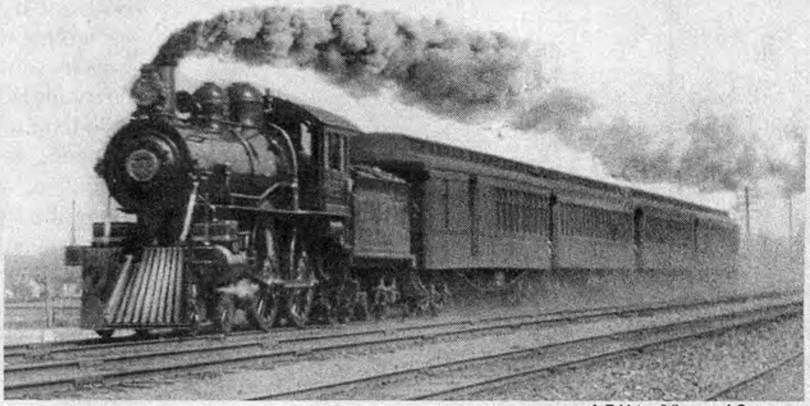


Figure 4
HIGH-SPEED RAIL AND MAGLEV IN CALIFORNIA
Here is another location where electrified railroad and maglev would operate in parallel in California: Along the Interstate 5 freeway, south of Bakersfield, a new electrified railroad line would connect through a new 32-mile-long tunnel under the Grapevine Grade. A maglev line would follow the freeway, going up the mountain. (An illustration of another California tandem route appears on p. 22.)

Source: Illustration by J. Craig Thorpe, commissioned by Cooper Consulting Co.

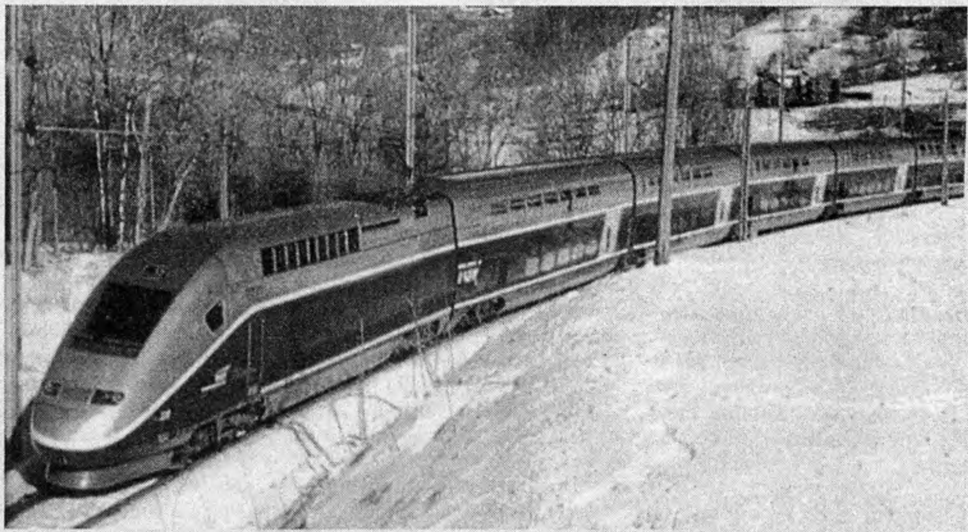
Why Electrified Rail Is Superior



A.P. Yates/Library of Congress

This 19th Century steam engine was photographed on May 10, 1893, in Syracuse, N.Y., when Engine 999, drawing the Empire State Express, made the record speed of 112.5 mph.

by Richard Freeman and Hal Cooper



TGV

France's TGV high-speed electric train. Nearly 80 percent of France's electricity is supplied by nuclear energy, and supports its nationwide grid of electrified railroads.

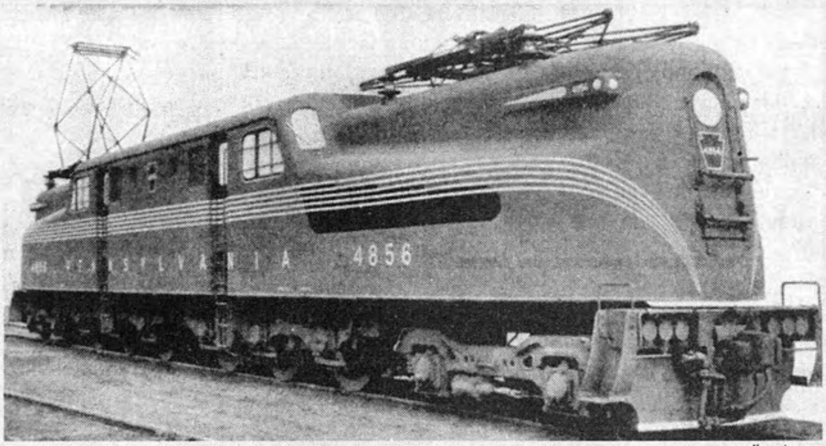
The fight to electrify the American rail system has been waged for more than 100 years. The superiority of electric-driven locomotives over steam-powered locomotives, and over the hybrid diesel-electric locomotives that are used today, is undeniable. A comparison of electrified rail to steam-powered rail, at the peak of the powers of each, brings out the stunning superiority and method of operation of electrified rail.

The steam-powered locomotive, an invention of the 1820s and 1830s, works on the following basis: On the locomotive of the train is a "firebox" into which coal is fed. The firebox heats a water boiler, making super-heated steam, which is under very high pressure. The super-heated steam is passed to cylinders (by a suitable valve arrangement), where it drives pistons. The moving pistons turn a main rod, which in turn, moves connecting rods that are attached to the locomotive's driving wheels. (This whole arrangement utilizes a system of gears.)

Five limiting features are obvious. First, the train can only achieve a certain speed. The best steam locomotives in the 1940s, using super-large cylinders, and in some models operating two parallel sets of super-large cylinders, could only achieve top speeds of 125 miles per hour, without a load of cars. Second, on a steep grade, a steam locomotive could lose as much as half of its pulling power. Third, a steam locomotive could be in the shop for as much as 40 to 50 percent of the time. Fourth, it must drag its own fuel and water supplies (for boiling into super-heated steam) along with it, usually in a "tender car." The steam locomotive must haul many tons of coal and 2,500 gallons of water or more. Fifth, the steam locomotive is inefficient: It consumes nearly two times as many BTUs of energy to carry a ton-mile of cargo freight as does an electric locomotive.

At the dawn of the 20th Century, electrification of rail had been introduced in the United States, poised to become a reality. It grew in small steps, so that by the early 1930s, 3,000 route-miles[1] had been electrified, at least several hundred of them through the assistance of President Franklin Roosevelt's Public Works Administration.

An indisputable advantage of electrified rail is that it does not carry its own power generator/power supply with it. The system begins with a stationary electricity-generating plant far away from the locomotive, which can use any source of fuel—say, nuclear—to generate the electric power. The electricity is transmitted by transmission lines to a set of wire lines that hang overhead of the train track, called the catenary lines. A device on top of the locomotive—called a pantograph—makes continuous contact with the catenary system, transmitting electricity continuously into the locomotive. (A transformer steps down the voltage). The electricity is directed to motors which are attached to the wheels, and power them.


clipart.com

An early 1940s U.S. electric locomotive. By the 1930s, U.S. rail had 3,000 route-miles electrified—three times today's electrification. The pantograph and catenary line can be seen at upper left.

The electrified train system produces benefits of great significance: First, one leading system, the French TGV, cruises at 180 mph (290 kph), a speed closely approximated by electrified systems in several other European nations and Japan. Second, the electrified train system uses no petroleum. Third, several electrified trains can use "regenerative braking systems" (by essentially transforming the motors into generators) which capture electricity when braking, save great wear and tear on brake shoes, and so on. Fourth, the electrified train uses half as many BTUs to carry a ton-mile of cargo freight as do steam-powered locomotives, and maintains a sizable energy efficiency over other transport systems.

The close of World War II marked the end of the dominance of steam-powered locomotives—a demise that should have come a half-century earlier. Certainly, the bright prospect of the United States moving toward electrified rail was beckoning. But this move never occurred; it was sabotaged by Wall Street banking interests.

The Post-World War II Highway Detour

In the period after World War II, an alliance of the Anglo-American bankers, the oil cartel, and the Morgan/Dupont-controlled General Motors organized to stop the electrification of U.S. rail. First, they worked to pass the Interstate and Defense Highways Act of 1956. Ostensibly the product of a Presidential task force on this subject headed by General Lucius Clay, the Act was to provide a centralized series of corridors for the continental movement of goods during war and other emergencies. However, the above alliance shaped it to spread suburban sprawl, suburban real estate bonanzas, and the explosive growth of the petroleum-consuming car and truck market, which came to dominate the nation's transportation system.

The Act created an enormous annual flow of government money into highway building, so that during the past 50 years, $2.5 trillion has streamed into building and repair of U.S. highways and roads, while Amtrak must beg to get a paltry $1.8 billion per year barely to survive. In 2004, some 8.75 million trucks were turned loose on the highways, carrying 25,000- to 100,000-pound loads. The heavier the trucks become, the more they rip up the highways—as the damage increases geometrically with heavier trucks—requiring greater repair. The surge in truck traffic, in particular, and also passenger cars, has grown to such unwieldy proportions, that for hours of each day, the highways don't function. Various urban planners now propose building highways with six lanes in each direction.

In 1943, during World War II, 73 percent of America's intercity freight traffic (by tonnage) travelled by rail, and only 5 percent travelled by truck—and the system worked. By 2001, the percentage of freight moved by rail plummeted to 42 percent, while truck freight rose to 28 percent. Except for the coal moved by the railroads, trucks today carry more goods.

The bank/oil cartel/automotive alliance carried out a second assault in the post-World War II era. It dismantled much of the existing electrified rail, leaving less than 1,000 electrified miles in America. As steam-powered locomotives were phased out, there was a shift toward diesel-electric hybrid locomotives, which now comprise 99 percent of the U.S. fleet.

Diesel-Electric Locomotives

There are two most important points about diesel-electric locomotives. First, think of putting a diesel engine onboard just to power a generator for an electric locomotive. The same thing could be done simply, without the diesel engine, by transmitting outside electricity into the locomotive. Second, consider that a diesel-electric locomotive has a 450- to 500-gallon diesel fuel tank. Collectively, these hybrid locomotives consume *3.8 trillion gallons* of fuel per year. Thus, the electric locomotive has been reduced to an appendage of the burning of petroleum.

The rail system has been both technologically and physically degraded, especially since the Staggers Act of 1980 deregulated the industry, and the sharks and asset-strippers moved in. There was a ferocious "rationalization" of rail lines. In 1980, Class I railroads operated 164,822 route-miles, but by 2004, that was reduced by 40 percent, to 99,000 route-miles. In the same period, the railroads settled on a survival strategy: Loading up on the transportation of coal. Coal is a legitimate fuel source for electricity generation, but its role and use should not be exaggerated. In 2004, 43 percent of all tons shipped on the rail system were coal. This ties down the rail system. The transport of other goods is lagging. Over the past three decades, the rail industry's shipment of non-coal goods, per household, has fallen dramatically.

A Great Project Approach Is Needed

The long-suppressed electrification of America's dilapidated rail system is an undertaking which could only be achieved by the fight for and adoption of Lyndon LaRouche's April 13 emergency proposal to the U.S. Senate,[2] which called for a retooling of the auto sector to deploy the immense volume of advanced machine tools and hundreds of thousands of skilled workers it still commands, to produce the goods for the electrification infrastructure.

We present here the crucial elements, which, being done in tandem, put great demands on the economy. Consider the bill of materials for the tremendous array of goods that would go into each element.

(1) *Electric locomotives:* In 2003, the Class I railroads (the nation's largest railroads)[3] operated 20,711 locomotives, all of them diesel-electric. About half these locomotives (10,350) travel on the most heavily travelled 42,000 route-miles cited above. An attempt could be made to retrofit the diesel-electric locomotives into all-electric locomotives, but that is a complicated procedure. Thus, the retooled auto plants would have to take the lead in building 10,350 all-electric locomotives.

(2) *Catenary lines and transmission lines:* To electrify these routes, requires building an overhanging system of catenary lines above the tracks, to transmit the power to the trains. From electric power plants, electricity would be carried by transmission lines to the catenary lines. This means 42,000 miles of catenaries, and tens of thousands of miles of transmission lines.

(3) *Substations:* These bring power from high-voltage levels to lower voltages, and also act as phase-breakers, because when current travels more than 40 miles, there are severe voltage losses. More than 1,000 substations would be built, one every 40 miles.

(4) *Double-tracking:* When trains come from opposite directions on a specific route sharing the same track, both must slow down at some point, using a side track to clear one another. If that happens several times on a route, the overall trip speed is considerably slowed. A double-tracked route provides a set of tracks for travel in each direction. Of the 42,000 route-miles selected for electrification, only 10,000 to 12,000 are double-tracked, but heavy usage makes virtually all of them candidates for double-tracking, calling for tens of thousands of miles of new track. The bill of materials to lay each new mile of track is: 370 tons of steel, 535 tons of cement, and so on. Also, steel is required for the culverts.

(5) *Nuclear power generating plants.* The 42,000 route-miles of electrification would require a complete overhaul of America's energy policy: Its inadequate energy grid now suffers blackouts and shortages. To electrify these route-miles would require adding new electric-generating capacity of 50,000 megawatts (MW) in order to generate 383 trillion kilowatt-hours of electricity during the course of one year. This would represent a 5.3 percent increase of the U.S. installed (summer) generating capacity.

To do this, the United States would have but one choice: to move forward with a vigorous nuclear energy policy. This cries out for mass-production techniques for nuclear power production. Retooled auto plants could make several of the components.

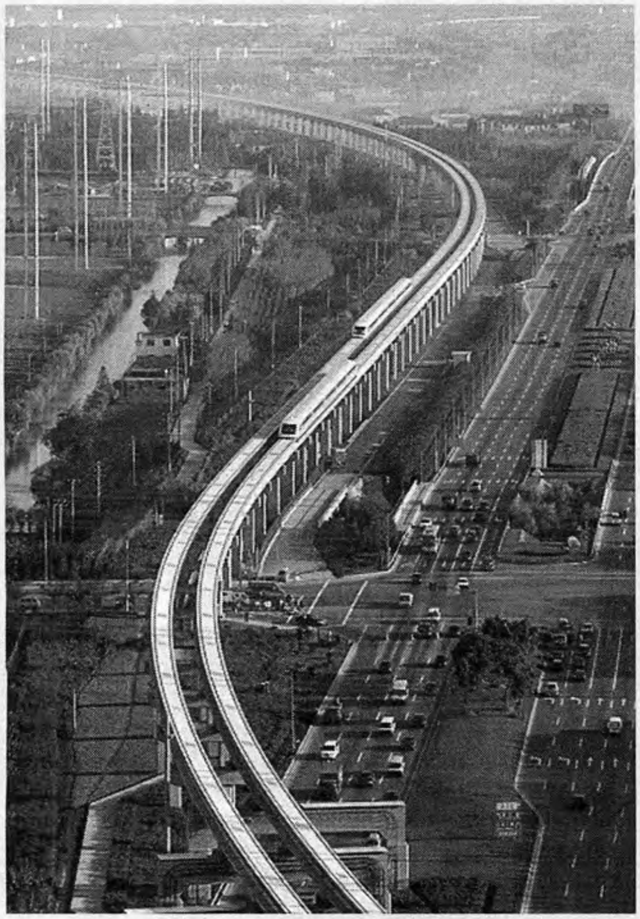
Gearing Up Physical Production

We have briefly examined five elements that are indispensable for the electrification of America's rail system. Needless to say, there are many more elements of importance that could be considered: signalling systems; grade separations (underpasses and overpasses to cross the track); passenger cars, hopper cars, and intermodal cars; train stations; components such as couplers, cooling systems, etc.

The most important thing is getting physical production geared up to produce the critical features of this great infrastructure project. Its production will employ at minimum 250,000 workers, most of them skilled, in producing the array of goods from the final locomotives and transmission lines, to the semi-finished goods like steel, copper, and aluminum, and the components like cooling systems, to the final on-site construction. There is a price attached to each element; for example, the cost of an electric locomotive is about $3.5 million, so that 10,000 such locomotives would cost $35 billion. Preliminary projections are that the entire project would cost in the range of $400 to $500 billion, and take 10 to 15 years.

However, the system will permit the economy to leapfrog ahead technologically. Electrified high-speed rail passenger travel will occur at 150-190 mph; freight will travel at approximately 90-110 mph (for safety's sake, coal and a few other commodities are best served travelling at lower speeds). By contrast, 75 mph is the legal limit of passenger cars and freight-carrying trucks, and in reality, in traffic, they travel at a fraction of that speed. The electrified system will radiate these benefits, and the associated higher productivity, through the main corridors of every part of the nation.

Given the speed and other advantages of electrified rail,[4] it will be possible to take trucks off the road in two ways. First, there are categories of freight that are best shipped by rail. Second, in a process that is in its infancy: Trucks can do short-haul via railroad. A truck picks up a product, drives to a railroad, is strapped onto a rail flat car, and shipped to



This 225-mph magnetically levitated train operates between Shanghai and its airport, a distance of 20 miles. The design is the Siemens Transrapid.

another city, where the driver and truck disembark to make the delivery. By these two processes, within 15 years, one-third of truck traffic could be shifted to rail.

However, the production of goods for electrification of 42,000 rail route-miles cited above, is based on working to accommodate the current volume of rail freight, and factor in a small annual increment. Were we to succeed in transferring one-third of truck freight to rail, this would require a *second round* of increased production for electrified rail.

Magnetic Levitation

As forceful as the effect that rail electrification would have in transforming the economy, there is still a higher level: magnetic levitation. In "maglev," the magnetic forces generated by the interaction between the bottom of the transport vehicle and the rail, lift, propel, and guide a vehicle along a guideway, so that it "flies" on a magnetic cushion. This eliminates wheel-on-wheel friction, which slows all traditional modes of railroad transport. Current generation maglev systems cruise at speeds of 245 mph (392 kph), and can reach top speed of 300 mph (492 kph), four times the current average speed of U.S. freight and passenger travel.

Maglev would start in the 5,000 miles of corridors that are the most densely populated. It would require a *third round* of rail production gear-up, including an additional 25,000 to 50,000 gigawatts of nuclear-generating capacity, meaning that with electrification and maglev, the nation's generating capacity would have to increase an impressive 10 percent.

Railroad electrification, including maglev, becomes possible only when the economy is mobilized and the mammoth production capability represented by the retooled auto sector, is brought into play. Without this capability, electrification of this scope would not be possible.

Such a mission will emerge from a political fight. Adoption of LaRouche's emergency proposal would save the auto sector in precisely such a manner, as to generate a technological revolution in rail and cascading productivity that will aid in reconstructing the nation.

Richard Freeman is on the economic staff of the Executive Intelligence Review, *and is working with Hal Cooper in elaborating a national railway policy.*

Notes

1. A route-mile is a mile of actual route that a train travels. A route of 50 miles represents 50 route-miles. This route may be double-tracked, thus having a total of 100 miles of track (and even more track in sidings, and yards), but still have only 50 route-miles.

2. LaRouche's Emergency Memo to the U.S. Senate can be found at www.larouchepac.com.

3. Class I railroads have $277 million or more of revenues per year. In practice, each of America's Class I railroads has more than 10,000 miles of track.

4. A truck consumes nearly 2.5 times as many BTUs of energy to carry a ton-mile of cargo freight, as does an electric locomotive.

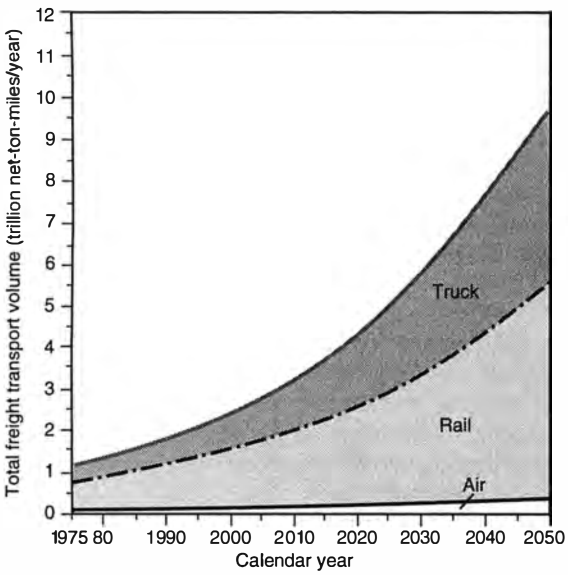


Figure 5
TRUCK INCREASE DOMINATES INTERCITY FREIGHT TRANSPORT
Without electrification, if present trends continue, truck traffic will dominate U.S. intercity freight transport. Here, total U.S. intercity freight transport by air, rail, and truck, from 1975-2050. Projections are based on current trends.

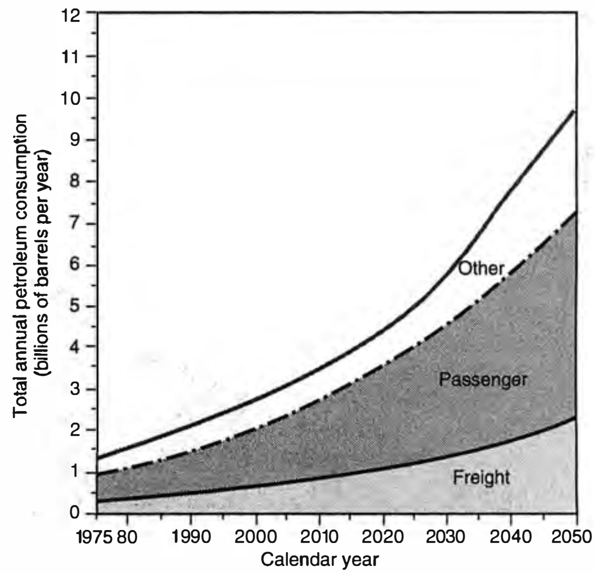


Figure 6
PETROLEUM CONSUMPTION WILL ZOOM UPWARD WITHOUT RAIL ELECTRIFICATION
If the United States does not electrify its railroads, and move more freight by rail, the petroleum used to carry freight and passengers will increase from 1.463 billion barrels in 1980 to as much as 9.603 billion barrels a year by 2050—more than the present national total petroleum use.

(Continued from page 25)
1980, to 40.9 percent in 2000, at an average annual rate of increase of 3.3 percent per year for truck traffic over the 20-year period.

The percentage of freight carried by railroad has dropped from 62.5 percent in 1980 to 58.5 percent in 2000, with an annual average rate of increase in rail freight traffic volume of 2.5 percent per year. It is expected that the volume of total freight traffic will triple between 2005 and 2050, if present trends continue into the foreseeable future, as shown in Figure 5.

Similar results are reported for intercity passenger travel in the United States between 1980 and 2000. The total intercity passenger traffic increased from 1,468 billion passenger-miles per year in 1980 to 2,494 billion passenger-miles per year in 2000, at an annual rate of 2.65 percent per year. The portion carried by car decreased from 82.4 percent in 1980 to 76.6 percent in 2000, as the total automobile traffic increased by 2.3 percent per year during this period. The portion of these passenger trips carried by air increased at a much faster rate of 4.2 percent per year, from 229 billion passenger miles per year in 1980, to 530 billion passenger-miles per year in 2000, as its market share increased from 15.6 percent in 1980 to 21.2 percent in 2000. The portion of the total passenger trips taken by rail remained below 1 percent of the total during the period from 1980 to 2000, so a significant increase in rail travel would require major changes.

Reducing Transportation's Petroleum Budget

In the absence of major policy initiatives, such as the electrification of intercity railroads and major intermodal diversion from road or air to rail, the amount of petroleum to be used in the transport of freight is expected to increase from 380 million barrels per year in 1980, to 580 million barrels in 2000, to as much as 2,353 million barrels per year by 2050, if the present trends continue, as shown in Figure 6. The total annual petroleum consumption in the transportation sector is expected to increase from 1,463 million barrels per year in 1980, to 2,508 million barrels per year in 2000, to as much as 9,603 million barrels per year by the year 2050 (which is more than the present national total). The passenger sector would predominate.

The present petroleum consumption totals appear to be clearly unsustainable, in view of the present and future limitations on world oil supplies. Clearly, national railroad electrification is going to be needed for purely national-economic and energy-security reasons, as the expected oil demand will exceed expected oil supplies.

The electrification of railroads for freight transport would ultimately replace this petroleum consumption with other energy sources, by generating electricity at central power plants. The preponderance of energy consumption for freight transportation is for truck transport, with essentially all of the energy supplied by burning diesel fuel or gasoline refined from petroleum. Shipments of freight by truck constitute 41

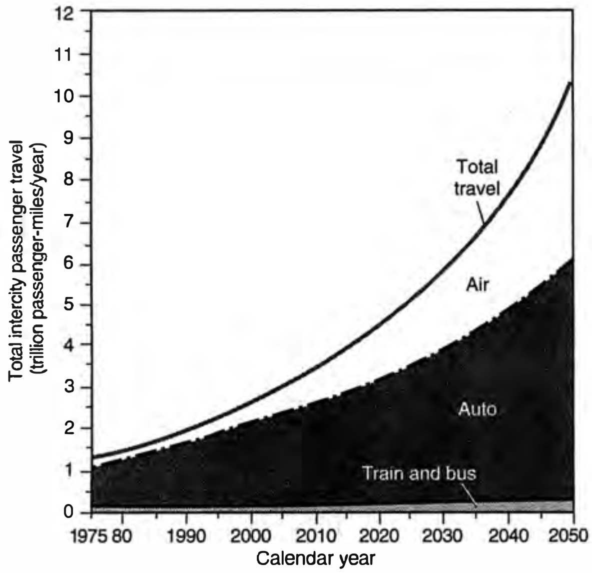


Figure 7
AUTOMOBILE TRAFFIC WILL INCREASINGLY LOCK THE HIGHWAY GRIDS, WITHOUT ELECTRIFICATION AND MAGLEV
If present trends continue, oil-dependent auto and air passenger transport will continue to increase.

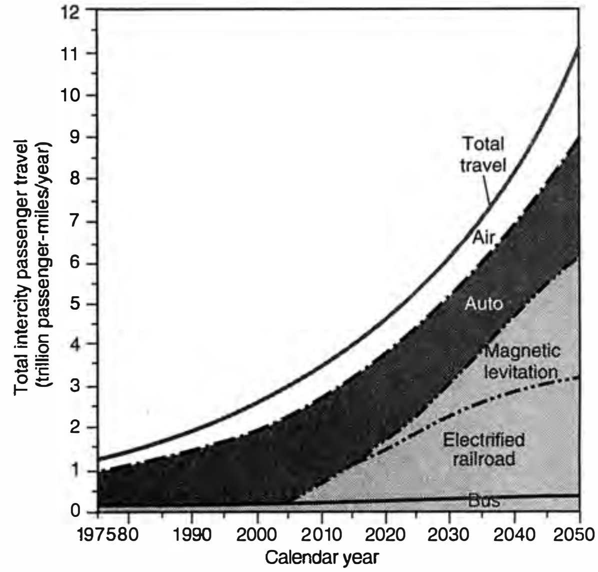


Figure 8
ELECTRIFICATION AND MAGLEV WILL GREATLY REDUCE PASSENGER AUTO AND AIR TRAVEL
With the introduction of electrification and maglev, the projected trends (to 2050) for U.S. intercity passenger transportation will reduce highway and air travel.

percent of the total movement in ton-miles, but require 57 percent of the total energy consumption in the form of petroleum. In contrast, railroads move 58 percent of the intercity freight but require only 26 percent of the total energy required for intercity freight transport.

The diversion of a significant portion of the intercity truck traffic from road to rail would significantly reduce the overall level of petroleum consumption, Electrification would increase the oil savings for the three alternative 10,000-, 26,000-, and 42,000-route-mile electrified rail networks, from 52 million barrels per year, to 73 million, to 94 million barrels per year. There would also be an estimated transport cost-savings resulting from electrification of the railroad with the comparative transport cost of 6.15 cents per net ton-mile for truck transport, 4.20 cents per net ton-mile for diesel trains, and 3.50 cents per net ton-mile for electric trains.

As a result, the electrification of the railroads would give shippers a net overall transport cost-savings from $7.1 billion per year for the minimum network, to $12.8 billion per year for the maximum network based on year 2000 freight traffic volumes.

The electrification of the railroad would also result in a reduction of petroleum consumption for those cargoes going by railroad. The petroleum savings which would result from the railroad traffic alone would increase from 33 million barrels per year for the minimum 10,000-route-mile network to 66 million barrels per year for the maximum 42,000 route-mile network. The total petroleum savings resulting from both the intermodal diversion of the trucks from road to railroad, plus the electrification, would increase from 85 million barrels per year for the minimum network, to 160 million barrels per year for the maximum network, excluding air freight service. The overall cost-savings resulting from the railroad electrification plus the intermodal diversion of truck traffic from road to rail would also result in a net transportation cost-savings to shippers, which would increase from $11 billion per year for the minimum 10,000 route-mile network, to $20 billion per year for the maximum 42,000 route-mile network.

It is also important to identify the potential petroleum savings which could result from the intermodal diversion of passenger traffic from air or auto to rail.

The proposed implementation of a national railroad electrification network could substantially reduce the need for oil-dependent air and auto modes for intercity passenger travel—by more than half, by 2050, as shown in Figure 7. The role of magnetic levitation becomes critical in the future for replacing air travel as a relatively time-competitive transportation mode for passengers. In contrast, the conventional electrified railroad-network will serve as a feeder service for shorter trips, as the means for diverting automobile traffic to the more energy-efficient and non-petroleum-dependent rail mode. The potential petroleum savings from intercity passenger transportation are potentially much greater than for freight transport, based on present-day traffic volume conditions (Figure 8).

However, there is a very blurred line which separates intercity trips and intracity trips, so that the above values are optimistic, to at least some degree. Estimates of the potential

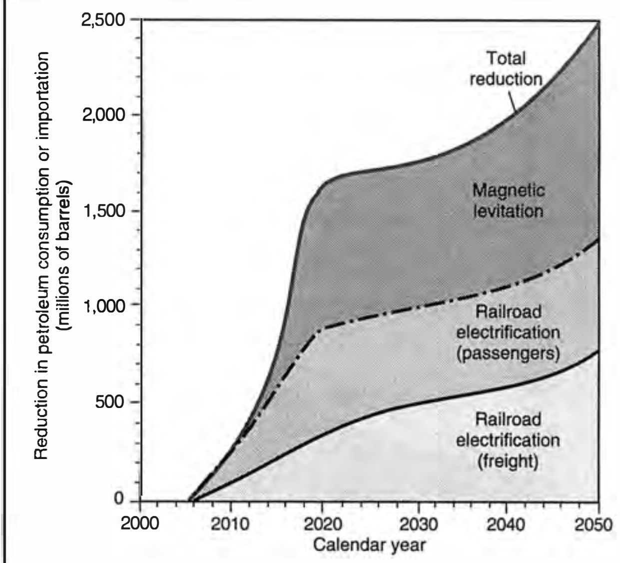


Figure 9
U.S. PETROLEUM CONSUMPTION PLUMMETS WITH ELECTRIFICATION AND MAGLEV
The introduction of electrified rail and magnetic levitation will produce these estimated reductions in the import and consumption of petroleum, (2005-2050). These reductions are equivalent to 61 percent of the present import level, and 37 percent of the total oil consumption level per day in the United States.

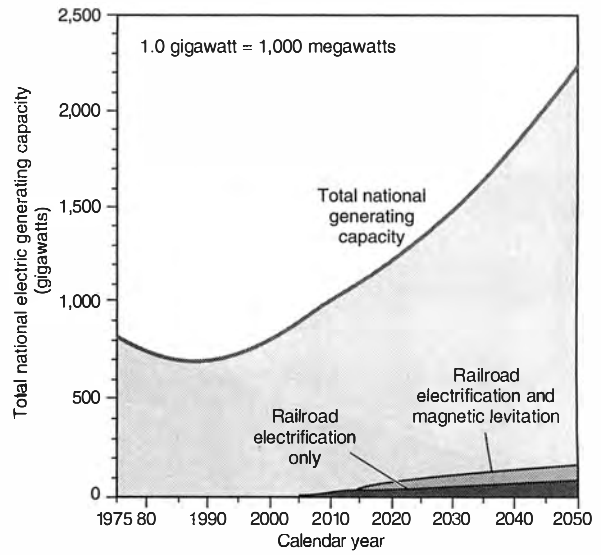


Figure 10
ELECTRIC-GENERATING CAPACITY REQUIREMENTS FOR ELECTRIFICATION OF RAIL AND MAGLEV
The electrified railroad and magnetic levitation networks will require an increase in the total national electric-generating capacity from 2.9 percent of the 2010 total, to 9.1 percent of the 2030 total.

impacts of national railroad electrification and magnetic levitation for both passenger and freight transport for intercity trips are illustrated in Figure 9. The results show that the potential reductions in petroleum consumption could be as much as 2,780 million barrels per year by 2050, or the equivalent of 7.6 million barrels per day. These reductions in petroleum consumption resulting from transportation are equivalent to 61 percent of the present import level of 12.3 million barrels per day, and 37 percent of the total oil consumption level of 20.5 million barrels per day in the United States.

New Electric Power

The proposed 42,000-mile electrified railroad network to be built along the existing rail lines will require as much as 96,000 megawatts of new generating capacity by 2050, with 52,000 megawatts for freight, and 44,000 megawatts for passengers, plus another 67,000 megawatts for the proposed 42,000-mile magnetic levitation route. To some extent, the electrical energy can be provided from the existing power plants in the United States through the electric utility transmission grid network. However, it will become necessary to construct additional electric-generating capacity in order to meet the future need for electricity, in addition to providing the energy required for the proposed electrified railroad network and for the planned magnetic levitation network.

Present electric-generating capacity in the United States is approximately 810,000 megawatts, with an annual electricity consumption requirement of about 3,500 billion kilowatt-hours per year. Coal constitutes 51 percent of the existing electric generating capacity in the United States, but provides 56 percent of its electricity. Nuclear power constitutes 14 percent of the generating capacity but provides 23 percent of the nation's electricity. Natural gas and fuel oil combined comprise 24 percent of the national generating capacity, but only 12 percent of its electricity, because these are normally the higher-price fuels. Hydroelectric power comprises 10 percent of the national electric generating capacity and 9 percent of its electricity, while other renewable energy sources comprise about 1 percent of both the electric-generating capacity and its electricity.

