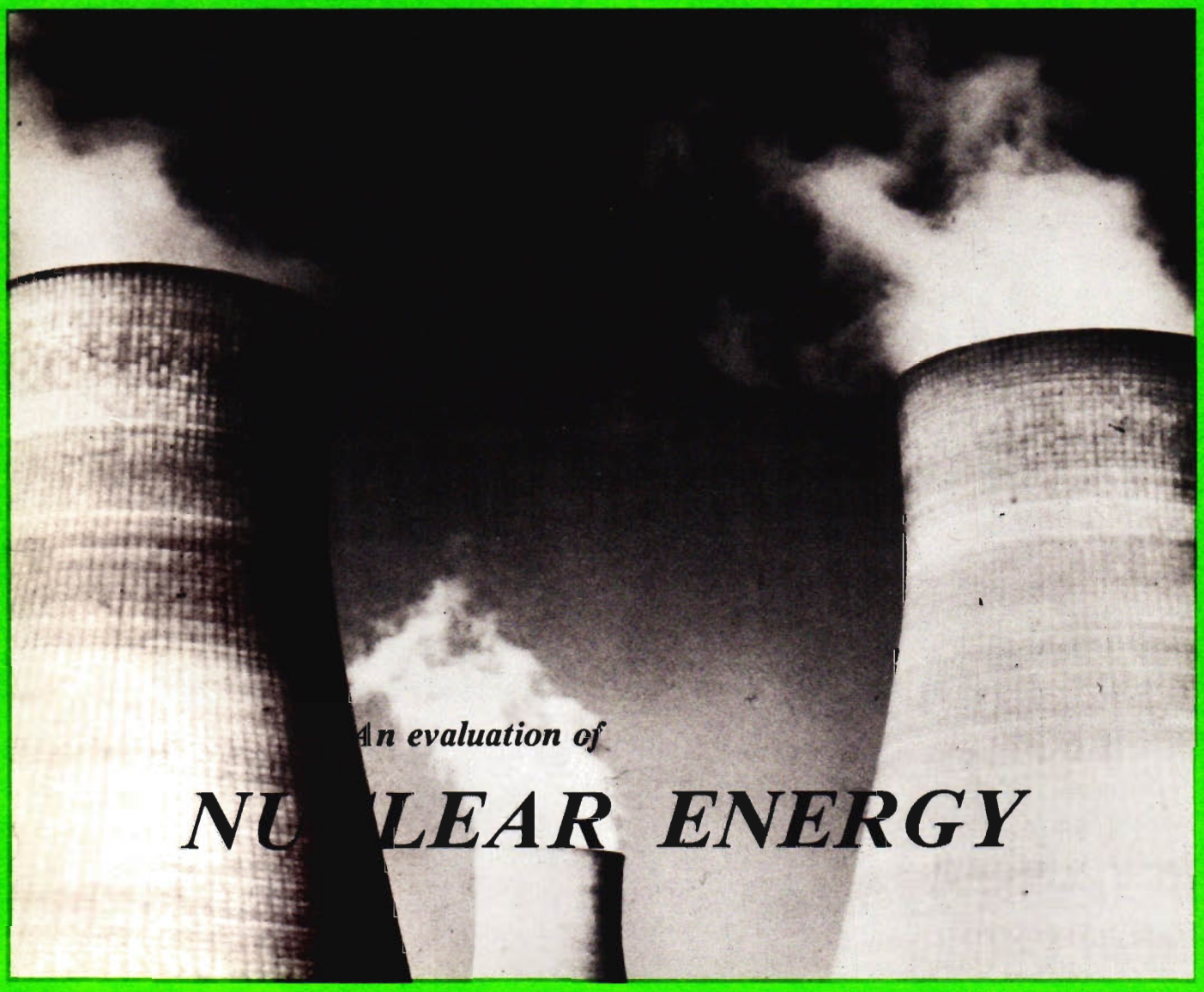
JOURNAL OF THE AMERICAN SCIENTIFIC AFFILIATION

An evangelical perspective on science and the Christian faith

(US ISSN 0003-0988)



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"The fear of the Lord is the beginning of Wisdom." Psalm 111:10

VOLUME 32, NUMBER 2 **JUNE 1980**

MEMBER EPA EVANGELICAL PRESS ASSOCIATION

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AMERICAN
SCIENTIFIC
AFFILIATION

JUNE 1980 PRINTED IN THE UNITED STATES OF AMERICA VOLUME 32, NUMBER 2

HOW SIMPLE LIFE WOULD BE IF ONLY THINGS WEREN'T SO COMPLICATED!

How common it is for all human beings to seek simple solutions to life's problems. Conservative Christians and engineers are two classes of people who probably find the simple solution particularly attractive. Many conservative Christians have been handed the "answers" to all of life's problems in a complete systematic theology. They seek security in the assurance that they hold absolute knowledge. Life may look complicated, but it really is not: Jesus is the answer. It is the liberals and the confused humanists of the world who try to complicate the situation and insist that the biblical message of salvation through faith in Christ is theologically simplistic. It is the simple wisdom of God that puts to nothing the foolishness of men. And *in this*—certainly the conservative Christian is basically right.

Many engineers are trained for years in curricula that prepare them to seek the single correct answer following the single correct set of procedures until they arrive at a final result, which—by being quantitative—is essentially simple. A couple of summers ago I held an informal seminar called, "What's A Nice Person Like You Doing in Engineering?" It proved to be fairly traumatic for the trained engineering student to come to grips with the world of paradox and complementarity, of uncertainty and unknown roads. Within the context of the known—or the mostly known—the engineer is basically right in his approach.

But the living of life demands far more than this of both Christian and engineer. The Christian may know that Christ is the answer, but find it much more difficult to determine what the question is. By assuming that justification and glorification come together, he forgets that long and painful *process* of sanctification: the task of applying Christian faith and principles to the very real problems of a very upset world, in which the specific issues are not themselves dealt with biblically. The engineer may be on sure ground when he interpolates from experience and empirical data, but he is on less sure ground when he tries to extrapolate to phenomena in the future within the context of personal, political and economic reality. By assuming that technical problems can be dealt with independently of our whole human interrelated responsibilities, he is often led to insist that solutions are relatively simple after all. Perhaps the most afflicted of all is the conservative Christian engineer or scientist—and, I presume, that this is one reason why we are attending this Annual Meeting.

The simple answer is epitomised by the political slogan, and the general belief that all that is needed is to

This is one of three keynote addresses on the theme, "Choices We Face," presented at the 1979 Annual Meeting of the American Scientific Affiliation at Stanford University, Stanford, California.

choose "the right side" and then chant it into success. We have seen the placards held high: "Nuclear energy is as natural as sex." "No more Nukes!" "More Nukes and Less Kukes!" "We Can Live Without Nuclear Energy!" I'm waiting for "Make love, not nuclear energy" to surface. A newspaper report quoted a young man's solution to the gas crisis:

> Since this gas thing is a big hoax, I think we should just take the OPEC nations and blow them up and take their oil. That will solve the gas crisis.[1]

It is amazing how difficult it is for people to realize that the problems we face are not simple—and that they are not, by and large, simply due to someone else being nasty to us. How difficult to realize that the most brilliant of us is often ignorant—as well as possibly malicious. Another Letter to the Editor made an incredible statement along this line.

> I am shocked at the apathy of all our upturned faces waiting for Skylab to fall from the sky next week. . . . It is hard for me to believe that, in a country as advanced as the U.S., our scientific and technical know-how can't at least detect a few hours in advance where Skylab will fall. . . . And this in a country that can send men into space and bring them back safely.[2]

We face the very grave danger of believing that science is omnipotent, and therefore attributing any failure to human malevolence. Having rejected the possibility of ignorance or impotence, the author above then continues with his solution:

> NASA is right on our back door. I think we should let our "research" neighbor know how we feel. We picket spots like Diablo Canyon, but turn our eyes away from the fact that the odds given for *someone* to be hit and killed next week are 152 to 1, and that's *not* infinitesimal. Let's shout out our objections to NASA, the City Council, Civil Defense, and anyone else who should help us.[2]

Simple answers, simple causes, simple motivations, simple solutions are almost always false and illusory when we are dealing with the problems of the biological, sociological and spiritual organism known as human life on this planet.

Daniel Moynihan had wise words in his farewell address to the President's Cabinet in 1970:

> A century ago the Swiss historian Jacob Burckhardt foresaw that ours would be the age of 'the great simplifiers,' and that the essence of tyranny was the denial of complexity. He was right. This is the single great temptation of our time. It is the great corruptor, and must be resisted with purpose and energy. What we need are great complexifiers, men who will not only seek to understand what it is they are about, but who will also dare to share that understanding with those for whom they act.[3]

The contention that the right course of action can always be easily known is a delusion. Situation ethics, for example, betrays us when it portrays "doing the loving thing" as the *answer* to our difficult choices. "Doing the loving thing" is the *problem*—not the answer. What does it mean to do the loving thing in the real world in which we live? We could well adopt Moynihan's words as a motto on which to meditate: "*The Essence of Tyranny is the Denial of Complexity.*" There is no substitute for hard work, sound scholarship, authentic science, and biblical theology—if we are even to begin to rise to the challenge.

I was impressed by the advice of James F. Allcock, Purchasing Manager for the British Gas Corporation:

> I believe that a Christian can be persuasive quite beyond his station in life. He should be diligent above the rest and I believe that he should be clear headed above the rest because he dare face the truth and tell the truth and face with courage the conflicts of opinion which are the stuff of the business life. But I do not think that either prayer or flair will see you through. There is no substitute for a profound competence at your job and this will be the source of your persuasiveness.[4]

Neither "prayer nor flair" alone, but hard work and "profound competence."

Before someone points it out, let me confess that even my urging you to avoid the simple approach is *itself* in some ways too simple! For we are faced with the paradox that although a simple solution does not exist for a complex problem, the only way to start any kind of solution in the context of human society is to produce a simplified analysis of the problem! We in the ASA know this truth only too well. Our position that the question of evolution, for example, is a complex one and should be faced slowly and carefully with all possible inputs from science and the Bible, has not—at least as far as numbers influenced are concerned—had the same degree of appeal and apparent success as the approach of others of our brethren who see the issue simply and can give at a moment's notice the whole and complete answer. Every four years we see the presidential campaign degenerate from the meaningful to the simple to the simplistic to the absurd; yet how else does the democratic system work?

There *is* one simple truth that appears to be almost inescapable: we are living on a finite earth with finite resources and finite capabilities for being changed from its natural state. When the finite capabilities of the earth are pressed to their limit, something drastic must change in the way that human beings view their relationship to the earth and to one another.

Although we are now daily being forced to change our perspective, we have—one might say from the beginning of the human race until the last ten years—lived as if the earth were not finite, as if it were so big that it remained constant and unaffected by our presence and our activity. We have thought of *ourselves* as living *on* the earth, but we have not reckoned with the fact that this kind of separation is to a large extent a fiction: our lives and the life of the earth are bound together. Francis Schaeffer has emphasized for us that although from the perspective of redemption mankind is unique and separated from the rest of creation, from the perspective of creation mankind is one with all the other creatures and creaturely things that God created.[5]

Some Foolish Thoughts

Bear with me for a few moments of foolish thought. Consider that until 100 years ago the world's supply of energy came only from burning wood. Then came the use of coal, followed by oil, and natural gas. We have used the fossil fuels in a sequence in which their desirability has increased but their availability has decreased. We all know the benefits to society that accrued because

of this succession—although there are still some old-fashioned minds who might question whether the actual extent of these benefits are as great as we think they are. But we have not paid much attention to the *cost* of these developments. We have lost sight of the fact that the very process of energy production is and always has been destructive in some way of human life and values.

We have not paid much attention to the shattered lives of our coal miners and the price they have paid in black-lung disease. When we think about stepping up coal production by orders of magnitude, we should think about these things.

We have not paid much attention to the men who have spent years underground mining for precious metals, frequently at the cost of their health or their lives. We forget that in ancient times metal mining was usually the fate of condemned criminals or slaves.

We are only now coming to realize how heavily our national foreign policy is controlled by our thirst for energy. Art Buchwald is a political humorist, but like all such humor it is most pungent because of a core of truth. In a recent column on "Good Guys and Bad Guys," he said,

> The President of Mexico, Jose Lopez Portillo, is a good guy though he has publically scolded our president at a luncheon. Mexico has large quantities of oil and gas. President Somoza of Nicaragua is a bad guy because he violates human rights and doesn't have any oil or gas. Libyan leader Muammar Khadafy is a good guy because although he violates human rights and supports terrorism he does have oil and gas. Prime Minister Menachem Begin of Israel is a bad guy because he won't give up the West Bank of the Jordan. President Carter has been very harsh about Begin because he knows Israel has no oil and gas.[6]

I am wondering—in these foolish thoughts that you are putting up with—whether perhaps we didn't make a serious mistake in judgment some 100 years ago. I wonder if we had been able to assess the implications of our growing energy usage then, and the forms it was taking, whether we might not have been wise to develop quite differently, if we could! I am wondering in these foolish thoughts, if maybe, just maybe, the earth wasn't really intended to support the kind of living that we have imposed upon it in the last 100 years. Our energy-thirsty world, and of course I speak particularly of the Western World where energy exploitation has been maximized, has led us to so pollute the air in centers of population that serious dangers to health grow yearly and the falling of acid rain because of sulfur dioxide in the air becomes a common and recurring danger, to so infiltrate our life with chemical additives and biologically active materials that we often don't know the effect until years and tragedies later, to so increase the carbon dioxide content of the atmosphere that profound and life-upsetting changes in earth's climate and ability to produce food may well occur within the next 100 years because of the greenhouse effect, and to so rapidly use up non-renewable resources in the form of minerals and metals that drastic steps will be needed to prevent major shortages in the near future.