The electricity growth rate in the United States is approximately 2.0 percent per year, as is its expected growth in electric-generating capacity, in order to maintain adequate reserve margins. If these growth rates continue into the foreseeable future, the electric-generating capacity in the year 2050 is estimated to reach 2,155,000 megawatts, which is 165 percent greater than at present. The electric generating-capacity requirement for the proposed railroad electrification network alone will increase from 27,000 megawatts in 2010, to as much as 96,000 megawatts by 2050, as illustrated in Figure 10. The increase in generating-capacity requirement for magnetic levitation will begin in 2015, at less than 10,000 megawatts and increase to 67,000 megawatts by 2050. The electricity requirement for the

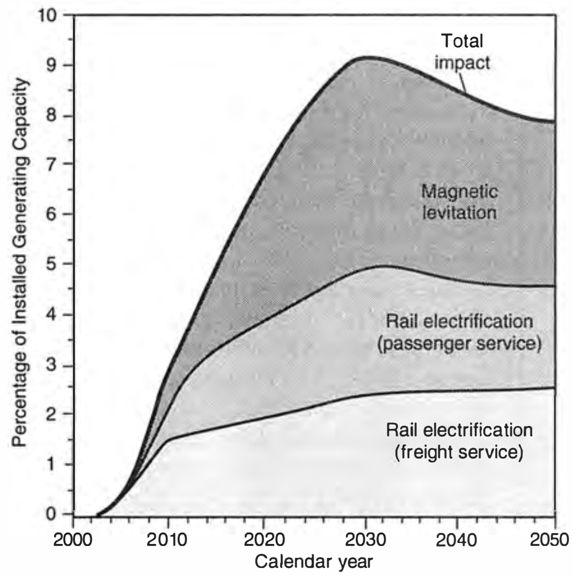


Figure 11
RELATIVE IMPACT OF ELECTRIFICATION AND MAGLEV ON U.S. ELECTRIC-GENERATING CAPACITY (2000-2050)

There is an initial rapid increase in electricity requirements as the magnetic levitation network gears up between 2020 and 2030, but after that, the maglev requirements level off. Hence the downturn in the graph between 2030 and 2050. Maglev requires 40 percent of the total rail electrical consumption; passenger rail uses 28 percent; and freight rail uses 32 percent of the total rail electrical consumption.

combined electric railroad and magnetic levitation network will increase from 27,000 megawatts to 163,000 megawatts by 2050.

The electrified railroad and magnetic levitation networks in combination will require an increase in the total national electric-generating capacity from 2.9 percent of the total in 2010, to 9.1 percent of the total by 2030, and then decrease to 7.6 percent of the total by 2050, as shown in Figure 11. The reason for the up-and-down in demand is that there will be a rapid increase in electricity requirements as the magnetic levitation network starts up between 2020 and 2030, which becomes relatively less after 2030 until 2050, because the rapid increase in electricity demand has already occurred. The magnetic levitation system will require 40 percent of the total rail electrical consumption, while the electric railroad will use 60 percent, of which 32 percent will be for freight transport and 28 percent will be for passenger transport.

The estimated capital cost of the fixed facilities infrastructure for the electrified railroad and magnetic levitation systems is presented in Table 1. The total capital cost of the electrified railroad system is expected to increase from $250 billion for the 10,000-mile route, to $735 billion for the 42,000-mile system, and to $800 billion by 2050 with the additional facilities improvements, expansions, and upgrading. The per-mile capital cost of the electrified railroad is expected to decrease from $25.0 million per mile for the 10,000-mile route system to $17.5 million per mile for the 42,000-mile system.

The parallel capital cost of the magnetic-levitation system is expected to increase from $500 billion for the 10,000-mile system at $50.0 million per mile, to $1,700 billion at $35.0 million per mile for the 42,000-mile system. For the combined

Table 1
ESTIMATED TOTAL CAPITAL INVESTMENT REQUIREMENTS BY YEAR FOR NATIONAL RAILROAD ELECTRIFICATION AND MAGNETIC LEVITATION (in billions of dollars)

This summary of the expected cumulative capital investments required by year for the construction of the proposed 42,000-mile electrified railroad and the parallel 42,000-mile magnetic levitation network is grouped as fixed facility (track and guideway) and variable facility (locomotives and power plants) investments. The costs are in year 2005 constant dollars.

	Route-Miles		Fixed Facilities Investment			Variable Facilities Investment			
Calendar Year	**Electric railroad**	**Magnetic levitation**	**Electric railroad**	**Magnetic levitation**	**Fixed facilities**	**Electric locomotives**	**Power plants**	**Variable investment**	**Total capital investment**
2005	0	0	0	0	0	0	0	0	0
2010	5,000	0	150	0	150	100	55	155	305
2015	10,000	5,000	250	100	350	125	70	195	545
2020	26,000	10,000	500	250	750	170	160	330	1,080
2025	35,000	16,000	650	500	1,150	200	190	390	1,540
2030	42,000	25,000	735	1,150	1,885	230	220	450	2,335
2035	42,000	35,000	775	1,500	2,275	275	245	520	2,795
2040	42,000	42,000	800	1,700	2,500	285	250	535	3,085
2045	42,000	42,000	800	1,900	2,700	310	260	570	3,270
2050	42,000	42,000	800	2,000	2,800	335	330	665	3,465

Table 2
ESTIMATED UNIT CAPITAL COSTS OF SINGLE- AND DOUBLE-TRACK ELECTRIFIED RAILROAD LINES
(in 2005 constant dollars)

Cost element	Single-track dollars/mile	Double-track dollars/mile
Track construction	1,500,000	2,500,000
Electrification system	1,300,000	1,800,000
Signalling and communication	400,000	700,000
Subgrade and drainage	300,000	500,000
Unit cost	3,500,000	5,500,000
Other civil construction	7,000,000	12,000,000
Total cost	10,500,000	17,500,000

Table 3
EFFECTS OF DESIGN AND MAXIMUM SPEED ON THE CAPITAL COST FOR ELECTRIFIED RAILROAD LINES

Operating speed (miles/hour)		Unit capital cost (dollars/mile)	Total capital cost (Millions of dollars, 42,000 miles)
Passenger	Freight		
80-90 [1,3]	60-80 [1,3]	1,500,000-2,500,000	65,000-85,000
90-110 [1,4]	80-90 [1,4]	5,250,000-6,000,000	220,000-250,000
110-150 [1,4]	90-110 [1,4]	15,000,000-17,500,000	550,000-735,000
350-500 [2]	350-500 [2]	35,000,000-50,000,000	1,470,000-2,100,000

Notes
1. For conventional railroad lines.
2. For magnetic levitation routes.
3. Diesel-powered railroad lines.
4. Electric-powered railroad lines

systems, the total system capital cost is expected to increase from $750 billion at 20,000 miles in total, to $2,000 billion for the 84,000 mile systems by 2050 with all of the additional improvements.

The capital cost estimates for the electrified railroad are shown in Table 2 for the single-track and the double-track configurations. The actual unit costs are estimated as between $1.3 million and $1.8 million per mile for single-track and double-track electrification, respectively. The direct unit capital costs for the single-track and double-track configurations range between $3.5 million and $5.5 million per mile, respectively, with the trackage, civil works, electrification, and signalling all included. However, the need to build major bridges and tunnels plus grade separations and trenches or elevated viaducts raises the average total unit capital cost to an estimated range from between $10.5 million and $17.5 million per mile, respectively. These unit capital costs are very much a function of the required operating speeds for the trains, as presented in Table 3.

The total capital investment for the electrified railroad system for intercity freight and passenger transport is expected to range from $305 billion in 2010, to $1,105 billion in 2030, to $1,330 billion in 2050, as shown in Figure 12(a). The greatest part of this investment is for railroad fixed facilities, which are expected to increase from $150 billion in 2010, to $735 billion in 2030, to $800 billion by 2050. The purchase cost of the new electric railroad locomotives is expected to increase from $100 billion in 2010, to $235 billion in 2030, to $335 billion in 2050. The estimated capital cost of the new power plant generating capacity is expected to increase from $55 billion in 2010, to $140 billion in 2030, to $195 billion in 2050, as additional electricity is required.

The development of the proposed magnetic levitation network will have a considerably greater capital cost than for the electrified railroad network of the same route distance, as illustrated in Figure 12(b). The capital investment in the magnetic levitation fixed facilities and attached guideway vehicles is expected to increase from $100 billion in 2015, to $1,150 billion in 2030, to $2,000 billion by 2050. The associated power plant capital costs are expected to increase from $70 billion in 2020, when the system begins operation, to $100 billion in 2030, to $135 billion in 2050 based on a unit capital cost of $2,000 per kilowatt of installed capacity, which would be typical of a new nuclear power plant. The total capital investment in the magnetic levitation system would increase from $100 billion in 2015, to $1,250 billion by 2030, to $2,135 billion by 2050.

The total capital investment in the combined electric railroad and magnetic levitation system will increase from $305 billion in 2010, to $2,355 billion in 2030, to $3,465 billion by 2050, as the combined network size increases from 5,000 miles to start, to 10,000 miles, to 50,000 miles by 2030, to 84,000 miles by 2040. Approximately 58 percent of this new investment will be in fixed facilities for the magnetic levitation, with another 23 percent, or $800 billion, associated with the electrified railroad. The remaining 19 percent of the total capital investment will be broken down almost exactly equally between the power plants, with $330 billion, and $335 billion for the electric locomotives, for a cumulative total of $3,465 billion by the year 2050 for the entire integrated system. A summary of the expected cumulative capital investments required by year for the construction of the proposed 42,000-mile electrified railroad and the parallel 42,000-mile magnetic levitation network is presented in Table 1.

Although seemingly a very large capital investment is required for electrified railroads and magnetic levitation, it

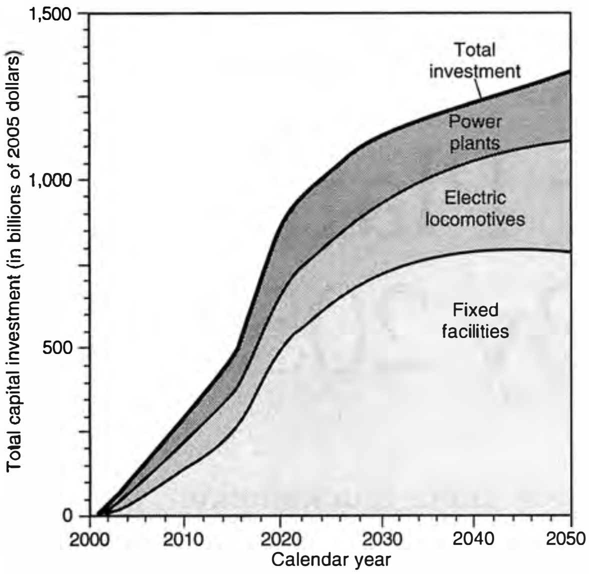


Figure 12(a)
FUTURE CAPITAL INVESTMENT IN U.S. RAILROAD ELECTRIFICATION (2000-2050)
The total capital investment for the electrified railroad system for intercity freight and passenger transport (including power plant construction) is expected to range from $305 billion in 2010 to 1,105 billion in 2030, to $1,330 billion in 2050. Most of this is for railroad fixed facilities.

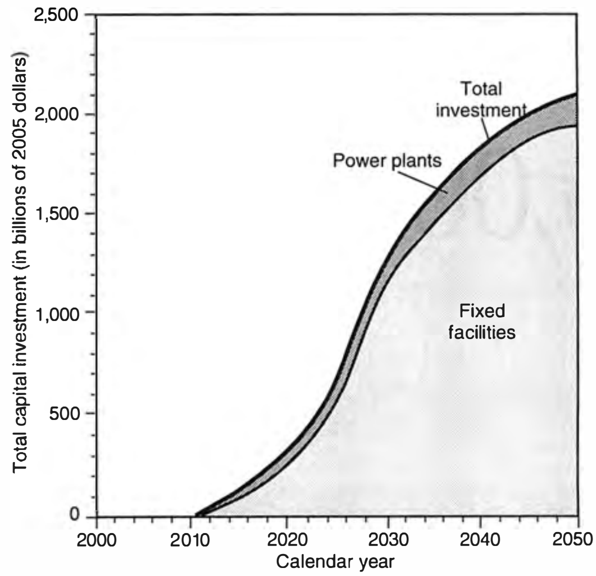


Figure 12(b)
FUTURE CAPITAL INVESTMENT IN MAGNETIC LEVITATION NETWORKS (2010-2050)
The capital costs for the magnetic levitation system are greater than those for the same route distance of the electrified railroad network. Most of the investment is in fixed facilities and guideway vehicles. The cost is expected to increase from $100 billion in 2015, to $1,150 billion in 2030, to $2,000 billion by 2050.

must be realized that the continued importation of foreign oil will involve a cost which is expected to increase from the present $230 to $250 billion per year to as much as $500 to $900 billion per year by 2050, if not remedied. If up to 30 percent of this oil import cost can be reduced by the above electrified railroad and magnetic levitation system, then an import cost reduction of as much as $150 to $300 billion per year can be realized by its construction. Many jobs will be created by the above electrified railroad system along with considerable transportation cost-savings to travellers and shippers.

In conclusion, it is proposed to construct a 42,000-mile electrified railroad system along the existing railroad lines for the transport of freight and passengers at speeds of 100 to 150 miles per hour, including intermodal trucks hauled by rail between cities, and to supplant car travel for trips of less than 300 to 400 miles. In addition, it is proposed to build a new 42,000-mile-long magnetic levitation system generally along the interstate highway medians for very high speed passenger and high-value cargo transport at 350 to 500 miles per hour to replace air travel for trips of less than 500 to 1,000 miles. This new proposed electrified transportation system is expected to ultimately cost up to $3.5 trillion over 45 years at an average annual cost of $75 to $80 billion. This system can ultimately result in a reduction in overall oil use of up to 2,480 million barrels per year, or up to 30 percent of the expected oil imports, and would require an increase in the national electric-generating capacity of up to 163,000 megawatts, or 7 to 9 percent of the expected overall national total of 1,500,000 megawatts by 2050.

The proposed financing for the construction of this future electrified rail and magnetic levitation transportation system is through long-term bonds and loans provided through a newly created National Infrastructure Development Bank (NIDB). This bank would be able to issue credits, guarantees, and currency entirely separate from the existing Federal Reserve Bank System, which has shown itself to be at best reticent about, and in the worst case opposed to, major infrastructure development projects. Loan and bond guarantees could be provided through commercial banks to private companies, as well as direct loans and grants to the federal, state, and local governments for the above energy and transportation infrastructure-development projects. The prescription for economic and infrastructure policy proposed by Lyndon LaRouche is the only way this and similar infrastructure projects to promote prosperity through the general welfare, can be realized as a superior alternative to the present insane free-trade/free-market/fiscal-austerity fascism, so rampant in government and business circles today.

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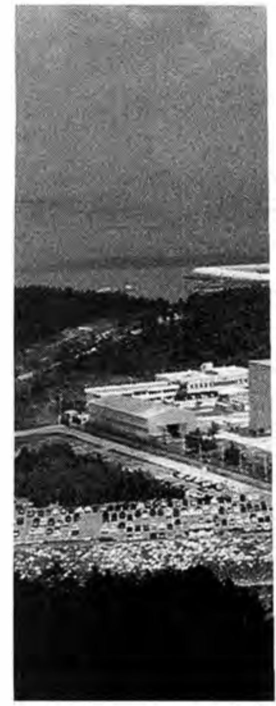
How to Build 6,000 Nuclear Plants By 2050



by James Muckerheide

A plentiful energy supply is the key to bringing the world's population up to a decent standard of living. We asked an experienced nuclear engineer how many nuclear plants we would need, and how to get the job done. Here are his answers.

In 1997-1998, I made an estimate of how many nuclear plants would be needed by 2050. It reflects an economy that is directed to provide the energy necessary to meet basic human needs, especially for the developing regions.

The initiative required is not unlike what the U.S. government did under Roosevelt to bring electric power to rural areas; to provide transportation by building roads and highways, canals, railroads, and airlines; to develop water supplies and irrigation systems, to provide telephone service, medical, and hospital services; and many other programs that were essential to lift regions out of poverty. That is, to meet the needs of people outside of the mainstream of economic life, even if those people are the farmers providing our food and clothing, miners providing our coal and steel, and so on.

However, as economist Lyndon LaRouche has proposed, we need to do more to meet those needs, both within the United States and for the developing world, to bring those people into the economic mainstream, instead of leaving them just as cheap sources of our labor and raw materials.

At the same time, in the last five years, we have seen greater worldwide recognition that nuclear power is essential. There is increasing support by industry and governments, compounded by recent changes in oil and gas supplies and costs, and there is increasing recognition of the essential role of nuclear energy by some responsible environmentalists. Initiatives in industry and the political environment are gearing up to implement nuclear power. But they are timid and leaderless in the United States and Europe compared to most of the rest of the world.

Unfortunately, current economic concepts expect that such decisions are to be made for individual plants, one at a time, by private interests, only when they are assured that they will be competitive (that is, assured to be profitable). Attempting to make such decisions, even with "guarantees," must therefore compete for private financial resources. But those resources can see greater returns in making movies or reselling mortgages. Such decisions are therefore going to be too little (too little energy), and too late (too little lead time) to adequately address national and international infrastructure requirements.

Government and industry leadership that is directed to meet the national interest must make the public interest decisions to produce essential infrastructure, instead of being limited to providing small, incremental, *ad hoc* profit opportunities. They must enable the critical private interests and industries, which must do the work, to get on with the business of competing to deliver the essential technology and services. The great manufacturing, materials, construction, and services enterprises can produce the infrastructure required to engage the world population in tremendous economic growth, modelled on the U.S. growth of the mid- to late-19th Century, and the mid-20th Century, which would pale in comparison.

The Role of Nuclear Energy

The projections I made for nuclear energy in 2050 simply took the role of nuclear energy to provide for roughly one third of the energy demand in 2050, which was taken to grow by about a factor of 3 from 2000. But, of course, that begs the question: Can fossil fuels continue to provide energy at the same level, or a moderate increase as today, to produce about one third of the energy demand in 2050? And can hydro, wind energy, and other alternatives (for example, tidal and wave energy), provide the other third, also the equivalent of 100 percent of today's total energy use?

We must, however, consider that any significant reliance on


Courtesy of Korea Hydro & Nuclear Power Co., Ltd.

Korea's Yongwang nuclear complex with six reactors.

solar energy runs the enormous risk of another "year without a summer," and possibly longer, following large volcanic eruptions. This occurred twice in the 1800s—Tambora in 1815, and Krakatoa in 1883. Under these conditions, billions of people would die in a world of 9-10 billion people, and dozens of mega-cities of more than 20 million people each, if we don't have adequate nuclear power or fossil fuel supply capacity to provide the "back-up power" required after going weeks or months with the Sun being blocked over the entire northern hemisphere.

So, nuclear power in 2050 would supply about 100 percent of current energy use. Since nuclear energy produces about 6 percent of world energy use today, that is an increase of roughly 18 times current use. This is fewer than the 6,000 plants I projected in 1997, more like 5,100 equivalent 1,000-megawatt-electric (MWe) plants.

But nuclear energy needs to be used for more than just electricity. This includes, for example, desalination of seawater, hydrogen production from water to displace gasoline and diesel fuel for transportation, process heat for industry, and so on. This could also include extracting oil from coal, from tar sands, and/or from oil shales for transportation and other uses, in addition to the use of hydrogen.

Note that, here, nuclear energy does not displace coal, oil, and gas. It just limits the increase in demand. If we need to displace fossil fuels, we need even greater nuclear energy use—along with other alternatives. However, there are limited practical alternatives to provide bulk energy supplies to meet the human needs of the world population, which is growing in numbers, and, to a lesser extent, in improved human conditions. That still leaves the question of how much oil and gas are being depleted, and coal to a lesser extent. If oil and gas production can not be maintained up to about 100 millions barrels per day, this could require an even greater commitment to nuclear energy, especially if nuclear energy is needed to extract oil from tar sands, oil shales, and coal.

This means that about 200 percent of current energy use would still have to come from fossil fuels and alternative sources. This leaves the questions: Is this possible? Can enough oil and gas be discovered, extracted, and refined? Can enough coal, tar sands, and oil shales be converted to displace current oil and gas supplies? If so, how much energy will this use? And how much will this increase per capita energy use?

Policies to reduce carbon emissions may affect this mix of energy supplies, but whether or not that is done, there are pollution-control costs and other cost pressures limiting supply that will make fossil fuels more costly in any event. We need to consider this in the light that nuclear energy can be produced indefinitely at roughly the cost that it can be produced today.

The alternative is to continue "business-as-usual." These conditions are even now producing international conflicts over oil and gas supplies, large environmental pollution costs in trying to increase fossil fuel production, and high costs to try to subsidize uneconomical "alternative" energy sources. This is leading the world into economic collapse, without

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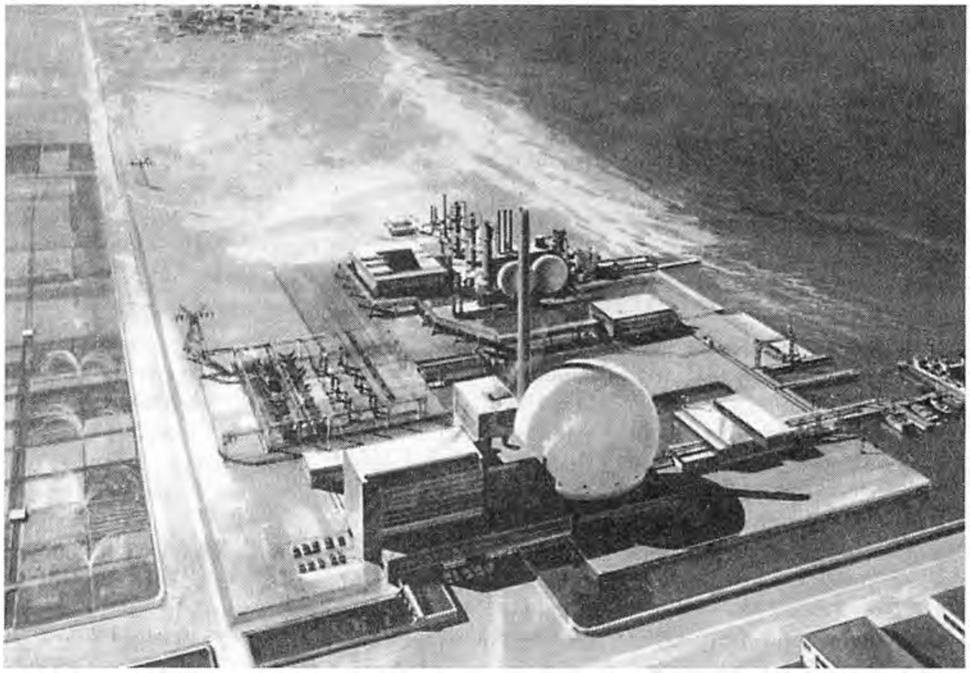
A woman in India prepares cow dung, to be used in place of firewood. To bring the developing sector fully into the 21st Century will require tripling today's energy supply, with one third of the total coming from nuclear.

J.P. Lafonte/United Nations

will have limited population increases. The developing world will add 3 to 4 billion people, with increases from reproduction and with the addition of undeveloped regions to the developing world totals. The current development in China and India, and elsewhere, indicates the enormous growth now in progress. Today, if anything, such development projections may be understated.

The industrialized world can be more energy efficient. Per capita energy use may be 65 to 75 percent of current use. However, there will be greater energy demands for new applications as necessary, such as the use of desalination to produce water, and hydrogen from water, and oil from coal, and so on, using more energy to extract end-use energy.

The developing world will substantially increase per capita energy use, to 40 to 50 percent of current per capita energy use in the developed world. Going from a bicycle to a motor scooter, may require only a few gallons of fuel per year, but it's a large increment over the amount being used with the bicycle. And motorbikes lead to cars. Even in the last 5 to 10 years, there has been an enormous increase in vehicles, in China especially, and in other developing regions. These are large populations, more than 2 billion people, and their need for oil is becoming enormous.



Nuclear energy will be used for many applications, such as desalination of seawater. This 1960's sketch is of a nuplex, an agro-industrial complex centered on a nuclear power plant. It is located on the seacoast, making possible the large-scale irrigation of farmland.

adequate energy supplies. That will produce a world in which the rich will feel the need to acquire the significant resources of the economy, with the growing disparities in income and wealth that we are again seeing even in the developed world, and frustration in the developing and undeveloped world from limits on their ability to function economically.

Calculating Energy Demand

To evaluate projections of energy demand, I looked at the literature on per capita energy use in the developing and developed worlds: the size of current and projected populations.

World population will increase from today's 6 billion-plus people to an estimated 9 to 10 billion people by about 2050 (unless there are even greater wars of extermination and genocide). The developed world, with fewer than 1 billion people,

It is virtually inconceivable that world governments have allowed (and even fostered, in the case of Germany and others) this unambiguously devastating condition, known to all, to reach this stage of crisis, unaddressed.

Therefore, if we are to achieve a world that is providing the energy required for developed societies, along with substantial relief of human suffering and deprivation (while limiting the enormous environmental and economic costs of large increases in fossil fuel demand), energy use in 2050 will be roughly three times the level of energy use of 2000.

Why Accelerate Nuclear Power ?

With world energy currently relying on oil, coal, and natural gas, there are limits on the oil and gas that are available. Without fully considering untapped proven and unproven reserves in the ground, in the near- to medium-term we need to increase the current 80 million barrels per day of oil. This will push the competition for oil to dangerous levels in 5 to 10 years, and without more aggressive oil supply development, it will be much worse in 15 to 20 years.

But we aren't taking the actions needed to prevent those conflicts. People talk about wars over oil, including both Iraq wars. China has become a significant player in bidding for oil. Beyond its own region, it is negotiating future supplies from Iran and South America. But large-scale initiatives to meet energy needs in order to limit future conflicts are generally inadequate. China and India have taken major initiatives. Russia will also make significant contributions. There will be an economic war, as well as possible shooting wars. In that war, China already has the substantial leverage of its enormous dollar holdings—more than $600 billion. But if, at some point, U.S. and European monopolies on oil from the Middle East and elsewhere are seen as severely damaging to China's need for oil to maintain its development, we will increase global tensions significantly.

At the same time, fortunately, the United States and China have large supplies of coal. China has enormously expanded coal production and use over the last 20 years. It produces 65 percent of its total energy from coal. It is currently opening about one coal plant *per week*. But this has come with enormous environmental destruction, from using older, cheaper, quicker technologies, both to mine it and to burn it, covering many cities and rural areas with black soot. This has had substantial health consequences, in addition to about 6,000 deaths per year to miners.

China has already expressed its intent to reduce dependence on coal; it is pushing the growth of hydropower—which it is doing with the large dam projects—and nuclear power, and many wind power projects. But because of current high costs, and allowances for intermittent generation, wind power is not now planned to be a significant contribution to China's long-term national energy needs.

Large dams also come with enormous environmental costs, plus the massive relocation of people, and other social costs, in addition to having to move power over long distances. These dams also provide (and must provide) enormous benefits for both flood control and the transfer of large quantities of water from the South to the North of China. These dam projects need to go ahead. There are presently dozens of locations that have been identified as good hydro power dam locations. But, just as in the United States, the Chinese are running out of ideal locations to site hydro power dams. There are also significant losses of arable land, plus the significant social and economic costs of moving and relocating masses of people as land is flooded. So there are fewer benefits to be gained from hydro power, and some costs that must be relieved, instead of being able to depend on dam-building for "renewable" hydro power, to solve its longer-term energy needs.

Nuclear Energy is Competitive and Cost-effective

Nuclear power is currently competitive and cost-effective. Numerous pragmatic current and recent construction projects around the world provide a strong basis for cost projections in the United States, Europe, and other locations that do not have current experience. Electricity from available nuclear power plant designs is lower than current costs from recent coal and gas plants, and reasonable projections of electricity costs from future coal and gas plants. But to some extent, nuclear power can be the victim of its own success. In the competitive market, some see new nuclear plants potentially causing electricity prices to come down, possibly to the point that the plant is not competitive, or at least that it reduces the return on investment. This could depress the owner's stock price. In addition, the construction of many new nuclear plants could also reduce the demand for, and therefore the price of, gas and coal, which could also affect nuclear plant competitiveness and stock prices.

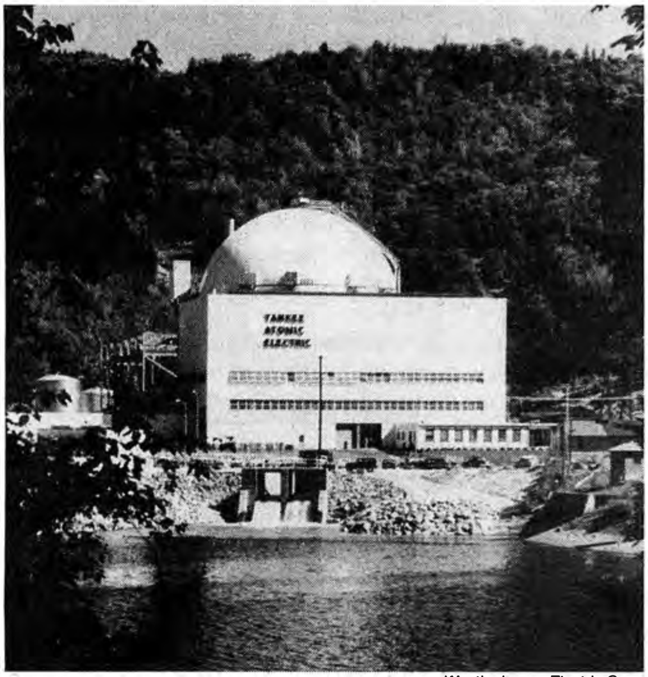
There is a popular view that nuclear power is the high-cost option. However, during the 1968 to 1978 nuclear power construction period, there were economic benefits even when there were almost 200 plants ordered, and being procured and constructed, with massive construction costs. Our current 103 operating plants, and more, were ordered between 1967 and 1973. From 1970 to 1978, we were buying and building many more plants that did not get completed. All of those plants established strong competition with oil, gas, and coal. (Burning gas for electricity was prohibited in the United States in 1978, and only went into effect in 1990.) But the competitive pressure brought down the fossil-fuel-generated electricity a great deal. Electric ratepayers in the United States saved billions of dollars in oil, gas, and coal fuel costs over almost three decades.

Of course, the companies building those plants don't see that on their balance sheet. But those are real cost reductions to the ratepayers and the economy as a whole—to the general benefit of the nation—even if the people building the plant do not see a return on their own investment, and even if the oil, gas, and coal companies see these lower prices as a loss, or at least a lost opportunity.

So, without the nuclear option, we lost that competitive pressure. Prices are not constrained by that competition and have been increased, along with increased demand for scarce oil, gas, and coal resources. So, if we build nuclear power plants, even before a significant number of plants are operational, and especially if we have the ability to build a plant in four to five years for large plants, or we have a series of plants of the modular type that can be constructed to begin operations on shorter schedules, we will have an effect of reducing the excessive demand for, and costs of, coal and gas for providing electricity—to the benefit of the whole economy. We must consider that as part of the economic equation that doesn't presently exist, in the way we evaluate nuclear power costs.

We have developed methods to apply "externalized costs" in evaluating alternative energy sources. This is a step toward recognizing that the financial balance sheet does not fully measure the non-monetary values of energy to the economy. But we should also consider "externalized benefits" to evaluate such non-monetary benefits. This includes the benefits of reducing energy prices to the economy, the value of energy security, and so on.

Of course, people still consider the very high costs of the large nuclear plants ordered in the early 1970s. But these suffered the unanticipated effects of high component and labor costs, design changes in process after the Three Mile Island accident, and long construction times with high financing costs.



Westinghouse Electric Corp.

The 600-megawatt Yankee Atomic Electric plant in Rowe, Mass. was the third commercial plant in the United States. Now decommissioned, it operated for 31 years, starting in July 1961. Yankee Rowe was built before high interest-rates and construction delays slowed down nuclear development.

Most of the cost in the 1970s and 1980s was the result of the interest rates hikes instituted by Paul Volcker. But the other side of that coin is in considering the relative financing advantage with demonstrable 4- to 5-year construction schedules and even less, instead of 6 to 7 years in our original *ad hoc* planning and construction experience when we were building them all *de nouveau* on each site. Today, we are prepared to manufacture and pre-build modules, reducing construction schedules to limit that long-term financial exposure, even if there were increases in interest rates.

Then, there were relatively long construction schedules, increases in financing rates, and also delays in construction after the Three Mile Island accident, so that, instead of 6 or 7 years, construction became 10, 12, or 14 years—in some cases, more than 20 years. But we can ignore the outliers. They were delayed for various reasons other than just construction schedules.

Even the plants that took 10 or 12 years were the result of weak engineering and construction management. The good, knowledgeable, hands-on engineering companies during that time, like Duke Power, did not have plants that were excessively delayed. They were able to manage design and construction changes without dropping the ball.

But, in any event, future projects will undertake plant construction with approved designs, with "constructability" incorporated in plans. The current generation of early plants are simply artifacts of the historical first phase of nuclear power plant design and construction, just as the Ford Tri-Motor and the DC-3 are artifacts of the first phases of passenger aircraft.

Mass Plant Production to Follow the Land-Bridge

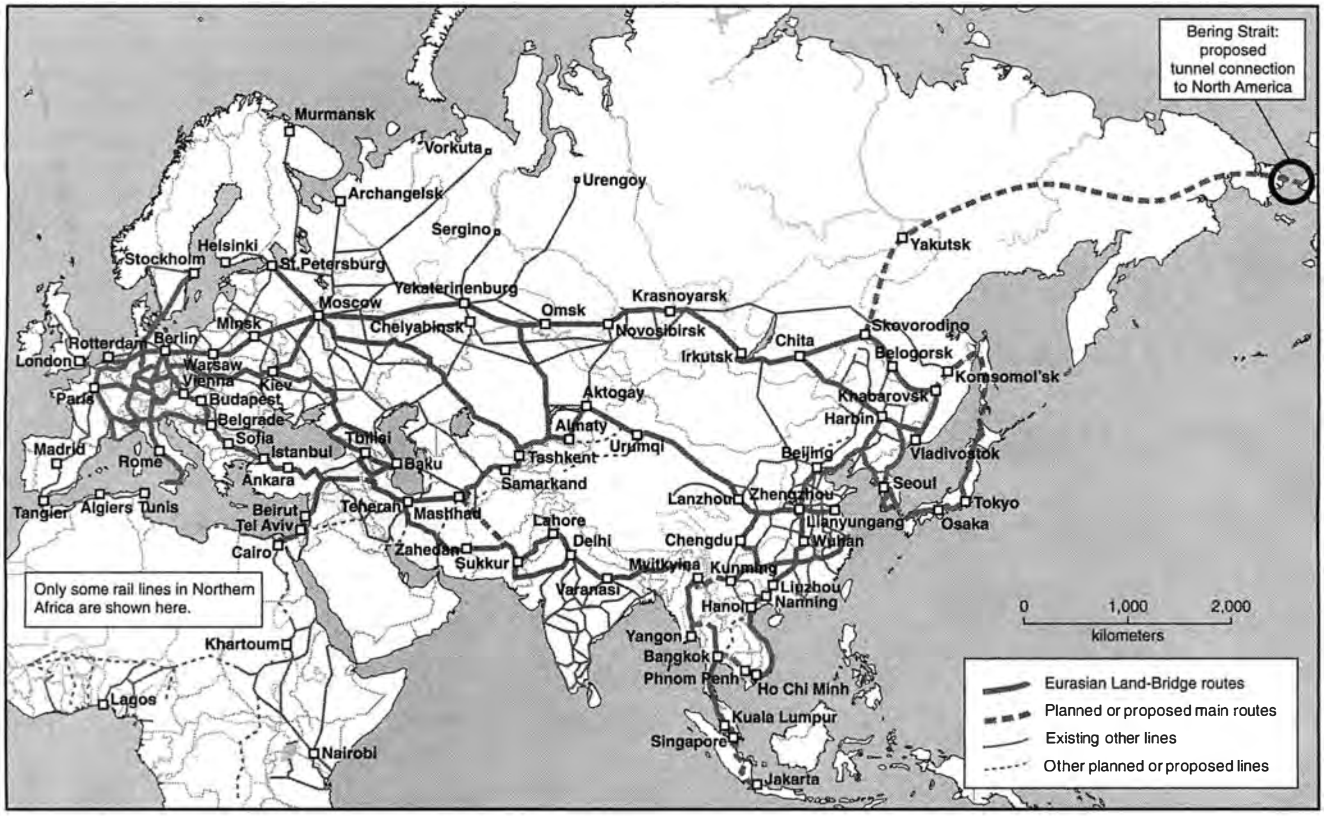
Strategic development and implementation of nuclear plants is like the Eurasian Land-Bridge concept: building networks, not just building out linearly as the United States did in moving to join the East and West in building the transcontinental railroad. It is more like the following period in railroad history, when simultaneous railroad lines were tying together the country; for example, the north and south in bringing Texas cattle to the Chicago stockyards, supported by the telegraph with its ability to implement network communications. The process is explicitly oriented to develop along a strategic path, rather than *ad hoc* plans to develop energy sources and communications around cities that grow as a result of a non-planned, non-networked, model. Or, to be more precise, the city-region is the network, even in large cities where water and power had to be brought from hundreds of miles away. Intercity infrastructure needs to be integrated with intracity-regional systems.

Such strategic plans anticipate growth of large nodes that require substantial infrastructure, which rely on and include power requirements—as in industrial complexes and large cities of more than a few hundred-thousand people. We can consider a little separately the mega-cities of 20-plus million people that are being created. They require an obvious, localized, large energy component, with a primary role for electricity, but with a heavy demand on the transportation capacity to supply the population and industries, and export the products of the cities. The growing cities of an integrated industrial economy are networked by transportation and communications. Electrification of the railways, and non-electric energy for heat, for example, to provide desalinated water, must be considered.

Electric grids also require that power loads be balanced, which further requires planning in a network strategy, instead of linear development as occurred in the early United States, where, even after the beginning of installing electricity, "the grid" was essentially localized to cities.

In building out a network, we can take a manufacturing mode with the construction of nuclear plants to supply the network that is growing an industrial economy, instead of a focus on the major cities as occurred with the original U.S. electric power system development. This fragmented result of *ad hoc* private decisions, responding to individual profit opportunities, had to later be fixed by government, including, for power, government agencies like the great Tennessee Valley Authority (TVA), the creation of the Rural Electrification Administration, and so on, to bring the nation together. As still is true today, this could not have happened effectively by leaving *ad hoc* decisions with the private financial interests, focussing on assured quick-return profit opportunities in individual projects. It could be delivered by corporate America when given the opportunity, just as with the great dam projects, providing power and water for cities and irrigation, and even recreation, with the associated economic development of the American West.

So, nuclear power plant construction should be transformed from the mode of plant-by-plant construction of *ad hoc* projects, into a manufacturing-based strategy. France is a prototype. In 1973-1974, a national decision was made to build nuclear plants in convoy series, to make decisions on designs



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This map of the main trunk lines proposed for the Eurasian Land-Bridge gives an idea of the route, moving west from China's east coast, that nuclear development could follow. Envisioned in the Land-Bridge concept is the building of industrial development corridors along the route, where new cities—agro-industrial and educational centers—would be the vehicle for bringing interior regions out of poverty, developing their human and mineral resources.

and to install those designs multiple times, with evolutionary enhancements in size, costs, and safety for future plants. This puts many plants on line in a manufacturing planning mode rather than constrained by plant-by-plant decision-making and plant construction mode only as individual project profits can be reasonably assured.

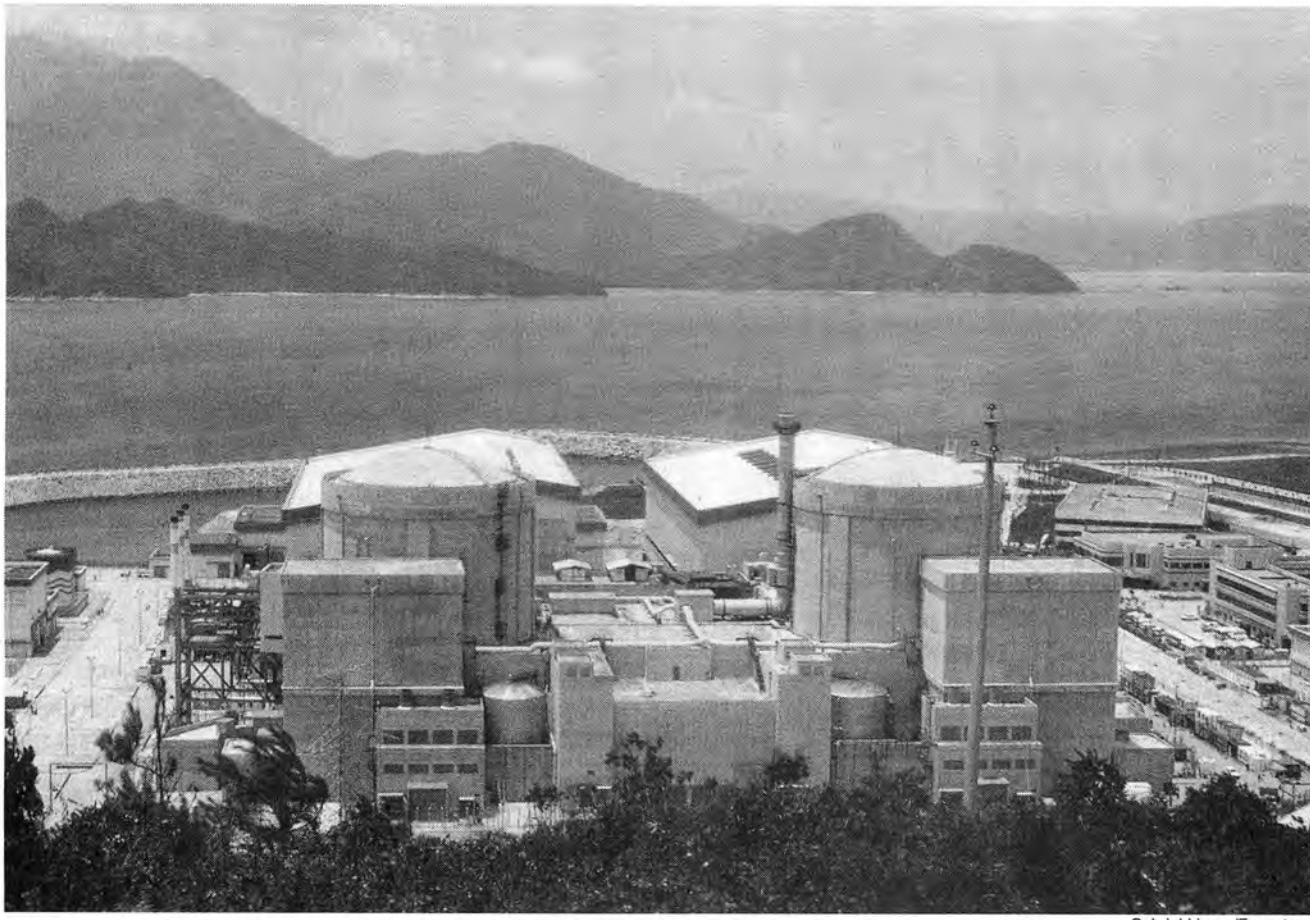
This enables the ability to take advantage of mass production, with programmatic commitments to make the vessels and major components to support a plant assembly approach. Individual plants would be installed to meet the electric power market needs. This is especially true of the modular gas reactors.

There are areas that have high power demands now—southern China for example. In addition, there are developing areas extending inland to produce energy for local development along a Silk Road model. Initial energy demands in such areas are not enormous, so that instead of large light water reactor plants, we could incrementally build dozens of modular units over decades, combined with evaluating power to eventually be fed to, and supplied from, the growth of the larger regional and national grid.

Installation sequences would dynamically respond, to both lead and follow growth. We could build two or four plants in one location, and move down the road 200 miles and build two or four more; then build two or four more at the original location as the demand grows. This would be very responsive to local conditions and growing demand over time, while the central facilities would build units in a long-term planned strategy for a number of pressure vessels per year. Although the 285-MWe GT-MHR (General Atomics' gas-turbine modular helium reactor) modular plants are small, compared to light water reactors, the pressure vessels are as large as 1,200-MWe pressurized water reactors (PWRs). When, 10 or 20 years later, we need to expand the capacity to build pressure vessels, we will work with the manufacturers either to expand existing facilities or to select and develop other locations.

So, we have the railroad model: Start at key nodes, and expand toward other nodes. The railroad development in the United States is a kind of paradigm. It shows that we need a central strategy. But the people doing the work were competing for contracts and building from, and developing, private industrial growth. President Lincoln and the Congress made national decisions to establish routes, public domain issues, incentives, and so on, that were required to support that kind of strategic development. So, governmental direction and vision are needed, with private participation. This has to establish the framework in which the private industries can compete and succeed, to implement that vision in the national economic interest.

We need a similar government vision now on behalf of the nation as a whole, with an orientation to critical infrastructure, that recognizes the human and economic needs, that rely primarily on low-cost energy. This should not be done by government directly, as was done, for example, with the TVA. But



Gabriel Liesse/Framatome

Areas with high power-demands today will need larger plants. This Guangdong Nuclear Power station, at the eastern end of the Land-Bridge in China, has two French-built pressurized water reactors, each 985 megawatts-electric.

it must reflect a vision that enables the private sector and the public to be engaged, to inspire people to see that their future security and opportunities are going to be provided by adequate development and growth in the national and world economies, that are geared to meet human needs. Otherwise, we are all going to be in a real crisis, that will become increasingly visible to the general public, as our lack of adequate economic infrastructure, especially for energy supplies, with associated environmental and financial costs, will be increasingly seen as overwhelming the nation, and the world.

Five Basic Types of Nuclear Plants

We need to implement available plant designs. There are five basic types needed, and there will be more in the future: advanced light water reactors (ALWRs), high-temperature gas-cooled reactors, breeder reactors for the long term, a small packaged reactor for remote and long-term operation without refueling, and small reactors for merchant shipping and other small non-electric-power requirements. The Canadian Advanced CANDU reactor, with a good technology base, is also a candidate to be installed extensively in a large worldwide reactor implementation program.

We clearly have ALWR plants that are well-suited to provide large quantities of baseload power. Because of the inherent safety of these plants, as was documented in the "Policy Forum" in *Science* magazine (Sept. 20, 2002, p. 1997), there are substantial opportunities to reduce the capital costs and construction schedules of these plants over time, as designs can be improved to better reflect safety requirements. However, building one or two units at sites is not very effective. LWR plant sites should be four to six units, and more in many cases. They would be located in areas where large population densities and industrial infrastructure warrant these bulk electric-generation capacities.

At the same time, for high-temperature industrial applications, and relatively remote and developing populations, we need the modular high-temperature gas reactor plants—either the pebble bed modular reactor (PBMR) or the General Atomics prismatic fuel gas-turbine plants (GT-MHR). These modular ceramic-fueled reactors enable incremental planning and flexibility. If we plan on 100 units per year, we can implement that manufacturing plan before deciding the locations of modules, although the primary locations for energy requirements in the network would be known. But implementation over the decades would be able to accommodate demographic and development changes in growth of power, process heat, and so on. At the same time, we can develop the production capacity for the ceramic fuel needed to support that number of plants.

One of the difficulties of the past has been with *ad hoc* decisions of utilities about plant types. In the United States, this was influenced by the light water reactor development technology undertaken for warships by the U.S. Navy, with its need for high power-density reactors, while the utilities did no reactor development to optimize reactors for commercial applications. However, that optimization effort is now being undertaken, in respect to ALWR plants, including the new "passive" designs, and the modular gas reactors, with some limited work ongoing on more advanced reactors under the international "Generation IV" program led by the U.S. Department of Energy.

The gas reactors, the ceramic-fuel reactors that were being built starting in the 1960s, did not have enough plants to optimize fuel production, after orders for the large high-temperature gas reactors (HTGR) plants were cancelled in the early 1970s. The fuel was costly, and there are questions about fuel recycling, although the high burnup of this fuel, including the reduction of plutonium and actinides, limits the inefficiencies that are associated with non-recycled LWR fuel. The HTGR fuel waste greatly lowers disposal costs. However, rational standards and technologies for spent fuel and high-level waste disposal will lead to greatly reduced waste disposal costs in general. There were materials constraints in the 1960s and 1970s, compared to current materials technology. There was more use of CO_2 than helium for reactor heat transfer. In addition, gas turbines today have the advantage of a great deal of large jet engine and combined-cycle turbine technology, which avoids the need to operate with a steam cycle.

The Modular HTGRs

The reactor designs ready to be developed for mass production are the modular high-temperature gas-cooled reactors that have uranium-carbide ceramic-microsphere fuel. The German-designed pebble bed reactor from the Jülich research center was a 15-MWe prototype that operated from 1967 to 1989. It is now being developed for Eskom in South Africa as a 135-MWe pebble bed modular reactor. China also has an operating 10-MWe operating prototype, and is designing a commercial plant. In the United States, the General Atomics design is a 285-MWe prismatic fuel gas-turbine modular helium reactor, the GT-MHR. A prototype plant is being designed with the Russian nuclear agency for construction in Russia, to burn plutonium fuel.

I have long favored HTGRs. I was at Bechtel when the large HTGR plants were ordered by Baltimore Gas and Electric and others in 1971. I also participated in the Department of Energy meetings with industry on the modular HTGR program in the early 1990s.

Of course, in practice, we will initially build the ALWRs that are already designed and now being certified by the U.S. Nuclear Regulatory Commission, and the French-German EPR, and the Russian large PWR, which are being constructed today. These apply where large nuclear power capacities for electric generation are needed, especially in China, India, South America, Russia, Europe, and the United States. But we must also aggressively pursue the gas reactor prototype development, to enable design acceptance for modular gas-cooled reactors, so that they are available for the smaller electric power systems that have less technology and people infrastructure.

The prototypical gas reactor plant has four units with a single control building. But in practice this model is flexible, to be expanded with another control building with another four units going out, or expanding the control building to run additional reactors. There are flexible ways to build out the number of modules at a site, and to sequence modules at more than one site, in case of site installation constraints.

But that's a detail. We need to be able to accept the designs to be able to produce the plants over more than a decade, independent of the commitment of where to build those units, and to plan their associated fuel facilities, pressure vessels, and so on. As noted above, the pressure vessel for the General Atomics 285-MWe GT-MHR is roughly the same size as the pressure vessel for a 1,200-MWe PWR.

Uranium reactors use less than about 1 percent of the energy from the uranium fuel. Breeder reactors use fuel recycling to obtain 60 to 70 times the energy value from the uranium resources. Breeder reactor plants are not needed quickly. However, with a large commitment to nuclear power to meet world energy needs, we must develop breeder reactors and plant designs, and fuel recycling. Fuel recycling will start with the use of mixed plutonium-uranium oxide fuels, with a later introduction of breeder reactors.

The small reactors can be applied to many specific energy applications to replace costly fuel oil for transport; for example, to power oil tankers and container ships. Major industrial applications can be powered by small reactors, not unlike the extensive experience that has been obtained from operating nuclear-powered warships, ice breakers, and power plants for the Antarctic and other remote locations. We need to develop small reactor designs for such commercial applications.

Some power applications can also be met by using radioisotopes that can be extracted from recycled fuel, especially from strontium-90.

The Mass Production Road to 2050

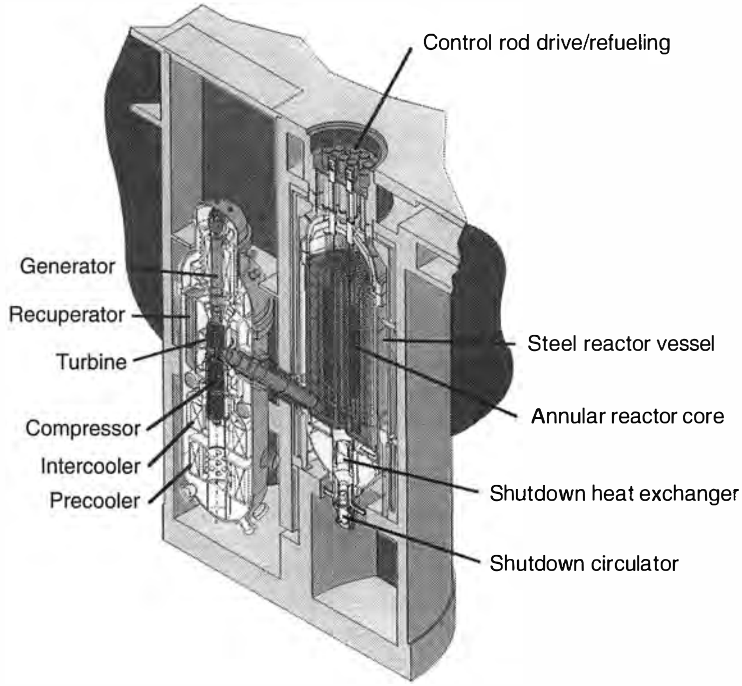
Because the time frames for these construction requirements are long, and we need significant contributions to power supplies by 2020, we can't just follow exponential growth curves to put a lot of the power on line in the decade from 2040-2050. Note that my projections are for a nominal 6,000 units of 1,000 MWe. There would be many more units if there were many modular gas reactors. On the other hand, there may be many 1,600-MWe plants of the French-German European PWR design. This plant design is now being built in Finland, and one is planned in France.

But to produce that number—6,000—plants by about 2050, we can not just increase production exponentially. We need a substantial amount of nuclear electricity before 2030, and we want to install a construction capacity that would also produce a stable plant production rate for the future, to meet both a nominal energy growth and to replace old power and other energy plants. Consider that China is building roughly one new coal plant per week now, and the United States has about 100 coal plants on the drawing board. These plants and hundreds of others will need to be replaced after 2050.

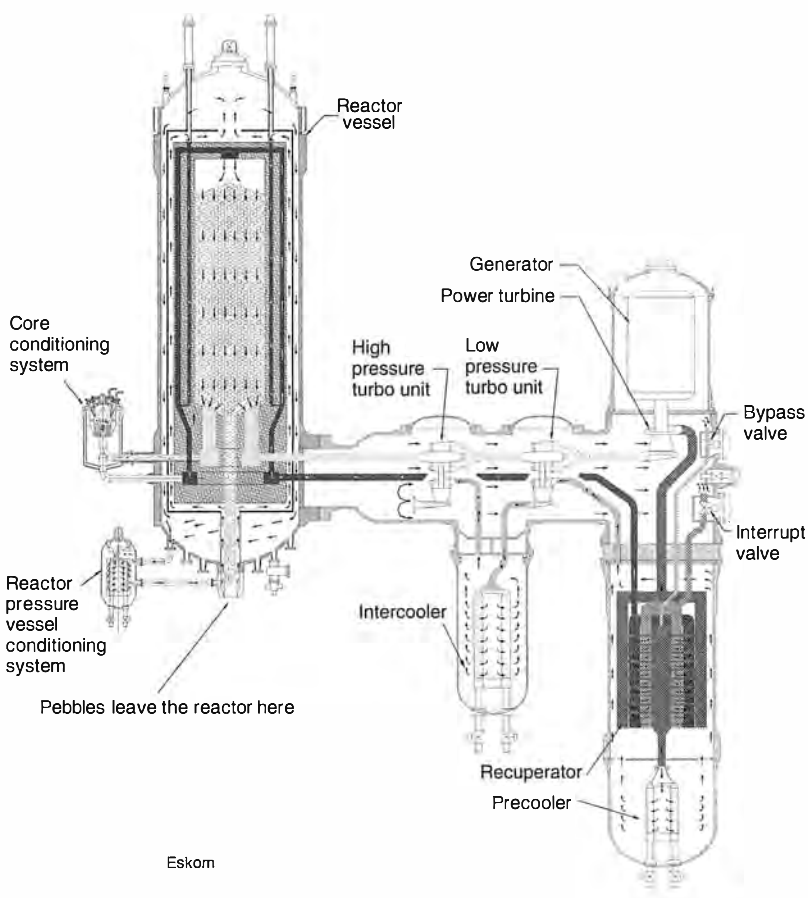
Obviously, we would install much of that capacity between

GT-MHR: GENERAL ATOMICS' MELTDOWN-PROOF REACTOR

The reactor vessel (right) and the power-conversion vessel (left) are located below ground, and the support system for the reactor is above ground, in this 285-megawatt-electric reactor design. This is a gas-turbine modular high-temperature gas-cooled (helium) reactor. Its ceramic fuel particles are embedded in 2-inch-long rods, which are stacked up in columns and inserted into a hexagonal fuel block. Helium can be heated to higher temperatures than water, so the outlet temperature is 1,562° F, compared with the 600° F of conventional nuclear plants.



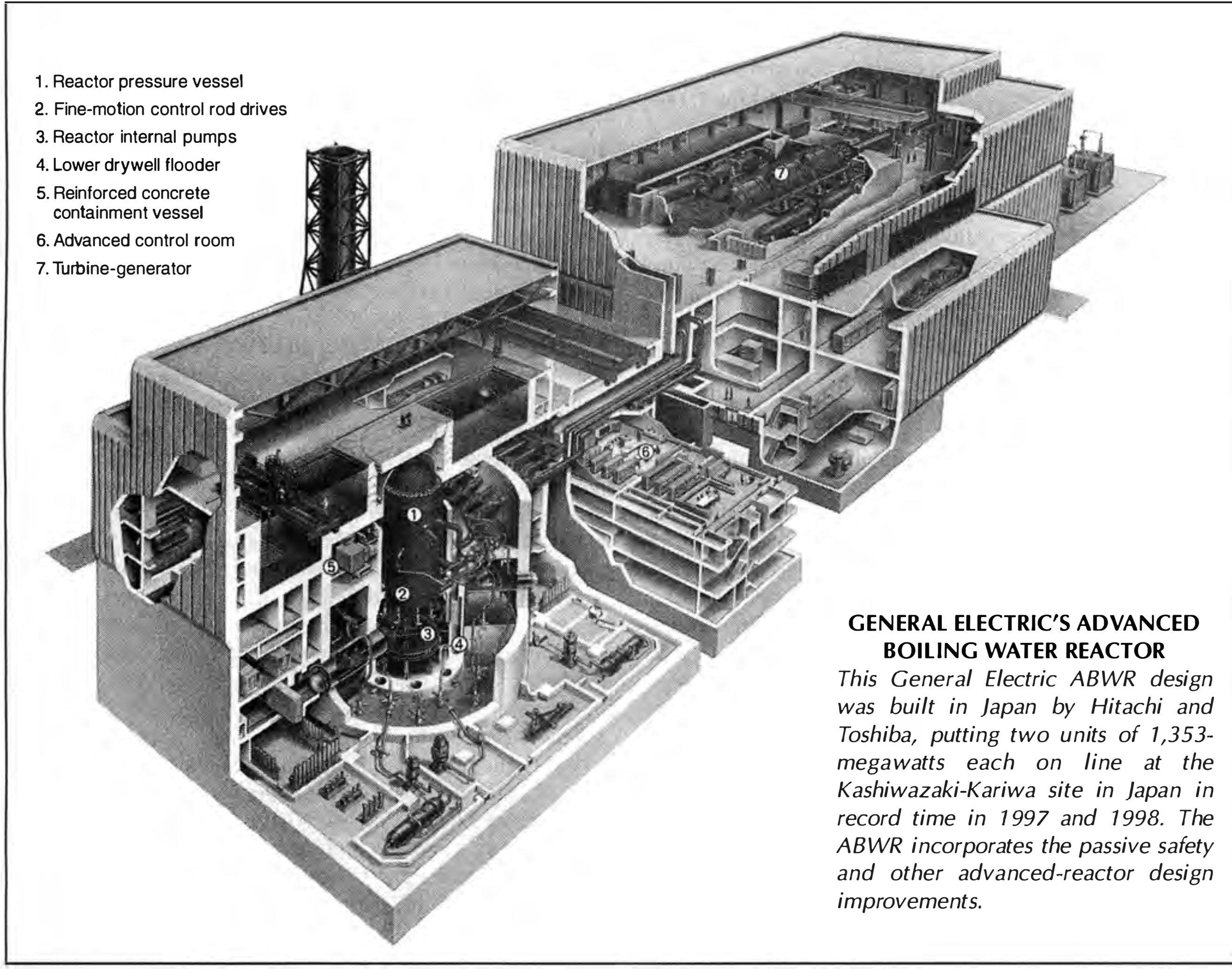
Source: General Atomics



Eskom

PBMR: SOUTH AFRICA'S PEBBLE BED MODULAR REACTOR

This Eskom reactor design is 110-megawatts-electric, and is located below ground. The ceramic fuel particles for this high-temperature gas-cooled (helium) reactor are formed into fuel balls (pebbles), which are about the size of tennis balls. Helium gas is inserted at the top of the reactor, passes among the fuel pebbles, and leaves the reactor core at a temperature of 900°C. It then passes through three turbines, to generate electricity and then cycle back to the reactor.



GENERAL ELECTRIC'S ADVANCED BOILING WATER REACTOR

This General Electric ABWR design was built in Japan by Hitachi and Toshiba, putting two units of 1,353-megawatts each on line at the Kashiwazaki-Kariwa site in Japan in record time in 1997 and 1998. The ABWR incorporates the passive safety and other advanced-reactor design improvements.

2030 and 2050. But to get from here to 2030, we have to re-examine how we plan, and commit, to installing nuclear plants. We need to go beyond the current idea that we would only commit to constructing one plant in the U.S. in 2010, and then, building something like 10 plants in the next 10 years, to 2020, in the United States. That's a long way from 2,000 or so in 2030 in the world.

Fortunately, other countries are doing more to meet the need, as publicly reported in planning announcements, even if that is still inadequate. Hopefully, and I expect that, much more is being done in some key organizations and institutions around the world.

Fuel supply, of course, requires a large expansion of uranium extraction, conversion, enrichment, and manufacturing, along with implementing adequate fuel reprocessing to use plutonium-uranium mixed oxide fuel, and later breeder reactors, to create more fuel than they consume to produce power. This uses the large inventories of depleted uranium created by enriching uranium for power and, especially in the United States and Russia, from building atomic weapons. India is also developing a thorium-based breeder reactor to take advantage of its thorium resources, and limited uranium.

We have to commit to manufacturing the pressure vessels and other large components in mass quantities, contracting now, instead of waiting for future *ad hoc* contracts from individual companies. Even when they decide to build in four-unit plants, there are substantial overheads and delays to develop contracts, which are subject to the *ad hoc* process of integrating such plans into the production capabilities of vendors, with, again, rising costs and/or extended schedules, as negotiations are entered for limited production capacity, with high risks perceived for commitments to expand manufacturing capacity vs. the assurance that the industry will not collapse again.

We must also commit to working on evolutionary designs that can reduce the cost of current and future plants. For example, current requirements for containment pressure and leakage, radiation control, including ALARA (the as low as reasonably achievable standard), and so on, can be based on realistic analyses, while enhancing nuclear power plant safety. In addition to engaging the manufacturing industries directly, we must engage the major national and international standards organizations, and other international non-governmental organizations, in this project.

Such competition in the original nuclear plant construction process in the past led to very high component and materials costs. Individual companies would still have to develop plans and contracts for new plants, but those plants would come from national policies that engage the developed and developing countries to commit to the production and installation of nuclear power plants to produce a large, worldwide plant manufacturing capacity.

To have 6,000 units in 2050, exponential growth would result in building about 400 units per year in 2050, but with fewer in the early decades. But a plan for more rapid growth to a level long-term production capacity to support long-term energy growth and replacement of old plants and fossil fuels, would result in producing up to 200 new units per year. We can plan for 6,000 equivalent units taking our present operating plant capacity as about 300 1,000-MWe equivalent units (from about 440 actual units).

There are about 30 units now in construction in the world, with construction times of five to six years, so we are now building about 6 units per year. This will substantially increase in the next two to three years. So we can take something more than 10 units per year as a current baseline, although we can more rigorously examine pressure vessel capacity. We can plan for a rapid increase in current capacity to a level about 200 units per year around 2040. Current and near-term nuclear power plant construction experience is a sound basis to adopt initial plant designs and major suppliers.

The Production Schedule

The production effort to get to 5,000 or 6,000 plants by about 2050, can be estimated by starting from the existing 300 equivalent 1,000-MWe plants and the plants now under construction, so that there will be about 320 equivalent 1,000-MWe plants in 2010. There is a current production capacity of at least 10 plants per year, which needs to be evaluated as a basis for developing additional capacity.

To build 5,000 plants by about 2050, production can be increased to build an average of about 30 plants per year between 2010 and 2020, which would add another 300 plants, for a total of about 620 plants in 2020. Building an average of about 75 plants per year from 2020 to 2030, adds 750 plants; building 160 plants per year between 2030 and 2040, adds 1,600 plants; and building 200 plants per year between 2040 and 2050, adds 2,000 plants. This results in about 4,970 equivalent 1,000-MWe plants.

To achieve 6,000 plants by about 2050, requires pushing plant production to an average of about 40 plants per year between 2010 and 2020, which adds 400 plants; 125 plants per year between 2020 and 2030, which adds 1,250 plants; 180 plants per year between 2030 and 2040, which adds 1,800 plants; and 220 plants per year between 2040 and 2050, which adds 2200 plants. This results in about 5,970 equivalent 1,000-MWe plants.

This building schedule does not take into account the currently operating plants that would be closed before 2050. That may be about 75 percent of the 440 currently operating plants, but those will be the older and smaller units, at perhaps a loss of about 200 of the 300 current equivalent 1,000-MWe plants. To make up for this loss, about 7 plants per year, in addition to the above schedule, would have to be built between 2020 and 2050.

We would focus primarily on the required fuel cycle capacity and major component manufacturing, and primary materials and infrastructure, including the required people, to produce nuclear units more like the way we build 747s, with parts being delivered for assembly from around the world.

Note that "manufacturing" applies to on-site and near-site support of construction by producing major modules outside of the construction area of the plant itself. The modules built on-site in Japan to construct the two 1,356-MWe ABWRs (advanced boiling water reactors) in about four years each, which came on line in 1996 and 1997, weighed up to 650 tons and were lifted into the plant.

The World War II and TVA Precedents

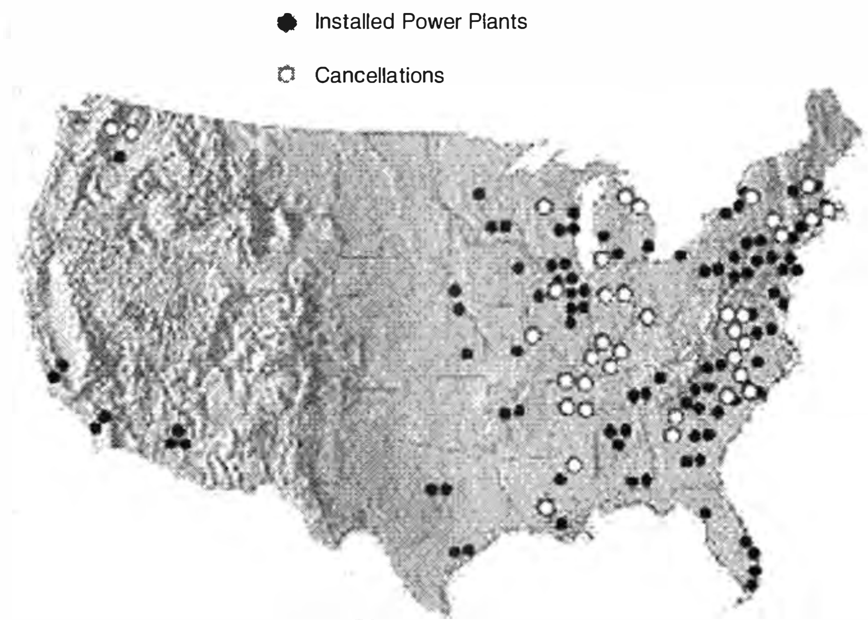
We have the experience of the expansion of production capacity in a few years before and during World War II. President Roosevelt anticipated the need, by engaging industry leaders before the U.S. entry into the war, including earlier production to support U.S. merchant marine shipbuilding, and to supply Britain and Russia using the "lend-lease" program. Henry Kaiser built Liberty ships, which took six months before the war, delivering more than one per day.

The early TVA experience built large projects that integrated production and construction, with labor requirements and capabilities. Unfortunately, as with many large organizations, the later management failed to fully understand and maintain the capabilities that were largely taken for granted as the historical legacy of the organization, with inadequate commitments to maintain that capability. However, there are examples of maintaining those capabilities, in organizations like DuPont and the U.S. Nuclear Navy.

In addition, our original nuclear power construction experience demonstrates that these capabilities are readily achievable. Today there are 103 operating nuclear units in the United States, ordered from 1967 to 1973. Earlier units were the small prototypes that are now shut down. Many units ordered in that period had vessels and major components, and containment construction materials in place or in process. In addition, there are a number of plants that were built in that period that have been shut down, some of which should not have been, if the decisions had been made in the interest of the ratepayers and the general economy, instead of only by and for the utilities, which could then access hundreds of millions of dollars in decommissioning funds.

There were about 200 units in production and construction by the early 1980s. So, even with little management coordination, poor management by many owners and constructors, with plant owners, vendors, and constructors jockeying for position and running up costs in the marketplace, we were building about 20 units per year.

But we got ahead of ourselves. Costs were driven up by competitive bidding for limited production capacity and capital constraints, but, more important, there was much lower electricity growth following the 1973 oil embargo, which had not returned to near pre-embargo rates as had been expected by many in the industry. The then-existing excess baseload plant capacity was sufficient to satisfy the slower growth in demand for two decades, relying primarily on coal, which we have in abundance, and in the 1990s, by building low-cost natural gas-burning plants, when the cost of gas was very low. This provided high



CANCELLED U.S. NUCLEAR PLANTS

The map shows the currently operating 103 U.S. nuclear plants, plus the sites where new nuclear plants were planned, ordered, and then cancelled in the 1970s and early 1980s. We need a national energy plan that will mass-produce standardized nuclear plants now, and site them where power is needed—to supply desalinated water for the drought-stricken areas in the Southwest and West, and to power the re-industrialization of the Midwest, for example.

short-term returns to the electricity-generator companies, but at high long-term energy costs and energy security risks to the nation—and the world. That was an obvious failure to do competent planning, which has clearly exacerbated our current inadequate ability to provide for long-term energy needs of the U.S. and the world, with rising costs that are threatening the world economy.

A more responsible national policy in the 1980s would have acquired some of the abandoned nuclear power plant projects in the national interest (those capable of being maintained to salvage the sunk costs), to be completed when needed to provide new baseload capacity, depending on the costs of coal and gas. In the same way, today, the nation should acquire the bankrupt GM plants from those who have destroyed them, and who would dismantle them, for short-term gain, while losing essential installed national economic infrastructure.