Proponents of nuclear energy frequently defend themselves by saying, "The modern protest against a new source of energy with some dangers is not new. Why, when coal mining started a hundred years ago, there was the same kind of protest. And everyone knows how foolish that protest was." Sometimes, in my foolish thoughts, I wonder how foolish it really was.

How High the Cost?

One of the great ethical questions brought on by our present situation is this: *How indifferent can the majority be to the suffering of the minority needed to produce a good for the majority, and how indifferent can the minority be to the deprivation of the majority needed to preserve a good for the minority?*

How many coal miner's lives are we willing to shorten for the benefit of the rest of the society? How many sacrifices should the rest of society make to minimize danger to coal miners?

If any of us knew that a human being would die in order for us to have an hour's worth of electricity—and particularly if we knew that human individual involved—few if any of us would insist on having our electricity anyway. But if we are told that there is a 1% chance that a human being will die if we have one hour's worth of electricity, we stop to think. That's still too big a risk, we probably decide—for on the average one human being would still die for every 100 hours of electricity. It will be hard to do without those 100 hours of electricity, and maybe the 1% change is overestimated, so maybe . . . But if we are told that there is a one in a million chance that a human being will die sometime in the next 10 years for our one hour's worth of electricity, and if that human being is someone we will never know, who lives in poverty in a strange land as part of a foreign culture, we do not hesitate for long. Give up one million hours of electricity in order to save the life of some poor wretch who would probably die anyway from some other disease—surely that is too great a price to pay! We take the electricity and hope that we will not learn of its cost.

Is one human life worth one million hours of electricity? You may still be of the opinion that one human life is worth *any* sacrifice. But you'll forgive me if I don't believe you! Otherwise wouldn't we live differently? Wouldn't we refuse to carelessly use energy supplies because we know that men and women have inevitably lost their lives in obtaining them for us? Wouldn't we use an energy-related basis for our purchasing priorities? Wouldn't we work for the abolition of the automobile because we know that thousands of lives are lost each week only because automobiles are being driven—not considering the indirect costs of automobile pollution but only the direct loss of life through automobile accidents? Wouldn't we accept a massive reduction in the availability of energy that would drastically change the way we live—not necessarily for the worse, however—rather than press for the expansion of energy production by whatever means, whether fossil fuel or nuclear?

George Mavrodes has given us a penetrating parable called "The Salvation of Zachary Baumkletterer."[7] Baumkletterer takes seriously the poverty, hunger and need of others in the world and refuses to eat or use more

than "his share" of the total world's resources. Many try to dissuade him, including his Pastor, when his health is affected. Finally he collapses at his desk at work and is taken to the hospital. When he is at last discharged, the Dr. in attendance says, "I can practically guarantee that he'll be as good as new, fully cured. . . . Some of the treatments we have now are just amazing. And when the hair grows back over his temple, you won't even be able to see the scar." Was Baumkletterer wrong? If he was, *do we know why* and what he should have done instead, caring the way that he did?

We have "progressed" so far from the ecological balance of nature that almost every action we take to sustain life in one area threatens it in another. How safe must an action be before it is taken? We would like to reply, "It must be absolutely safe." But then we realize that it could never be taken.

I have heard some Christians say that Christians never have to choose between the lesser of two evils, but I think they have never thought very deeply about the real problems of the imperfect and sinful world in which we live.

Are There Limits?

In spite of this situation, there are still many today who face the future with equanimity, not based on any basic Christian trust in the sovereignty of God over His creation, but based on human ability to resolve all technical problems and move on to the bigger problems of reshaping human society and nature.

I share with you just two such technical problems for your consideration. They concern the finiteness of the earth as the site for a growing human population, and the finiteness of the earth as the source of minerals and metals in the presence of a growing population. My immediate reference is a book, *Consequences of Growth*, by Columbia University physics professor Gerald Feinberg,[8] but I suspect that his suggestions would be fairly generally held by a number of others.

The solution to the finiteness of the earth with a growing population is the colonization of space. Colonization of earth characterized the day of the "infinite earth" with lots of room at the open frontier. Development of the wheel, the boat, the train and the airplane pushed back every frontier on earth so that they are all gone. But space travel is the new freedom—the freedom to push back the frontiers off earth into the universe! As in the vision of Arthur Clarke in *2001*, mankind's freeing of itself from the confines of earth by rocketing into space is today's evolutionary counterpart to the first time that pre-human creatures threw their weapons into space and moved to a new cultural form. Space colonies will consist of hollow rotating shells, producing their own gravity and their own internal environment, obtaining their materials and minerals from the moon and the asteroids. Each colony will support something like 10,000 people. Such colonies are proposed to make a major difference in the number of human beings that the universe can support. But a simple consideration of the fact that the present population of the earth is about 3 billion people, indicates that a 1/3 increase in the human population of the universe would require 100,000 such space colonies.

Now you may pigeon-hole me as being old-fashioned and without vision, but this does not seem to me to be any kind of solution to the population problem, technical or otherwise. *If we can afford to do it*, there may well be interesting and informative activities that we can carry on in space. But to suppose that this is a viable method to allow for a large increase in human population seems to me totally unreasonable. Forgetting for the moment the energy and resource problems in putting up a vast number of such space colonies, such speculation seems to always assume that human nature will somehow change in the process. It never seems to occur to anyone that such space colonies would probably be engaged in intercolony warfare before many generations passed. That we can export human beings into space but leave human nature behind appears to be a general fallacy of such thinking.

The solution to the finiteness of the supply of raw materials for the earth is to obtain whatever we need from the earth's crust itself. Having shown that the contents of rock in the top 100 meters of the earth's crust contain sufficient materials and minerals to meet our needs for a long time into the future, Feinberg proposes that we need only destructively treat several square miles of land each year to a depth of 100 meters to obtain all the resources of this type we will need. This would, it is true, require a capital investment equivalent to 25 years at the current rate in the metals industries, and a technology assessment far more long-range than anything successfully carried out yet. But these are, after all, only technical problems.

We have moved rapidly away from the ecological equilibrium of planet earth. In my foolish thoughts earlier I speculated that we might have chosen to avoid this by different choices in the past. I do not call it optimism to believe that further rapid divergence from ecological equilibrium is the solution for the future.

A Final Limit

There is one aspect of the finiteness of the earth that cannot be omitted, and about which there is no debate. Let us suppose that new acceptable sources of energy are developed so that we have more energy available than we know what to do with. We still cannot use this energy beyond a certain amount without drastically altering the temperature, climate and productivity of the world. When the amount of energy expended on earth (and this includes all sources of energy except terrestrially-collected solar: fossil fuels, nuclear fission, nuclear fusion, even solar energy intercepted in space and beamed to earth with microwaves) becomes of the order of 1% that regularly received on earth from the sun, we can expect the average temperature to rise by about 1°C. As a consequence we can expect a shifting of agricultural regions from fertile to infertile, a magnification of the CO_2-related temperature rise, and a melting of the polar ice caps. If, in the future, the energy usage of

the rest of the earth were brought up to that of the US, and if we in the meantime did not increase our usage by more than a factor of two over that at present, we would be already worldwide within a factor of two of this limit! In fact, in major industrialized areas of the world (e.g., New York city that survives only because of the heat sink of New Jersey) we are already *at the limit*. Even the greatest technological success on earth is not going to budge this limit.

Simple Solutions in Other Areas

Our discussion has been concerned almost exclusively with the area of energy and materials. But concern with the danger of simple solutions and sloganeering extends to many other issues as well. Abortion, for example, lends itself admirably to sloganeering. At a petition table on Palmer Square in Princeton, we recently saw the following gem: "If men got pregnant, abortion would be a sacrament."

Pro-abortionists are "pro-choice" and "pro-women's rights"; anti-abortionists are "pro-life." Pro-abortionists speak as if the developing fetus were a material attachment to the woman's body like a wart or an appendix; anti-abortionists speak as if the barely fertilized blastocyst were a whole human person.

It is only by refusing to become politicized by such sloganeering, and by being willing to step back and allow truth to be more important than our own possibly fallible perceptions, that such issues can be treated at all in the real world with real responsibility.

Disagreement Among Christians

It may well be that many of you will not agree with some of the points I have tried to make. *That is all right.* I make no claim for having a corner on the truth.

We can be sure that there is *a* Christian approach (or possibly several) to any problem we face. But to say that there is a Christian approach does not mean either that such an approach is *uniquely* Christian, or that such an approach is something that all Christians can easily agree on.

The details of the best Christian approach—as distinct from the motivation—to technological problems should not be expected to be *uniquely* Christian: a weapon to be taken up in conflict with non-Christian interests. When a child falls into a well, both the Christian and the non-Christian come up with the same solution: pull the child out. Clearly this is the best Christian approach, but there is nothing about lowering a rope and pulling that is uniquely Christian or has apologetic value in itself. I once had a paper turned down by a leading Christian magazine with the comment that it appeared to be "only practical" and not uniquely Christian. We must get past this barrier and learn to thank God for the practical solutions to practical problems.

We also cannot expect that all Christians are going to agree on what that solution should be in every case. As Allcock warned us in the earlier quotation, the Christian cannot expect to make a meaningful contribution by prayer and flair alone, but must be prepared for lots of hard work. Christians who accept different facts will normally come to different conclusions. Lots of hard work in a complicated area may lead—at least for a time—to the honest conclusion that we do not know enough to answer the question dogmatically or conclusively; caution, concern and more hard work are the only answers for the Christian.

Climbing on either the pro- or the anti- bandwagons and carrying signs or getting petitions signed is often only an easy road; I call you to a more responsible action than that. I call upon you to know what is to be known, and to recognize what is not known. I call upon you to separate fact from culture, established demonstration from optimistic hope, and absolute condemnation from biased prejudice. I call upon you to be faithful stewards of Jesus Christ, willing and anxious to play in your personal life's example and in your social contacts the role of caretaker and deputy of God's world for God's people.

Let us not allow differences in interpretation of what it means to act in a Christian manner with respect to the problem we face, create dissensions or name-calling among us. Let us never be guilty of making our own faulty and limited technological judgments the cause of breaks in the fellowship of the Holy Spirit. But let us realize that differences in Christian opinion are a call for more work, more prayer, more understanding, more patience, more humility, and more openness to new inputs.

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A Theological View of Nuclear Energy

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Nuclear energy has been discussed most extensively in terms of its scientific, technical and engineering aspects. More recently, with the increasing public controversy over nuclear electric power, the political, sociological, and ethical aspects of nuclear energy have been extensively discussed. There remains a third category, the theological, of important relevance to this controversy, and this has not been discussed at all in any systematic or primary way. Such a discussion, if it is to be undertaken at all, must approach its subject from an explicit recognition of the relationship of man and nature to God and the insights and requirements that that relationship entails.

The terms of reference of such a discussion are normally excluded under accepted canons of scientific discourse. The point of view, methodology, and presuppositions of theology have generally seemed alien to science, and a discourse on any subject from a theological perspective has been properly excluded from journals addressed to a scientific or technological audience. Now that the nuclear controversy has become a major concern of the World Council and National Council of Churches and numerous other religious groups, however, it may be in order to indicate to such an audience how the controversy appears when viewed theologically, as distinct from ethically.

The basis for this discussion is the understanding of nature, man, and God revealed through the historic experience of Israel as witnessed in the literature that came to constitute the Hebrew Bible and the Alexandrian Greek Septuagint. Thus, it confines itself to theological categories derived from the religious heritage common to the three great monotheistic world religions. Theological aspects specific to Judaism, Christianity, and Islam would need to be covered in separate essays. A theological perspective on nuclear power derived from Hinduism, Buddhism, and other oriental religions would be quite different, and the contrast between such a treatment and the one developed here would be interesting and informative.

Nuclear Energy in Creation

From the first use of fire by primitive man to the middle of this century, the only fuels available to man for heat and work have been chemical. For a long time the primary fuel was wood and dung; then came peat and coal, and finally oil and natural gas. Burned with the oxygen in the air, these fuels have been man's primary source of energy apart from direct solar heat and wind power. Through long use, they have seemed a natural and normal part of the world as God made it and a universal component of all creation. In contrast, the recent employment of nuclear energy in electric power plants seems to many an abnormal and unnatural intrusion by technological man—a man-made addition to the created order as God designed it. Seen in this way, nuclear energy and its products, such as radioactive wastes and plutonium, are looked upon by many as contrary to God's purpose in creation and inherently and irredeemably evil.