Needed: A National Plan in the Public Interest

There was, and is, no adequate mechanism to make decisions in the public interest based on the value of nuclear power plants to the economy, including environmental and energy security benefits. In a rational world operating in the long-term public interest, it would have been better to have completed many of the plants that were under construction, including mothballing coal plants, and preventing the construction of gas plants instead of overturning the prohibition against burning natural gas for electric power.

But, we hadn't built well-designed nuclear plants, although the later designs of those we built were greatly improved. Those plants are the foundation for the Westinghouse and General Electric advanced LWRs and passive design plants that are being certified by the U.S. Nuclear Regulatory Commission today.

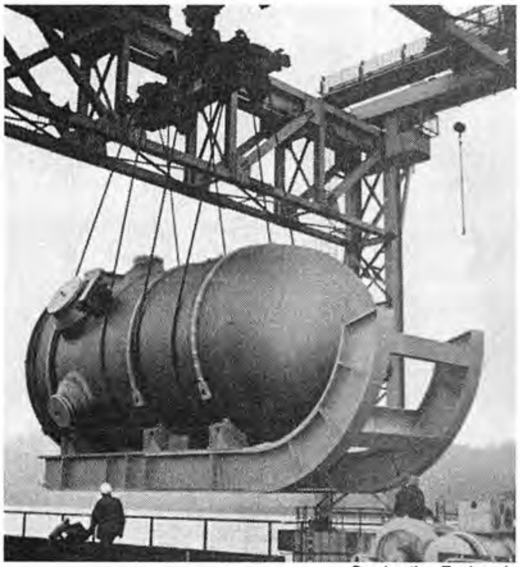
France is the premier example of the alternative model, of making national decisions on both the need to build nuclear power plants (because France did not have the coal or gas that was available in the United States), and the decision to select standard designs to evolve in series, applying the worldwide experience with many early plants.

In contrast, the United States built plants one at a time, because each was a separate contract, for separate owners. Each design was independent, although with some sharing of knowledge and technology. Starting about 1971, as with France, there were initiatives to build "standardized nuclear units" for multiple utilities. But the United States had no institutional capability to make effective decisions in the national interest. This was especially true after the Atomic Energy Commission was dismembered in 1974.

To some extent, we blew up the economic system in competing for massive amounts of capital, as well as the engineering and procurement system, in trying to push all of those plants out at the same time—without national policies and plans that could make that possible. The utility regulatory process that had been in place since the 1930s should have been fixed to meet the realities of future power needs from earnings, when the conditions of lower-cost electricity from new plants no longer applied.

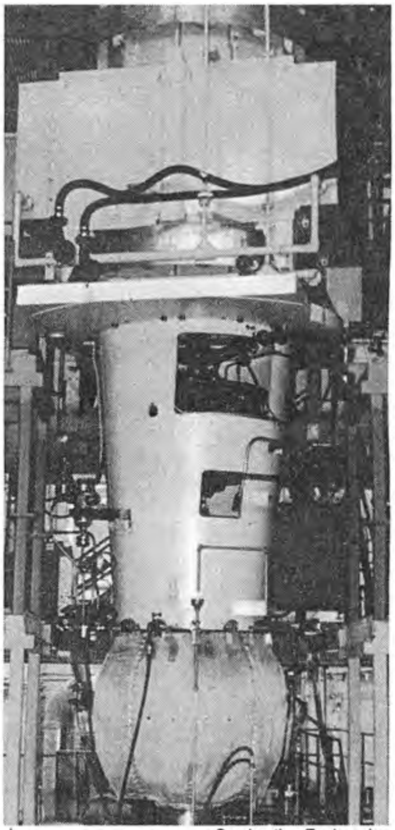
Government needs to put in place the public/private initiative, with national and international authorities to make the requisite strategic and operational decisions on the plant designs to be built, and to make initial commitments to develop the production capacity by the primary vendors. The plants can be put in a manufacturing pipeline. The utilities will identify sites, power needs, and their capability and responsibility to construct and operate the plants, from available plants and positions in the manufacturing pipeline. Volume production would be adjusted to meet demands. This will reduce conflicting demands for resources, including labor, and as with France, enhance high quality designs and production, and reduce wasteful and redundant investment in technology.

Today, an element of that capability exists in the new U.S. Nuclear Regulatory Commission rules that provide for certified reactor designs. This enables a utility to select from "available" regulatory-approved designs. But this general principle needs



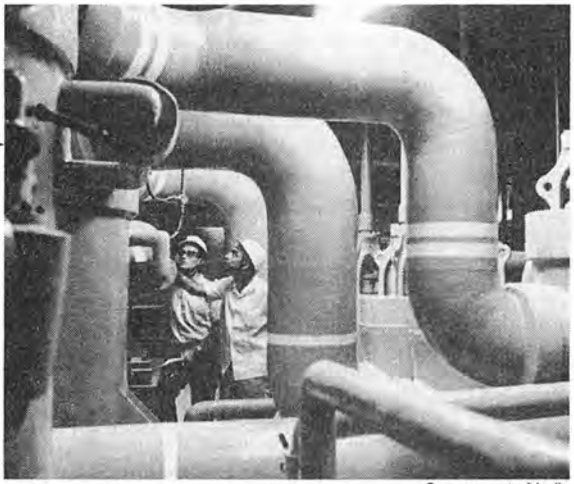
Combustion Engineering

◄ *The United States no longer has the capability to build nuclear pressure vessels. This stainless steel pressure vessel was designed and fabricated by Combustion Engineering in the late 1970s.*



Combustion Engineering

▲ *A high-capacity coolant pump, produced by C-E/KSB Pump Company in the late 1970s. The pump was assembled and tested in a full-flow loop at the manufacturing facility, before being shipped to the nuclear reactor site.*



Government of India

Pipes are another component that will be needed in large quantity. Here, the inside of the Tarapur Atomic Power plant in India, which supplies power to two major states. ►

to be applied to complete units, for procurement and licensing, not just to the reactor designs. Current work is developing Construction/Operating License applications for current and in-process certified reactor designs. These are, in effect, the initial standard plants available to be selected for construction. However, private interests have limited ability to plan and commit to develop the production capacity which can provide the cost advantages to establish a productive industry to meet the essential energy needs of the 21st Century.

China's Ambitious Nuclear Plans

It is useful to look at what China is doing. The Chinese have announced a significant commitment—32 new units by 2020. But China is still authorizing the construction of plants proposed by local utilities and requesting tenders for contracts with vendors on a project-by-project basis. Its current tender is for 2 plants with 4 units, for 2 utilities. This approach is reasonable, considering that China is still gaining experience with plants and vendors, including its own plant design and construction capability. The Chinese also have their own successful PWR construction, now in operation, and their own pebble bed gas reactor, with a 10-MWe prototype operating. This is also influenced by the advantages of obtaining foreign financing from vendor countries for plant construction.

I expect that China is evaluating plant designs and vendors, mostly PWRs, with CANDU reactors that were recently completed, and that it will develop its optimum national plans in the next few years, instead of continuing to make separate contracts for each plant and having an *ad hoc* strategy about how many plants it is building. I also anticipate that by 2020 the Chinese will have more than these 32 additional plants that they have announced. They can decide well after 2010 to build plants to be operating in 2020.

Note that China has a contract with France specifically on the French experience with its national nuclear power plant design and construction planning process.

So, building the relatively few plants currently in the pipeline in China should support making decisions on plant designs and development programs, including the pebble-bed gas-cooled reactor. That effort is aggressively promoting the

PBMR as the primary nuclear solution in China. They are undoubtedly planning to produce process heat. I am unaware of plans in China to produce hydrogen to reduce the demand for oil for transportation.

China is where the United States, the United Kingdom, France, Russia, and Canada were roughly 30 years ago. To implement nuclear power, the Chinese need to select and develop standard designs, and decide how to implement them, for example, as in the United States where projects are local utility decisions in participation with a consortium for multiple plants, with engineering and contracting, with vendors competing, to provide those designs. Or they can go the route of France, which abandoned its gas reactors and adopted the Westinghouse PWR design, committed to build many plants, and then to the siting of those plants. Of course, it helped that France had one national utility, EdF, in a national regulatory environment, as opposed to the United States, which had the legacy of *ad hoc* development for short-term profit in hundreds of utilities regulated by each state.

China will likely combine large light water reactors and the PBMRs. This works for most of world nuclear energy needs, where large power centers can readily adopt multiple PWRs, while developing areas and industrial needs are met by gas reactors with many smaller modules. These modular reactors are designed to be simpler to operate and to be implemented to dynamically follow power demands, with four, eight, and even more modules at a given site, while still being a manageable undertaking.

However, the bottom line to this is that this entire enterprise should be the subject of more strategic formal multi-national planning and negotiations to enhance China's ability to develop its nuclear power plant capacity most cost-effectively, as a matter of international support as well as national strategic decision-making. The need to reduce competing demands on oil and gas is in the interest of the world, as well as of China.

The Industrial Gear-up Required for Mass Production

What kind of industries would have to gear up—steel, concrete, new materials, nuts and bolts, and reactor vessel producers?

The cornerstone of manufacturing for an accelerated program is in fuel supplies and reactor pressure vessels, along with steam generators and turbines, and large pumps. Much of the piping and plumbing, power systems, cables, instrumentation and other systems, plus the concrete and steel for the containment and other buildings, are high volumes of materials, but these should be more readily met within the general industrial production of concrete and steel, and other industrial components and equipment.

This also contributes to redevelopment of essential production capacities that need to expand and to be retooled, along with reactivating substantial steel capacity.

The fuel supply is critical. Initially, uranium mining can readily be substantially expanded. However, high-grade uranium supplies will be exhausted, along with surplus nuclear weapons materials, requiring the use of lower-grade ores. But, ultimately, uranium can also be extracted from ocean water, at only about 10 times the extraction costs of lower grade ore, where it is replenished from natural discharges into the oceans. Because, unlike other fuels, the cost of uranium is a relatively small fraction of the cost of producing nuclear energy, such an increase does not substantially affect the costs and advantages of nuclear power. Extraction of uranium might be effectively done in conjunction with desalination plants and hydrogen production. Uranium from seawater, combined with breeder reactors provide redundant pathways to assure supply. This makes it clear that these resources are good for thousands of years.

The need for conversion and enrichment capabilities would be substantial, along with fuel assembly manufacturing, including the need to establish large-scale ceramic fuel manufacturing for the high-temperature gas reactors, and develop reprocessing facilities to extend uranium fuel supplies. Initially, this would be done by making plutonium-uranium mixed oxide (MOX) fuels, and then later developing breeder reactor fuels.

Following the Eurasian Land-Bridge

As to where the facilities would be located: The whole idea of Land-Bridge development applies here. Today, pressure vessels are built in a few locations and transported around the world. But in planning for necessary nuclear power plant construction, it would be rational to locate pressure vessel, steam generator, large pump and valve manufacturing, and other major component facilities relative to the major plant construction and transportation locations, along with steel sources. These decisions would be made with the industries and countries that would produce the components.

Initially, two or more major pressure-vessel facilities might need to be developed to be able to produce about 20 vessels per year. These would be massive facilities. With an initial target to ultimately produce 200 plants per year in the 2040s, we would decide later whether to develop 10 to 20 such facilities around the world, or to make larger and fewer facilities. This will reflect the capabilities of the various companies that must do the work. We can get that capability into simultaneous production. We can construct the large PWRs in four to five years, even three-and-one-half years or so, and down to two years for the gas reactors, using factory production, and on-site manufacturing production of modules. On-site plant construction is therefore more of an assembly process, as well as the construction process that we normally think of in building large concrete and steel structures and facilities.

Manufacturing facilities would be located with consideration of the known and anticipated locations of future power plants, steel suppliers, transportation capabilities, and so on. A constructive competitive environment can be established to keep the system dynamically improving and reducing costs, with necessary elements of competition and rewards to the companies and people producing the components.

We have done this to some extent in the past in building the railroads and the TVA, the Nuclear Navy, and other major programs such as the space program. Of course, there have also been many poor and costly government program decisions that were made to satisfy political and private interests in developing facilities and services. Some of this is also "necessary overhead," as long as it falls short of outright corruption, and the building of "roads to nowhere" that do not contribute to the national purpose, to the productivity of the economy, and to meet essential human needs.

Our experience with the railroads, and the Interstate Highway system, and economic infrastructure development growth in general, is that it's not just a matter of providing transportation from point A to point B, as it is with marine shipping. Here, the development created is more from developing the track-side part of the world than just meeting the needs of transporting goods around the world.

The Political Framework

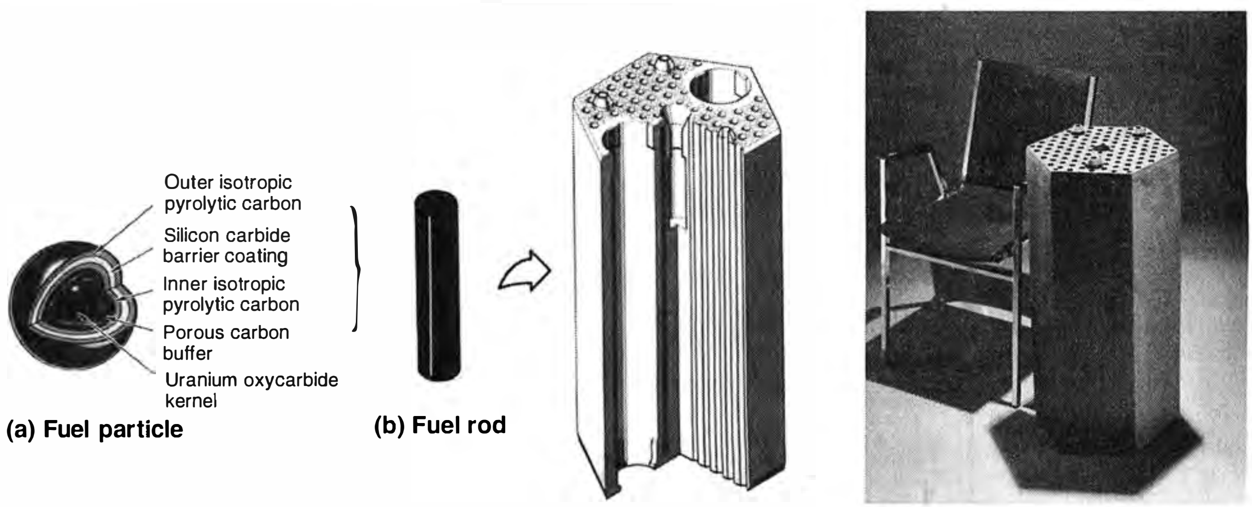
So, how do we proceed with this ambitious building and development program? We need both top-level direction and authorization, and private-sector initiatives.

Certainly, the fundamental decisions can only be made at the top. An organization must be created that has the resources and authority to make plans and commitments. But just how centralized that would be beyond the essential commitments and responsibilities for infrastructure planning and financing, how it works as a government/private sector implementation program, is flexible.

Private initiatives can be authorized, directed, and supported by government, more like the transcontinental railroad development. It was justified by national needs for mail delivery and military purposes, which also supported stage coaches and early airlines development, providing guarantees and funds for services. Or it can be a more centralized government role, like the TVA development, but thinking of this like Admiral Rickover thought of it, in using the private sector and competition to build the U.S. Nuclear Navy: Get the private sector to develop and deliver the technology, while government makes major strategic and programmatic decisions, contracting to undertake production capacity to meet demanding specifications and performance requirements.

The COMSAT/INTELSAT model was advocated by President Kennedy to engage the private sector to interconnect the world through a for-profit organization with substantial participation by the private-sector communications companies. This was done even though AT&T was prepared to implement its own system based on its successful TELSTAR satellite, which would have required tracking antennae to follow medium-orbit satellites across the sky, providing service to the most lucrative markets. COMSAT provided for geosynchronous satellites to cover the whole world, and INTELSAT supported the formation of satellite communications companies in many nations, to avoid having to patch world communications together after *ad hoc* projects to provide communications satellite service to the most lucrative markets (as AT&T had been prepared to do).

We need a dynamic, competitive, management-driven



(a) Fuel particle **(b) Fuel rod** **(c) Fuel block element** **(d) Fuel block element**

Source: General Atomics

FUEL PELLETS FOR THE MODULAR HELIUM REACTOR

The fourth generation ceramic fuels, pioneered by General Atomics, will stay intact up to 3,632°F (2,000°C), which is well above the highest possible temperature (2,912°F or 1,600°C) of the reactor core, even if there is a coolant failure. The tiny fuel pellet (a) is about 0.03 inch in diameter. At the center is a kernel of fissile fuel, uranium oxycarbide. This is coated with a graphite buffer, and then surrounded by three successive layers, two layers of pyrolytic carbon and one layer of silicon carbide. The coatings contain the fission products within the fuel kernel and buffer. The fuel particles are mixed with graphite and formed into cylindrical fuel rods about 2 inches long (b). The fuel rods are then inserted into holes drilled in the hexagonal graphite fuel-element blocks, (c) and (d). These are 14 inches wide and 31 inches long. The fuel blocks, which also have helium coolant channels, are then stacked in the reactor core.

The particle containment is similar for both the General Atomics GT-MHR and the Eskom PBMR. In the PBMR, however, the fuel particles are embedded in graphite and formed in tennis-ball-size balls, called pebbles. In both reactors, there are hundreds of thousands of fuel particles.

enterprise, to prevent becoming trapped or captured by either private interests or self-serving government bureaucracies that don't, or don't continue to, perform well, either on the technology side or on the economic side. Such failures leave the national interest hostage to self-serving organizations and financial interests, whether private or governmental.

Consider the building of the transcontinental railroads in the United States, where the Union Pacific and Central Pacific were chartered to do the job, with subsidies, but they had to raise their own money, with government direction and guarantees. This was compromised in many ways, however, including buying Congressional support with Credit Mobilier stock for changes favorable to the owners, and so on. That was not a clean process.

But after false starts with little progress, while self-serving work was being done, primarily in land-grabbing with the 10-mile track-side lands given to the Union Pacific owners, President Lincoln and the Congress created incentives that led to progress. Eventually the companies had to compete as to how far they were going to build out to where they would meet, and be rewarded for how much of the intercontinental connection they had respectively built. And for many years it was a substantial competition that had them going "hammer and tong," as we would say, to build out from San Francisco and from the Missouri River at Omaha, Nebraska. Lincoln had to pick the starting point, which was itself a political reward for electoral support.

Learning from Other Great Projects

This job is even more vast. But there are lessons to be learned from the railroads, the TVA, and other great projects to implement essential public purposes. The railroad conditions, before and after the Civil War had the complications of procuring and delivering materials to Nebraska and California, with most of the financial and corporate interests in New York and Philadelphia, and government participants in Washington, along with involvement by some states. They had a problem getting labor, until the Chinese were recruited by the Central Pacific, and Union and Confederate Army soldiers were recruited to do the job by the Union Pacific after the war. Pay and conditions were poor, which is part of the down-side of relying on private interests to do the job, before labor standards had been established.

Thomas Durant, who headed the Union Pacific effort, saw that most of the wealth would be generated from developing the track-side land and resources. The companies weren't making much progress on actually building the railroad, so Lincoln worked to shift incentives to have to build so many miles of track, and the company with the most miles of track at the end was going to make more money. Without that, the Union Pacific would have built out only slowly, focussing more on developing the more valuable track-side land resources. When they were building out, the Central Pacific was trying to get past Salt Lake City, Utah, to the coal deposits in the Wasatch mountains. They failed to do that when they could only get to Promontory Point, where the railroads joined up. But construction was being driven by rewards in obtaining such resources.

So, there are lessons from considering where the interests and values are in developing an economy, beyond just thinking of it as a point A to point B transportation construction project, unlike ocean shipping. Or the need to have airlines serve smaller cities as well as the large cities.

In the final analysis, the world will work by people maximizing their financial rewards. The question is, are they doing it consistent with the larger objectives of the economy in serving the public interest, whether that is by using a more centralized government program to develop the TVA, or by engaging the private sector more directly, as with the railroads. This is as opposed to corrupt actions by financial interests or government agencies that steal the public treasure for self-serving purposes.

The early development of the airline industry is another model of combining private and government interests, but with inadequate government responsibility to meet the national interest since airline deregulation.

The Interstate Highway system is another model, where government directly funded construction. This was, and is, of enormous economic value, but it was also not done with an adequate balancing of the effects on railroads and cities by the financing models established by the Congress, rather than by a responsible government transportation agency, for example, in establishing and allocating fuel taxes. There was no one competing for ownership and profits, other than those doing the engineering or pouring concrete, nor were there rewards for building the most highway miles. On the other hand, there were many local interests working politically to influence routes and highway interchange access that were always at work. Those were government program decisions rather than private interests licensed to build highways between points A and B, to profit on being given roadside land and resources, and owning and selling interchanges to the highest bidding communities.

But historically, the transcontinental railroads, originally championed by Stephen Douglas, even with the major scandals, were a great and economically important success, as a national economic and political achievement. They captured the imagination of the country. When looked at closely, we find that it's like making sausage, or laws—we may not want to see how it's done, and who is just self-serving in the process, whether they are just normally biased by personal and local political advantage, or they are committing outright fraud. But programs today can generally control any significant fraud.

Achieving a great project transcends such details, and provides for the generation of great wealth for the economy as a whole, for the nation and the world. This wealth is greatly out of proportion to the costs from any such malfeasance.

I also like to be philosophical, considering that any such perpetrators of fraud, if not stealing from such great projects, would likely be stealing elsewhere, perhaps from our pension funds, and so on, that are much more of a zero-sum game.

We can also learn from the ongoing national economic development that was stopped by the 1873 financial collapse created by the international bankers, after they had failed to stop American development by instigating the secession of the South.

And we can learn from the subsequent role of Thomas Edison, and his aversion to the Wall Street financiers, to make an enormous individual contribution to overcoming that interruption in American development.

What a Nuclear Energy Initiative Can Bring to the World

First, even though such a nuclear power enterprise is an enormous project to salvage the world energy lifeline and to limit conflicts, while being a primary economic development engine, it is just the core of the larger decisions to provide adequate energy from coal and other technologies, plus other critical infrastructure required to provide for the human needs of the developing and undeveloped world, and expanding productive wealth in the developed world.

In addition, such a nuclear power and/or energy technology development initiative is also a foundation of common science and technology, and common purpose, for the world. It can be a model. It is a national and international enterprise, founded on government and private industry participation. It has the power to limit the non-productive machinations of both government and private financial interests that are in conflict, and constrain responsible government and private interests from working for greater general wealth and constructive progress for both the developed and developing world.

Nuclear power also has the advantage that it currently has a high international profile, and substantial, if relatively non-productive, ongoing national and international government organizations. For example, the United Nations, especially with the International Atomic Energy Agency, the International Energy Agency, and the Non-Proliferation Treaty, is essential to our need to safeguard uranium enrichment and plutonium production, plus many other institutional components. The major industry organizations are also more coordinated, with compatible technologies and capabilities that are more complementary than other equivalent

It's Not 'Waste': Nuclear Fuel Is Renewable

The first thing to know about nuclear waste is that it isn't "waste" at all, but a renewable resource that can be reprocessed into new nuclear fuel and valuable isotopes. The chief reason it is called "waste," is that the anti-technology lobby doesn't want the public to know about this renewability. Turning spent fuel into a threatening and insoluble problem, the anti-nuclear faction figured, would make the spread of nuclear energy impossible. And without nuclear energy, the world would not industrialize, and the world population would not grow—just what the Malthusians want.

The truth is that when we entered the nuclear age, the great promise of nuclear energy was its renewability, making it an inexpensive and efficient way to produce electricity. It was assumed that the nations making use of nuclear energy would *reprocess* their spent fuel, completing the nuclear fuel cycle by renewing the original enriched uranium fuel for reuse, after it was burned in a reactor.

When other modern fuel sources—wood, coal, oil, gas—are burned, there is nothing left, except some ashes and airborne pollutant by-products, which nuclear energy does not produce. But spent nuclear fuel still has from 95 percent to 99 percent of unused uranium in it, and this can be recycled.

This means that if the United States buries its 70,000 metric tons of spent nuclear fuel, we would be wasting 66,000 metric tons of uranium-238, which could be used to make new fuel. In addition, we would be wasting about 1,200 metric tons of fissile uranium-235 and plutonium-239. Because of the high energy density in the nucleus, this relatively small amount of fuel (it would fit in one small house) is equivalent in energy to about 20 percent of the U.S. oil reserves.

Ninety-six percent of the spent fuel can be turned into new fuel. The 4 percent of the so-called waste that remains—2,500 metric tons—consists of highly radioactive materials, but these are also usable. There are about 80 tons each of cesium-137 and strontium-90 that could be separated out for use in medical applications, such as sterilization of medical supplies. Using isotope separation techniques, and fast-neutron bombardment for transmutation (technologies that the United States pioneered but now refuses to develop), we could separate out all sorts of isotopes, like americium, which is used in smoke detectors, or isotopes used in medical testing and treatment.

Right now, the United States must import 90 percent of its medical isotopes, used in 40,000 medical procedures daily. These nuclear isotopes could be "mined" from the so-called waste. Instead, the United States supplies other countries with highly enriched uranium, so that those countries can process it and sell the medical isotopes back to us!

How Fuel Becomes 'Spent'

The fuel in a nuclear reactor stays there for several years, until the concentration of the fissile uranium-235 in the fuel is less than about 1 percent at which point, the nuclear chain reaction is impeded. A 1,000-MW nuclear plant replaces about a third of its fuel assemblies every 18 months.

Initially, the spent fuel is very hot, and is stored in pools of water which cool it and provide radiation shielding. After one year in the water, the total radioactivity level is about 12 percent of what it was when it first came out of the reactor, and after five years, it is down to just 5 percent.

Unlike other poisons, radioactive isotopes become harmless with time. This decay process is measured in terms of "half-life," which refers to the amount of time it takes for half of the mass to decay. Although a few radioisotopes have half-lives on the order of thousands of years, most of the hazardous components of nuclear waste decay to a radioactive toxicity level lower than that of natural uranium ore within a few hundred years.

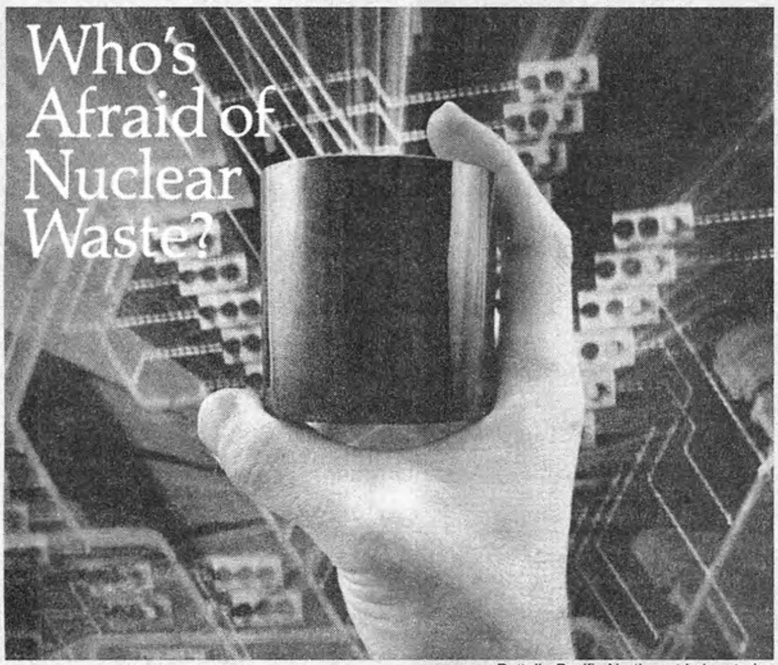
The spent fuel includes uranium and plutonium, plus all the fission products that have built up in its operation, and very small amounts of some transuranic elements (those heavier than uranium) or actinides, which have very long decay times. If this spent fuel is not reprocessed, it takes hundreds of thousands of years for its toxicity to fall below that of natural uranium.

What are we really wasting? The spent fuel produced by a single 1,000-megawatt nuclear plant over its 40-year lifetime, is equal to the energy in 130 million barrels of oil, or 37 milindustries.

In addition, such actual public/private mechanisms can transcend some of the destructive national conflicts and destructive financial conditions, to meet actual worldwide energy needs, and to actually implement essential nuclear power energy supplies to prevent world conflicts over energy—in the real world. This can provide an initiative with a productive purpose that can push current non-productive governmental and non-governmental organizations to replace non-productive dialogue and make actual progress in meeting the human needs of the world.

With any success, these mechanisms can also contribute to models that can address other substantial national and international purposes, to engage the developed and developing nations to enable solutions, beyond current "policy discussions." These mechanisms can enable productive cooperation, along with healthy competition, that can enhance relevant technologies, and lower costs, instead of seeing little actual progress in major projects. This can include basic infrastructure, health care, and drug delivery, education and communications, and so on. These initiatives can constrain costs, and preclude destructive financing costs on developing and undeveloped nations.

The nuclear power enterprise can reduce the coming world energy conflicts, create wealth, and be a model to address the inability to deliver technology and services to the developing and undeveloped world and bring these societies into the economic mainstream. This can be the primary economic engine, the wealth-generating machine, for the 21st Century.



Battelle Pacific Northwest Laboratories

A glass cylinder illustrating the total amount of radioactive waste generated for one person if his lifetime electricity needs were supplied by nuclear energy.

ESTIMATED ELECTRICAL ENERGY FROM DIFFERENT FUELS

Fuel	killowatt hours of electricity from 1 kilogram of fuel
Hardwood	1
Coal	3
Heavy oil	4
Natural gas	6
Natural uranium	50,000
Low-enriched uranium	250,000
Uranium with reprocessing	3,500,000
Plutonium with reprocessing	5,000,000

This comparison of the approximate electricity that can be derived from currently available fuels, indicates why nuclear energy was viewed as such a breakthrough and came under such attack from the Malthusians. When electricity is cheap and plentiful, populations can prosper.

Source: John Sutherland, "Nuclear Cycles and Nuclear Resources," June 27, 2003.

lion tons of coal, plus strategic metals and other valuable isotopes that could be retrieved from the high-level waste.

Why We Don't Reprocess

The United States, which pioneered reprocessing, put reprocessing on hold during the Ford Administration and shut down the capability during the Carter Administration, because of fears of proliferation. This left reprocessing to Canada, France, Great Britain, and Russia (plus the countries they service, including Japan, which is now developing its own reprocessing capability). In addition, new methods of isotope separation using lasers, such as the AVLIS program at Lawrence Livermore National Laboratory, were shut down, or starved to death by budget cuts.

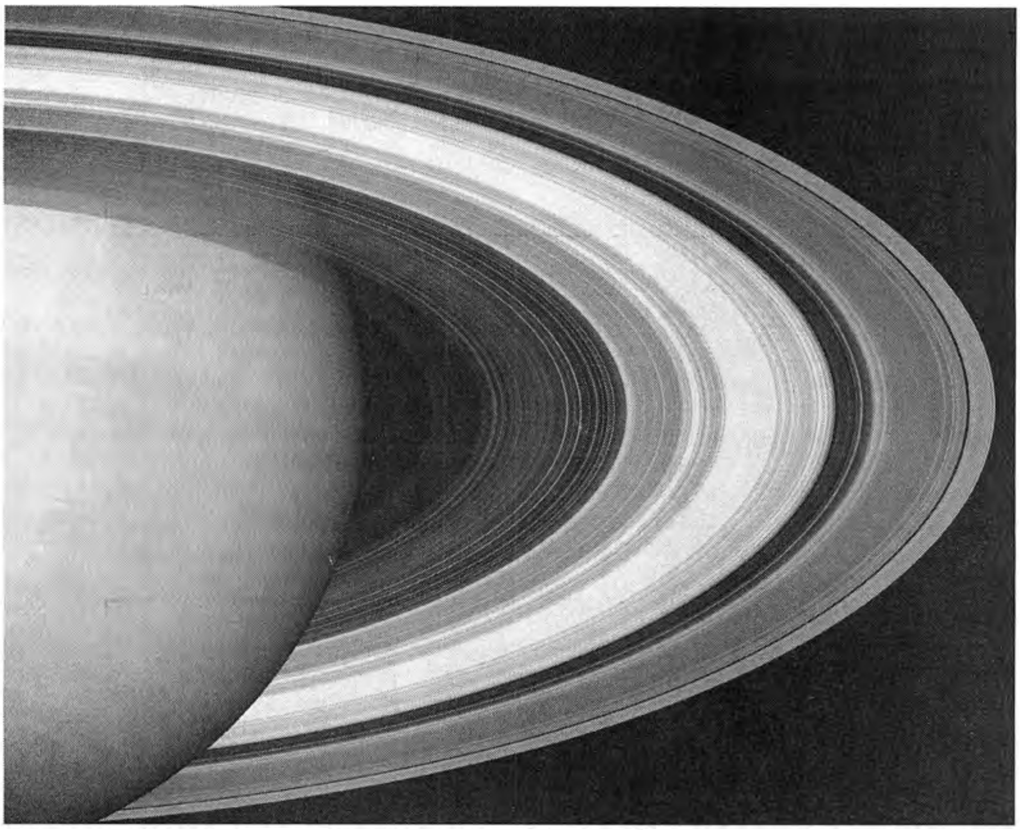
As a result, today we have 40,000-plus metric tons of spent fuel safely stored at U.S. nuclear plants, which the anti-nuclear fear-mongers rail about, even though they are the ones who created the problem. The plan to permanently store the spent fuel at the Yucca Mountain repository in Nevada, has become bogged down in what looks like a permanent political battle.

Technologically speaking, we can safely store nuclear waste in a repository like that of Yucca Mountain. But why should we spend billions of dollars to bury what is actually billions of dollars' worth of nuclear fuel, which could be supplying electricity in the years to come?

The commercial reprocessing plant in Barnwell, S.C. shut down in 1977, but we could start reprocessing at the national nuclear facilities at Hanford in Washington State, and at Savannah River in South Carolina. And we could have a crash program to develop more advanced technologies for reprocessing.

—Marjorie Mazel Hecht

Archimedean Polyhedra And the Boundary: The Missing Link



NASA/JPL

by Hal Wm. Vaughan

There's more to the structure of space than meets the eye, as you'll see in this geometry adventure, which takes you to the limits of the universe.

A view of Saturn's rings. The study of the Platonic and Archimedean solids reveals that space has a structure, and that structure exposes a discoverable intention, which has created a boundary.

"Geometry is one and eternal, a reflection from the mind of God. That mankind shares in it is because man is an image of God."

—*Johannes Kepler*[1]

Keeping in mind the above invocation, we are going to develop, through a sometimes good-natured *analysis situs* of the Platonic and Archimedean polyhedra, an examination of the limits that constrain physical space. My contention is that the boundary demonstrated by the construction of the Platonic solids can not be fully apprehended without involving the Archimedean polyhedra in the investigation. This discourse is not meant to substitute for your working through the discoveries of Carl Gauss or Bernhard Riemann, but is meant to fill a conspicuous gap in existing pedagogy. The Archimedean polyhedra are largely, and for quite sensible reasons, an unexplored area of study, and on that basis, my subtitle is emblazoned above, for all to see, as "The Missing Link."