This way of judging the status of energy in creation is the result of a limited perspective. In the universe as a whole the situation is just the reverse. From the perspective of God's creation as a whole, an ordinary fire is an extraordinary and exceedingly rare and abnormal phenomenon. It can occur only on a planet with a long evolutionary history of living things having an atmosphere containing free oxygen. In our solar system it is only possible on the earth. None of the other planets or planetary satellites have any of the ingredients needed for a fire. One would probably have to travel at least a thousand light-years away from the earth before encountering another planet on which organic fuels and free oxygen necessary for an "ordinary" fire would be available. In such a journey, however, nuclear energy would be everywhere encountered. Our sun is a natural nuclear power plant, and there are over a hundred billion other main sequence stars like it scattered throughout our galaxy. The billions of other galaxies similar to our Milky Way are equally thickly populated with them. Indeed, a large fraction of all the matter in the universe is incorporated in such "nuclear power plants." It is a sobering thought that God has made more of them than he has anything else.

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Reprinted from Nuclear News, *February 1979, pp. 79-83.*

It is true that this statement applies to fusion energy and not to fission, whose energy is released in the universe only following stellar explosions. But a universe from which nuclear power had been "outlawed" would be a dead universe, with no warmth, light, or life in it, and devoid of any creative potential.

Nuclear energy is the universal, common, and natural kind of energy in creation as a whole. Indeed, the other forms of energy are all derived from it. All the wood, coal, oil, and gas man has ever burned came from our natural nuclear power plant, the sun, through photosynthesis—so too with water power and wind power. Without realizing it until this century, we have really been dependent on nuclear energy all along. Now that we have begun to generate electricity directly in nuclear power plants of our own design and construction, we are merely tapping directly the universal energy source for all of creation that previously we have used only indirectly and derivatively.

Similar considerations apply to radioactive wastes. Less than a hundred million years before the birth of our solar system, an immense and cataclysmic explosion of a collapsing star, a supernova, generated enormous quantities of highly radioactive materials of all the chemical elements through thorium, uranium, and plutonium to californium. The radioactive wastes from this explosion were spewed out into the surrounding gas and dust from which the sun and its family of planets were formed four and a half billion years ago. The earth and all the other planets were loaded throughout with radioactive waste at their formation. Most of the original radioactivities, including plutonium, have long since decayed to stable elements in the intervening four and one-half billion years, but some with half-lives of a billion years or more, such as uranium, thorium, and potassium-40, are still present. The heat generated by their decay has given the earth's crust its plasticity and geologic dynamism, evident in the drift of continents, in earthquakes, and, most visibly, in volcanoes. When we bury deep in the earth's crust the radioactive wastes we generate, we shall not be adding anything foreign to it, nor will we ever add more than a minute fraction of what is already there. True, for a few centuries our wastes from nuclear power will be very much more intensely radioactive than their surroundings, but after some thousand years they will have decayed to a level comparable to that of natural radioactive ore bodies, and eventually they become less radioactive than the original uranium from which they were produced. Radioactive waste too is an integral part of the created order.

Plutonium is a natural and normal chemical element in the periodic table of the elements, with the same status in creation as silver, lead, or uranium. Here and there throughout the universe, in occasional supernova explosions, it is being made all the time. In at least one instance we know that one and three-quarters billion years ago, when the fissionable isotope of uranium of atomic weight 235 was four times as abundant as it is now, several natural "light-water reactors" intermittently went critical and generated a ton or more of plutonium.[1,2] This was in what is now the country of Gabon in Africa. Such natural fission reactors must have been a frequent occurrence in earlier stages of the earth's history. Once it is produced, plutonium radioactively transforms into uranium, essentially completely in less than a half million years. As a result, apart from man's nuclear activities, plutonium does not occur in the earth's crust now except in miniscule quantities generated all the time in uranium by cosmic ray neutrons. But this does not make it "man-made" or "unnatural."

One cannot reject nuclear energy or its products as unnatural or inherently evil and still retain the biblical doctrine of creation. In that doctrine God is "maker of heaven and earth, of all things visible and invisible," as the Creed of Nicea states it, or as it is said even more emphatically in the prologue to the Fourth Gospel:[3] "*All things were made through him, and without him was not anything made that was made*" (John 1:3). To do otherwise is to adopt a Manichaean view of creation, or a Zoroastrian dualism, in which the good parts of nature are created by God and the remainder by an evil power co-equal with him but independent of him. Moreover, in the universe as a whole, nuclear energy is clearly a great good, and so is to be accepted in the words of the First Epistle to Timothy, "*For everything created by God is good, and nothing is to be rejected if it is received with thanksgiving*" (4:4). There is no way we can claim that nuclear energy was not intended by God, or that some power other than God is responsible for it.

Nuclear Energy and Providence

When it was realized near the end of the last century and early in this century that the earth had been stocked, in addition to coal, with massive resources of oil and natural gas, it seemed marvelously providential. This immense energy gift has contributed enormously to man's welfare and potential, even though too much of this buried treasure has been thoughtlessly and foolishly squandered. At first this resource seemed limitless, but just as our domestic production of oil was beginning to dwindle and we realized that by the end of this century the enormous pool of oil in the Middle East plus other recoverable reserves elsewhere in the earth would also be declining, we have become aware that the earth has also been stocked with another, even more potent, and thousands of times more ample, energy reserve.

The gas diffusion plants in the United States which for thirty years now have been enriching natural uranium in its fissionable light isotope have also been discharging quantities of depleted uranium assaying about 99.8 percent in the abundant heavy isotope of atomic weight 238. These "tails" of the gas diffusion plants, as they are called, have been collected in steel drums, each containing over 9 tons. By now over 20,000 such drums have accumulated, and their number increases every day. With 10 passes through breeder reactors, some 70 percent of this uranium can be converted into the nuclear fuel plutonium by using an already developed and demonstrated technology. This amount of plutonium in nuclear power reactors can generate roughly the same amount of electricity as all the recoverable petroleum the earth ever contained or as much as the total recoverable reserves of coal in the United States. By the time breeder reactors are in general commercial operation, we will have in hand at least twice as much of this depleted uranium

already mined, processed, and purified. This enormous energy reserve provided for us just as the crisis of the exhaustion of our petroleum reserves has come upon us is surely an amazing instance of perfect timing in the revelation of God's providence. Moreover, it can be used with essentially no adverse effect on the environment, even including the final disposal of the radioactive wastes. The only thing in the way of our grateful acceptance of this gift is fear.

The Blessing and the Curse of Nuclear Energy

The ancient story of creation in the first chapter of Genesis concludes with a summary of what God accomplished in the crowning achievement of man: "*So God created man in his own image . . . and God said to them, 'Be fruitful and multiply, and fill the earth and subdue it; and have dominion over the fish of the sea, and over the birds of the air, and over every living thing that moves upon the earth*' " (1:27, 28). The long history of man on this planet has been marked by a steady increase in the human population and an ever-growing extension in the exercise of human dominion over all other creatures and the earth itself ("*let them have dominion . . . over all the earth . . .*" [1:26]. The twentieth century seems to be the one destined finally to see the fulfillment of this commandment. Man *has* been fruitful and multiplied and by the end of the century will just about have filled the earth. A jet flight over almost any part of the earth provides a convincing demonstration of the reality of man's dominion. Everywhere the cities and highways, the fields and factories of man are evident on the land, and on the oceans his boats and ships and supertankers plow the sea lanes. Man is rapidly approaching the limit both of his fruitfulness and of his dominion.

The benefits of man's God-given dominion have long been extolled in glowing treatises on progress and utopian visions of scientific and technological achievement. Only recently have the dangers and threats of unrestrained dominion begun to be widely recognized and discussed in terms of ecology and the environment. In what has turned out to be a landmark paper, Lynn White, Jr.,[4] found the cause of our ecological crisis in this same passage from Genesis. But he was speaking of dominion exercised as a mindless domination of nature, a practice not peculiar to Western Christian civilization. This is evident from the ecological damage wrought by the engineering and agricultural achievements of classical pre-Christian Rome. The biblical understanding of man's dominion over the earth is one of stewardship rather than domination, as is evident from the symbolic meaning of Eden as a garden that man is responsible for tending and as is made vividly explicit in the following passage from Deuteronomy:

> For Yahweh your God is bringing you into a good land, a land of brooks of water, of fountains and springs, flowing forth in valleys and hills, a land of wheat and barley, of vines and fig trees and pomegranates, a land of olive trees and honey, a land in which you will eat bread without scarcity, in which you will lack nothing, a land whose stones are iron, and out of whose hills you can dig copper. And you shall eat and be full, and you shall bless Yahweh your God for the good land he has given you.
>
> Take heed lest . . . when you have eaten and are full, and have built goodly houses and live in them, and when your herds and flocks multiply, and your silver and gold is multiplied, and all that you have is multiplied, then your heart be lifted up, and you forget Yahweh your God. (8:8—14) . . . Beware lest you say in your heart, "My power and the might of my hand have gotten me this wealth." You shall remember Yahweh your God, for it is he who gives you power to get wealth. . . . (8:17—18).

The true religious model of dominion in Western civilization is to be found in the extraordinary pastoral symbiosis of man and nature that the Benedictines slowly achieved as their monasteries spread over Europe and England. At the same time, however, dominion can become an intolerable burden that man may long to lay aside, as with the Franciscans in contrast to the Benedictines. But this is not possible. It is inescapably linked to man's freedom and so is not only a wonderful gift but a terrible and agonizing dilemma for sinful man. Jesus ben Sirach puts this dilemma forcefully in a remarkable passage in the *Apocryphal* book of *Ecclesiasticus*, "*It was he [Yahweh] who created man in the beginning, and he left him in the power of his own inclination. . . . Before a man are life and death, and whichever he chooses will be given him*" (15:14, 17). Because he is free, man cannot escape exercising dominion, but the consequences of his choices are always under judgment. When his choices are self-centered and made without reverence and without responsibility for the care of the earth and its creatures, they lead to destruction. Many despair of man now that he wields the power of nuclear energy and are convinced that because of his unredeemed sinfulness, he cannot be trusted in his use of it. Perhaps they feel that God erred in giving mankind this power to begin with. But rightly or wrongly, man has it and has no other choice but to accommodate himself to the reality of his situation.

For a full appreciation of the biblical understanding of dominion, the quoted passage from Genesis at the beginning of the Pentateuch must be balanced with one at its end in the closing portion of Deuteronomy, "*I call heaven and earth to witness against you this day, that I have set before you life and death, blessing and curse; therefore choose life, that you and your descendants may live*" (30:19). The immensity of the potential blessing of nuclear energy has already been noted in the section on providence. But the equal immensity of its potential curse is a present reality in the ever-proliferating arsenals of nuclear weapons throughout the world. Never before in his historic experience has man been faced with a potential for blessing and for curse of such an ultimate magnitude involving the whole earth and all its creatures.

For the first 15 years of the nuclear age our talents and energies in the United States were mainly devoted to realizing the destructive potential of nuclear energy. Only in the last 15 years have they been applied to a first beginning in the realization of its beneficial potential. Now, however, a growing number of voices are being raised against this effort. They urge us to refuse the blessing and so, in effect, to settle only for the curse of nuclear energy.

In an address on the subject of nuclear energy to the Fiftieth American Assembly at Arden House in 1976, Sen. John Pastore of Rhode Island eloquently brought out the full implications of such a fateful choice. Speaking as chairman of the then Joint Congressional Committee

on Atomic Energy, he reviewed his experience of the awesome magnitude of the destructive potential of the United States' arsenal of 30,000 nuclear warheads. Then he said that the only way he personally could in conscience exercise his responsibility in the Congress was to do all in his power to develop the beneficial potential of nuclear energy. Without that opportunity, he would have had to refuse any personal involvement with it.

It is essential that we devote our best talents and efforts to finding ways to prevent the misuse of nuclear energy, to prevent the potential curse from being realized, but a refusal of the blessing is not one of them.[5] In heightened form this is the age-old dilemma of sinful man's freedom and responsibility in the exercise of his God-given dominion over the earth.

Nuclear Energy and the Conquest of Fear

A pervasive theme through the Bible is one of overcoming fear. Fear produces a paralysis of action and must be overcome by a confident acceptance of life as it is given man to be lived in spite of all its risks. From a biblical perspective, fear is to be overcome by faith in God and trust in his good purposes, which he accomplishes in such mysterious and unexpected ways. Especially in man's use of energy has the overcoming of fear and the choice between blessing and curse been dominant.

There was a time when primitive man shared with all the other animals of forest and steppe a paralyzing fear of fire and fled in terror from it whenever it broke out. Fire was then exclusively a curse, with no blessing in it. But at a crucial turning point in his history, man came through to the other side of fear and, instead of fleeing from fire, brought it right into his living quarters and thereafter tended and nurtured it. The curse of fire remains with us today as each year it takes its toll of human life and property. Uncontrolled outbreaks of fire continue to be fearful events. But out of the boldness and confidence of the decision to use it have come a multitude of blessings. Its heat sustained man through the last ice age, greatly increased his nutrition through cooking, and made possible pottery and glassware and the smelting of ores for metals. Today we take many precautions to reduce its curse, and we have discovered many more of its blessings. Today no one questions the validity of this first energy choice, but initially there must have been numerous fearful voices raised against it, or at least howls of dismay.