By the time we are done, we will have constructed the geometrical equivalent of an imaginary toolchest which will then be available for your use in later efforts. This chest has an array of tools, arranged in two different drawers. One set of tools is realized on the surfaces of three spheres and comes from a place somewhere "above" the spheres. The other set is ren-

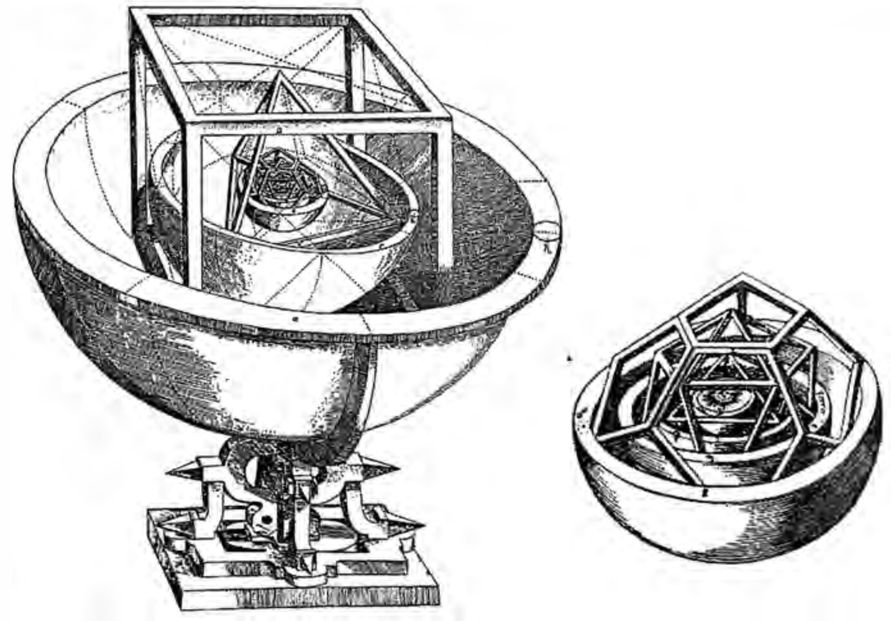


Figure 1
KEPLER'S PLANETARY ORDERING

Johannes Kepler (1571-1630), who discovered the principle of gravitation during his studies of the movements of the planets in the Solar System, saw a coherence in the harmonious ordering of the planets in their orbits, and the harmonious ordering of the nested Platonic solids.

This is an engraving of Kepler's determination of the orbits of the planets, from his Mysterium Cosmographicum. *His ordering, beginning from the circumsphere defining the orbit of Mercury, are: octahedron, icosahedron, dodecahedron (of which the insphere is Earth and the circumsphere is Mars), tetrahedron, and cube.*

dered in two dimensions, even though it was developed from a three-dimensional lattice. I haven't invented any of these tools. Some of them have been known for decades, others for millennia, but the sets have never been assembled in this fashion before; nor, to my knowledge, has the insistence been presented that these tools, as sets, be used in the workshop of your mind.

Why Archimedean Polyhedra?

Study of the Platonic solids reveals that space is not just an endless checkerboard; it has a structure, and the structure exposes a discoverable intention, which has created a boundary.

There are five, and only five shapes that are convex polyhedra with regular, congruent faces whose edge-angles and vertices are equal: the Platonic solids (Figure 3). You can only make these five shapes within those constraints, and hence the limit. When you try to make more regular solids, say, by putting 6 triangles, or 4 squares together at a vertex, you don't get a solid at all; you can't do it, no matter how hard you try. The fact that your grand project of regular-polyhedron manufacture is brought to an abrupt halt after only five successes, says that there is more to the universe than meets the eye. Something in the make-up of everything you can see is different from *what* you see. That is the importance of the Platonic solids. They prove that we don't know what we are looking at.

The uniqueness of the Platonic solids proves that we are not living on a checkerboard at all; we are living in a goldfish bowl. The limits are real. Admittedly, most people spend their time looking at the rocks and bubbles in their bowl, or they choose to play checkers on the nonexistent checkerboard, and wonder how long it will be until feeding time.

I wanted to know what the shape of the fishbowl is. Just how do the Platonic solids relate to the limit? How does it work? Does the visible universe push through the infinite like a ship through the ocean, and are the regular polyhedra the wake? Is the discrete manifold bashing against the continuous manifold like a subatomic particle in a cyclotron, and are the Platonic solids the little pieces spinning off in a bubble tank? Or is it like graphite dust on a kettle drum head, when sounding different notes causes the dust to dance in different standing-wave patterns? What is it? What's going on?

For about 10 years I watched the Platonic solids, hoping they would show me something about the structure of the universe. I put cubes inside dodecahedra, tetrahedra inside

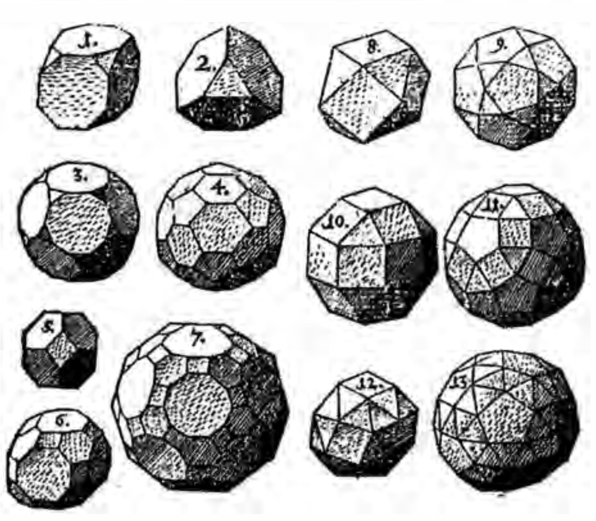


Figure 2
KEPLER'S ARCHIMEDEAN SOLIDS
Kepler did extensive studies of polyhedra, and made these drawings of the Archimedeans, which was part of his geometry tool chest.

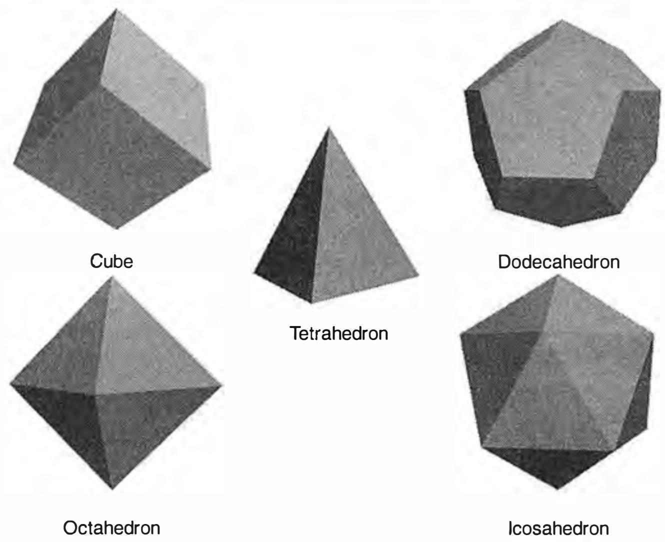


Figure 3
THE FIVE PLATONIC SOLIDS
The Platonic solids are convex polyhedra with regular, congruent faces whose edge-angles and vertices are equal. These are the only Platonic solid figures that can be constructed, hence the limit: cube, octahedron, tetrahedron, dodecahedron, and icosahedron. The cube and octahedron are dual-pairs, as are the dodecahedron and the icosahedron. Dual-pairs have switched numbers of faces and vertices, with identical numbers of edges.

cubes, octahedra inside tetrahedra; I paired duals, stellated those that would stellate, and sliced cubes and tetrahedra to see what their insides looked like. None of these "interrogation protocols" worked; they still wouldn't talk.

I knew about the Archimedean solids and didn't want to have anything to do with them. Compared to the nice, 5 Platonics, there were 13 Archimedeans, which is bad enough. Plus there was an infinite series of Archimedean prisms and *another* infinite series of Archimedean anti-prisms. And on top of that they all have duals, the Archimedeans, the prisms, and anti-prisms; and they are not duals of each other like the good old Platonic solids are, either. Each of the 13 Archimedean shapes has a unique dual that isn't an Archimedean solid, and all the prisms and anti-prisms have unique duals, too. Infinity times 4 plus 13 Archimedeans *twice* was too much. Archimedeans weren't for me. The 5 Platonics did their job; I could handle that just fine.

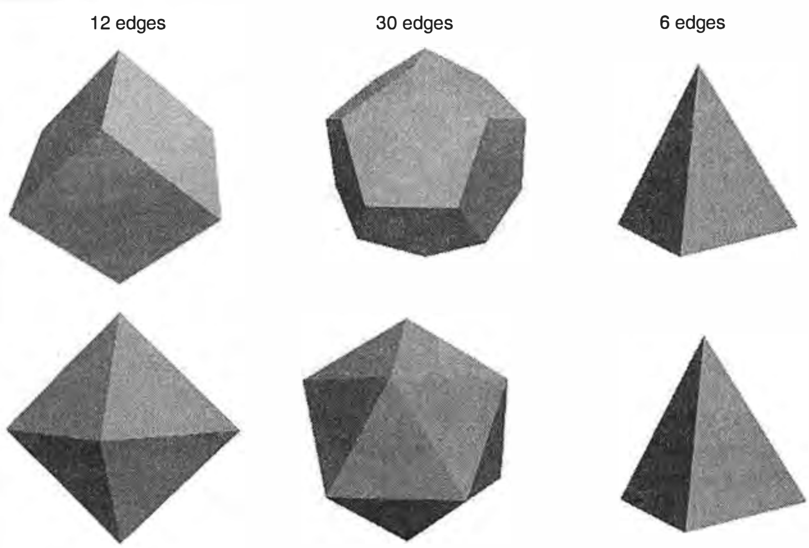


Figure 4
THE PLATONIC DUALS
Note that the tetrahedron is the dual of itself.

Spheres Were My Downfall

You can arrange each Platonic solid so that its vertices can touch the inside of one sphere. When you do that, it is said to be inscribed in the sphere. The center of each face of a Platonic can also touch another sphere. So can the center points of their edges. A different sphere can touch each location on each polyhedron. This comes from the regularity of the Platonic solids. Spheres are important because they represent least action in space. Just like a circle on a plane, spheres enclose the most area with the least surface.

Spheres represent the cause of the limit you run into when you try to make more than five Platonic solids. Just like the guy in Flatland,[2] who saw only a circle when a sphere popped into his world, the sphere is the highest level of least action we can apprehend with our senses alone. Perhaps the vertices of a Platonic solid don't define a sphere, but the sphere (or the nature of space that makes the sphere unique) is what limits the Platonics. That's more likely. Spheres are what the limit looks like to us if we're paying attention.

That's an important part of studying geometry. How does the infinite impact the universe we can see? Where does the complex domain intersect our domain? It's hard to see. The guy in Flatland looked at a circle and saw a line segment; never mind the sphere that created the circle that looked like a line to him. We aren't in much better shape than he was, when we are looking at spheres. Spheres, without the proper shading, just look like circles to us.

Spherical Geography

A straight line on a sphere is a great circle, like the equator of the Earth. Look at a globe; we are talking about geometry (Geo = Earth, metry = measure), right? Great circles are why Charles Lindbergh flew over Ireland to get to Paris. There are no parallel straight lines on a sphere. Any two great circles intersect each other, not once, but twice, at exactly opposite sides of the sphere.

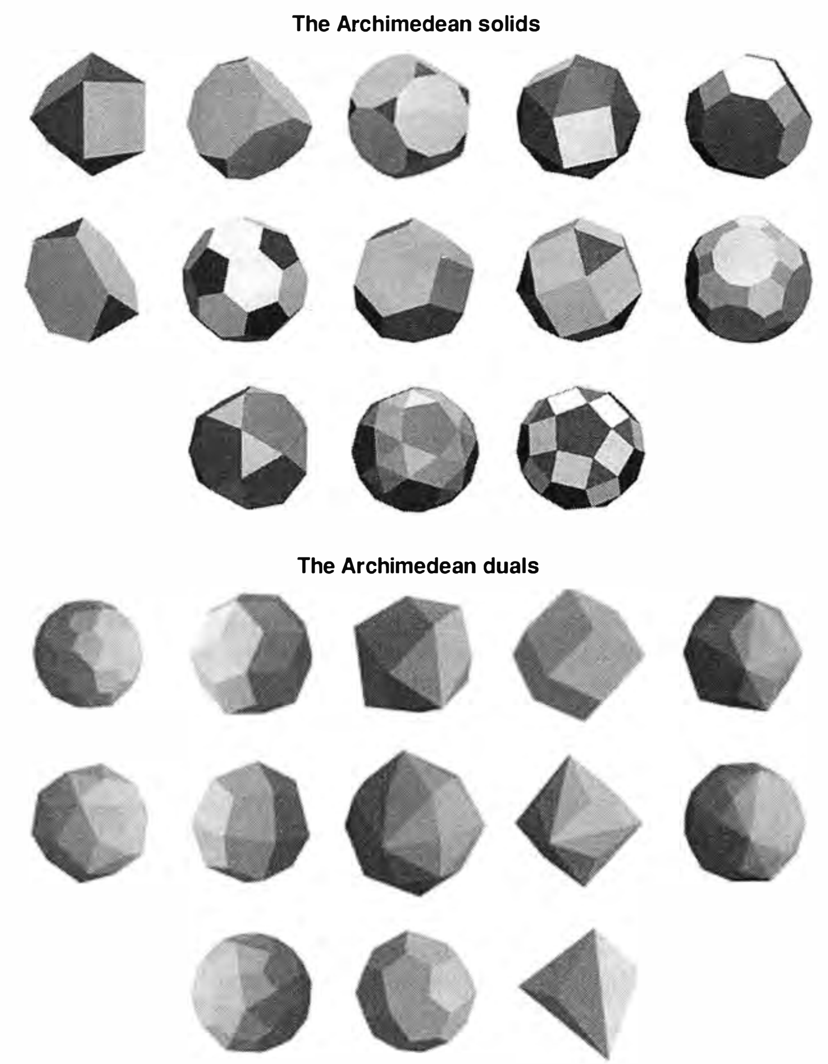


Figure 5
THE 13 ARCHIMEDEAN SOLIDS AND THEIR DUALS
All hell breaks loose. The polyhedral neighborhood becomes very crowded. There are 13 Archimedean polyhedra, and they all have duals.

You can do a neat trick with least action on a sphere. I saw this first in a videotape of a class given by Larry Hecht (editor-in-chief of *21st Century* magazine), and later Lyndon LaRouche featured the process in his paper "On the Subject of Metaphor" in *Fidelio* magazine.[3]

If you divide a great circle on a sphere with another great circle, they divide each other in half, as stated above. Picture the equator and what we laughingly call the Greenwich Meridian on Earth. Of course the two great circles don't have to be at right angles to each other; either of them can rotate around the points where they meet (in this case in the Gulf of Guinea, off Ghana, and in the Pacific Ocean, where the equator and International Date Line meet—Figure 8).

If you want to see how great circles divide each other in even divisions other than just in half, then the fun begins.

Take our original two great circles. Go to where they meet, off Africa, and move west on the equator until you hit the Galapagos Islands and stop. You are ready to create a third great circle. Turn right and go north. You zip over Guatemala, then over Minnesota, the North Pole, where you intersect the second great circle, Siberia, China, Indian Ocean, equator again, Antarctica, the South Pole is another intersection, South Pacific, and you are back where you started, having intersected the equator twice and the International Dateline/Greenwich great circle twice, too.

Now what do you have? The equator is divided into 4 equal parts by the other 2 great circles. So is the International Date Line great circle, and so is our new great circle. Three great circles dividing each other into 4 equal parts. The sphere of the Earth was just divided into 8 equilateral, right triangles by our 3 great circles (Figure 9). The great circles intersect at 6 locations. I wonder how many different ways you can divide great circles evenly with other great circles?

We got 4 even divisions with 3 great circles, how about 3 even divisions? Well, if you take the equator, or, I hope by now a 12-inch-diameter embroidery hoop, and divide it by other great circles into 3 parts, you don't get 3 parts. You get 6 parts, because pairs of great circles meet at opposite points of the sphere. There are no odd-numbered divisions of a great circle by other great circles. Let's see what these 4 great circles do. First, make sure the 3 great circles dividing your original one are also evenly divided into 6 segments by each other, and see what we have: All 4 circles are divided into 6 equal parts—spherical equilateral triangles alternating with spherical squares above and below the original circle, and triangles surrounding each pole.

Six squares and 8 triangles; does that sound familiar?

Anyway, we are about to hit a limit here, just to warn you. The only other way for great circles to evenly divide themselves on a sphere is with 6 of them dividing each other into 10 even segments. Try dividing one great circle into 5 equal parts—you can't do it; it will make 10 divisions, just like 3 forced 6. This is very hard to see if you haven't done it yourself—so, do it yourself. You can get a pair of 12-inch-diameter embroidery hoops for about a dollar. What you end up with is really pretty, too. It is a metaphor you can hold in your hand.

Twelve spherical pentagons and 20 spherical triangles. That sounds familiar too.

Three hoops, 4 hoops, and 6 hoops; and no other combination will evenly divide great circles—another limit, just like the

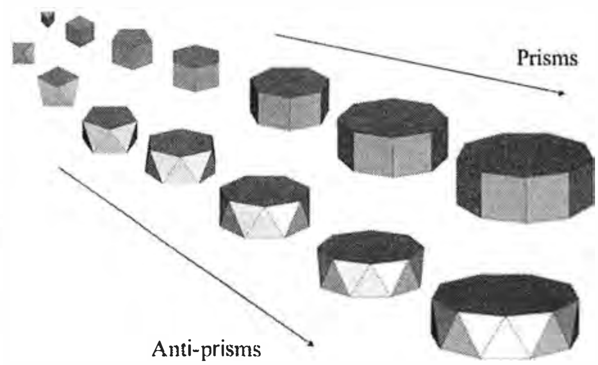


Figure 6
PRISMS AND ANTIPRISMS
There are infinite series of the prisms and the anti-prisms, and they all have duals too.

NASA

Figure 7
OUR EARTHLY SPHERE
The sphere represents least action in "three dimensions." A great circle is a straight line in spherical geometry.

Platonic solids are limited in number. (See Figure 9.)

But, this is the killer: Look at the 4-hoop construction. See the 12 places the hoops intersect each other? There are 6 around the middle, 3 on top and 3 on the bottom.

Well, if you stacked up identical marbles, you could put 6 marbles around one marble on a flat surface. Make sure that each of those 6 marbles have 6 around them, too. Keep doing this over and over, and cover your whole floor with a neatly arranged layer of marbles; then get ready for the second level. In the second layer, you could put 3 marbles around any one marble in the first layer, either in the 12, 4, and 8 o'clock positions, or alternately, in the 2, 6, and 10 o'clock positions. Choose one of the two arrangements and add enough marbles, and you will complete the second level, which will look just like the first level.

When it comes time to do the third level, you have a decision to make. You can put the third level in one of two orientations. You can put them directly over the marbles in the first level, or you can take the path less travelled: Put the marbles over the position you *didn't* select for the second level. If you do this, and keep the pattern up until you fill your room entirely with marbles, you will have two things, besides a heck-of-a-lot of marbles. One is a room filled with the *most* marbles that could possibly be put into the room, no matter what other method you used to stack them up: They are "close-packed." The other thing is this: Look at any marble. Where does it touch the other marbles? It touches 6 around the middle, 3 on top and 3 on the bottom—just like the intersections of the 4 hoops! The even divisions of 4 great circles generate the very same singularities where the hoops intersect, that close-packing of spheres does where the spheres touch. (See Figure 10.)

Remember that I didn't want to construct the Archimedean solids? Here's how it happened.

The spherical faces of the 4-hoop construction represent an Archimedean solid called the cuboctahedron: "Cube-octahedron" is 6 squares and 8 triangles. The dual of the cuboctahedron is called the rhombic dodecahedron. Dodecahedron means that it has 12 faces, like the regular Platonic dodecahedron; and rhombic means the faces are rhombic in shape, that is, diamond-shaped rather than the pentagonal shape you are used to. The rhombic dodecahedron is the shape of the honeycomb that Kepler discusses in the "The Six-Cornered Snowflake" paper.[4] Rhombic dodecahedra fill space. That means you can stack them up with no air between them. Because spheres close-pack in a way that generates the vertices of cuboctahedra, the dual of

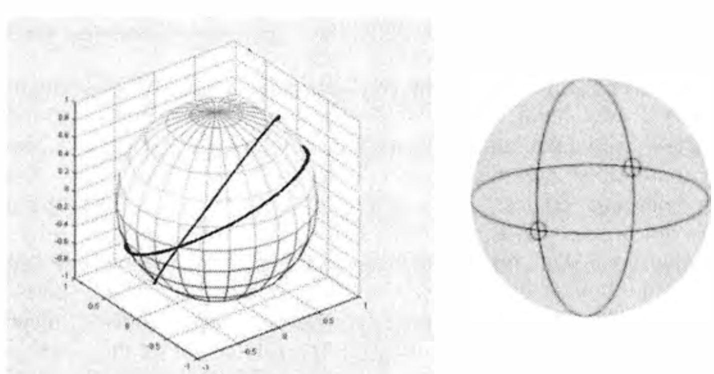


Figure 8
GREAT CIRCLES INTERSECTING
Great circles intersecting each other on a sphere always divide each other in half. That is about as "least action" as you can get.

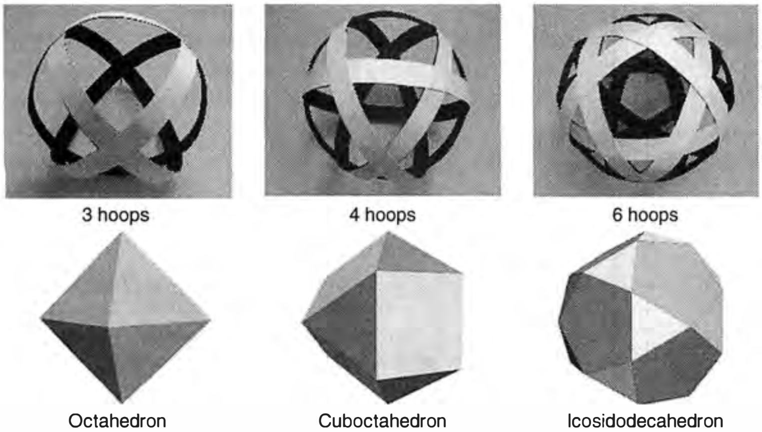


Figure 9
GREAT CIRCLES AND SPHERICAL POLYGONS
There are only three ways great circles can divide themselves into even sections which result in spherical polygons.The 3, 4, and 6 great-circle hoops represent the spheres which contain the great-circle figures below them: octahedron, cuboctahedron, and icosidodecahedron.

the cuboctahedron, by definition, can fill space. Now this wouldn't be so earthshaking, except for this fact: There is only one other polyhedron in the entire universe that has all of its faces identically shaped, and can fill space the way the rhombic dodecahedron does; that is the cube. Just those two with that limit—the cube and rhombic dodecahedron—and nothing else fills space.[5]

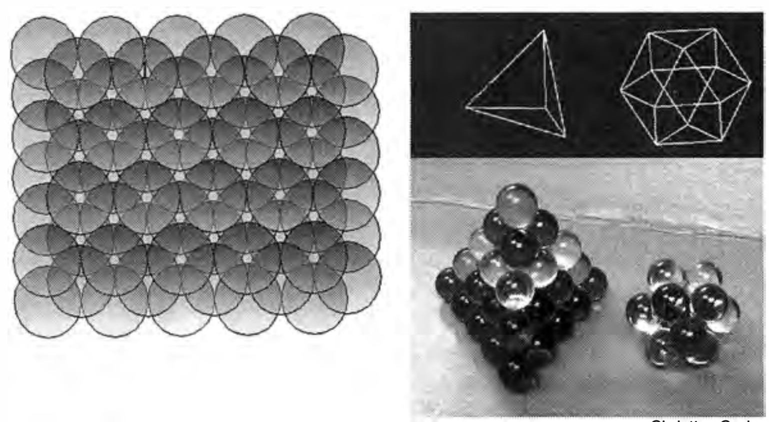
When Larry Hecht pointed this out on the videotape I saw, my heart sank. I knew that I was trapped; I had to construct the Archimedean solids,[6] because the dual of one of the Archimedeans had expressed a relationship to the same kind of limit that the Platonic solids express. This is the same limit that the great circles represent when evenly dividing themselves. It was all one package.

I was cornered. I felt like that old bastard Parmenides, who was trapped by the young Socrates into laboriously defending his life's work, rather than playing mind games with a group of bright young people. Socrates had accused Parmenides' henchman, Zeno, of lying to advance Parmenides' theories. Zeno and Parmenides responded not by losing their temper, but by trying to recruit Socrates to their way of thinking (the best defense is a good offense, even back then), but Socrates maneuvered *Zeno* into having Parmenides go through the *whole* thing. Parmenides didn't want to, and said, ". . . and so I seem to myself to fear, remembering how great a sea of words I must whirl about in."[7] Yes, I was caught.

What Most People Think Archimedean Solids Are

Here are the 13 different Archimedean shapes: Two of them, we are told, are more regular than the others, and are called "quasi-regular." You have already run into them; they are the cuboctahedron and the icosidodecahedron, which are defined by the 4- and 6-great-circle constructions. The cuboctahedron has the 6 square faces of the cube and the 8 triangular faces of the octahedron. The icosidodecahedron has 12 pentagonal faces like the dodecahedron and 20 triangular faces like the icosahedron. (See Figure 12.)

The next five of the Archimedeans are not a big problem to visualize either; I call them the truncated Platonic group (Figure 13). There is one of them for each Platonic solid, and they include the only polyhedron that people regularly kill and die for to this day, the truncated icosahedron, which is in the shape of a soccer ball.[8]



Christine Craig

Figure 10
CLOSEST PACKING IN SPHERES

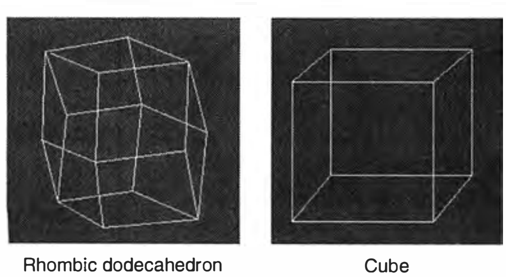


Figure 11
SPACE-FILLING POLYHEDRA
A Platonic solid, the cube, and the dual of an Archimedean, the rhombic dodecahedron, are the only two space-filling polyhedra with identical faces. The rhombic dodecahedron is the shape of the honeycomb cells made by bees. Can you see the hexagons implicit in the figure?

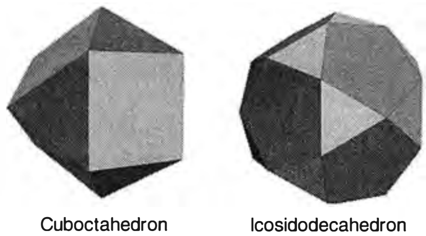


Figure 12
QUASI-REGULAR POLYHEDRA
The quasi-regular polyhedra are the great-circle figures containing the dual Platonic solids reflected in their names.

In each case you can imagine starting with a Platonic solid. For each Platonic face, however, there is a face with twice the number of sides. For example, the truncated cube has 6 octagonal faces instead of the 6 square faces of a cube. Where the Platonic solid had a vertex, there is now a face, which looks like the faces of the dual of the original Platonic solid. The truncated cube has 8 triangular faces, located where the cube's vertices were, situated in the same axis as the octahedron's faces. This works for the others, too. The truncated octahedron has 8 hexagonal faces and 6 square ones. The truncated tetrahedron has 4 hexagonal faces from the 4 triangles of the tetrahedron. The tetrahedron's dual is the same shape as itself, so you have 4 triangles in the truncated tetrahedron, too. The truncated dodecahedron has 12 ten-sided faces and 20 triangles, while the truncated icosahedron has 20 hexagons and 12 pentagons.

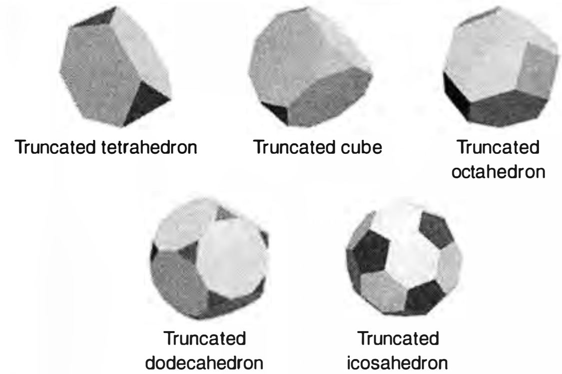


Figure 13
TRUNCATED PLATONIC GROUP
These are the Archimedean polyhedra which appear to result from truncation transformations on the corresponding Platonic solids.

That wasn't too bad. We are done with 7 out of 13 already.

It does get stranger from here on out, though. In ascending order of weirdness, you next have a pair of solids, which I call truncated quasi (quasi, for short) because they are truncated versions of the quasi-regular Archimedean solids. These are the truncated cuboctahedron and the truncated icosidodecahedron (Figure 14). Where the cuboctahedron has squares and triangles, the truncated cuboctahedron has octagons and hexagons. In addition, where the cuboctahedron has 12 vertices, the truncated cuboctahedron has 12 square faces. Where the icosidodecahedron has pentagons and triangles, the truncated icosidodecahedron has 10-sided faces and hexa-

Figure 14
TRUNCATED QUASI-REGULAR SOLIDS
The great-circle figures (the quasi-regular polyhedra) can also be truncated, giving the truncated cuboctahedron and the truncated icosidodecahedron.

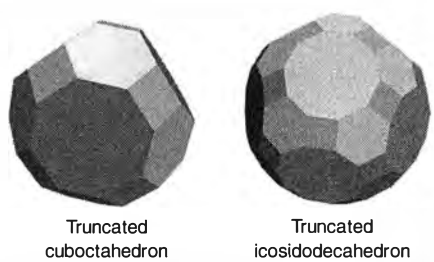
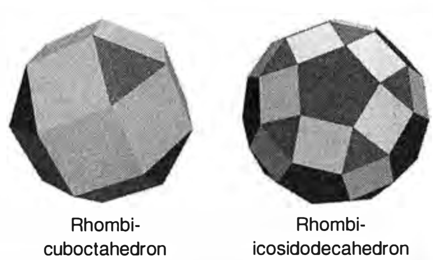


Figure 15
RHOMBIC QUASI-REGULAR SOLIDS
Transformations can also be made on the great-circle (quasi-regular) Archimedean polyhedra, leading to the rhombic great-circle figures, the rhombicuboctahedron and the rhombicosidodecahedron.



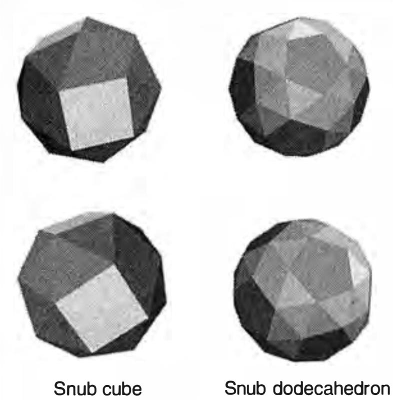


Figure 16
SNUB LEFT- AND RIGHT-HANDED
There are two sets of snub polyhedra in the standard Archimedean arrangement: the left- and right-handed snub cubes, and the left- and right-handed snub dodecahedra.

gons, with the addition of 30 square faces where the icosidodecahedron vertices were (Figure 14).

The next pair, the rhombicuboctahedron and the rhombicosidodecahedron, are simpler, but one of them is harder to see. These are called rhombi-quasi polyhedra, and they have the same square faces from the vertices of the quasi-regular solids as the previous pair does, but the other faces are the same shape as those of the quasi-regular solids, themselves, not double the number, like in the quasi, above. The rhombicosidodecahedron has 12 pentagons, 20 triangles and 30 squares for faces, and looks kind of obviously what it is, but the rhombicuboctahedron has 18 square and 8 triangular faces (Figure 15). This confused me when I first saw it, because the squares, even though they looked alike, actually came from two different processes (the square faces of the cube, and squares from the vertices of the cuboctahedron). This is the kind of ambiguity that can drive you nuts, until you realize that the whole point of what you are doing, in the geometry biz, is finding this kind of puzzle, and solving it.

Speaking of ambiguity that can drive you nuts, the last two Archimedeans are the snub cube and the snub dodecahedron. The snub cube, mercifully has 6 square faces. So far so good, but it also has 30 triangular faces. The snub dodecahedron has the expected 12 pentagonal faces, and *80* triangular faces. If you think that's bad, I'll tell you that there really are two different snub cubes and two different snub dodecahedra. They are made up of the same parts, but the way they are put together makes them look like they are twisted to either the left or the right (Figure 16).

That's it; those are the 13 Archimedean shapes.

The way these shapes are traditionally organized is apparent from their names. There are three sets arranged by dual-pair type: the tetrahedron, the cube/octahedron, and the dodecahedron/icosahedron. One set contains only the truncated tetrahedron. The next one contains the truncated cube and truncated octahedron, the cuboctahedron, the rhombicuboctahedron, the snub cube, and the truncated cuboctahedron. Finally, you have a set containing the truncated dodecahedron and truncated icosahedron, the icosidodecahedron, the rhombicosidodecahedron, the snub dodecahedron, and the truncated icosidodecahedron.

Now, I tried a more clever approach, asking why the tetrahedron group was such a little, nubby family, while the other Platonic solids have such nice big families?

What Archimedean Polyhedra?

Act 1, scene 1 of *King Lear:*

REGAN: Sir, I am made
Of the self-same metal that my sister is,
And prize me at her worth. In my true heart
I find she names my very deed of love;
Only she comes too short. . . . [9]

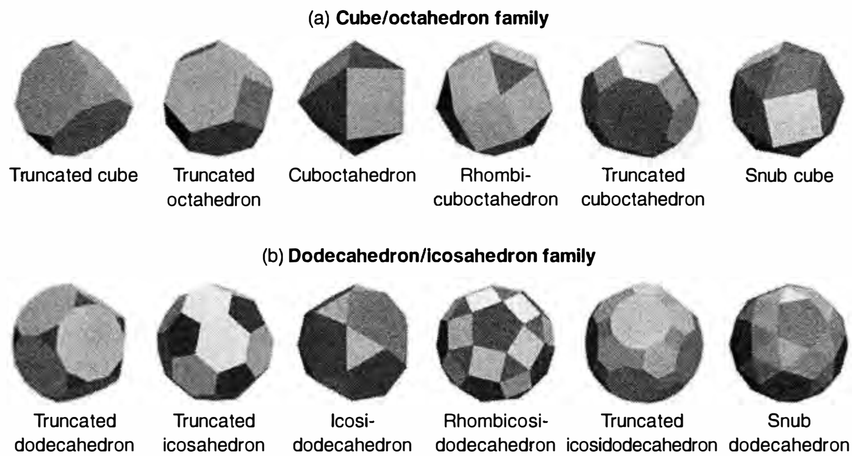


Figure 17
STANDARD ARCHIMEDEAN ARRANGEMENT
Two families of polyhedra are related to the Platonics: the cube/octahedron family, and the dodecahedron/icosahedron family. The truncated tetrahedron sits alone in the tetrahedron family.