The most terrifying natural manifestation of fire on earth is an erupting volcano. The conquest of the fear of the manifestation of such overpowering destructive force was a decisive turning point for Israel and of profound significance for all subsequent human history. In the wild barrenness of the Arabian desert east of the Gulf of 'Aqaba, known in the Bible as the land of Midian, are a number of extinct volcanoes. One of these, known as Sinai, was periodically active in the thirteenth and twelfth centuries B.C. For all the bedouins, Hebrew and Aramean alike, the terrifying god of this volcano was Yahweh (Jehovah), in whose presence all alike were filled with terror. But one of the Hebrews, named Moses, changed all that. Taking the Hebrew tribes with him on a pilgrimage to Sinai, Moses in their presence braved the fearful hubbub and trumpeting of the mountain and climbed it through the thick cloud of volcanic ejecta that shrouded it to meet, as they believed, Yahweh face to face. The account in the Bible of this extraordinary event goes:

> On the morning of the third day there were thunders and lightnings, and a thick cloud upon the mountain, and a very loud trumpet blast, so that all the people who were in the camp trembled. Then Moses brought the people out of the camp to meet God; and they took their stand at the foot of the mountain. And Mount Sinai was wrapped in smoke, because Yahweh descended upon it in fire; and the smoke of it went up like the smoke of a kiln, and the whole mountain quaked greatly. And as the sound of the trumpet grew louder and louder, Moses spoke and God answered him in thunder. And Yahweh came down upon Mount Sinai, to the top of the mountain; and Yahweh called Moses to the top of the mountain, and Moses went up (Exod. 19:16—20).

As a result of this experience, the tribes that were later formed into Israel came through to the other side of fear. Instead of being immobilized with fright before the blazing and terrifying power of Yahweh, they came to rejoice in his presence with a wild exhilaration. They believed that for some mysterious reason he had chosen them from among all the other peoples of the desert to be his and in his presence they were filled with some of his indomitable power. The memory of this transformation of fear into boldness persisted for centuries as may be seen in the references to it half a millenium later in Deuteronomy 4:11, 32-33 and 36 ("*he let you see his great fire*") and 5:4-5, 22-27 and even much later in Hebrews 12:18-21. Israel's exhilaration in the presence of the God of the volcano is expressed in several Psalms such as ". . . *who* [Yahweh] *touches the mountains and they smoke!*" (104:32) and vividly in Psalm 18:7—15. But it was not only in the volcano that Yahweh flamed forth. A storm with its thunder and lightning, and looking as though detached and floating free from a volcano, was also a manifestation of his power. This is evident in the vision of the volcano as a pillar of cloud by day and of fire by night in Exodus 13:21, 22 seen in the storm that accompanied the Israelites and delivered them in their flight from Egypt; in the opening portion of the Song of Deborah in Judges 5:3-5 hailing a storm apparently coming from Sinai across Edom to the scene of the battle; and in Psalm 29 describing a storm coming in from the Mediterranean.

The conquest of the fear of fire has had many facets and rewards other than the possibility of utilizing its physical energy. Since the Industrial Revolution, the introduction of other energy sources has been accompanied by widespread fear that in time had to be overcome. When railroads were first introduced in the last century, they were met by extreme fear reactions. Their locomotives belching smoke and fire, hissing loudly, and puffing steam were a terrifying sight when first experienced. Electricity, as a natural phenomenon, was viewed for centuries only as a curse, and at the turn of this century, when it began to come into general use as a technology, it too was accompanied by widespread fear. It was a new and unfamiliar force, invisible and mysterious, and it inspired deep, subliminal fears. There was, of course, a real basis for some of this fear. Electricity is, in fact, quite dangerous, and a healthy fear of it has resulted in great strides in insuring its safe use. Man

has found ways of conquering his natural fear of steam and electricity so that they no longer paralyze him into rejecting these gifts. He has chosen to reap their blessings while at the same time laboring to reduce their curse.

We stand today on the threshold of reaping the blessings of nuclear energy. It is a gift many times more ample than any of the other energy gifts buried in the crust of the earth, and, as discussed earlier, our knowledge of matter and of the solar system have shown us that it is God's energy choice for the whole of creation. As with man's earlier energy thresholds, fearful voices are raised against it, and we are urged to reject its blessing. People fear for the safety of nuclear electric generating plants. They fear plutonium as such, as well as the possibility that it might be diverted from electric power to weapons. They have a pathologic fear of radiation and radioactivity. They conjure up in their minds fearful scenarios of what might happen accidentally or by evil intent. Many of these fears have a real basis in fact, and to overcome these, major development efforts have been and are under way. But a large portion of current fears of nuclear energy are irrational, grossly exaggerated, and unnecessarily paralyzing.[6] These fears will gradually subside as nuclear energy assumes its destined role in the future course of humanity. The real fears will always be there because nuclear energy is inherently dangerous. But it already has demonstrated a much better safety record and a far better environmental record than coal, and both records will improve with experience. We already have made a choice in favor of developing the blessing of nuclear energy, and mankind as a whole will surely not turn back merely because we are afraid to go on. The admonition in the Wisdom of Solomon in the Apocrypha, "*for fear is nothing but a surrender of the helps that come from reason*" (17:12), is applicable to the current public reaction to nuclear energy. But these fears, too, as with others in the past, will in time moderate and be overcome. Let us hope that the time required will not be long because the world energy problem worsens with every passing year.

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Biblical Mandates and the Human Condition

Kenneth A. Martin

In the preceding article, William Pollard offers a theological justification of nuclear power. Although the perspective is somewhat unique, the basic approach is similar to that taken by most proponents of this energy source. First, the choice to "go nuclear" is presented in grave terms (e.g., Alvin Weinberg's Faustian bargain). Here, Pollard describes it as "of such ultimate magnitude" as to involve "the whole earth and all its creatures." The general argument then proceeds to assert that in reality there is no choice. The nuclear option is portrayed as the only real option available. Even if serious drawbacks are acknowledged by these advocates, they are said to be overshadowed by the lack of other feasible ways to satisfy our nation's voracious energy appetite. The choice is frequently reduced to one of nuclear power or "freezing in the dark." Pollard's arguments are typical in this regard. Ignoring all alternatives to the nuclear society, he asserts that the breeder reactor is our destiny and the sooner it is accepted, the better life will be for us all.

Specifically the author suggests the following points in defense of nuclear energy: (1) He maintains that nuclear power and radioactive substances are not inherently or irredeemably evil as some allege. Instead, he argues that they are commonly occurring in the universe and thus should not be viewed as man-made or unnatural.

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(2) He then speaks of God's providence. During the past 35 years, the United States has been accumulating radioactive tailings from both nuclear weapons and nuclear fuel fabrication. Suitable as breeder fuel, Pollard implies that the existence of these tailings represents God's provision for our energy future. (3) He asserts that we already suffer the full curse of nuclear technology (weapons) and consequently would be foolish to now turn away from the blessing (electric power generation). Pollard apparently sees no additional threat to world peace in the development and deployment of the breeder reactor. (4) Finally, he suggests that since the breeder has a "predestined" role to play in the energy future, it would be wise to gratefully accept this technology as soon as possible. Some, he says, have always feared technological advance, but such irrational fears should not be allowed to block the road to progress.

Conspicuously absent from Pollard's theological view is a discussion of human fallibility and sinfulness. Neither does he acknowledge the Christian's responsibility to look beyond the criteria of technological capability and circumstance to the requirements of justice and love in fashioning a response to the energy question. Both of these points however are crucial to any Christian view of energy technologies. What follows is a more detailed discussion of each of the preceding points.

Nuclear Energy: Natural or Unnatural?

Pollard assigns nuclear energy a major role in his theory of creation, but this assumption is apparently open to dispute. In fact, Victor F. Weisskopf, a nuclear physicist and head of the physics department at M.I.T. has recently written:

> . . . . We may forget about fission if we are interested only in the major features of our world. This is even more true about the chain reaction itself. Nature has not made much use of it. Recent evidence indicates that a natural chain reaction happened a billion years ago below the soil of Africa but to our knowledge it never played any role in the development of our universe.[1]

Important or incidental to the mechanism of creation, nuclear reactions and radioactive substances unquestionably exist. It would be a mistake to view these or any other part of the created universe as inherently evil. But nuclear reactions are predominantly extraterrestrial phenomena and as such are generally inappropriate in the earthly setting. Nuclear dynamics may be "natural" to a system as broadly defined as the universe, but they are dormant on earth and as such are "unnatural" in this environment. Likewise, plutonium may be naturally occurring in some distant corner of the galaxy but in our environment this element is a deadly man-made toxin, completely incompatible with life. God may have created billions or even trillions of stellar nuclear power plants, but in His infinite wisdom, He placed them well out of human reach.

Nuclear Energy and Providence

There is great risk in depending too heavily on circumstances for God's leading. It is theologically naive to assert that the breeder is God's energy provision for the future simply because the United States has accumulated 20,000 drums of radioactive tailings for which there is currently no acceptable means of disposal. If we are to be guided by providence, might it not be more reasonable to look to the truly renewable energy sources (solar, wind, water, biomass etc.) with which God daily supplies the planet? They are certainly less susceptible to human malevolence and have been available for considerably longer than 35 years. Henry A. Bent describes God's energy provision as follows:

> Had man managed to make a mammoth nuclear reactor sited safely 93 million miles away, discovered how to store its radiant energy in a multitude of attractive forms, learned how to release that energy metabolically, and managed to keep the whole process going for millions, perhaps billions of years, he would be so pleased with his handiwork he might not seek dangerous, less attractive ways of providing power.[2]

Biblical norms and not providence are to be the Christian's ultimate guide. We are called of God to be members of a global community and charged with the responsibility of caring for the creation. Accordingly, Vernon Ehlers has stated:

> As redeemed humans we have a responsiblity to work toward a just allocation of all resources, including energy resources.[3]
>
> The divine design of the ecosphere embodies a marvelous and intricate pattern of natural processes and cycles. Our use of energy should seek, as much as possible to learn from this "university of

nature" so that we develop patterns of resource development and use which avoid disruption of the ecosphere.[4]

It is not enough to say that electricity should be generated by breeder reactors simply because it might be possible to do so. Christians must look beyond technological feasibility in their evaluation of potential energy sources. The solutions we support must be those that protect human freedom and dignity, promote peace and are consistent with the call to stewardship.

Scientists' Declaration on Nuclear Power

From the Declaration presented to Congress and the President of the United States on the 30th anniversary of the atomic bombing of Hiroshima and signed by more than 2,000 biologists, chemists, engineers and other scientists . . .

". . . the country must recognize that it now appears imprudent to move forward with a rapidly expanding nuclear power plant construction program. The risks of doing so are altogether too great. We, therefore, urge a drastic reduction in new nuclear power plant construction starts before major progress is achieved in the required research and in resolving present controversies about safety, waste disposal, and plutonium safeguards. For similar reasons, we urge the nation to suspend its program of exporting nuclear plants to other countries pending resolution of the national security questions associated with the use by these countries of the by-product plutonium from United States nuclear reactors."

Union of Concerned Scientists *August 6, 1975*
1208 Massachusetts Ave., Cambridge, MA 02138

For the Christian then, energy solutions must flow from biblical mandates. Human justice requires that energy sources suitable to both developed and developing countries be pursued. The breeder reactor is not such a source. It is feasible only in a centralized society with a sophisticated electrical transmission network. Nuclear technology is complex, capital intensive and requires a small, highly trained work force, one difficult to assemble even in a highly developed society. (Consider the report of the Kemeny Commission). Exporting this technology to developing nations tends to exacerbate their problems. It increases their dependence on foreign energy companies, foreign banks and foreign governments. It compounds employment problems and generally widens the gap between the rich and the poor, the powerful and the powerless within the country. Energy sources adaptable to small-scale, decentralized application are more appropriate to give people the ability to determine their own destiny. The United States is in a particularly important position to develop such technologies. To endorse breeder commercialization and thereby deemphasize or ignore soft-path technologies is to show serious disregard for global needs. Christians are called to resist such self-centered behavior.

Stewardship of the earth is another biblical mandate. Every increase in energy use has a negative impact on the environment (increasing air, water and thermal pollution, carbon dioxide buildup and radiation exposure). Elimination of energy waste must then take precedence over expansion of energy supply. Extravagant, inefficient and foolish uses must be opposed. The answers to many of today's problems lie in a philosophy of "enoughness" and in harmonious collaboration with nature in selective control based on ecological understanding and the stewardship ethic.

Christians should increasingly turn their attention to the responsibilities of these and other such biblical callings in formulating responses to social and political policies that are based solely on pragmatism and expedience.

Nuclear Energy: The Blessing and The Curse

There are many risks associated with breeder technology that Pollard fails to discuss. Principal among these are the concerns of nuclear weapons proliferation and the implications of what might be called the "human factor." Both have theological antecedents. Critics charge that breeder development and deployment will increase the threat of nuclear war. If this is true, Christians, who are called by God to be peacemakers, have a moral and spiritual obligation to resist the spread of this technology. It makes little sense to try to secure a better life by using a form of energy that increases the threat of self-destruction. Furthermore, since human fallibility and sinfulness are foundational tenets of the Christian faith, believers should be extremely wary of any technology that can so magnify the error or sin of one person as to affect tens or even hundreds of thousands of people.

Proliferation: Nuclear power is historically linked to nuclear weapons and this relationship has figured decisively in its development. The following capsule history was offered by Hannes Alfven, Nobel laureate in physics as part of a lecture given at the 1978 Nobel Symposium on "Ethics for Science Policy."