Figure 18
THE TRUNCATED CUBE
The truncated cube has 6 octagonal faces where the cube had 6 square faces, and 8 triangular faces where the cube had 8 three-face vertices.

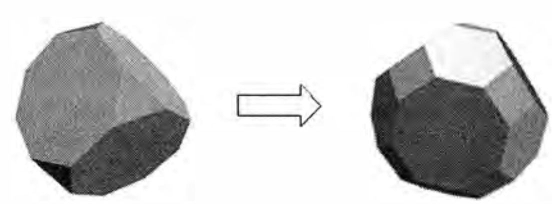


Figure 19
FROM THE TRUNCATED CUBE TO THE TRUNCATED CUBOCTAHEDRON
The truncated cuboctahedron retains the 6 octagonal faces from the truncated cube, but 8 hexagonal faces replace the 8 triangular faces. Additionally, 12 squares appear where the cube's edges were.

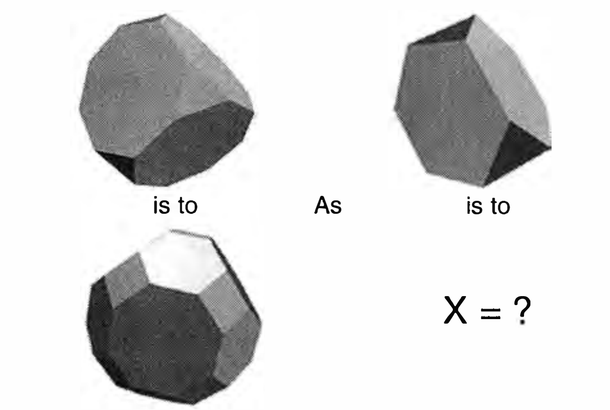


Figure 20
ANOTHER TRANSFORMATION TO PRODUCE ?
The truncated tetrahedron (upper right) has 4 hexagonal faces in place of the tetrahedron's triangular faces, and 4 triangular faces where the tetrahedron had vertices. Transform it analogously to the transformation of the truncated cube to the truncated cuboctahedron. Retain the 4 hexagonal faces from the truncated tetrahedron, and add 4 more hexagonal faces to replace its triangular faces, then add 6 squares, one for each tetrahedron's edge. What do you get?

After I saw Larry Hecht's class, I did make all the Archimedean solids. It took weeks, and I highly recommend that readers do the same. You can look at a still picture of them, or nowadays even download an interactive file from the internet, but it isn't the same as planning how many of each face you need, constructing the faces, and trying to fit them together so that it looks like it is supposed to. Anyway, in making the Archimedean solids, I became more and more upset at the injustice being meted out to our little friend, the tetrahedron. Not only did he have to pretend he had a dual by acting

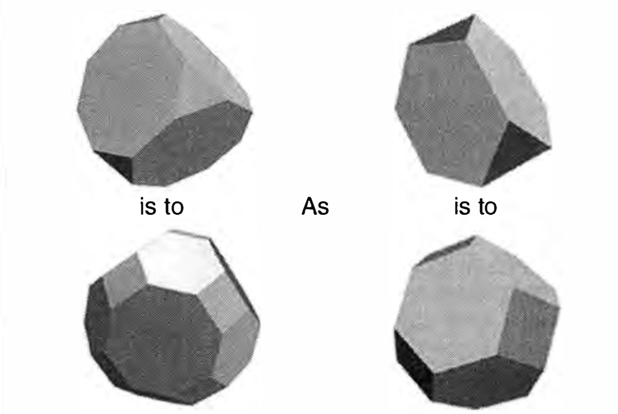


Figure 21
A TRUNCATED TETRITETRAHEDRON
Eight hexagons, 6 squares! A truncated tetritetrahedron—a new role for the Archimedean solid also known as the truncated octahedron.

the part himself, but where the other Platonic dual-pairs have 6 or 7 Archimedean solids associated with them (if you count left- and right-handed snubs separately you get 7 each), the tetrahedron had only one Archimedean to play with.

I decided that this injustice would not stand. But what could I do about it? One thing I knew, I wasn't going to mess with the dodecahedron family—80 triangles in a snub dodecahedron? So, the cube family it is. The truncated cuboctahedron looked busy enough to get my teeth into, and the truncated cube looked to me like what was happening on it was clear enough, so that's where I started. I set up this puzzle: What would you get if you did to the truncated tetrahedron the same thing that was done to a truncated cube to get a truncated cuboctahedron? You know, *A* is to *B* as *C* is to *X*. What could be easier? (Figures18-21.)

The truncated cube has 6 octagonal faces, and so does the truncated cuboctahedron. The truncated cuboctahedron has 8 hexagonal faces where the truncated cube has 8 triangles. So far so good. And the truncated cuboctahedron has 12 square faces, where the cube has 12 edges. That is the *A* is to *B* part. Now for the "*C* is to *X*" part: The truncated tetrahedron has 4 hexagonal faces, so *X* has 4 hexagonal faces, too. Four triangular faces become 4 other hexagonal faces, and the 6 edges of a tetrahedron become 6 square faces in *X*. What is it? What do we have? Four plus 4 hexagonal faces are 8 hexagonal faces and 6 square faces. Eight hexagonal faces and 6 square faces; it has to work.

It does! Eureka! A new polyhedron lives! The tetrahedron has another family member. It's alive! I've invented a new Archimedean solid: 8 hexagons and 6

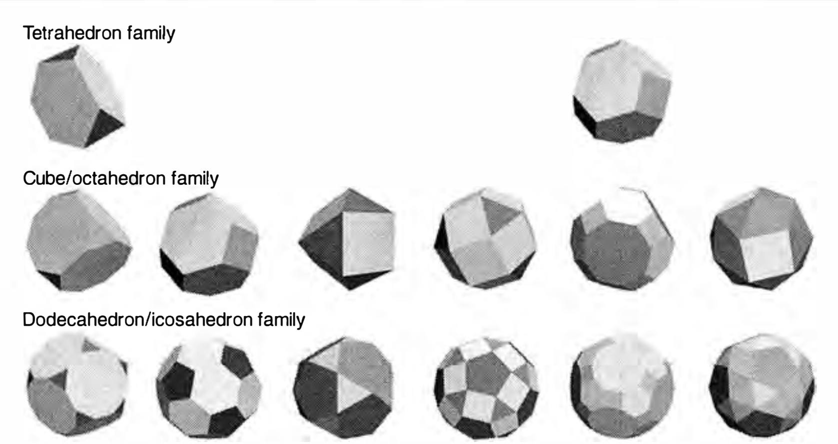


Figure 22
AN ADDITION TO THE ARCHIMEDEAN SOLIDS
The tetrahedron family now has two members.

square faces, and it has all of its fingers and toes. It looks just like. . . .

Wait a Minute

What does it look just like? We have already *done* 8 hexagons and 6 squares, and if it is an Archimedean solid with regular faces, and all, then they both have to be the same shape: the truncated octahedron.

Yes, look at it, the truncated octahedron, 8 hexagons and 6 squares, is sitting in the tetrahedron family, acting like a truncated quasi, a *truncated tetritetrahedron.* The cube family is intersecting with the tetrahedron family. The shape of the truncated octahedron is acting like a truncated tetritetrahedron, just like F# on the piano is also G-flat. They are "enharmonic shapes."

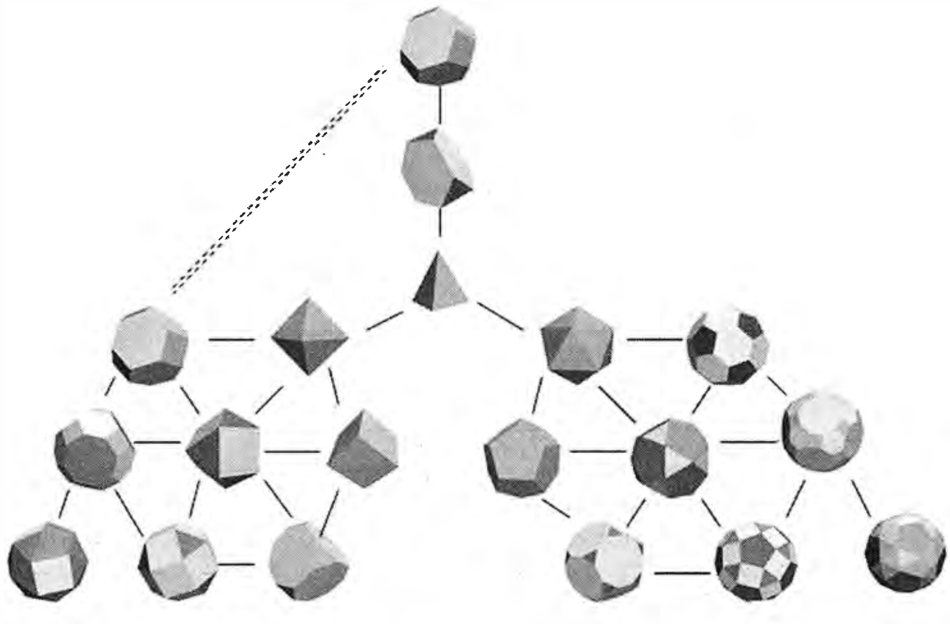


Figure 23
THE SHAPE OF SPACE
Another view of the Archimedean families.

When I first discovered this, I was so happy, I almost forgot entirely my mission of grilling the Platonic solids for their secrets. I made an attractive, nicely colored poster with the pretentious name, "The Shape of Space," which had the Platonic and Archimedean solids arranged in the symmetrical cube/octahedron and dodecahedron/icosahedron families, centered on the quasi-regular polyhedra; and the truncated tetritetrahedron was connected to the cube family with little dotted lines. It was pretty, and took some time to make, but completely ignored the fact that the tetrahedron still had a long way to go to achieve the equal rights it deserves as a fully vested Archimedean solid and head of a family.

At that point, LaRouche put out his "Metaphor" paper, in which he hit the great-circle question really hard. The "Metaphor" paper set me to thinking again. I had supposed that the sphere had to be a major waypoint on the route to the creation of the Platonic solids; and the quasi-regular solids (the cuboctahedron and icosidodecahedron) were clearly generated by even divisions of great circles on a sphere; and LaRouche made no bones about the fact that *the* way to construct the Platonic solids was with great circles on spheres. But why, then, was the epitome of clean, least action resulting in an oddball hodgepodge of two Archimedean solids and one Platonic solid? (Figures 24.)

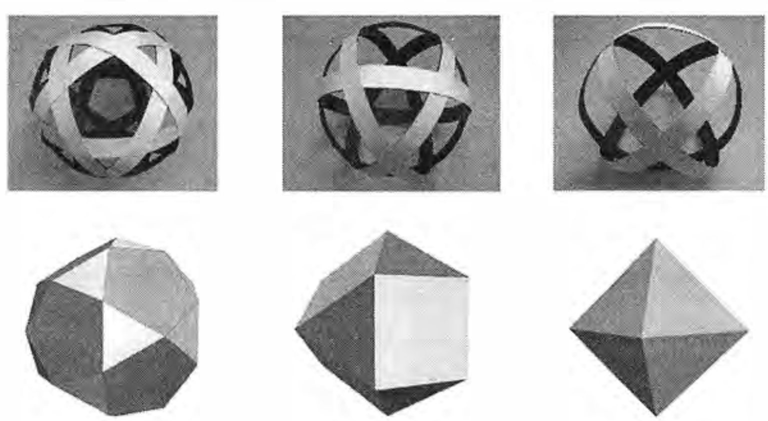


Figure 24
EVEN DIVISIONS OF GREAT CIRCLES
The epitome of clean, least action—even divisions of great circles on a sphere—results in the oddball hodgepodge of two Archimedean solids and one Platonic solid.

This was really messy. When I first wrote about this 10 years ago I said, "How anomalous." What I meant to say was, "Is the Composer of the universe a spaz?" Who would design something that odd?

What bothered me was the apparent unevenness of the pattern in my shape-of-space chart. It was that tetrahedron family that was out of place. I *finally* decided to look in that direction.

I knew that while the cube was the dual of the octahedron, and the dodecahedron was the dual of the icosahedron, the tetrahedron was the dual of itself. Well, in order to examine

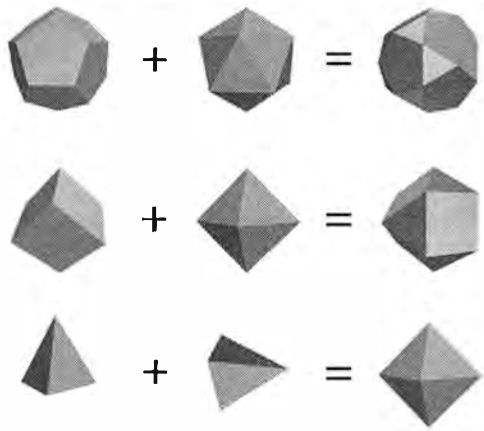


Figure 25
THE GREAT CIRCLE FIGURES AND DUAL PAIRS
Two of the polyhedra formed by great circles have faces reflecting the dual pairs of Platonic solids. The 12 pentagonal faces of the dodecahedron and the 20 triangular faces of the icosahedron create an icosidodecahedron. The 6 square faces of the cube and the 8 triangular faces of the octahedron create a cuboctahedron.

Because the tetrahedron is the dual of itself, you could say that there is a dual-pair of tetrahedra, too. You take the four triangular faces of one tetrahedron and the four triangular faces of the other tetrahedron and create—a tetritetrahedron, also known as an octahedron.

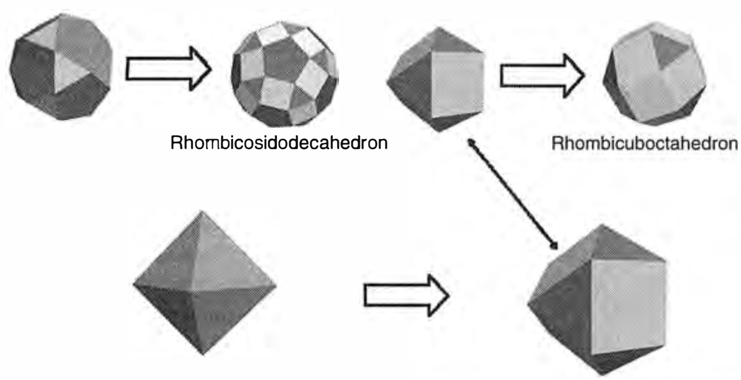


Figure 26
THE RHOMBIC TRANSFORMATIONS
In the cube/octahedron family, the rhombicuboctahedron can be formed by taking the cuboctahedron and adding squares in place of all its vertices. In the dodecahedron/icosahedron family, the rhombicosidodecahedron can be formed by taking the icosidodecahedron and adding squares in place of all its vertices.

Similarly, in the tetrahedron family you would start with the octahedron (or as we would call it in this family, the tetritetrahedron) and add squares to the vertices. That gives us the cuboctahedron again, known as the rhombitetritetrahedron in this enharmonic incarnation.

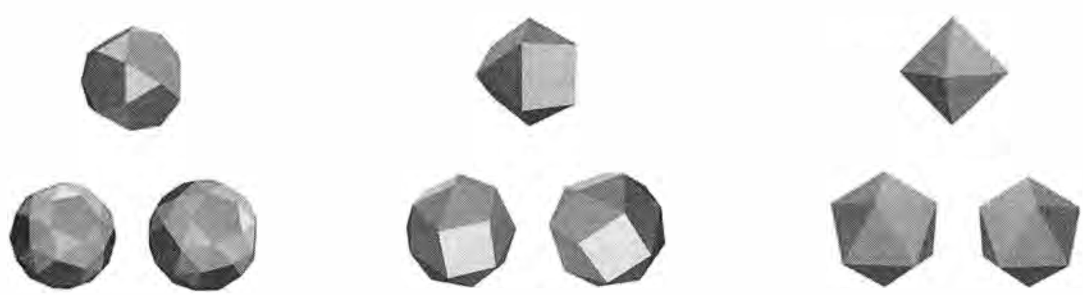


Figure 27
THE SNUB TRANSFORMATIONS
To make a snub cube, surround the square faces of a cube with an alternating lattice of triangles, with one triangle for each edge of each of the cube's faces, and one triangle for each face of the cube's dual, the octahedron.

To transform the great-circle (quasi-regular) icosidodecahedron to its snub, add 60 more triangles to the 12 pentagonal faces of the dodecahedron and the 20 triangles of the icosahedron—2 triangles for each of the icosidodecahedron edges.

And for a snub tetrahedron, take 4 triangles for the tetrahedron's faces, 4 triangles for the other tetrahedron's faces, and 12 triangles. That's 20 triangles, 2 for each of the tetritetrahedron (octahedron) edges—left- and right-handed, of course. Yet another enharmonic solid is revealed—the icosahedron—known in this relationship as the snub tetrahedron.

Vertices	Faces	Edges	Polyhedron	Polyhedron	Vertices	Faces	Edges
8	12	18	Triakis tetrahedron	Truncated tetrahedron (both of them)	12	8	18
14	12	24	Rhombic dodecahedron	Cuboctahedron	12	14	24
14	24	36	Tetrakis hexahedron	Truncated octahedron	24	14	36
14	24	36	Triakis octahedron	Truncated cube	24	14	36
26	24	48	Deltoidal icositetrahedron	Rhombicuboctahedron	24	26	48
38	24	60	Pentagonal icositetrahedron	Snub cube	24	38	60
32	30	60	Rhombic triacontahedron	Icosidodecahedron	30	32	60
26	48	72	Disdyakis dodecahedron	Truncated cuboctahedron	48	26	72
32	60	90	Pentakis dodecahedron	Truncated icosahedron	60	32	90
32	60	90	Triakis icosahedron	Truncated dodecahedron	60	32	90
62	60	120	Deltoidal hexecontahedron	Rhombicosidodecahedron	60	62	120
92	60	150	Pentagonal hexecontahedron	Snub dodecahedron	60	92	150
62	120	180	Disdyakis triacontahedron	Truncated icosidodecahedron	120	62	180

Figure 28
THE ARCHIMEDEANS AND THEIR DUALS

these anomalies, I decided to see if the tetrahedron family could be made to conform to the pattern created by the other two families.

If the tetrahedron is the dual of itself, then the truncated tetrahedron should show up in the pattern twice also. That makes sense.

The quasi-regular slot in the other families could be thought of as forming thus: Take the 6 square faces of the cube and the 8 triangular faces of the octahedron, and create a cuboctahedron. Take the 12 pentagonal faces of the dodecahedron and the 20 triangular faces of the icosahedron and create an icosidodecahedron (Figure 25). So, in the tetrahedron family you take the 4 triangular faces of the tetrahedron and the 4 triangular faces of the *other* tetrahedron and create. . . . The quasi-regular polyhedron in my hypothesized tetrahedron family was the octahedron, the very same figure that I had constructed for that slot using LaRouche's great-circle method earlier. That was amazing, even electrifying.

In an instant I went from a perception of a cluttered universe and a nice tidy theory, to a more orderly universe and a pet theory blown to smithereens.

Now I was sure I could fill up the empty spaces in the tetrahedron family. I only had two left to do. The rhombicuboctahedron looks like it is formed by taking the cuboctahedron and adding squares where the edges were (Figure 26). The rhombicosidodecahedron looks like you take the icosidodecahedron and add squares where its edges were. In the tetrahedron family you would start with the octahedron (or as we would now call it in this family, the tetritetrahedron) and add squares to the edges. What do you get? The result was a figure with 8 triangles and 6 squares—a cuboctahedron—a polyhedron already created, which we could now call the rhombitetritetrahedron, in this new, enharmonic incarnation.

This was getting interesting. I now had three polyhedra from the cuboctahedron family serving double-duty in the tetritetrahedron family, and there was one figure left: the "snub tetrahedron," if there were such a thing. Snubs (the snub cube and the snub dodecahedron) weren't on my "favorites" list. They were messy; they didn't have the same number of faces that the rest of their families did. The snub cube had 6 squares, all right, but had 32 triangles! The snub dodecahedron had the expected 12 pentagons, but 80 triangles, as already mentioned, and it wasn't clear what they all

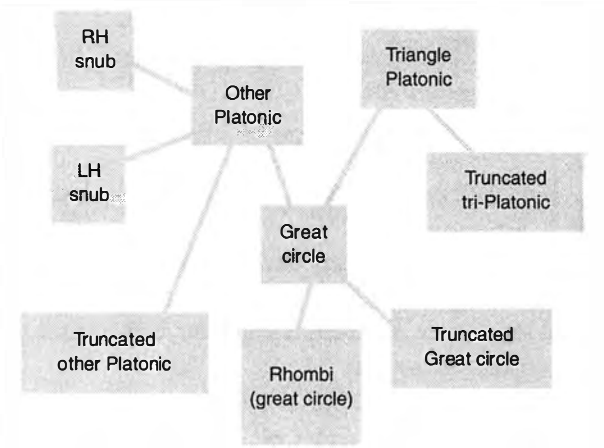


Figure 29
THE POLYHEDRAL FAMILY RELATIONSHIPS
This is one way of looking at the family relationships within any of the polyhedral families.

were doing or why. This was about the last time that an anomaly like that irritated me. I started to look forward to them after I did the work represented by the next paragraphs.

To make a snub cube, you surround the square faces of a cube with an alternating lattice of triangles. You have one triangle for each edge of *each* of the cube's faces, and one triangle for each face of the cube's dual, the octahedron. Six square faces and 6 times 4 sides is 24 triangles, plus 8 octahedral triangles makes the 32 triangles (Figure 27).

Likewise, in the snub dodecahedron you surround the pentagons in the same manner. Now, to create the supposed snub tetrahedron you would surround 4 triangles with the same pattern of alternating triangles. That is, 4 faces with 3 edges each, which would give you 12 triangles; add 4 triangles from the tetrahedron and 4 triangles from its dual. That would give you a figure made up of 12 plus 4 plus 4: 20 triangles. Do we have something like that already? Yes, of course we have 20; it's called the icosahedron! The icosahedron is also a snub tetrahedron, and the icosahedron is from the dodecahedron family, too, not the cube family. The dodecahedron family is enharmonically participating in the tetrahedron family, as well! All of a sudden, the snubs didn't seem so bad after all. They had filled up the tetrahedron family. The pattern was complete.

We now have three totally symmetrical families of polyhedra. Each family has the same number of members as the other two families, performing the same function in each family. Starting with even divisions of great circles on a sphere, with the 3, 4, and 6 hoops; each family has a polyhedron directly mapped from the vertices of the hoops. Every family also has two Platonics, duals of each other, whose faces are contained in the previous figure. They have a truncated version of each Platonic, a rhombic version of the great-circle figure, a truncated version of the great-circle figure, and a snub figure, left- and right-handed. The families are connected by three polyhedra in the cuboctahedron family and one member of the icosidodecahedron family, appearing in the tetrahedron family as "enharmonic" solids.

This was a milestone, but I wasn't done. One huge batch of work I foresaw was, how do you arrange the families so that both their symmetry *and* their interconnections are clear? That would be an updated and more accurate version of my old "Shape of Space" poster.

The other issue that came up some time later, as a surprise, was that each of the Archimedeans has a dual. How do they fit into the pattern?

Another big issue was this: Clearly, the Composer of the universe didn't hack off the vertices of a cube with a knife to make a truncated cube. How directly do great circles participate in the construction of the Archimedeans, or Platonics for that matter?

Where Archimedean Polyhedra Meet

We began with the assumption that space wasn't just an endless checkerboard. In investigating the limits of visible space, starting with the Platonic solids as symbolic of shapes that were formed by the confines built into the nature of creation, we fashioned a set of three, symmetrically ordered families of polyhedra, each containing Platonic and Archimedean solids.

The families are connected by three polyhedra shared by both the cuboctahedron and the tetrahedron families as enharmonic shapes. These are polyhedra that look alike, but whose genesis and usage in this scheme, make them different. There is also one member of the icosidodecahedron family that is enharmonically shared with the tetrahedron family as well. No member of the cube or dodecahedron family touches each other, but both of those families touch the tetrahedron family.

The significance of this arrangement goes back to the age-old appreciation of the uniqueness of the Platonic solids. The limit built into the universe is manifested in the fact that you can construct only five shapes that conform to the restrictions that define the Platonic solids. That same limit restricts the number of ways that the great circles divide each other evenly. There are only three ways to do it. Once you recognize the way the families intersect, you realize that you are looking at three symmetrical families, which contain three pairs of Platonic solids, generated by three sets of great-circle figures.[10]

After I remanufactured all the Platonic and Archimedean solids with the faces of each solid instructively colored, I wanted to develop a pedagogy that would enable people to see both the symmetry of the families and how they intersected. My set of all these polyhedra had the cube, and all faces of other polyhedra that shared the cube's orientation and function, colored green. The octahedra and its kin were yellow. One tetrahedron was red, with its dual orange. The dodecahedron and its co-functionaries were dark blue, and the icosahedron was light blue. The faces which represented variations on the vertices of the great-circle polyhedra, were colored white, black, or gray, depending on how many sides the faces of their Archimedean duals have. This arrangement showed the symmetry of the families brilliantly, but left the intersections of the families up to the imagination.

My first attempt to rectify this shortcoming looked like a model of a molecule—a rather alarming molecule, at that (Figure 29). A ring of 6 spheres represented the members of each family. These spheres represented the Platonic solids,

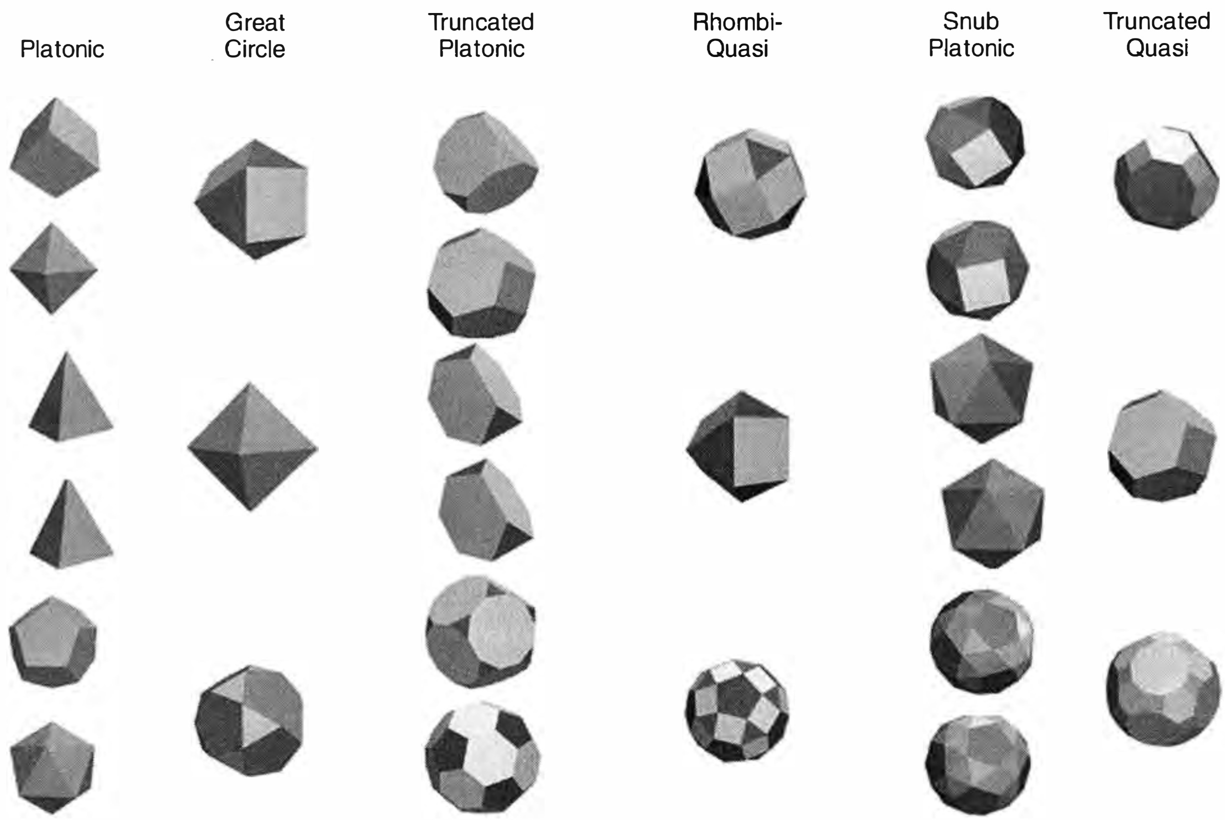


Figure 30
THE COMPLETE SET OF ARCHIMEDEANS
This is one way of looking at the family relationships within any of the polyhedral families.

both truncated Platonic solids, the truncated great circle, and the rhombic great-circle figure, all arranged around the great-circle figure itself. There was a tail attached at one Platonic, representing the snub figures. I later refined this arrangement to one that looked like one of a set of jacks: 6 balls, one above, one below, up, down, left, and right of the central ball, with one hanging off to the side.

I actually made three of these sets out of Styrofoam balls and toothpicks, and attached them to each other in the appropriate manner. If you did it just right, you could join the three families where they intersect, indicating the connections made by the enharmonic solids, with the octahedron touching the tetritetrahedron, the cuboctahedron touching the rhombitetritetrahedron, the truncated octahedron touching the truncated tetritetrahedron, and finally the icosahedron touching the snub tetrahedron.

I did it, but it was a mess. It was very hard to keep the construction from falling apart. And even when it held together (though it accurately represented what I wanted to show), you couldn't really see it. It had a decided Rube Goldberg quality.

This wasn't what I wanted at all. You had the sheer beauty of great circles on a sphere: Least-action pathways on a least-action surface, dividing themselves evenly and creating symmetrical families of polyhedra, which intersected in an ironical way, typifying the kind of certainty you can only find embedded in a metaphor, which, of course, is the only way to speak the truth. This truth represented a visible image of the unseen limits placed on physical space by the creating force of the universe. I didn't think a pile of crumbling Styrofoam was the right way to show this. I was stuck at this point for some days. Then I had an idea; I decided to display this irony ironically.

The irony was this: The unseen, uncreated domain, which bounds and is creating our universe, has limited our ability to create regular polyhedra and, as stated, proved that the universe is not shaped like an endless checkerboard. How to show this? Put it on a checkerboard.

Do What?

This really cheered me up. In discussing these polyhedra you have three attributes to contemplate, their faces, the edges where two faces meet, and the vertices where the edges and faces meet. For example, the tetrahedron has 4 faces, 4 vertices and 6 edges; the cube, 6 faces, 8 vertices and 12 edges. The reason the octahedron is the dual of the cube is that the octahedron has 8 faces where the cube has 8 vertices, 6 vertices where the cube has 6 faces, and 12 edges, which cross the cube's 12 edges at right angles. You get the idea. To map the polyhedral families,

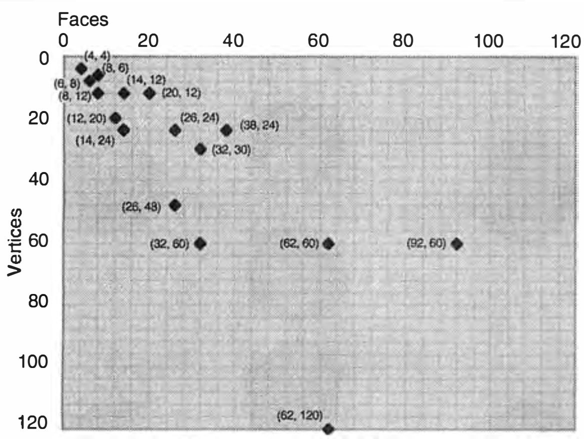


Figure 31
TWO-DIMENSIONAL GRID OF PLATONIC AND ARCHIMEDEAN POLYHEDRA

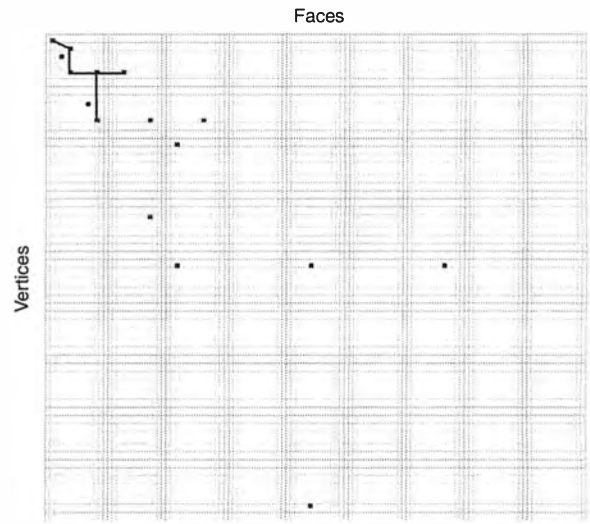


Figure 32
THE TETRAHEDRON FAMILY HIGHLIGHTED
The connected dots represent the tetrahedron family, masquerading as a small Deinonychus *dinosaur.*

find the location for each member on a three-dimensional grid, where each axis of the grid represents one of the attributes of the polyhedron: faces, edges, and vertices.

Since I was working with graph paper on a clipboard, I started by using only two axes at a time. I found it most effective to examine the faces and vertices on the two-dimensional graph paper and just ignore the edge-axis. (There is another irony here that took me years to understand, but no shortcuts). What I found at the time was really something. (See Figure 31)

I put the dots on the graph paper. It looked like a confusing mess, but when I connected each family's dots with colored ink, its clarity almost jumped off the paper. It looked like a star chart with constellations drawn on it. The constellation of each family looked like a primitive cave painting of a bird—a crane or pelican—or better yet, a theropod[11] dinosaur, one that looks like the *Tyrannosaurus rex.* The Platonics were located at the tip of each dinosaur's mouth; the great-circle figures were the heads and the truncated Platonics were the little front claws. The rhombic great circles were the bodies, the snubs the tips of the tails, and the truncated great-circle figures were the feet.

I had a "little" 8-foot-long, red *Deinonychus* dinosaur,[12] with its mouth closed representing the tetrahedron family; a medium-sized 16-foot, green *Ceratosaurus*[13] with its mouth open a little as the cube family, and a huge blue 40-foot-long *T-Rex*[14] with its mouth open wide, as the representative of the dodecahedron family. This was a lot of fun.

One thing that seemed funny to me was that the "truncated Platonic" pairs—the truncated cube and truncated octahedron, for example—both mapped to the same place, even though they had very different appearances. The same thing happened with the truncated dodecahedron and truncated icosahedron. Look at the truncated cube and truncated octahedron, or even more striking, the truncated dodecahedron and truncated icosahedron. They don't look at all alike, but each pair happens to have the same number of faces, vertices, and edges. Well, one polyhedron for each dinosaur claw.