> At the time of the Manhattan Project scientists generally believed that all new discoveries would benefit mankind. The bad conscience which many Manhattan scientists had as a result of making the nuclear bomb compelled them to believe that enormous benefits of "peaceful" nuclear energy would compensate for the terror of nuclear arms. With this rather naive excuse the Atoms for Peace projects got enthusiastic support from the nuclear physicists who rightly had the reputation for being the brightest and most influential scientists of that era.
>
> Many governments reacted favorably to the pressure of the scientists, probably because the "peaceful" use of nuclear energy gave them an excellent opportunity to keep the military option open and still officially do nothing but sponsor an extremely fascinating commercial project. The cost of nuclear energy was not important—it seldom is for military or quasi-military projects—but to make it appear commercially attractive it was claimed to be cheap.
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> The development of nuclear energy proceeded successfully and almost undisturbed for a quarter of a century. Then a few biological and medical scientists blew the whistle, claiming that its environmental impact was unacceptable. The nuclear establishment immediately realized how dangerous this criticism was and tried to suppress it. How the controversy has escalated during the last ten years is well-known.
>
> The nuclear industry, supported by most nuclear physicists (right or wrong, my science!), claim that no realistic alternatives exist; the environmentalists claim that nuclear energy is dangerous and that there are several more attractive alternatives which in reality are cheaper.
>
> Especially important is the connection between the spread of nuclear technology and the proliferation of nuclear arms. As we

> have noted, 25 or 35 years ago governments in some industrialized countries invested heavily in "peaceful" nuclear energy mainly because they wanted to keep the atomic bomb option open. The same is done today in several developing countries.[5]

President Carter's recognition of the increased risk of nuclear weapons proliferation from breeder deployment has prompted him to call for a halt to nuclear fuel reprocessing and breeder reactor development. Henry Rowen of Stanford University and Albert Wohlstetter of the University of Chicago, both prominent academic specialists on nonproliferation issues, in 1979 completed a study commissioned by the Department of Energy and other governmental agencies. "The Rowen-Wohlstetter study asserts that, over the last three years, all the legs to the argument that the connection between the fuel cycle and proliferation is slight have been cut off, including the idea that the plutonium from a power reactor is denatured to the point that it cannot be used reliably as a weapon."[6] In fact, last year the United States government declassified a report that it had exploded a Hiroshima-size nuclear weapon made from reactor grade plutonium, a feat the breeder proponents have previously claimed to be impossible. It is becoming increasingly clear that the export of nuclear power technology (particularly breeders) is tantamount to the export of nuclear weapons technology. Support for this policy then represents not only tacit acceptance of the normalcy of nuclear weapons, but also the willingness to broaden and expand this awesome threat. The world has not yet seen the full curse of this technology.

Human Fallibility: The nuclear industry expresses great confidence in their complex and highly-developed systems and safeguards. It is not enough however, for these systems to work in a technological paradise; they must also work in the real world. And nothing is so unsettling about real world operation as the human factor. Human ecologist Garrett Hardin of the University of California, Santa Barbara has described it this way:

> A chain is no stronger than its weakest link. Systems theory and sophisticated technical devices can improve the nonhuman link in the chain leading to atomic energy. But what can be done about the human link? Very little, I submit. This is why Weinberg called for a "priesthood"—something far more reliable, far more devoted than ordinary human beings—something there seems little possibility of creating in this agnostic age. "If wishes were horses, beggars would ride." If caretakers were priests atomic energy would be safe.[7]

Proponents of nuclear power frequently fail to take seriously the human condition. Many appear to believe instead that upward mobility in technology is matched by upward mobility in moral and ethical matters as well. But there is no technological solution to the problem of human malevolence. Any realistic estimate of human nature which recognizes humanity's technical and moral fallibility must conclude that nuclear technology represents a grave risk to our world.

Nuclear Energy and Fear:

Pollard seemingly would have us believe that nuclear energy is no different than any other human technology; that to fear its development and deployment is as foolish as fearing fire or electricity or the locomotive. Nuclear energy is however, quantitatively different from chemical energy as Victor Weisskopf points out:

> Today physicists are dealing with cosmic processes...The fission chain reaction was one of the first of these cosmic processes which led to major technological applications. Two hundred million electron volts per atom—20 million times more than the most powerful chemical reaction—is cosmic and not ordinary fire. And the first major application was a destructive one which ended World War II by killing a quarter of a million people with two bombs. It is not surprising therefore that people are fearful and bewildered, and have misgivings even in regard to the more benign applications of nuclear energy.[1]

Nuclear energy is not ordinary fire. It has magnified human potency to the degree that world-wide destruction is now possible. Dare we not fear such power, particularly in the hands of sinful beings? God never intended His people to be paralyzed by fear. Indeed he wants to set us free from senseless superstition and irrational fear. Rational fear, on the other hand, has a very legitimate place in God's design. It is given to warn of danger and it is given to motivate us to action.

The public's growing apprehension of nuclear power is increasingly grounded in reality. We have seen the power of the atomic bomb and are learning more about the risks of radiation exposure. Terrorism is a reality in our society and we realize the tremendous danger of nuclear proliferation. We have considered the implications of perpetual storage of radioactive waste and at Three Mile Island we came to the brink of a major reactor accident. Most importantly, we know the resources human beings bring to the task of managing the atom. Contrary to Pollard's assertion, it is not irrational fear we are being asked to put aside but sound judgment.

God has given us dominion over the earth but included in that dominion is the responsibility to make moral and spiritual choices concerning how we use our knowledge and to what ends. For humans to ignore their moral limitations is to set themselves up as gods. And to refuse to make moral judgments is to deny responsibility in dominion. We must not let our technological capacities make our decisions. May we always add wisdom to our knowledge.

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Gems of Wisdom and Wrong Conclusions

Vernon J. Ehlers

It was with genuine anticipation that I sat down to read Pollard's article, "A Theological View of Nuclear Energy." We Christians are often remiss by not applying our faith to contemporary problems, and based on Dr. Pollard's earlier work I assumed he would have a genuine contribution to make to this particular topic. After reading the article, I have mixed feelings. There are gems of wisdom in the article, but unfortunately they are accompanied by a number of wrong conclusions.

Let us begin by pointing out what is good: Pollard has an excellent understanding of stewardship and dominion, as exemplified by his statement that "the biblical understanding of man's dominion over the earth is one of stewardship rather than domination . . ." I am mildly surprised that he does not include a reference to Genesis 2:15: "The Lord God took the man and put him in the garden of Eden to *till* it and *keep* it." Theologian friends inform me that a better translation is that man is to "serve" the land. Thus the dominion discussed in Genesis 1 is modified by the concept of stewardship and service presented to us in Genesis 2. Our task as Christians then is to *serve* the land, just as the land "serves" us in enabling us to meet our needs.

In spite of Pollard's excellent understanding of dominion as service and stewardship, he goes astray by introducing extraneous concepts; extraneous in the sense that, although related to Biblical events, they are not an integral part of the Christian framework derived from Scripture. As an example, his discussion of fear (although interesting) is a general discussion with a few examples drawn from the Bible, but it does not use any particular theological framework as a basis for the discussion. It is certainly true that humankind has been fearful of each new technological development, and has been hesitant to use even the most beneficial. However, that does not mean that every new development should immediately be embraced, without fear, and used to its fullest. I believe the sense of fear with which we are endowed is very useful. It is primarily a fear of the unknown, and reflects a healthy respect for that which we do not yet fully understand. The biggest difference between our present fear of nuclear energy and previous fears of fire, electricity, and the locomotive arises from the scale of the danger, both in space and time. Although it is true many persons died as a result of electrocution, very few persons were affected outside of those actually working with electricity; the damage was confined to the death or injury of those participants. The situation with nuclear energy (and many other modern developments) is that the dangers extend far beyond the user, both in space and time. A release of radioactivity from a nuclear plant affects many "innocent" persons. Furthermore, because the long-term genetic effects of radiation are poorly understood, we may possibly be affecting future generations by adding to the ambient radioactivity levels surrounding us. In view of this, I believe our fear of nuclear energy is well-founded, and we should be doubly cautious in developing this energy source.

This is not to say that we must abandon nuclear energy. As Pollard correctly points out, all of creation, including nuclear energy and its associated potential for production of useful power, is a gift from God and as such is "good." However, the evil, as Pollard again correctly points out in another context, arises from the use man makes of these gifts from God. In his mind, nuclear weapons are evil; nuclear power is good. I do not believe the division is that simple. One might even be able to argue (although I certainly would not) that nuclear weapons in a certain context might be good. I believe one can certainly argue (and I am willing to do so) that nuclear power plants may be either good or evil, depending on their design and construction, their mode of operation, the validity of the need they satisfy, etc. Clearly, rushing an inadequately tested plant into operation, as was done at Three-Mile Island, is not good. Nevertheless, there are many situations in which nuclear power can be used productively and safely.

I have particular problems with Pollard's discussion of nuclear energy and creation. As I understand his argument, he states that because God created the universe so that its essential power source is nuclear, and because most of the matter of the universe is encompassed in stars (which are in fact nuclear reactors), therefore it is obvious that God intended to have us use nuclear power. I find this argument both misleading and fallacious. If one follows that line of reasoning logically, I believe one can construct a much stronger case for solar energy. The nuclear reactors that God has created are placed far from

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us in space, and only one of them is of any use to us as an energy source. Furthermore, throughout the many years from creation until now the Earth has depended primarily on that one nuclear reactor (the Sun) for energy, and that energy has always been delivered to us in a benign fashion through electromagnetic (thermal and light) radiation. Thus it appears to me that the logic of Pollard's argument demands that we rely exclusively on solar energy, which is the energy source all other organisms on earth rely upon for existence. In other words, I conclude that we should use nuclear energy, *but that the reactor should be kept 93,000,000 miles away*!

Pollard's last argument, that the appearance of nuclear energy upon the scene just as we are depleting our petroleum and natural gas resources reveals a providential role for nuclear energy, although intriguing, once again is misleading. Obviously God's providence manifests itself in many ways, but to equate providence with the coincidental development of a particular energy source as another nears depletion is to equate our self-centered choices with God's plan. We should recall that the development of nuclear energy resulted from development of the most destructive weapons the world has ever known. Can we truly call this providential?

One final comment: to my mind the article does not represent "a theological view of nuclear energy," but rather "a Christian's perspective on nuclear energy." Perhaps my understanding of the discipline of theology is different from Dr. Pollard's, but it appears to me that we have in this article not theology but rather an attempt, by a Christian, to provide a biblically related justification of his previously adopted viewpoint on nuclear energy. Only Pollard's discussion of dominion and stewardship reflects good theology; I only wish that he had used this as a framework to discuss our stewardly responsibilities, as crew members of Spaceship Earth, as we seek to develop new energy sources.

I fear that these comments are more negative than positive. Such is not my overall intent. Pollard has much good to say, and I applaud him for his willingness to display his Christian perspective on this contemporary issue. I am delighted to see an article of this nature appear in a journal such as *Nuclear News*, and Dr. Pollard is to be commended for his work not only in this article but in other books and articles he has written. However, I do not regard this article as a definitive discussion of the topic, but rather as a stimulus to further study and thought. The context in which this article and its responses are appearing in the *Journal of the American Scientific Affiliation* indicates that Dr. Pollard is admirably fulfilling that purpose. I hope that he may continue to do so, and that others may join him in this effort.

The Sierra Club's Position on Nuclear Power

Nuclear power is beset with problems that give cause for great concern. Most crucial are disposal of radioactive spent fuel and wastes, reactor safety, and possible illegal diversion of nuclear material for blackmail or weapons construction.

We oppose the licensing, construction and operation of new nuclear-fission plants until these problems are solved and regulatory machinery is established to guarantee the solutions.

Environmental and safety problems of existing reactors should be evaluated case by case. When necessary, power, temperature and heat-transfer rates should be reduced to increase safety margins in large plants.

The Sierra Club favors repeal of the provisions of the Price-Anderson Act that create an artificial public subsidy of the nuclear industry by limiting maximum liability and providing federal insurance for nuclear power-plant owners.

We oppose the introduction or expanded use of plutonium separation or any other technology or system that would increase the net risks of diversion or release of fissionable materials or that would contribute to the proliferation of nuclear weapons. For these reasons, we oppose the separation and storage of plutonium for any purpose.

—From "Nuclear Power and the Sierra Club." The full text is available for 25¢ from Sierra Club Information Services, 530 Bush Street, San Francisco, CA 94108

Human Responsibility and Human Liberation

Robert Case

"The theologian is concerned about the human being as a subject with freedom and responsibility before the mystery of God."
Karl Rahner

The present article undertakes a discussion of human responsibility and freedom before God in relation to commercial nuclear energy, and concludes that the evidence suggests that the nuclear program in its present form cannot be reconciled with fundamental theological conclusions. Two major currents of theological thought are of special importance in this investigation: a renewed awareness of human responsibility for the care of creation on the one hand, and a deepened perception of the reli-

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gious significance of the process of human liberation on the other. While Christian theologians have been especially active in dealing with these dimensions,[1] it is expected that both will be acknowledged to be grounded in the Judaeo-Christian biblical tradition.

In particular, these remarks are also intended as a response to Dr. William Pollard's article, "A Theological View of Nuclear Energy," in which the author argues that we should overcome our fears of nuclear energy, stressing that the conquering of fear is one of the principal accomplishments of the Sinai Covenant, wherein Moses vanquished the terror produced by the mountain's volcanic fire. Further, Dr. Pollard urges us to see nuclear energy as "God's energy choice" for the whole of creation, pointing out that the sun's energy is a product of nuclear fusion, and the galaxies are populated with such natural "nuclear power plants." Moreover, as regards nuclear energy from reactors, "man has it and has no other choice but to accommodate himself to the reality of his situation."