You could see each family clearly on the chart, and the intersections, too: the tip of the mouth of the green *Ceratosaurus* touched the head of the red *Deinonychus*; the head of the *Ceratosaurus* touched the body of the *Deinonychus*; and the neck of the *Ceratosaurus* touched the foot of the *Deinonychus.* At the same time, the mouth of the blue *T-Rex* touched the tip of the tail of the poor little *Deinonychus.* This really worked nicely, and it gave you the impression that you weren't looking at a static thing. Those dinosaurs were going to start chewing any minute. You could also see how the enharmonic polyhedra were, in fact, in both families, filling different roles.

The dinosaur mouths were open different amounts. That made me stop and look. It seemed to mess up the symmetry of the families. I knew something was funny with the way I was thinking about this, and I had a glimmer of anticipation, like the change in the way the air feels before a thunderstorm. *Why weren't my supposedly symmetrical families absolutely identical on the chart?*

I had an idea—superimpose the families to see if they really were the same shape. They looked the same, but, you never know. Here's how it works: The vertices of the dodecahedral Archimedeans were at 30, 60, and 120; the cubic Archimedean vertices were at 12, 24, and 48; and the tetrahedral vertices were at 6, 12, and 24. All I had to do was put the dots on one grid that had three different scales. If the families were symmetrical, then the dots would be in the same place. The differences in dodecahedral Archimedean vertices were 30 and 60; the differences for the cubes were 12 and 24, with the tetrahedrons at 6 and 12. That should work.

The scale for the faces of the Archimedean polyhedra was the same idea. The dodecahedral Archimedean faces fell at 32, 62, and 92. The cubes were 14, 26, and 38; with the tetrahedrons at 8, 14, and 20. This worked too, with differences of

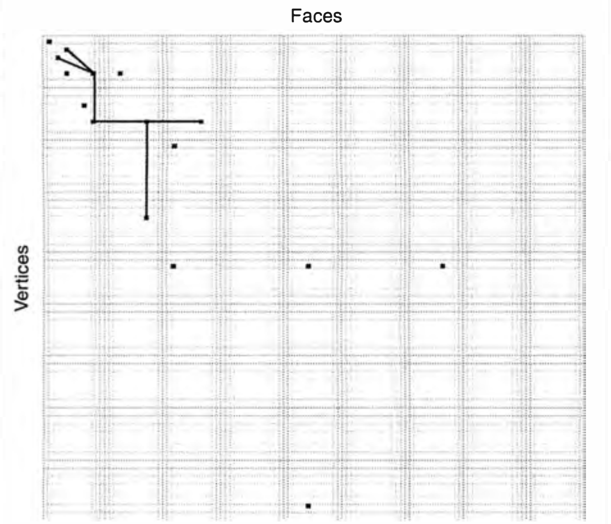


Figure 33
THE CUBE FAMILY HIGHLIGHTED
The cube family resembles a mid-sized Ceratosaurus *when its dots are connected.*

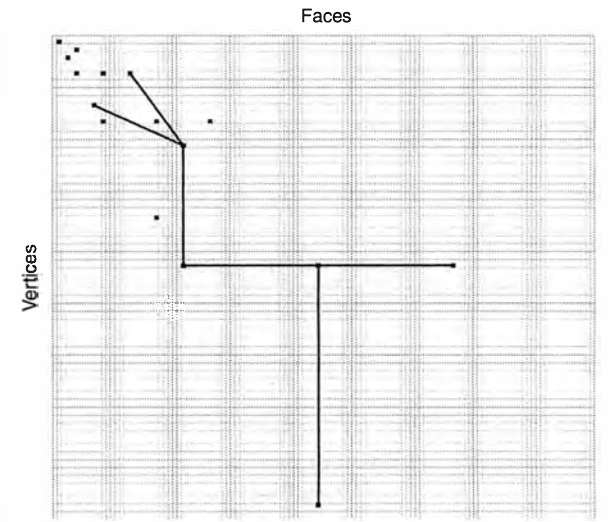


Figure 34
THE DODECAHEDRON FAMILY HIGHLIGHTED
The dodecahedron family as a huge T-rex.

30 for the dodecahedral, 12 for the cubic, and 6 for the tetrahedral. The Archimedean solids of each family exactly mapped onto the Archimedeans of all the other families. The Archimedean polyhedra families really were symmetrical.

One little nagging, hint of a question. The cube, dodecahedron, and tetrahedron all mapped onto each other too, when I overlaid the families of Archimedeans, but the octahedron and icosahedron each fell in a different place. That was why the mouths of the dinosaurs seemed to be open wider, as they got bigger. The bigger the dinosaur, the wider the mouth—maybe that had something to do with Darwin, but I doubted it. It was a puzzle, but by this time I was working so fast that I didn't stop.

This was a situation I was used to by now, in the geometry work. I had a nice theory, a beautiful picture to show, and one fly in the ointment. I found that you don't have to ruthlessly hunt down the anomalies and destroy them. Believe me, if you do the work, they'll find you. (What you do have to do is enjoy being caught by the anomalies, unlike the "Bread Scholars" that Schiller denounces, who try to cover up anomalies.[15])

Why weren't my symmetrical families symmetrical? Those damn dinosaurs had their mouths open different widths. I will tell you why, but we are going to have to go around the long way to get there.

Three Dimensions, If You Got 'Em

I did feel a little bad to be working with only two dimensions of my three-dimensional grid at one time. So, I got a slab of Styrofoam and some small wooden dowel-rods. I made a face- and vertex-grid on a piece of paper, cut the dowels to the length of the edge-axis on the same scale plus an inch, put the paper on the Styrofoam, and poked the dowels through the paper at the proper place an inch into the Styrofoam. The upper ends of the dowels represented the location in 3-D where the polyhedra should be located. I was so happy with this that I made a piece of cardboard which had pictures of each Platonic and Archimedean polyhedron on it. The cardboard would sit on the Styrofoam, next to where the dowels were, so you could see what each dowel represented.

I had hoped that looking at the pattern in three dimensions would directly portray some neat secret about the unseen force that shapes the Platonic and Archimedean solids. Maybe it would be a 3-D spiral, or waveform, or some exotic shape like a pseudosphere.

It didn't.

It looked to me like all the polyhedra fell in one plane, a plane tilted with respect to the other axes, but just a plane! Upon reflection, this shouldn't have been a surprise, if I had had more mathematical training. The phenomenon was an artifact of what has been sadly named Euler's formula. Each of the polyhedra is subject to this curious fact: The number of faces, plus the number of vertices, minus the number of edges is always 2.

Tetrahedron: $4 + 4 - 6 = 2$.

Snub dodecahedron: $92 + 60 - 150 = 2$, and so on.

This would explain why all the solids, mapped the way I was doing it, ended up in a plane. It did make it easier to show. I could still accurately display the real three-dimensional graph on a two-dimensional piece of paper after all, but it lacked the pizzazz of having the more trendy hyperbolic waveforms in my graph.

'The Universe, and All That Surrounds It'[16]

In LaRouche's "Metaphor" paper, which was published when he was in prison, at the height of my activity in these matters, he made it quite clear that great circles on a sphere were the way to create the Platonic solids. My one overriding thought while working on this project was, "Spheres are primary; how does

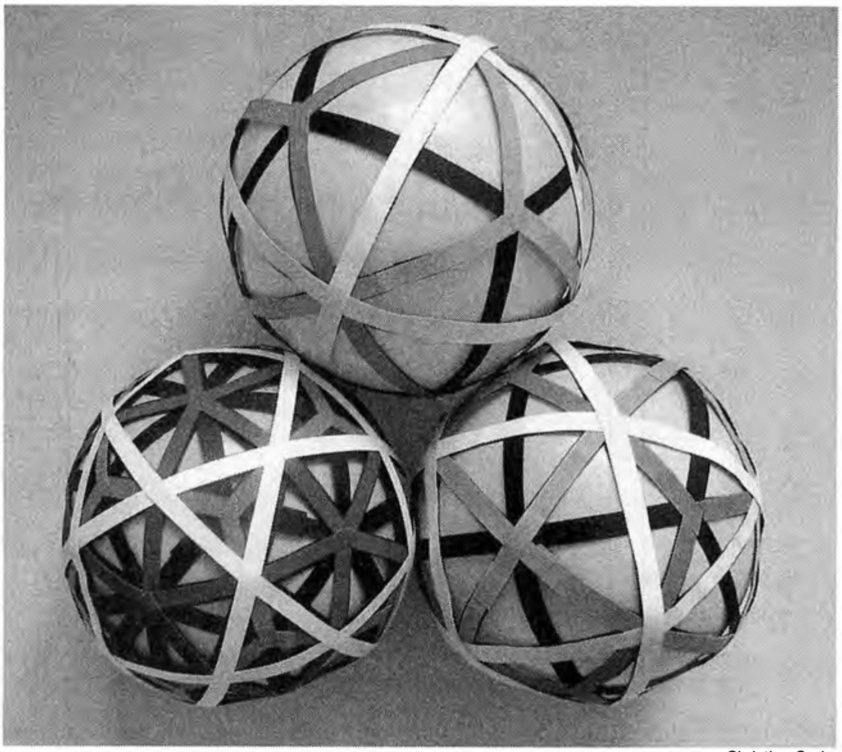

Christine Craig

Figure 35
GOD'S GRAPH PAPER
The 6-, 9-, and 15-great-circle spheres, with the fundamental 3-, 4-, and 6-great circles of the Platonics superimposed on them. These are made of half-inch strips of colored poster board glued into the great circles. White balloons were inflated within to enhance visibility.

this come from a sphere?" A sphere is the highest level of least action we can apprehend with our senses alone.

The regular 6-hoop sphere, the icosidodecasphere, has 12 pentagonal and 20 triangular areas that the great circles sweep out. To locate a dodecahedron in this arrangement, you put each of its 20 vertices in the center of one of the 20 spherical triangles of the icosidodecasphere. Likewise, the icosahedron's 12 vertices would go into the 12 spherical pentagons of the icosidodecasphere. If you look at a dodecahedron alone, you see that it is like every other polyhedron we are dealing with, except the tetrahedron, in this way: It is made up of features that reappear on opposite sides of the figure. Each face has a parallel face that is on the other side of *the* dodecahedron, so a dodecahedron is really made up of 6 pairs of parallel faces. Likewise, the vertices all have another vertex exactly opposite to it on the other side of the dodecahedron. The edges do too. Look at the 30 edges of the dodecahedron. If we imagine the dodecahedron inside a sphere that touches each of its vertices and imagine a segment of a great circle connecting each vertex to form a dodecasphere, then we are ready for action.

Take any edge on the spherical dodecahedron, the dodecasphere. This is a segment of a great circle. Extend the segment in a straight line on the sphere. The line (great-circle path) cuts through the center of the next face, cuts a different edge in half at right angles, cuts through the center of another face and then joins up with the edge on the opposite side of the dodecahedron. It continues on until it returns to the original great-circle segment. If you can see it (it is really hard), you will find that it takes 1 great circle to cover 2 edges of the dodecahedron. Since there are 30 edges on a dodecahedron, it takes 15 great circles to define a dodecahedron.

Fifteen great circles! I can barely see 4 great circles when I'm looking right at them. How can I visualize 15?

Remember the Bread Scholars? You have to do it. For safety's sake, don't use 15 embroidery hoops for this. Use a half-inch strip cut the long way from a piece of poster board. Mark the strips where they will intersect before you cut them out. There is a lot of technique involved in getting them to work, but that's part of the fun, too.

Remember the dodecahedron inside the icosidodecasphere? The center of each of the dodecahedral edges touches a vertex of the icosidodecasphere. There are 30 edges to a dodecahedron, and 30 vertices in an icosidodecahedron, and they are, indeed, in the same orientation. Because that's true, look at where the 15 great circles go. They all bisect the vertices of the icosidodecasphere, clean as a whistle.

Look at an icosahedron inside an icosidodecasphere. Remember that? 12 vertices are inside 12 spherical pentagons. The center point of the each of the icosahedral edges touches each icosidodecasphere at the vertex—30 and 30, its just like the dodecahedron. The 30 edges of an icosidodecahedron would make 15 great circles, just like the dodecahedron did. In fact they are the very same 15 great circles.

Now look at this process backwards. You start with a sphere—least action in the visible domain. Straight lines on the sphere, great circles, intersect each other to give you even divisions. This can be done in only three ways, with 3, 4, and 6 great circles. Take the 6-great-circle sphere, the icosidodecasphere, and bisect each angle where the 6 great circles meet at each vertex with another great circle. These 15 great circles have created the vertices of both the dodecahedron and the icosahedron. You have done it: least action, to spheres, to Platonic solids.

Now, you could slice up a dodecahedron to make the other Platonic solids without using the other regular great-circle figures, but why use 18th Century methods, as FDR said to Churchill?[17] Use the even divisions of great circles directly.[18]

OK, who's next? The cube and octahedron in the 4-hoop cuboctasphere are next. This is a little easier. The cube fits into the cuboctasphere with its 8 vertices in the centers of the 8 spherical triangles. The centers of its 12 edges hit the vertices of the cuboctasphere, and if you extend its 12 edges, you get 6 great circles. This is the same pattern as before, but with fewer components.

The octahedron is a different kettle of fish. It fits into the cuboctasphere all right: the 6 vertices in the center of the 6 spherical squares of the cuboctasphere, with the center points of the 12 edges at the vertices of the cuboctasphere. *But* you don't have to extend the edges to make complete great circles. They already are complete great circles, because the octahedron, in spherical form, is also the tetritetrasphere, the three-great-circle figure of the tetrahedron family. In the icosidodecasphere, you had 15 additional great circles, each shared by the icosahedron and the dodecahedron. In the cuboctasphere, you have 6 great circles used by the cube, and another 3 by the octahedron, for a total of 9. Nonetheless, the cube and octahedron are generated by the 4 great circles of the cuboctasphere with exactly the same method that created the dodecahedron and icosahedron.

For the tetritetrasphere, we almost get back to normal. If you put a tetrahedron in a tetritetrasphere, its 4 vertices go into alternating spherical triangles, and the centers of its edges map to the vertices of the tetritetrasphere. Extend the edges of the tetrahedron and you get 6 great circles. The other tetrahedron fits into the unused spherical triangles of the tetritetrasphere, and its edges lie in the same 6 great circles as the first tetrahedron's do.

This is the least-action pattern. 6 regularly divided great circles generate 15 others, which define the dodecahedron and icosahedron. Four regularly divided great circles generate 9 others, which define the cube and octahedron; and 3 regularly divided great circles generate 6 others, which define both tetrahedra. That's the pattern. The irony here is that the 6 other great circles that define the cube are the same 6 great circles that define both tetrahedra, but they in no way resemble the regularly divided arrangement of 6 great circles that are the icosidodecasphere. The cube/tetrahedral sharing of the same irregular set of 6 great circles, is why you can put two tetrahedra in a cube, as in the Moon/Hecht model of the nucleus of the atom.[19]

In the middle of all these lovely trees, I remembered something about a forest. The reason that I started investigating Archimedean solids in the first place was because the rhombic dodecahedron filled space like a cube; and no other shape in the universe, which had only a single kind of face, did that. It was as obvious as the nose on my face, that the rhombic dodecahedron isn't an Archimedean solid at all. It doesn't have regular faces. It is the dual of an Archimedean.

What About the Duals?

So, I constructed the Archimedean duals, too, all of them.[20] (See Figure 28.)

The way Archimedean dual polyhedra relate to the Archimedeans is instructive. The sphere that encloses and touches each vertex of an Archimedean solid touches the center of each face of the dual. All of the faces of a dual are the same shape, although some of them can be flipped over in a left-handed/right-handed way; and none of their faces is regular. As we will see, the Archimedean duals are harder to discuss, because of the irregularity of the faces, but I've come to believe that they are, at the very least, as important as, and as primary as, the Archimedean solids themselves.

Tetrakis hexahedron
(6 circles)

Disdyakis dodecahedron
(9 circles)

Disdyakis triacontahedron
(15 circles)

Figure 36
THE ARCHIMEDEAN DUALS AND THE GREAT CIRCLES
The dual of each and every Archimedean solid is directly mapped by the 15, 9, and 6 great circles derived from the 6, 4, and 3 evenly divided great circles—except for the pesky snubs.

The last dual solid I made, the disdyakis triacontahedron, was the dual of the truncated icosidodecahedron. It has 120 identical little right triangles for faces. As I was putting it together (I actually cut out 120 triangles and taped them together), I realized that the edges of this polyhedron were also great circles. That seemed interesting, but this was such a busy construction, that I couldn't see exactly what I had made at the time. (This realization also points out the importance of actually constructing the real polyhedra, rather than just looking at them.)[21]

I thought about the great-circle question for days. I had my whole set of 48 polyhedra hanging in my bedroom. There were a heck-of-a-lot of great circles dividing up the disdyakis triacontahedron into 120 triangles. Were there 15 great circles in the disdyakis triacontahedron? Were they the same 15 great circles that define the dodecahedron and the icosahedron? Could that be possible? Was the universe designed with such precision and charm that the process that created the dodecahedron and the icosahedron directly mapped to the dual of the truncated icosidodecahedron? It seemed like it should be, but was almost too much to hope for.

I went to sleep one Saturday night thinking that, if the families of polyhedra were indeed symmetrical, and the disdyakis triacontahedron was really mapped this way, then the edges of the dual of the truncated cuboctahedron, the disdyakis dodecahedron, should be made out of the 9 great circles used to make the cube and octahedron. In addition, the edges of the dual of the

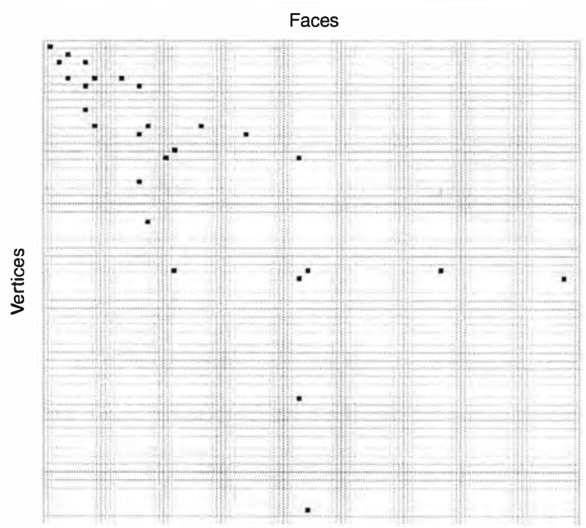


Figure 37
TWO-DIMENSIONAL GRID OF PLATONIC AND ARCHIMEDEAN POLYHEDRA AND THEIR DUALS

enharmonic truncated tetritetrahedron, the tetrakis hexahedron (which looks like a truncated octahedron), should map to the 6 great circles that make the two tetrahedra. When my eyes opened on Sunday morning, I was looking right at the tetrakis hexahedron. I saw the 6 great circles in the figure as plain as day.

This really got me moving.

It turns out that the dual of each and every Archimedean solid is directly mapped by the 15, 9, and 6 great circles derived from the 6, 4, and 3 evenly divided great circles; all of the duals except for the pesky snub cube and snub dodecahedron, are right there. The snubs are a special case, which will become more apparent, the more work we do. The duals of the truncated quasis use all of the faces defined by the great circles. The duals of the others combine some of the faces to make up rhombic and differently shaped triangular faces. It is worth the trouble of constructing the Archimedean duals just to see how this works.

The realization of the role of the great circles in the construction of the Archimedean duals made me determined to integrate the Archimedean duals into my system. How do the duals map onto the grid on which I had already placed the Archimedean solids?

These names mean something about the number of faces.

The dual of the truncated tetrahedron, the triakis tetrahedron, looks like a tetrahedron that has each face divided into three faces. There are three identical triangles in each original face of the tetrahedron. Their edges go from the center of its face to the vertex, and are pushed out a little at the center of the tetrahedron's face. I suppose the "triakis" means 3 and "tetrahedron" means, as we know, 4-sided. The first pair of these polyhedra I made were out of black poster paper, as their faces were triangles.[22] The other names are also as instructive, but not very catchy.

What you see when you add the Archimedean duals to the map, is a symmetrical pattern, like a Rorschach ink-blot test made up of dots.[23] (See Figure 37.)

As I started to do the additional mapping, I decided to go whole hog. You may remember that there are two infinite series of Archimedean solids that we have ignored so far, the prisms and anti-prisms. A prism can be constructed by taking any regular polygon from an equilateral triangle up to an equilateral bazillion-sided figure. Hang squares with edges the same length as those of your original polygon on that polygon, so each edge of the square touches an edge of the polygon and the two adjacent squares. Then put a polygon just like your original one on the bottom, and you have an Archimedean prism. (See Figure 38.)

For example, you can start with a regular hexagon, hang squares from each of its edges, and put another hexagon on the bottom. It looks like a hatbox. This is an Archimedean solid too. One sphere would touch each vertex, and one sphere would touch the center-points of both hexagons, and one sphere would touch the center-points of all squares. This is true for all of the Archimedean prisms. As you get into the higher numbers of sides, the prisms get thinner and thinner, eventually resembling a coin, or CD. As for the duals, the prism duals are all made up of isosceles triangles. The dual of the 6-sided prism, the hexagonal dipyramid, would have 12 triangles—6 isosceles triangles pointing up, like a tee-pee, and 6 pointing down. See: "dipyramid," two pyramids stuck together at their bases. As you add more edges, the triangles get longer and longer until they take on the aspect of a stretched-out dowel with sharpened ends, until you finally give up because there are too many sides.

Anti-prisms are similar to prisms, but are made with triangles rather than squares, hanging from any regular polygon—from an equilateral triangle on up. There are as many triangles as there are edges on both the top and bottom polygon. The triangles are put together alternately, so that they look like a child's drawing of shark's teeth. A 6-sided anti-prism has 12 equilateral triangles around the circumference, and hexagons on both top and bottom. The dual of an anti-prism is made up of a 4-sided figure that looks like an arrowhead. They are called trapezohedrons. The more sides the anti-prism has, the more pointy the arrowhead. The dual of the 6-sided anti-prism has 12 faces: 6 arrowheads pointing up, meeting at their points, and 6 pointing down.

There is a pattern here: the faces of the prisms are always two more than the number of polygonal edges, the vertices are always twice the number, and the edges are three times the number.

Figure 38 (b) shows the progression of the anti-prisms. The pattern here is: The faces of the anti-prisms are always two more than twice the number of the polygonal edges, the vertices are always twice, and the edges are four times the number.

To chart the duals of the prisms, switch the face and vertex numbers, just as with every other polyhedron.

There is something going on that I haven't mentioned yet: The 4-prism is the cube and the 3-anti-prism is the octahedron. Look at all the work the dual-pair of the cube and octahedron do. First, they each are Platonic solids and duals of each other. Second, the octahedron is also the tetritetrahedron, the figure directly created by the even divisions of three great circles, and parent of the tetrahedron family; and the cube is its dual, perhaps called the rhombic hexahedron in that incarnation. Third, the cube is the 4-prism, one of that infinite series; and the octahedron is its dual, a dipyramid—the one

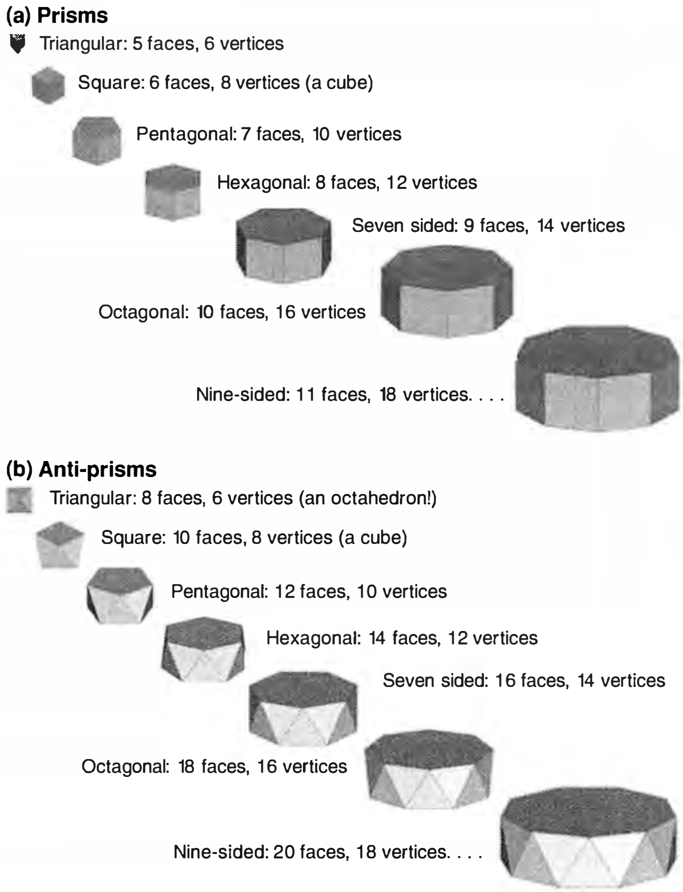


Figure 38
PRISMS AND ANTIPRISMS
The series of prisms and antiprisms goes on infinitely.

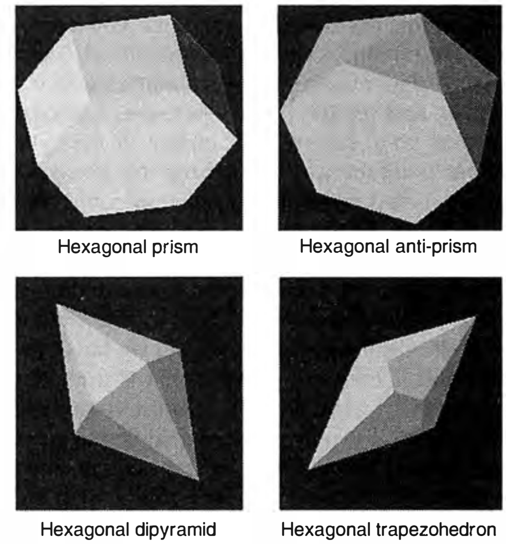


Figure 39
MORE PRISMS
Pictured here are a 6-sided prism, anti-prism, and their respective duals.

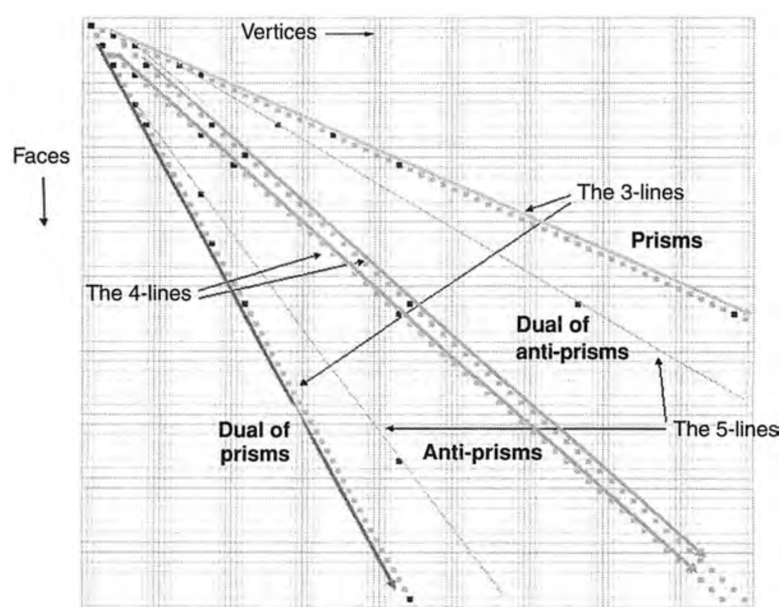
with equilateral triangular faces. Fourth, the octahedron is the three-anti-prism, the first of that infinite series; and the cube is its dual, a trapezohedron with equilateral faces.

Let's go to the grid. (See Figures 37-38.)

The Chart

There is quite a lot going on here, so I'll try to break it down. The dominant thing you see after you

Figure 40
CHARTING THE PRISMS AND THEIR DUALS
When the faces and vertices are gridded, the prisms and their duals go off in two different straight lines that seem to start at the tetrahedron. At the second prism dual-pair—the 4-prism (cube)—the anti-prisms and their duals start, with the 3-anti-prism (octahedron), which is also the dual of the 4-prism. The entire chart is contained in three pairs of straight lines. The prism and dual-of-prism lines—the "3-lines"—meet at the tetrahedron; the anti-prism and dual-of-anti-prism lines—the 4-lines"—run parallel, and very close to the "dual line," while the "5-lines" connect all three snubs and their duals, and meet the "3-lines" at the dodecahedron and icosahedron (the snub tetrahedron).



put all the dots on the graph paper, is the wedge that the prisms and their duals make. Since you are mapping dual-pairs, the chart is completely symmetrical. There is an imaginary line down the center of the pattern where you could put a mirror, and see the place where the dual of every mapped point on your side would appear in the mirror. The only mapped point that actually falls on this line is that of the tetrahedron, as it is the dual of itself. You could also call this line the pyramid line, as any pyramid you can construct would fall on this line. Pyramids are all duals of themselves. A pyramid with a million-sided base would have a million-and-one faces, and a million-and-one vertices, with 2 million edges. The tetrahedron is the simplest pyramid we have, with a base of 3 sides, and is the only pyramid that is a regular polyhedron. Since every pyramid is the dual of itself—and even though the tetrahedron is the only pyramid qualified to be mapped on our chart—they all would map right down the center dual line, if we bothered. You could fold the chart in half on the dual line, or pyramid line, and every other polyhedron would touch its dual.

The prisms and their duals go off in two different straight lines that seem to start at the tetrahedron. At the second prism dual-pair, the 4-prism (cube), the anti-prisms and their duals start with the 3-anti-prism (octahedron), which is also the dual of the 4-prism. They run in parallel lines very close to the pyramid line.

This intersection spot, where the cube and octahedron are, is the location of the most intersections of functions on this chart. Does that have something to do with the ease with which we conceptualize a cube? Cubes are easy to picture: Up, down; front, back; left, right.

The whole chart represents the boundary layer between our perceived universe, and the unseen process of creation. In dissecting this wonder, we find the snubs, and the dodecahedron family as a whole, on the far side of the singularity from us—the "dark side of the Moon," if you will. The cube, in contrast, is the nearest and most familiar point in this process. (Can singularities have sides?)

All of the Archimedean duals which have 3-sided faces occupy the same spot on the graph as a dual of an Archimedean prism, even though they are not the same shape (except the octahedron, which is the dual of a prism—the cube). All of the Archimedean polyhedra which pair with those duals fall on the same spot as one of the prisms. These are the truncated quasis and the truncated Platonics. (The truncated icosidodecahedron maps to the same location as the prism with 60-sided faces; the truncated dodecahedron and truncated icosahedron map to the prism with 30-sided faces; the truncated cuboctahedron maps to the prism with 24-sided faces; the truncated cube and truncated octahedron (truncated tetritetrahedron) map to the prism with 12-sided faces, the truncated tetrahedron maps to the prism with 6-sided faces). The duals of the Archimedeans match the duals of the prisms.

All Archimedean duals which have 4-sided faces fall on the same spot on the graph as a dual of an Archimedean anti-prism. The Archimedeans which pair with those duals co-occupy a spot with the anti-prisms themselves. These are the rhombi-quasis and the great-circle figures (the rhombicosidodecahedron maps to the anti-prism with 30-sided faces; the icosidodecahedron maps to the anti-prism with 15-sided faces; the rhombicuboctahedron maps to the anti-prism with 12-sided faces; the cuboctahedron (rhombitetritetrahedron) maps to the anti-prism with 6-sided faces; and the tetritetrahedron (octahedron) maps to the most famous prism of all, the cube).

The Archimedean duals, like all duals, owe the shapes of their faces to the nature of the vertices of their dual-pairs, and vice versa. An octahedron has faces made up of equilateral triangles, whereas the cube has 3 edges meeting at equal angles. The duals of the great-circle figures all have 4-sided faces, because the great circles meet, creating four angles. The rhombi, and all truncated Archimedean duals have 3-sided faces.

Only the snubs and their duals, which have 5-sided faces, fall on the chart in a place not already defined by the prisms or anti-prisms. Even they lie on their own straight line on the chart which intersects the prism line at the icosahedron. This implies that the snubs make up a category of their own. The whole chart is contained in three pairs of straight lines. The prism and dual-of-prism lines, the "3-lines," meet at the tetrahedron; the anti-prism and dual-of-anti-prism lines, the "4-lines," run parallel, and very close to the "dual line," and meet the "3-lines" at the cube and octahedron, while the "5-lines" connect all three snubs and their duals, and meet the "3-lines" at the dodecahedron and icosahedron (the snub tetrahedron).

The separation of the "5-lines" of the snubs is another example of their uniqueness.[24] It is not that they are snubbing the other polyhedra, of course, but there should be another infinite set of polyhedra, which would fall under the snub polyhedra. They would be like the prisms and anti-prisms, except with five-sided duals. They don't exist because they are not constructable in the discrete universe. The snub polyhedra are as close as you can come, because of the limit imposed by the nature of space. My opinion is that the angel in Dürer's *Melancolia* is trying to construct such a set, but is frustrated by the limits of physical space, and is thus, melancholy. The dual of what the angel has made in the woodcut would have 3-sided faces, at any rate, and such a series would show up on my chart at the same location as every other prism, and not on the 5-line at all. This just shows how impossible the project is.

Where the Platonic solids fall on this chart, is highly instructive, and can be understood in the context of the next paragraphs.

Once you map the Archimedeans and their duals, you can answer the question I asked about the location of the Platonics in that scheme. Do you remember when we superimposed the three families of Archimedeans? The dodecahedron, cube, and tetrahedron all fell in the same spot, but the octahedron and icosahedron seemed to randomly miss the target. The dinosaur mouths were open different amounts. Well, do the same superimposed mapping with the duals of the Archimedeans and the Platonics. The icosahedron, octahedron, and tetrahedron all map to the same place, and the dodecahedron and cube splatter somewhere else.

This is awesome.

From the perspective we have just established, the cube and dodecahedron belong to the same set of polyhedra as the Archimedean solids, while the icosahedron and octahedron belong with the Archimedean duals. If you map the Platonic polyhedra that way, the families are completely symmetrical, and once again the beauty of creation has smashed one of my

Figure 41
Melancolia, by Albrecht Dürer. Notice the large polyhedron behind the figures.

pet theories into the mud.

When the icosahedron and octahedron enharmonically act as Archimedean solids themselves, as snub tetrahedra and the tetritetrahedron, then they map as Archimedeans and the dodecahedron and cube map as Archimedean duals. The tetrahedron, as the point of the wedge on our graph, and dual of itself, participates in both sets.

The Platonic solids all occupy the 3-lines. The icosahedron and dodecahedron occupy the 5-lines as well, because the dodecahedron is a 5-sided-face dual of the snub tetritetrahedron (icosahedron). The cube and octahedron occupy the 4-line as well, because the cube is a 4-sided dual of the tetritetrahedron (octahedron). Most ironically, all the lines intersect at the tetrahedron, even though it is neither a prism nor the dual of a prism.

The Chart in the Back of the Book

This is a lot to keep in your head. When I was reviving my activity with the Archimedean families, a way of keeping the families and their relationships straight in my mind came to me. Don't tell anyone this trick, until they have done all the above work.