Nuclear Energy Not Inherently Evil

There are two preliminary points that should be stated categorically. The first is that opposition to commercial nuclear power ought not to be construed as opposition to science or to the development of technology. Science is a basic human enterprise of great significance and of potentially immense benefit to humanity as a whole. The opposition to nuclear power discussed here is a criticism based on the historical and social conditions of a particular industry. The second point, and one which is related to this view of science, is that nuclear energy is not to be thought of as inherently evil; it is, rather, human beings who are capable of sin and of violations of justice. This article seeks to discuss criteria for evaluating whether the power of the atom is being abused by persons, and by institutions composed of persons. In this sense, one can begin to understand the ways in which scientific work can be misused to render it contrary to human welfare and the development of human community.

"Natural" Nuclear Energy

One step in making this evaluation is to regain a sense of perspective about the place of "natural" nuclear energy in human evolution, both cosmically and historically. The fact that plutonium and other transuranic elements were present in great abundance millions of years ago should not at all imply that they must have any particular role today. In fact the absence of plutonium in "recent" history made possible the evolution of many species, humans included, for which this element is almost incredibly toxic.[2] Further, our understanding that the sun is a "fusion reactor" must not be separated from the acknowledgment that it is 93 million miles from earth, a providential distance.

Human Stewardship

The fundamental relationship of human beings to the biosphere—the thin band of water, earth and atmosphere that is the Creator's gift and which marvellously supports the multiplicity and variety of life—is set forth in the recent Policy Statement of the National Council of Churches:

> Human beings are made by God as persons-in-nature, co-creatures in reciprocal relationships with everything else that God has made. As an integral part of creation, humanity shares in its finite nature. Only after making this basic affirmation does the Bible declare that humans are distinctive because they are created in God's image. Persons are unique in their capacity to respond to God in faith and hope, to their human neighbors with love, and to the non-human part of creation with respect and responsible care.[3]

Thus humans have a "stewardship," one which assumes immense meaning in terms of the potential technological impact on the biosphere, both globally and for hundreds of generations to come. A technology, therefore, which poses a risk of irreversible global damage demands enormous caution in deciding about its use. The structure and history of commercial nuclear energy present evidence of fundamental problems that require solution before responsible stewardship could approve continuation of this program on a commercial scale.

A typical nuclear fission plant contains an amount of radioactive material which exceeds the fallout of a thousand Hiroshima-type weapons. The fear is not that these plants will explode like an atomic bomb, but a large portion of this material is gaseous and could easily be carried by the wind for many miles if accidentally released. Lethal to humans in its immediate path, the dispersed radioactivity would cause long-term cancers and genetic damage. The accident at Harrisburg has raised this spectre in the minds of people the world over.

Radioactive Waste

Further, no safe way has yet been devised to dispose of the millions of gallons and thousands of metric tons of deadly radioactive waste. These wastes, created when spent fuel is removed from the reactor, are among the most dangerous cancer-causing substances known, remaining harmful for centuries and in some cases millenia. In the short history of nuclear power, numerous leaks of both high-level and low-level (materials, clothing, and tools used in connection with the nuclear cycle) materials have occurred. Thirdly, present safeguards are inadequate to keep plutonium from being hi-jacked by terrorists or obtained by any nation which possesses reprocessing facilities.[4] India showed by its 1974 nuclear detonation that "the peaceful atom" can be made to yield weapons. These three elements: danger of catastrophic meltdown and release of radioactivity, lack of solution to the waste-storage problem, and threat of nuclear weapons proliferation from the worldwide marketing of nuclear reactors—are serious structural problems of the nuclear industry.

History of Nuclear Energy

The actual history of nuclear energy, moreover, is studded with mishaps, operator errors, design defects, shoddy construction practices, quality control corruption, and security lapses.[5] Operating reactors have shown a lower than advertised reliability; new reactor models have been marketed before being properly tested and analyzed; an entire industry has been constructed without having a complete plan—both as regards waste stor-

age and as regards shortages of uranium, a nonrenewable fuel;[6] ambitious efforts have been made to expand nuclear sales into nations which could ill afford an expensive new technology which does not meet the basic needs of the population.

In short, the structural problems of the nuclear industry have been complemented by a historical record which has served to undermine popular confidence that the biosphere will be protected. Finally, yet another problem is described in a remarkable paper of Professor Jean Rossel, delivered at the July, 1979, conference at M.I.T. on Faith, Science, and the Future: the slow and steady radioactive pollution of the biosphere that is a concomitant of the nuclear program, even under the assumption of no mishaps.[7] It would seem that the kind of ahistorical technological optimism evidenced in Dr. Pollard's article is no match for the weight of all these burdens. A sense of responsible stewardship is encouraging Americans everywhere to echo the Policy Statement of the National Council of Churches: "We support a national policy which will not need to utilize nuclear fission."

Is Nuclear Energy Necessary?

For many people, the last remaining argument in favor of nuclear energy is that it is "necessary," particularly in view of supply shortages, notably as regards oil. Some have claimed that an enormous plutonium breeder reactor program is the way to meet these needs. But one should notice that a 1000 megawatt light water (uranium) reactor must operate for thirty years to supply the fuel for a 1500 megawatt breeder reactor. In the year 2010, a program of substitution would require 4500 light water reactors in operation to allow 6000 breeders in the year 2040. Even for this staggering program—with all its health, military, and civil liberties implications—the total amount of energy generated in 2040 would be only 50% of that *now* being produced by petroleum and a mere 10% of the extrapolated energy needs of the year 2040! Further, studies by Vince Taylor conclude that the economics of the situation forbids any significant substitution of electricity for oil, as for example in home heating.[8]

Such "necessity" arguments for nuclear energy all rest on the increasingly shaky premise that the energy problem is fundamentally a *supply* problem. Emphasis on supply has only exacerbated the problem, however, leading to exponential problems of shortages, costs, and pollution of the environment. On the other hand, there is overwhelming evidence that the energy problem is a productivity or *efficiency* problem. To continue the irrational wastefulness of the past generation while searching for a supply-solution is the height of impracticality. In fact, Americans have obtained 2.5 times as much energy in the past seven years through efficiency as they have through supply-expansion, including the Alaskan pipeline.[9] A number of recent investigations conclude that efficiency over the short term is the only solution to the energy problem,[10] and, coupled with timely introduction of solar-based technologies, society can move to a high-technology solar civilization in the 21st century.[11]

In far too many cases, support for nuclear power does not represent the overcoming of fear, but a hand-wringing fatalism:[12] "When God decides my time is up, it is up—and if it comes through radioactivity, that is God's will,

The Gift of Good Land

The Creator's love for the Creation is mysterious precisely because it does not conform to human purposes. The wild ass and the wild lilies are loved by God for their own sake; and yet they are part of a pattern that we must love because of our dependence on it. This is a pattern that humans can understand well enough to respect and preserve, though they cannot "control" it or even hope to understand it completely. The mysterious and the practical, the Heavenly and the earthly, are thus joined. Charity is a theological virtue and is prompted, no doubt, by a theological emotion, but it is also a practical virtue because it must be practiced. The requirements of this complex charity cannot be fulfilled by smiling in abstract beneficence on our neighbors and on the scenery. It must come to acts, which must come from skills. Real charity calls for the study of agriculture, soil husbandry, engineering, architecture, mining, manufacturing, transportation, the making of monuments and pictures, songs and stories. It calls not just for skills but for the study and criticism of skills, because in all of them a choice must be made: They can be used either charitably or uncharitably.

How can you love your neighbor if you don't know how to build or mend a fence, how to keep your filth out of his water supply and your poison out of his air; or if you do not produce anything and so have nothing to offer, or do not take care of yourself and so become a burden? How can you be a neighbor without applying principle—without bringing virtue to practical issues? And how will you practice virtue without skills?

The ability to be good surely is not the ability to do nothing. It is not negative or passive. It is the ability to do something well—to do good work for good reasons. In order to be good you have to know how—and this knowing is vast, complex, humble and humbling; it is of the mind and of the hands, of neither alone.

The divine mandate to use the world justly and charitably, then, defines every person's moral predicament as that of a steward. But this is hopeless and meaningless unless it produces an appropriate discipline: stewardship. And stewardship is hopeless and meaningless unless it involves long-term courage, perseverance, devotion and skill. This skill is not to be confused with any accomplishment or grace of spirit or of intellect. It has to do with everyday proprieties in the practical use and care of created things—with "right livelihood."

If "the earth is the Lord's" and we are His stewards, then obviously some livelihoods are "right" and some are not. Is there, for instance, any such thing as a Christian strip mine? A Christian atomic bomb? A Christian nuclear power plant or radioactive waste dump? What might be the design of a Christian transportation or sewer system? Does not Christianity imply limitations on the scale of technology, architecture, and land holding? Is it Christian to profit or otherwise benefit from violence? Is there not, in Christian ethics, an implied requirement of practical separation from a destructive or a wasteful economy? Do not Christian values require the enactment of a distinction between an organization and a community?

It is clear, I hope, that it is impossible to understand, much less to answer, such questions except in reference to issues of practical skill, because they all have to do with distinctions between kinds of action. These questions, moreover, are intransigently personal, for they ask, ultimately, how each livelihood and each life will be taken from the world, and what each will cost of the livelihoods and lives of others. Organizations and even communities cannot hope to answer such questions until persons have begun to ask them.

Wendell Berry

Reprinted from **Sierra**, *pp. 23, 24, Nov/Dec 1979*

too." This fatalism has nothing to do with the Judaeo-Christian teaching of God's providence, and serves to give God, as they say, a very "bum rap." This attitude removes people from their history, and immersion in history is essential for liberation.

Human Liberation

The theme of the person and community as *subjects* of history rather than objects, as involved in the process of human liberation, is rapidly becoming central to theological thought. For too long, Judaism and Christianity have been drained of much of their historical dimensions, when in fact they are deeply historic faiths. Both are immersed in the process of liberation, proclaiming that to know God is to do the works of freedom and justice. Liberation of the Children of Israel from Egypt by the hand of God is—together with the Covenant which is its complement—the central theme of the Bible. And Jesus' description of his mission is to be understood precisely in terms of this tradition: "The Spirit of the Lord is upon me because He has chosen me to bring good news to the poor. He has sent me to proclaim liberty to the captives and recovery of sight to the blind, to set free the oppressed and announce that the time has come when the Lord will save his people." (Luke 4/18-19)

The history and structure of commercial nuclear power reveal much when viewed from the standpoint of human liberation. For the history of nuclear power has been a history of oppression, and its present structure is one of oppression as well. Hundreds of uranium miners have contracted lung cancer from the radon-products of improperly ventilated mines.[13] Uranium mining involves the exploitation of the lands of native peoples of the United States, Namibia and Australia. Much of this land is sacred territory, and the willingness of nuclear interests to continue to assault the cultural integrity of aboriginal peoples is wholly unethical.

But the most profound oppression is imposed when human beings are treated as irrelevant, as secondary to the system of energy production through nuclear fission. If one turns to the record of the Three Mile Island accident, one finds Roger Mattson, official of the Nuclear Regulatory Commission charged with safety in the Harrisburg area, telling Washington: "I do not know why you are not moving people . . . I have told them here and I am telling you . . . we should be moving people." Millions have drawn the conclusion that the safety of the industry has been placed before the safety of people. Nuclear energy is valued more highly than persons.[14]

Anxiety about radiation is an important part of the process of liberation in relation to nuclear power. Just as an ahistorical technological optimism can lead to fatalism, radiation anxiety can grow into creative hope. Given the point of evolution at which the human race finds itself today, the psychiatrist Robert Jay Lifton calls such anxiety "the wisdom of the body."[15] It is a clear message that it is possible for humans to develop new "spiritual organs" in order to deal with a uniquely dangerous and irreversible threat which they cannot feel, hear, taste, see, or smell. Such anxiety offers a chance for survival, for liberation.

The theologian Hans Jonas invites us to consider that we are at a new ethical situation as humans, a situation where our response must be proportioned to the depth of the damage we can do to the biosphere.[16] Such an ethical response seems to be taking shape across the globe in the form of the antinuclear movement. It would be a misreading to see this movement as negative. A creative hope is at the heart of the opposition to nuclear power, one that sees the possibilities of a new system of energy and of industry. The resilience of human beings being liberated through hope is bringing into view new possibilities and new realities expressive of the human values that have been notably absent from the nuclear power program and its progenitor, the bomb. The struggle for liberation in regard to nuclear power and nuclear weapons may well represent the crucial theological issue of our age.

Persons everywhere are beginning to implement an energy system which is hospitable to international justice, has a rich and responsible relationship with the biosphere, and can move the human community along the path, as Dante put it, of "the love that moves the sun and the other stars."

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Nuclear Wastes

Ellen Winchester

For many determined proponents of nuclear power, finding a solution to the nuclear-waste problem has become the bottom line. Even after Harrisburg, they have faith that reactors can be made safe, if only the nuclear industry will shape up and follow the advice of experts. But without a solution for the waste-disposal dilemma, legions of smoothly running reactors will only compound the problem. Radioactive wastes from commercial and military production are already more abundant than all the water in the world's oceans could dilute without risking dangerous reconcentrations of radioactivity in marine organisms and sediments.