The number of edges of each member of the Archimedean families is evenly divisible by 6. If you divide each polyhedron's edge-number by 6 and look at the results as a one-dimensional graph, the tetrahedron family falls on 1, 2, 3, 4, 5, and 6. The cube family falls on 2, 4, 6, 8, 10, and 12; while the dodecahedron family falls on 5, 10, 15, 20, 25, and 30. The cube/tetrahedron enharmonic intersections are at 2, 4, and 6; with the dodecahedron/tetrahedron intersection at 5. That's it. The fact that both the cube and dodecahedron family have members with edges of 10 does not indicate an enharmonic intersection; they just have the same number of edges.

The utilization of the edge-axis in this way is why, when I first started mapping the Archimedean families, it was most convenient to use the faces and vertices for a two-dimensional view. The polyhedra seemed to bunch up in the edge-axis view, and made the chart sloppy. I thought that was a problem, and went on to do all the work recounted above. If I had realized that only using the edges for mapping, I could show both the symmetry and intersections of the families, I would have missed all this fun.

You can discourse on this topic, off the top of your head with this simple chart in your mind.[25] Or draw it out: 1, 2, 3, 4, 5, and 6 down the center of a piece of paper; 2, 4, 6, 8, 10, 12 on the right side; and 5, 10, 15, 20, 25, 30 on the left. Make sure that the numbers are lined up, 2 next to 2, 4 next to 4, and so on; circle all 2's, 4's, 5's, and 6's, and you're done. See Figure 40.

Once the idea is in your head, this is the only mnemonic device you will need.

So, What Do We Have?

In summary, we have created two sets of tools, useful in the philosophical examination of geometry, and, I might add, just as useful in the geometrical examination of philosophy.

The first set is the collection of great-circle figures: 3, 4, and 6 even divisions of great circles by other great circles, from which we create the 6, 9, and 15 other great-circle arrangements which give you the Archimedean duals, and the Archimedean polyhedra arranged in the three symmetrical families. The great circles are useful in the planning and construction of our polyhedra. All of these collections of great circles together, I've come to call "God's graph paper." (Figure 35).

The other set of tools is the mapping of the locations of the polyhedra onto a three-dimensional grid. You have the three families of Platonic and Archimedean solids, which look like three constellations, and show the symmetry and intersections of the families. Adding the duals of the Archimedean solids shows how the dual-pairs are mirror images of each other, while adding the prisms, anti-prisms, and their duals provides a framework for the other polyhedra, and highlights some of the processes that create the shapes. The various stages of this mapping are useful in seeing what has been constructed.

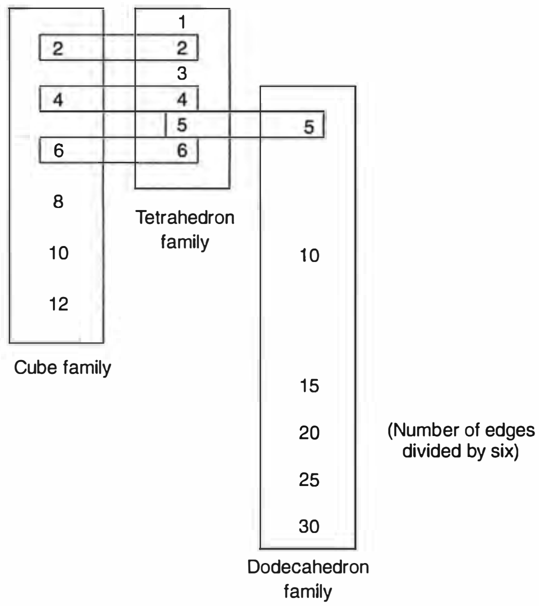


Figure 42
CHARTING THE FAMILIES OF POLYHEDRA
This is the chart at the back of the book, showing how the families of polyhedra intersect. The number of edges of each member of the Archimedean families is evenly divided by 6. If you divide each polyhedron's edge-number by 6 and plot the results in one dimension, this is the result.

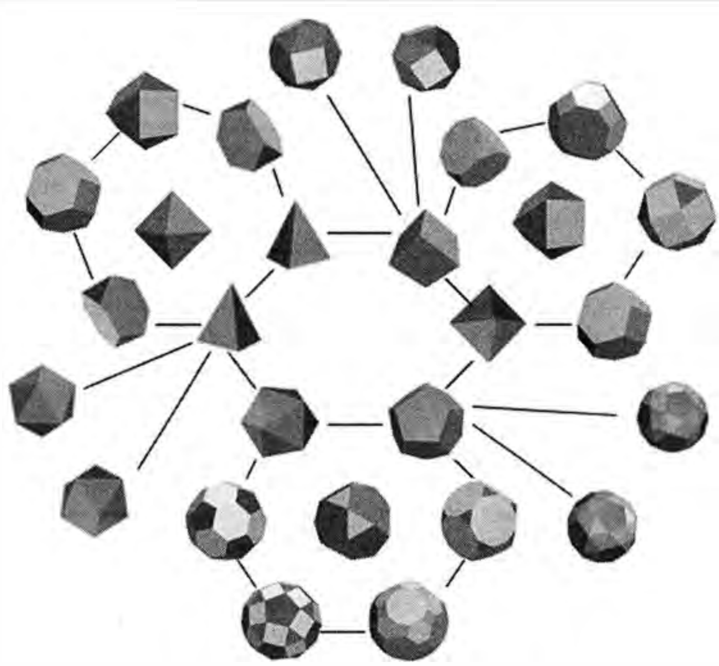


Figure 43
THE SHAPE OF SPACE II
The beginning of everything!

Gridding or mapping the positions of the polyhedra is a tool to examine the limits embedded in visible space. Don't look at the graph as a thing. It is picture of a small part of the ongoing process of creating the universe. Your examination of the chart is part of that process of creation. It would be nice to build a chart big enough to put models of the polyhedra where they appear on the grid. Even if we do that, even if we have a few city blocks to landscape, and the chart is big enough to walk around in, it won't be a *thing*. Imagine walking along the 3-line by each of the prisms, past the dodecahedron and the truncated tetrahedron, until you reach the cube. You stop and look across the little stream that represents the pyramid line, seeing the octahedron and the anti-prism row leading off to your right, and reflect on how many things the octahedron is doing at the same time, even while it appears to be just sitting there: Your thoughts at that moment are what's happening, not the models themselves.

These are really tools you can use to answer questions such as, how is the axis of symmetry different in the dodecahedron vs. the rhombic dodecahedron? They both have 12 faces, which are different shapes. How could there possibly be two dodecahedra with differently shaped faces? The Composer didn't sit down and cut out cardboard. How do the faces orient to each other in each polyhedron? Look at the 3-hoop and 9-hoop spheres. Clearly, the center of each face of the rhombic dodecahedron falls at the center of each edge of the tetritetrasphere, the evenly divided 3-hoop construction. Now look at the dodecasphere in the 15-hoop sphere. The center of each face of the dodecahedron also falls on an edge of the 3-hoop tetritetrasphere, but not in the center of the arc segment. Could it be that the center of the face divides the edge at the Golden Mean? I think it does. When you divide the arcs thusly, you have to choose either a right-handed or left-handed orientation. This is another indication of the dodecahedron family's affinity to the snub figures. Try picturing that without the great-circle constructions as a guide.

The relationships presented here are true, but what is the relevance? How that works is up to you. The last thing you want is a well-stocked tool box sitting unused in a closet. Make, or borrow an hypothesis and then do the constructions. Once you get the ball rolling, it becomes a self-feeding process.

As a final inspiration, some wisdom from Act I, Scene 5 of Mozart's opera *Don Giovanni*. Don Giovanni (Don Juan) foolishly lets himself get within arm's reach of a former, abandoned lover who is looking for him to make him marry her. He wants to have his servant, Leporello, save him by distracting her by recounting his lengthy list of Giovanni's amorous adventures:

He says (loosely), "Tell her everything."

Leporello, missing the point, either on purpose, or not, asks, "Everything?"

"Yes, yes, tell her everything."

"And make it snappy," she interjects.

"Well, ma'am, in this world, truly," says the embarrassed Leporello, "a square is not round."

See, everybody used to know that geometry was the beginning of "everything."[26]

Notes

1. Max Casper (1880-1956), *Kepler,* (Mineola, N.Y.: Dover Publications, Inc. 1993), p. 380.
2. Edwin A. Abbot (1838-1926), *Flatland, A Romance of Many Dimensions, with Illustrations by the Author, A. Square,* http://www.geom.uiuc.edu/›banchoff/Flatland/.
3. Lyndon H. LaRouche, Jr., "On the Subject of Metaphor," *Fidelio,* Vol. 1, No. 3, Fall 1992.
4. Johannes Kepler (1571-1630), *The Six-cornered Snowflake,* edited by Colin Hardie, (New York: Oxford University Press, 1966), 74 pp. This is a beautiful work.
5. My friend, Jacob Welsh, (b. 1989) has correctly pointed out that if you squash a cube the right way, and make all the faces identically diamond-shaped, this figure will also fill space. I maintain that a squished cube is still a cube, so let the merriment continue.
6. Magnus J Wenninger, *Polyhedron Models,* (New York: Cambridge University Press, 1971), pp. 12-13. Wenninger gives brief notes on construction techniques. My current practice follows his closely; however, when I started this project, I used wide, clear tape to cover each cardboard face, and then taped the individual faces together.
7. Plato, *Parmenides, or On Ideas, Logical,* unpublished translation from 1990 by Leslie B. Vaughan.
8. To show what I mean by this, here are some news reports from the internet:

   "One Critically Wounded during Rotterdam Soccer Riot—Rioting soccer fans may have returned fire at police during a clash in central Rotterdam Sunday night in which police shot into the crowd, wounding four people. . . ."

   "Rome Soccer Riot Was Planned—A hardcore of Lazio and AS Roma soccer fans worked together to spark the riot that caused the Rome derby to be abandoned on Sunday, politicians said on Monday. Police on Monday said they had arrested 13 supporters from both sides, some of them known hooligans, following a 6-hour pitched battle between police and fans that left more than 170 people injured. . . ."

   "Soccer Riot in Russia Kills One—Russian soccer fans rampaged near the Kremlin after their team lost to Japan in the World Cup on Sunday, setting fire to cars, smashing store windows and attacking a group of young Japanese musicians. At least one man was killed in the melee. . . ."
9. The late, great Fred Wills (1928-1992), former Foreign Affairs and Justice Minister of Guyana, hero of the Colombo conference and the Non-Aligned Movement, Shakespearean scholar, friend of Lyndon LaRouche, and cricket expert of international renown, taught me that the above quote is almost always useful, and incidentally, the oldest rhetorician's trick in the book. If someone has the misfortune to speak before you speak, you are in the perfect position to trump his or her lead, like Regan does to the other "bad sister," Goneral, in *King Lear.* You can adopt all their hard work as your own. Anything you add is by definition more than your unfortunate predecessor has said.

   That is my role here, to build on the work that our "non-checkerboard" faction has already done over the last 3,000 years or so. With any luck at all we can end up in better shape than Regan does later in *King Lear.* ("Sick, oh sick.")
10. Three symmetrical families; three pairs of Platonic solids; three sets of great circle figures: What is with all these threes? Now look, when we say that the cube has 6 faces, we don't mean "6" in a *Sesame Street,* "one, two, three, four, five, s-i-i-i-x," kind of way. The 6 faces of a cube are oriented a certain way: up, down, left, right, front, back. This 6 is not just a dead number, but is in the process of going from somewhere to somewhere. In fact, you wouldn't have those concepts of direction without a reference like the cube. If fact, the structure of the universe, which we are investigating here, determines where those 6 faces fall, and how they are shaped, and why they are unique. 6 doesn't just mean 6, at all. Likewise, the three families of Archimedean polyhedra are not just three, as in "three." The past is not the future, and certainly bears no topographical resemblance to the present. Past, present, future, your whole existence is shaped by the idea of three, but it is not just "a three."
11. *Theropods* (meaning "beast-footed") were a sub-order of Saurischian dinosaurs. They were fast-moving, bipedal carnivores (meat-eaters) with grasping hands and clawed digits. They looked like the kind of turkeys that could have *you* for Thanksgiving.
12. *Deinonychus antirrhopus,* "Terrible Claw upturned" was supposedly a lightly built, fast-moving, agile, bipedal (walked on two legs), bird-like dinosaur, which could grow up to 10 feet long and lived from 110 to 100 million years ago.
13. *Ceratosaurus,* the "Horn Lizard" is said to have been a powerful predator that walked on two strong legs, had a strong, "s"-shaped neck, and had a short horn on its snout. The *Ceratosaurus* lived from 156 to 145 million years ago and could be 15-20 feet long.
14. *Tyrannosaurus rex,* the "Tyrant lizard king," was a huge meat-eating dinosaur that lived during the late Cretaceous period, about 85 million to 65 million years ago. Until recently, *Tyrannosaurus* rex was the biggest known carnivorous dinosaur, at 40 feet long. Current teaching has it that the *Giganotosaurus* and *Carcharodontosaurus* are slightly bigger.
15. Friedrich Schiller, "What Is, and to What End Do We Study Universal History? 1789 Inaugural Address at Jena," translated by Caroline Stephan and Robert Trout, *Friedrich Schiller, Poet of Freedom, Vol. II,* (Washington, D.C.: Schiller Institute, 1988), pp.254-255.

    The course of studies which the scholar who feeds on bread alone sets himself, is very different from that of the philosophical mind. The former, who for all his diligence, is interested merely in fulfilling the conditions under which he can perform a vocation and enjoy its advantages, who activates the powers of his mind only thereby to improve his material conditions and to satisfy a narrow-minded thirst for fame, such a person has no concern upon entering his academic career, more important than distinguishing most carefully those sciences which he calls "studies for bread," from all the rest, which delight the mind for their own sake. Such a scholar believes, that all the time he devoted to these latter, he would have to divert from his future vocation, and this thievery he could never forgive himself.
16. Peter Cook (1937-1995), "Sitting on the Bench," *Beyond the Fringe,* (New York: Samuel French, Inc. 1963).

    Strange, but not odd, that a Cambridge-educated comedian would use this as a joke title for a book in a comedy review.

    ". . .I am very interested in the Universe and all that surrounds it. In fact, I'm studying Nesbitt's book, *The Universe and All That Surrounds It.* He tackles the subject boldly, goes from the beginning of time right through to the present day, which according to Nesbitt is Oct. 31, 1940. And he says the Earth is spinning into the Sun, and we will all be burnt to death. But he ends the book on a note of hope, he says, 'I hope this will not happen.' "
17. Elliott Roosevelt, *As He Saw It, The Story of the World Conferences of FDR,* (New York: Duell Sloan and Pearce, 1946), p. 36.
18. This is what LaRouche says to do in the "Metaphor" paper, but this is not how he says to do it. He says, "From the 6-hooped figure containing dodecahedron and icosahedron, the cube, octahedron, and tetrahedron may be readily derived." And it can. *However,* you may see how the Platonic and other polyhedra may be formed from the three sets of evenly divided great circles.
19. See Laurence Hecht and Charles B. Stevens, "New Explorations with the Moon Model," *21st Century,* Fall 2004.
20. Magnus J. Wenninger, *Dual Models,* (New York: Cambridge University Press, 1983), pp.1-6. Wenninger gives two methods to determine what the dual of any polyhedron is. Going through this with a group of people would make an interesting class.
21. Robert Williams, *The Geometrical Foundation of Natural Structure,* (Mineola, N.Y.: Dover Publications, Inc. 1972), pp.63-97. This section of Mr. Williams's book was significantly valuable to me when I first started constructing polyhedra. In particular, the face-angles of the dual polyhedra made this portion of the project possible, before I had read Wenninger's *Dual Models* book referenced in footnote 19.
22. Don't make a polyhedron all black, unless you are going to hang it in a nightclub. I was trying to highlight the fact that the Archimedean duals are made up of only 3-, 4-, or 5-sided faces by making them black, gray, or white, depending on how many sides the faces of the polyhedron had. However, you can't see what the black ones look like in a photograph. They do look mighty slick in person, though.
23. When I first saw the pattern, I thought it looked like a sampling of an amplitude-modulated envelope of increasing amplitude, running for three-and-a-half cycles of the modulating frequency. I later imagined that each family of Archimedean solids and their duals could be connected by a pair of sine waves 180 degrees out of phase with each other, either expanding from, or contracting on, the Platonics, for three or four cycles. I am far from complete in connecting each family's dots with curves, or sine waves, rather than dinosaur skeletons. It is more of an artistic proposition, than a scientific one. That could be because I haven't seen the pattern correctly. Perhaps a bright young person with a fancy computer program, or even a bright old person with a slide rule, could tidy this up.
24. My friend Gerry Therrien has spoken of how Kepler wrote about the attributes and genesis of the snub polyhedra. I hope he writes up his observations sometime. For now, look at the snub figures and then at any antiprism, and ponder the similarities.
25. Plato, *Meno.*

    This is funny: Plato has Meno express amazement that Socrates can't even tell him what virtue is, as Meno has spoken "at great length, and in front of many people on the topic." Later, when Socrates shows the slave why doubling the sides of a square won't double the area, Socrates says that, just a moment before the slave would have spoken at great length, and in front of many people on doubling the side of a square. Yes, Socrates did irritate a few people.
26. DON GIOVANNI: Si, si, dille pur tutto.

    (Parte non visto da Donn' Elvira.) DONNA ELVIRA: Ebben, fa presto. LEPORELLO: (Balbettando): Madama. . . veramente. . . in questo mondo conciossiacosaquandofosseché. . . il quadro non è tondo. . . .

IRON IN THE SUN

Nuclear Chemist Challenges Theory of Solar Origin

by Lance C. Feyh

For decades, Dr. Oliver Manuel, a professor of nuclear chemistry at the University of Missouri-Rolla, has been telling anyone who will listen that the accepted theory on the Sun's origin—that it was created slowly along with the planets in a huge collapsing cloud of hydrogen and helium—is seriously flawed.

"That story about the solar system's creation certainly doesn't match my findings," says Manuel, who, back in the 1970s, uncovered evidence supporting a different theory: that a supernova explosion created the Sun and planets.

Lately, it appears that Manuel's ideas aren't quite as far-fetched as they used to seem.

Atoms in the solar wind show that iron, oxygen, and silicon are the most abundant elements in the Sun, says Prof. Oliver Manuel. The University of Missouri-Rolla nuclear chemist is at center, with Prof. Fumihiko Suekane of Tohoku University and Dr. Hans Klapdor-Kleingrothaus of the Max-Planck Institute for Nuclear Physics.

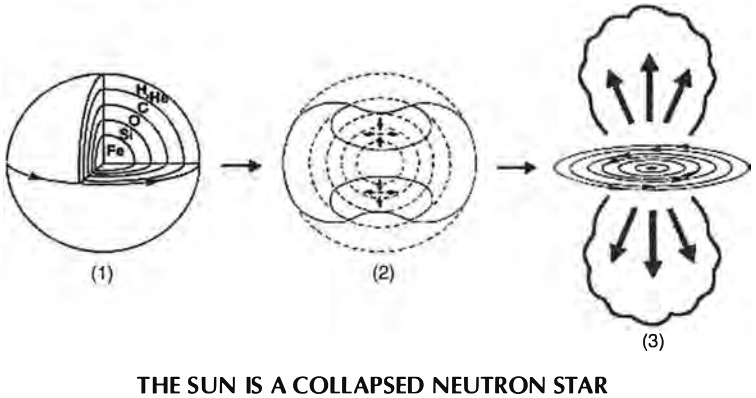
New findings at Arizona State University convinced a Chinese-American team of scientists that the origins of the solar system, indeed, were hotter and more violent than previously thought. After detecting clear evidence in meteorites for the past presence of chlorine-36, they concluded that a nearby supernova must have injected radioactive isotopes into the interstellar cloud of light elements that was forming our Sun and planets. The conclusions are reported in the Feb. 1, 2005 issue of the *Proceedings of the National Academy of Scientists.*

Manuel says these researchers are on the right track, but they have failed to realize just how close the supernova explosion was to our solar system.

"I am pleased the Chinese-Arizona State team of scientists recognizes this new evidence of a supernova at the birth of the solar system," Manuel says. "But our own studies show that fresh supernova debris formed the Sun and its planets directly. The hot radioactive debris never mixed with a cloud of hydrogen and helium."

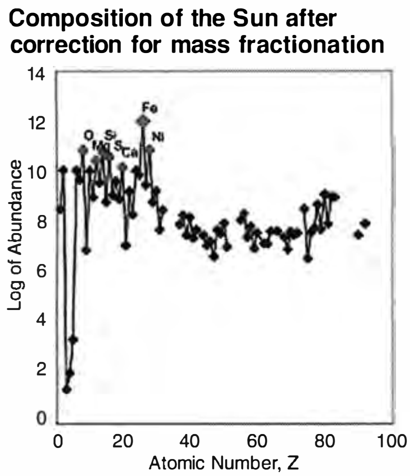
According to Manuel, the Sun itself used to be a massive star. He says the entire solar system was created out of highly radioactive debris when the star exploded as a supernova 5 billion years ago.

Manuel and a colleague hatched this theory in 1975. In 1977, their conclusions were published in the journal *Science.* In conjunction with this supernova theory, they suggested that iron from the supernova made iron meteorites, formed the interior of the new Sun, and created the iron



THE SUN IS A COLLAPSED NEUTRON STAR

In Manuel's theory, a massive spinning star becomes chemically layered near the end of its life, when asymmetric collapse occurs to conserve angular momentum (1). The infall of low atomic number elements causes an axially directed supernova explosion, producing a rapidly expanding bipolar nebula with an equatorial accretion disk (2). The Sun forms on the supernova core; cores of the inner planets form in the iron-rich region around the supernova core. The large, gas-giant planets form in the outer supernova layers (3).



When elemental abundances in the Sun's photosphere are corrected for mass fractionation, the most abundant elements inside the Sun are found to be iron, nickel, oxygen, silicon, sulfur, magnesium, and calcium—the same elements which William Draper Harkins found, 80 years ago, to comprise 99 percent of ordinary meteorites. These findings of nuclear chemist Oliver Manuel, also cohere with the nuclear structure hypothesis of University of Chicago physicist and physical chemist Dr. Robert J. Moon (1911-1989).

cores of the inner planets.

Because there is very little iron at the surface of the Sun, Manuel didn't have much luck convincing people that the heavy element played such an important role in the solar system's formation. The conventional wisdom was that the light elements seen at the surface of the Sun, hydrogen and helium, were prevalent inside the Sun and throughout the solar system. Last spring, the Arizona State team detected the footprints of iron-60 in a meteorite that circled the Sun for billions of years before landing on Earth. In a *Science* article, the team noted that iron-60 can only be made in a supernova.

"All of the iron in the Sun and Earth came with radioactive iron-60 from the supernova, along with many other radioactive elements," Manuel says. "Long-lived radioactive elements like uranium still survive, which is why the insides of the Earth are hot today."

Back in 1971, Manuel reported in *Science* the discovery of short-lived plutonium-244 inside the Earth. Like iron-60, plutonium-244 can only be made in a supernova blast.

Prior to the Galileo probe that entered Jupiter in 1996, Manuel and a University of Missouri-Rolla graduate student predicted that the hydrogen and helium in Jupiter would contain "strange xenon," made by nuclear reactions in the outer part of the supernova. Data from the Galileo probe confirmed that prediction.

In Manuel's model of the solar system's creation, heavy elements stayed close to the Sun and congregated to form terrestrial planets like Earth, while the light elements from the outer layers of the supernova formed the big gaseous planets like Jupiter.

Although the Sun's surface is covered with hydrogen and helium, Manuel says he's absolutely convinced the Sun is made mostly of iron and other heavy elements that were left over from reactions inside the supernova.

"Our Sun is a huge plasma diffuser that sorts atoms by weight and moves lightweight elements like hydrogen and helium to its surface," he says.

In 1983, Manuel studied the solar wind and found that 22 different types of atoms had been sorted by weight.

"Atoms in the solar wind showed us that the seven most abundant elements in the Sun are iron, oxygen, silicon, nickel, sulfur, magnesium, and calcium," says Manuel. "The most abundant elements inside the Sun turned out to be the same elements that are most abundant in ordinary meteorites. The likelihood of this spectacular agreement being a meaningless coincidence is less than one in a billion."

As part of a continuing effort to prove he's been right all along, Manuel's latest publication shows that an additional 72 types of atoms in the outer layer of the Sun, or photosphere, are sorted by weight. Those results, and additional evidence suggesting that iron is the most abundant element in the Sun, will be published with co-authors in the next issue of *The Journal of Fusion Energy.*

For more information and articles by Dr. Oliver Manuel, see:

http://web.umr.edu/~om/

Letters

Continued from page 7

about the upshot.

I was a chemist on the project, in the "Madison Square Area," stationed at Yale University. I was in the Corps of Engineers, as a buck Sergeant. (If I'd been in the Navy, I'd have probably been a Lt.-j.g., but that's neither here nor there.)

On page 27, Mr. Wolfe says, "'Exceptional security arrangements' are in effect for a labor force that will swell to 150,000; few know the real purpose of their work."

True, General Grove was obsessed with "security." He even wanted to "classify" the value of Planck's constant! But saner heads prevailed.

As far as I know, the official figure for those involved in the "Project" was 65,000—but that's a quibble. There may have been ancillary workers not directly involved to account for the larger figure; however, to say that "few" knew the real purpose is just not true. We all knew exactly what we were about!

Many a bull session was devoted to the yield of the projected A-weapon, with lots of gruesome projections about just how bad it could be—none of which approached the reality! The "official" story, of course, was about the peaceful use of atomic energy; but we were military personnel in wartime! It was utterly stupid to try to sell us the idea that such a massive effort, bound about with "Q" clearances, was for future "peaceful" purposes!

(My own personal claim to fame was the development of a method of preparation of red oxide, and prevention of the corrosive effects of fluoride on stainless steel. Even then we knew fluoride was bad news!)

But we *knew* what we were doing—we hoped that there would be a demonstration somewhere to convince the Japanese that their war was lost, without the horrendous loss of life that did occur. But that hope was futile, as the author points out.

However, the hope and promise of atomic power was still there! And therein lies my remark, There is *nothing* wrong with nuclear power! There is a great deal wrong with people. As long as people are involved in it, the possibility of nuclear catastrophe is always present. For example: in 1945, to be a Nuclear Plant Operator, you had to have the equivalent of three Master's degrees—in Nuclear

Science, Mechanical Engineering, and Chemistry. Only very knowledgeable, well-qualified persons were entitled to work around a "Hot Box." Now, anybody can be a Nuclear Operator! The idea is that the "Fail Safe" systems will keep the plant safe, and therefore emergencies either will not happen, or can be easily dealt with. But, as John Gall points out in his seminal work, *Systemantics*, "When a Fail-Safe System fails, it fails by failing to fail safe."

There are, for example, many ways to deal with nuclear wastes—and burying them in a mountain criss-crossed by geologic faults is not one of them! I have expounded upon that subject frequently, but Senators, having small knowledge and less interest in the subject, have uniformly brushed me off. Maybe someday I will have a forum to express the ideas.

Edward G. Robles
Franklin, N.C.

L. Wolfe Replies

My reference to the "exceptional security" dealt with the fact that a good number of the employees were being monitored by FBI and other intelligence personnel, which was not normal, even for a wartime military project. According to other personnel whom I have talked to, there was a pervasive sense that "Big Brother" was watching. Although there was a very excited exchange of ideas among scientists and workers—as Dr. Robert Moon and others who were in the "center" of the work attested—it took place "in a box," and only among those directly involved with the project.

The vast labor force that I refer to includes the tens of thousands of construction and other workers involved in building the facilities in Tennessee, and then expanding them, as well as others in factories and shops who were involved in making components for research, both applied and otherwise. In these cases, there was most definitely a lack of total knowledge of the purpose of the project, although Mr. Robles and his much smaller group may have had more complete understanding of what was being done.

In addition, as the project reached fruition, obviously many more people knew exactly what was taking place.

As for Mr. Robles's other observations, it is certainly true that people with fewer qualifications than years ago, now work with nuclear materials and at nuclear facilities. That, however, is not generally the cause of safety or other problems, the which are greatly exaggerated by the media and the hysterical environmentalists. The latter represent a far greater threat to the safety of mankind than nuclear plant operators! And, such conditions that Mr. Robles worries about would be generally solved by a gear-up of new production of modern, safe nuclear power plants, and the great expansion of our nuclear workforce to meet these requirements.

I thank Mr. Robles for his contribution to our discussion of the past, and look forward to his help in making a future without the kind of Beast-men who created and dropped atomic weapons, and have now destroyed the peaceful use of nuclear technology as well.

Shocked by Shutdown Of FFTF Reactor

To the Editor:

I was shocked when I learned about the plan to permanently shut down the FFTF nuclear reactor. I deeply appreciate your efforts[1] to save the FFTF and was stunned by the recent execution of such a foolish decision. We have been lied to that the reason for the shutdown is cost of operation, when the clean-up expenditure is equal to what it would cost to operate the reactor for another 20 years!

We have been lied to, that there is no long-range mission that can be assigned to the reactor, when, in fact, we need a long-range research program to develop and deploy all the fuel cycles that are required to eliminate the actinide elements from nuclear waste, thereby dramatically reducing the storage requirement down to a few hundred years.[2]

With further development of controlled transmutation of elements, the storage requirement could be reduced even further. Finally, the FFTF was the only nuclear facility in the United States that could produce medical isotopes needed for cancer treatments, and especially the very promising liquid radiation treatment[3, 4]

Environmental organizations have betrayed their dishonesty by not rallying to support the recycling of nuclear waste as a research mission for the FFTF. At this point, the only logical course of action is to initiate a massive development and deployment of nuclear-energy-production technologies internationally.

We cannot continue to rely on fossil fuels;[5] we cannot continue to tolerate stupid excuses such as "it costs too much," and we cannot have peaceful international relations and stability if this is not done on an international scale. The foolishness behind shutting down the FFTF is only a small nugget of the mental dysfunction represented also by the foolish arguments that are being put forth to justify starting a nuclear war against Iran: Because the Iranian government had the indecency to implement a much wiser energy development policy than the barbarians who run things around our neighborhood.

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Notes

1. M.M. Hecht, 2005. "Save the Fast Flux Test Facility," *21st Century*, Spring 2005, pp. 68-73.
2. C.E. Till, 1999. "Nuclear Fission Reactors," *Rev. Mod. Phys.*, Vol. 71, pp. S451-S455.
3. See http://www.medicalisotopes.org/
4. J.M. Connors, 2005. "Radioimmunotherapy—Hot New Treatment for Lymphoma," *N. Engl. J. Med.*, Vol. 352, No. 5, pp. 496-498.
5. D.L. Goodstein, 2004. "Out of Gas: The End of the Age of Oil," (W.W. Norton & Company).

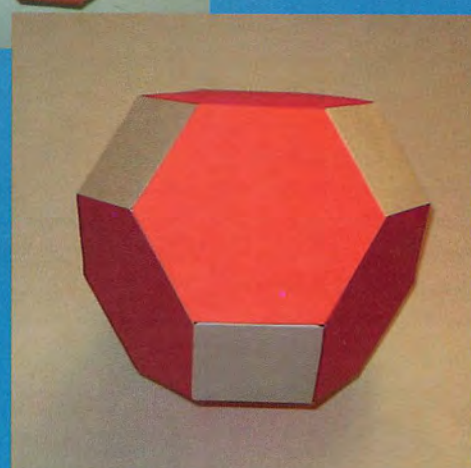
EXPLORING THE SHAPE OF SPACE

Space isn't an endless checkerboard, as Hal Vaughan shows in his feature article "Archimedean Polyhedra and the Boundary," which describes his exploration of the Platonic and the Archimedean solids. His arrangement of the polyhedra families takes you to the limits of physical space, challenging you to conceive of the unseen intention behind the order of the universe—and to construct the geometric solids yourself.

Truncated icosidodecahedron

Hal Vaughan with some of the models from his geometry toolchest.

Truncated cuboctahedron



Truncated octahedron

In This Issue

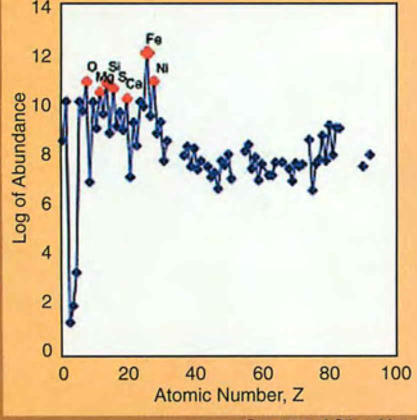
FRANKLIN ROOSEVELT'S ECONOMIC SHOCK FRONT

To revive the world's collapsing physical economic capability requires the "shock wave" effect of directed credit generation and massive investment in infrastructure building. This LaRouche Youth Movement case study of how Roosevelt's Rural Electrification Administration changed America provides a model for what is needed today, and serves as an introduction to the deeper issues in the LaRouche-Riemann approach to the science of physical economy.

SCIENCE and the LaRouche Youth Movement

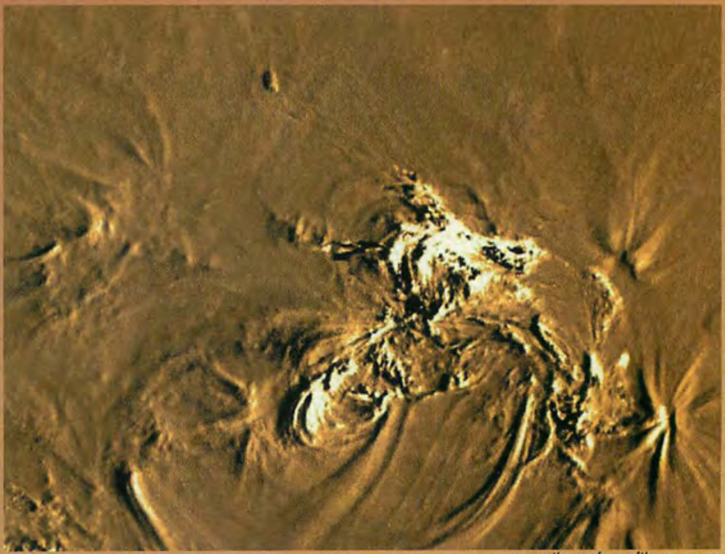
Members of the LaRouche Youth Movement in Los Angeles examine an apparatus consisting of three solenoids arranged in a triangular shape to demonstrate the effect of mutual interaction of the fields. Author Sky Shields is in center.

Composition of the Sun after correction for mass fractionation



Courtesy of Oliver Manuel

The abundance of elements in the Sun after correction for mass fractionation, according to Dr. Oliver Manuel.



www.thesurfaceofthesun.com

Running difference image of iron (Fe-IX,-X) from NASA's TRACE satellite imaging program suggests a solid surface to the Sun.

THE SUN'S CORE IS IRON

In the Astronomy Report, University of Missouri nuclear chemist Oliver Manuel presents his revolutionary findings that the Sun is made up of the same elements found on Earth and the meteorites—iron, nickel, oxygen, and silicon.

In related work analyzing NASA images of the Sun (right), independent researcher Michael Mozina recently found the emission lines for iron, calcium, silicon, and other elements, leading him to conclude that the Sun has a solid surface below the gaseous outer layer.