The tragic limit over which human hubris may have tripped is that nuclear waste stays poisonous practically forever; nobody has yet invented a container for it that won't leak, sooner or later. Environmental concern about radioactive waste has focused on four areas: the difficulty of containment, the different kinds of radiation, different forms of existing waste and the locations of radioactive waste.

For more than 35 years nuclear promoters have been saying that safely isolating nuclear wastes would be easy. Until very recently they were saying it would be so easy that it wasn't necessary to bother with yet. But even before the valve failed in the Three Mile Island plant's cooling system, nuclear engineers were becoming less confident about their ability to contain ionizing radiation under any and all conditions.

In mid-March the federal government's Interagency Review Group (IRG) on nuclear-waste management reported to the President that the scientific feasibility of government's and industry's favorite waste-disposal concept, dry storage in geologic repositories constructed deep in salt beds or hard rock, "remains to be established." This admission, though pitched in a low key, strikingly contrasts with an earlier draft's optimism about the feasibility of geologic storage for thousands of years. The final report, produced by representatives of fourteen federal agencies, further advised the President, who is expected to make the key decision on geologic storage before this article is published, that "the preferred approach to long-term nuclear-waste disposal may prove difficult to implement in practice and may involve residual risks for future generations which may be significant." The report stressed that the safety of disposing of high-level wastes in mined repositories could only be assessed by specific investigation at particular sites.

So far, only a few potential waste-repository sites have been subjected to rigorous geologic investigation: bedded salt deposits near Lyons, Kansas; granite formations in Sweden; and salt beds near Carlsbad, New Mexico (the Waste Isolation Pilot Plant, WIPP). The Kansas salt beds were found to be riddled with holes from commercial exploratory operations. In February, geologists advising the Swedish Nuclear Power Inspectorate gave a failing grade to a proposed storage site in granite. Geologists have raised basic questions about the safety of storing radioactive waste in *any* salt formations. The WIPP site, the most thoroughly studied by the United States Department of Energy (DOE), is currently the focus of heavy criticism from environmental scientists as well as from government nuclear scientists outside the DOE.

How Low is Low Enough?

So far, all the design concepts for geologic repositories plan for what at best amounts to slow leaks and *not* for

Reprinted from **Sierra**, *July/August 1979, pp. 46-51. Courtesy of* **Sierra**, *The Sierra Club Bulletin. For more information, contact the Sierra Club Radioactive Waste Campaign, Box 64, Station G, Buffalo, New York 14213.*

zero discharge of radioactive wastes. But this is not enough. A scientific consensus appears to be forming that *any* amount of radiation can cause cancer in man.

An unverifiable amount of cell damage is caused by already existing "background radiation" from cosmic rays, from emanations of the natural uranium and thorium in the earth's crust, and from residual radiation from certain natural elements in granite and other rock. Estimates of this natural radiation range from 100 to 250 millirem per person a year for whole-body doses. Since the average medical and dental exposure is 70 millirem annually, human exposure can quickly multiply above the natural background level with no increase from nuclear power or weaponry. Even a transcontinental airplane flight adds four millirem to the body's burden of exposure.

As more research is published on how much radiation is "safe" for human beings, scientists learn more about how unsafe even tiny increases above the background level can be. With no control possible, the damage done by the latter cannot be measured. Even lung cancer induced by tobacco smoking may be traced to the effect of particles of polonium, a radioactive element collected from the air by tobacco leaves and deposited in the lungs of smokers.

Different kinds of ionizing radiation—labelled alpha, beta, gamma and neutron—pose different hazards to living cells. Alpha-emitters such as polonium and fissile plutonium 239 can be transported in any kind of sealed container, even pockets or briefcases, without harming anyone because alpha particles can travel only short distances and cannot pass through the protective outer layer of human skin. But if an alpha particle is inhaled into the lungs, or otherwise given a chance to reach internal organs, it adheres where it is deposited and damages cells by accumulated radiation over the years. As little as 10-100 micrograms of plutonium 239 in the lung is probably enough to produce a 50% chance of inducing lung cancer. Reactor-grade plutonium is so highly refined that one tenth as much will do the same.

Alpha-emitting elements have very long half-lives; they include most of the actinides: actinium, thorium, protactinium, uranium, neptunium, plutonium, americium, curium and heavier elements, many isotopes of which are fissile. (Transuranic elements, a classification often used in the media, are actinides heavier than uranium.)

Beta particles, more than 7000 times lighter than alpha particles, can travel farther and penetrate skin more easily. Nevertheless, like alphas, they are most dangerous absorbed inside the body. Most products of nuclear fission, like those that threatened the countryside around the Three Mile Island reactor in March, emit beta radiation. Two that have received much attention are iodine 131, which concentrates in the thyroid gland, and strontium 90, particularly dangerous for infants and children because it is most readily absorbed by bone. Another beta-emitter, tritium, is a radioactive form of hydrogen that, as a constituent of water, spreads easily in the body and is therefore more easily diluted and less toxic. Radioactive krypton, routinely released from reactors, diffuses through the atmosphere and adds to the average total external dose of low-level radiation received by the public.

Most fission products also emit gamma rays. Like the neutrons produced by nuclear fission and fusion, gammas penetrate through skin, sinew and bone—as well as through heavy lead, steel and concrete shielding. X-rays are a lower-energy form of electromagnetic radiation, similar to gamma rays, that can penetrate the body and can also cause biological damage. Doctors and dentists are now encouraged to keep X-rays to a minimum.

New information is released almost daily concerning the heightened cancer incidence among workers exposed to low-level radiation in uranium mining and milling, military reprocessing (which recovers uranium fuel used in nuclear-powered ships and plutonium for bomb fabrication), nuclear shipyards, soldiers involved in nuclear-bomb testing and civilians caught in its downwind fallout. Recently Ralph Nader's Health Research Group asked President Carter to act on a National Academy of Sciences recommendation that allowable occupational exposure to low-level radiation be reduced ten fold, from 5 rem to 0.5 rem per year, the equivalent of 20 to 50 times the level of exposure of a chest X-ray.

The Nader group cited a British study that showed increased chromosomal damage in workers exposed to only 2 to 3 rem a year. Dr. Alice Stewart of the University of Birmingham, who has been working with a study of 35,000 living Hanford workers, says that prolonged low-dose exposure leads to proportionately more damage than a single, larger dose. At lower doses, the body is able to repair slightly damaged cells well enough for them to reproduce, passing on the damage to succeeding generations, or to make other damaged cells that weaken the body's resistance to disease and injury. Children born in southern Utah during the years when atomic bombs were exploded above ground have been reported by a University of Utah medical team to suffer 2.5 times the number of leukemia deaths as children born before and after the testing.

For 22 years the accepted wisdom has been that annual exposure of 170 millirem above background radiation levels was a permissible level for the general population. However, in 1977 the Environmental Protection Agency suggested 25 millirem as the annual limit. The Nuclear Regulatory Commission (NRC) has adopted that figure as the permissible dose to the public created by the nuclear fuel cycle.

Meanwhile cancer mortality is on the rise in the United States among all age groups. Chemical air and water pollution, food additives and increased ionizing radiation from bomb-test fallout, medical procedures and nuclear reactor operation all appear to be culprits, each synergistically augmenting the carcinogenic effect of the others. Given this knowledge, it seems evident that the release of carcinogens into air, water or the food chain should be reduced rather than permitted to escalate over time—as ionizing radiation from increasing quantities of badly stored wastes is all too likely to do. (The radio-

activity of commercial waste began to exceed that of military waste last year).

Mill Tailings

The problem of containing radiation from nuclear wastes begins at the uranium mine and at its adjacent mill, where uranium-bearing rock is crushed and processed and tailings are chemically separated from uranium. Currently 16 uranium mills in the United States process 10 million to 15 million tons of ore annually. Good ore contains 0.2% uranium by volume. The rest is tailings; about 140 million tons have accumulated so far in the United States, almost uranium-free—but not radiation-free. Uranium, decaying through the ages, has produced thorium and thorium's "daughter" radioactive elements, including radium and radon, which are sources of gamma radiation.

Because of thorium 230's long half-life (180,000 years), its daughter products will remain active pollutants for hundreds of thousands of years. Not until fifteen years ago, when alert public-health personnel discovered a higher incidence of cancer in people who lived in houses built with or on mill tailings, was their use in the construction industry and for roadbuilding in the West curtailed. But the problem with mill tailings persists; tailing dumps cover many acres of ground. Wind whips the tailing dust high into the atmosphere, where it is carried for long distances.

Covering existing tailings with asphalt or burying them and safely sequestering new tailings is an expensive project the Department of Energy's Nuclear-Waste Management Program is currently working on. The progress of its efforts to protect the atmosphere from radon, and groundwater from leached radium, will need continued public attention.

As part of its study of nuclear waste, the IRG postulated several energy futures for the nation—different estimates of energy use that would result in varying amounts of nuclear waste. Under IRG's "Case 1" postulate of 148 gigawatts (GW) of installed nuclear electric generating capacity in the year 2000 (the higher Case 2 scenario projects 380 gigawatts—today the U.S. has about 50 GW of nuclear capacity), 1.9 billion tons of tailings will have been produced by then. Legislation is before Congress that would authorize EPA to issue standards and criteria for mill-tailings disposal, and would establish the Nuclear Regulatory Commission's (NRC) licensing authority over active sites and DOE's authority over inactive sites. Assigning authority, however, cannot guarantee a solution of the gargantuan problem posed by the tailings.

Low-Level Wastes (LLW)

Next to mill tailings, low-level wastes, which contain small amounts of radioactivity and require no shielding, produce the largest physical mass of "nuclear junk" to be disposed of. They start accumulating at the mine shaft. Used equipment and such miscellaneous debris as gas filters, lab coats, paper towels and some liquid wastes solidified in concrete continue to accumulate through the entire fuel cycle. Some of it—trucks, parts of decommissioned reactors—is very bulky.

During most of the history of military and commercial use of the atom, low-level wastes have been buried in shallow trenches. A few years ago at the burial site at Maxey Flats, Kentucky, plutonium was found to have migrated as far as two miles from the site. Of six burial sites for commercial wastes, two (West Valley, New York, and Maxey Flats) are now closed. A third site, at Sheffield, Illinois, is already filled to its licensed capacity. The NRC had to order the Sheffield operator to continue patrolling fences and maintaining trenches after the site had been, in effect, abandoned.

Currently, commercial LLW is buried at Barnwell, South Carolina (where the state government limits quantities), at Beatty, Nevada, and at Hanford, Washington. The DOE has fourteen other burial grounds. No coordinated national program for LLW management exists yet. Niagara Mohawk Utility has applied for a permit to build a commercial LLW incinerator at a reactor near Oswego, New York, but the local Sierra Club is worried that scrubbers won't keep radioactive cobalt and cesium out of the air.

The DOE has selected a contractor to build an incinerator at the Idaho National Engineering Laboratory. Intended for operation by late 1986, the incinerator will take eight years to process the existing backlog of LLW. The rock-like radioactive slag residue will go to . . . wherever the government may decide to build a permanent waste repository.

Almost all low-level wastes are either solids or made solid with concrete, but some low-level liquid wastes at a DOE facility at the test site near Mercury, Nevada, are pumped 1000 feet down into an underground cavity created by a nuclear explosion. Unknown quantities of low-level liquids were solidified in cement and dumped at sea in the early days of nuclear development. It is worth asking whether the Nevada test-site disposal of liquid wastes could pass the skeptical scrutiny geologists, geochemists and hydrologists are currently giving to concepts for using geologic formations to isolate spent fuel and high-level wastes encased in steel and titanium.

Intermediate Waste Liquids

Intermediate-level waste liquids produced at the Oak Ridge National Laboratory are injected into a deep underground shale bed after first being mixed with grout. The grout solidifies and is intended to fix the wastes in place. Whether it does or not, over the very long periods that some of the waste remains radioactive, will remain in question for many thousands of years.

Transuranic (TRU) Wastes

Since both TRU waste (which contains more than ten nanocuries of transuranic activity per gram) and high-level waste contain long-lived actinides, they pose similar long-term containment problems and should be disposed of with equal care. Yet all existing commercial TRU waste is buried, along with much larger volumes of associated materials, in shallow trenches at commercial burial

sites (except at Barnwell, where the government of South Carolina ruled against it). Only Hanford continues to receive commercial TRU waste for burial.

The transuranic content of the DOE's TRU waste is mainly plutonium. Until recently most of it was buried, but several years ago, at Hanford, enough plutonium was found to have migrated from one burial trench to make a chain reaction possible. As a result, since 1970 DOE has stored TRU waste in a retrievable form. The major purpose of the proposed WIPP disposal site is to store DOE TRU waste produced at Rocky Flats in the fabrication of bombs and currently stored at the Idaho National Engineering Laboratory. The state of Idaho has repeatedly pressured DOE to remove this waste.

Airborne Emissions

The fact that radioactive particles can travel through the air has been widely known since Hiroshima. It became more immediately apparent at Three Mile Island. What is less widely known is that nuclear reactors routinely vent into the air small amounts of gaseous radioactivity, including the nuclides krypton 85, xenon 133, iodine 131 and carbon 14. To reduce air pollution as much as possible, airborne emissions from reactors, spent-fuel storage, fuel reprocessing, weapon-related activities and waste treatment processes such as incineration and vitrification are filtered through sand, fiberglass and other appropriate materials that themselves then become radioactive wastes.

A supposedly typical DOE chart of a filtration system in a spent-fuel reprocessing facility claims 99.97% efficiency before the gases go up a 200-foot stack. Emissions of radio-iodine are controlled by special absorbers. The DOE Nuclear Waste Management Program aims to develop "new capability in areas where more restrictive standards seem likely to apply in the future." It seems a virtuous intention.

High-Level Wastes (HLW)

High-level wastes are either spent-fuel assemblies or the fission products and actinides that remain in spent fuel after plutonium and uranium have been recovered in reprocessing. Approximately 73 million gallons of liquid high-level wastes, among the most toxic and hazardous substances known, are now on hand awaiting a permanent method of disposal. They are in various forms: extremely corrosive acid liquids; salt cakes; sludge in underground tanks; and granular, calcined solids stored in underground bins. They consist of fission products, including strontium 90 and cesium 137 (30-year half-lives), actinides and certain other radioisotopes. The relatively short lifetimes of the fission products produce rapid disintegration; most of the wastes' heat and radiation are dissipated within 600 years of their existence. But the slower-disintegrating actinides may persist for millions of years.

Originally, HLWs are liquids produced during the reprocessing of defense-program reactor fuel or the commercial reprocessing of spent fuel. Since the United States' only commercial reprocessing plant, owned by Nuclear Fuel Services and located in West Valley, New York, has been closed, high-level wastes are now produced only at DOE military facilities in Savannah River, South Carolina; Richmond, Washington; and Idaho Falls, Idaho.

New double-shell steel tanks are being constructed to replace leaking tanks at the Hanford Nuclear Reservation and to provide additional interim storage. High-heat-generating cesium 137 and strontium 90 are being isolated from other wastes and encapsulated separately to make handling the remaining wastes easier.

Problems other than leakage have arisen with high-level waste storage. Waste at West Valley neutralized with an alkaline solution has turned out to be very difficult if not impossible to remove from a carbon steel tank. After a dispute arose between the state of New York and the federal government over who was financially responsible for 600,000 gallons of waste and for the cost of dismantling the Nuclear Fuel Services plant at West Valley, both parties arrived at a tentative agreement that has been rejected by environmental groups. Under the agreement, DOE would accept major financial responsibility for West Valley and would use its spent-fuel pool to store up to 1000 tons of spent fuel, and its waste-burial grounds would be reopened. Environmental groups, including the Sierra Club's Nuclear Waste Task Force, can be expected to mount an effective campaign against any new scheme to encourage the accumulation of nuclear waste by storing it at West Valley while means for its disposal remain unknown.

Since the United States has deferred indefinitely reprocessing of commercial spent fuel, owing to concern over keeping plutonium out of the hands of hostile military powers or terrorists, commercial facilities for glassifying—vitrifying—wastes have not been developed here, as they have been at France's Cogema plant and soon will be at Britain's Windscale plant. Both plants, and the nations planning to use their reprocessing facilities, are counting on the development of geologic storage for these vitrified wastes.

Reprocessing contracts such as Cogema's promise to remove all but 0.5% of the plutonium from wastes, but experts view the promise as optimistic. Moreover, approximately three times as much americium is also left in the wastes; it decays into plutonium, so the plutonium content actually increases over the first 20,000 years. All of the other actinides and fission products are left in the reprocessed waste product. If recovered plutonium is used as fuel and is again cycled through more reprocessing, it will be added to successive waste streams to accumulate wherever the waste is stored, a fact generally overlooked by the proponents of "burning up" the actinides.

Spent Fuel

Nuclear reactor fuel rods, each about twelve feet long, consist of a packing of uranium-oxide fuel pellets and a zircaloy casing, called "cladding." Approximately 40,000 of them are arranged in assemblies for encasement in the core of a large reactor. After about three years of

fission, radioactive by-products slow down the fuel pellets' ability to sustain a nuclear reaction; the whole assembly is then considered "spent" and removed to a water tank for cooling and storage. Each year a 1000-MW light-water reactor discharges about 25.4 metric tons of spent fuel into storage pools adjacent to the reactors. Only one storage pool in the United States, operated by General Electric at Morris, Illinois (originally intended to store spent fuel for reprocessing), has accepted spent fuel from distant reactors, some 300 tons of it.

The storage pools at first were intended to store spent-fuel rods for five years, but since no alternative system of storage has been devised, some spent fuel from our oldest commercial reactors has been cooling in them for 20 years. The spent-fuel rods must be carefully separated from each other to prevent the start of a chain reaction in the pool. The rods grow brittle with age; their cladding weakens; their cooling water is vulnerable to cutoff; they contain higher levels of radioactive strontium and cesium than the reactor itself; and no one in his right mind considers permanent storage in a pool a good idea, whether at the generating plant or in a very large, centralized, "away from reactor" pool. Unfortunately no one has yet developed and demonstrated a better plan.

Meanwhile, nuclear engineers have designed methods for increasing the load in existing storage pools by re-racking; and some NRC spokesmen believe that the United States could continue existing and planned reactor operation with no storage other than the pools until the end of the century. According to the IRG, the U.S. has about 5000 metric tons of spent fuel now, with at least 71,000 tons anticipated by the end of the century.

From the point of view of the nuclear industry, all spent fuel is an energy resource that should be kept available for reprocessing into plutonium and uranium to be refabricated into nuclear fuel. Nuclear critics worry about keeping spent fuel cool and containing its radiation while adequate permanent isolation technologies are developed.

Decontamination and Decommissioning

All operating nuclear reactors and all nuclear-fuel processing facilities, including buildings, will sooner or later become nuclear wastes. Nuclear reactors themselves have an expected operating life of 30 to 35 years. The DOE has identified 560 nuclear facilities currently obsolete or expected to become obsolete in a few years. Nobody really knows how they will be decommissioned —if they can be—or how much it would cost. Estimates of decommissioning costs are not included in the rates of utilities using nuclear power. Closing obsolete facilities and guarding them forever—"mothballing"—has been suggested. So has encasing them in concrete. Neither idea sounds like a winner.

Dismantling the reactors is probably the only option that will be acceptable to environmentalists, but it does not answer the question of where and how the chopped-up reactor will be contained. The NRC's Peter B. Erickson is quoted in *Business Week* as saying that any mothballing plan must take into consideration an entire range of elements, including short-lived isotopes such as cobalt 60, dangerously radioactive for 100 years, and such long-lived substances as niobium 94 and nickel 59, with half-lives of 20,000 and 80,000 years, respectively, that require isolation for at least a half-million years.

Nuclear reactors looming through the mist on hillsides or the coastal horizon look as sturdy (and as eerie) as Stonehenge; 72 commercial reactors were operating in the United States at the time of the Harrisburg accident, with over 500 operating or in the planning stages worldwide. Like the other nuclear wastes, they won't go away by themselves.

The two plans for intermediate and permanent storage of high-level wastes or spent fuel have received considerable attention: the Swedish plan for storage in granite and the WIPP site in salt. They aim, at best, for 100 years of absolute containment by multiple barriers of casks, clay and rock or salt. During that time some fission products would decay to very low levels, but long-lived materials, the heavy-metal actinides capable of fission themselves, will probably slowly leach through corroded casings and dissolved glasses, through fissures in rock and underground aquifers into rivers and waterways. Eventually they will reach the oceans.

DOE is considering another plan to emplace nuclear wastes in clays on the sea floor far from any continental boundary. In case of a failure of containment, radioactive pollutants could reach the oceans even sooner.

The gamble with any plan yet proposed for storage of nuclear wastes is (1) that none of our descendants will breach the repositories through war or drilling for minerals; (2) that water and heat will not concentrate fissile materials to form inadvertent nuclear reactors capable of producing larger quantities of unconfined radioactivity; (3) that ice sheets, the geologic folding of the earth, or other unforeseen processes will not uncover the wastes; and (4) that none of the anticipated processes will happen faster than expected, causing the wastes to "bubble up through the earth two decades from now because in 1979 we made a wrong technical decision," as Senator Glenn worried aloud at a hearing on the IRG recommendations. It is a most unusual gamble; no one now alive is expected to lose, if all goes according to plan —unless a sense of guilt over endangering the future for our present comfort and convenience is a kind of loss.

A thousand years ago, the finest architectural and engineering talents in the western world were mobilized to build cathedrals. It is ironic and disheartening that comparable talents and even more sophisticated skills must today be devoted to devising foolproof garbage dumps.

Not An Avoidable Problem

William G. Pollard

Three questions may be asked about nuclear wastes: What are they? Where do they come from? and What will we do with them? The first two questions are adequately answered in the preceding article by Ellen Winchester on "Nuclear Wastes." The third, however, is a different matter. Those whose primary purpose is to oppose nuclear energy approach this question in one way, while those who are neutral or in favor of nuclear energy approach it quite differently.

There already exist in the world great quantities of high level nuclear wastes generated in the production of nuclear weapons. Sooner or later we must dispose of them regardless of our feelings about nuclear energy. They won't go away simply by wishing them out of existence. Those charged with the technical responsibility for the development of permanent disposal methods are convinced that it can be done with adequate safety by deep burial (600-1,000 m.) in several geologic formations including bedded salt, some shales, and granite. The remaining problems are mostly political, together with the difficulty of achieving a consensus on which among several ceramic or glass matrices for the wastes and particular geologic formations are best. Sooner or later we must settle on one among these alternatives and go ahead. It is not something we can continue to debate forever. At the same time all of these alternatives have a miniscule probability of ever returning even detectable radioactivities to the earth's surface and an essentially zero probability of returning amounts dangerous to human health. It is equally true that neither for this problem nor any other in the life of civilized man can absolute safety be absolutely guaranteed for all future time.

Those, however, who have little interest in contributing to this problem but are anxious to find telling arguments against nuclear energy take a quite different approach. For them the object is to demonstrate that the disposal problem has no solution. This is the case with Winchester's article. The opening sentence of the second paragraph sets the stage with the loaded statement, "The tragic limit over which human hubris may have tripped is that nuclear waste stays poisonous practically forever." In fact, after 600 to 1,000 years such waste is no more "poisonous" than natural wastes already in the earth in the form of rich uranium ores. After 10,000 years they are less "poisonous" than was the uranium from which they were originally derived. These are admittedly long periods, but they are hardly "forever." Later on after correctly characterizing the natural radiation dose from 100 to 250 millirem per year and the additional average medical dose as 70 millirem per year, it is stated "scientists learn more about how unsafe even tiny increases above the background level can be." What scientists have in fact learned is that no measurable health effects on either animals or man can be detected at all below 10 rads (10,000 millirem for man). This statement stands in the face of contrary opinions later attributed to Ralph Nader and Alice Stewart. Several such opinions including the one concerning uranium mill tailings are stated without any recognition that they have been discredited by competent authorities. One of the most surprising statements is that "Reactor grade plutonium is so highly refined that one-tenth as much will do the same" as plutonium 239.

It is strange that the Sierra Club should have seized on radiation and radioactivity as the ultimate environmental catastrophe. There must be hundreds of agents in our environment which are greater threats to human health than a radiation dose of 250 millirem or even 1,000 millirem per year. Yet articles such as this ask us to do without electricity for fear of added exposures of 10 millirem per year or less, or else force us to coal with its enormously greater real environmental insults. It is extraordinary to what lengths we can be driven by irrational fear!

See Dr. Pollard's earlier article on page 70 of this issue.

Far Greater Dangers than Nuclear

Bernard L. Cohen

The paper on "Nuclear Wastes" by Ellen Winchester proves only one thing, that nuclear energy is not "perfectly safe." However, that is not a practically useful conclusion, because no method for generating electricity is perfectly safe—coal and oil burning cause lethal air pollution, gas kills by asphyxiation and explosions, hydroelectric dam failures could drown hundreds of thousands in a few minutes, solar energy requires vast quantities of steel, aluminum, and cement whose production causes a wide variety of deadly pollution problems—and doing without electricity would be many times more dangerous than any of them. If the purpose is to show that we should not use nuclear energy because of the radioactive waste problem, then it must be shown *quantitatively* that these wastes do more harm to human health than the alternatives.

Dangers of Coal

I will therefore do what she has failed to do, to quantify the dangers of nuclear waste, and to compare them with the dangers of obtaining the same electricity from burning coal which is our only presently viable alternative. Typical estimates are that the wastes from coal burning, most of which are simply discharged into the air (air pollution) are at least 10,000 fatalities per year in the U.S. This may sound horrible, but it corresponds to a life expectancy reduction for the average American of only 13 days. To put this risk to an individual in perspective, it is the risk an overweight person takes in adding 7 ounces to his weight, or the risk of smoking one pack of cigarettes every 4 months, or the risk of a woman going 2.5 years without a PAP test (only 50% of women get them), or the risk of not having a smoke alarm in your home (only 15% of all homes have them), and it is four times *less* than the risk of driving small cars rather than standard size cars. It is only 2.5 times the risk of electrocution in using the electricity. Whether these 10,000 fatalities per year (plus 10 million cases of respiratory disease and $13 billion in property damage) are "acceptable" is a matter of opinion, but our society is accepting them. There are programs for reducing the effects, hopefully down to the region of 2000 fatalities per year, but these are progressing very slowly and many experts believe they are on the wrong track. Nevertheless we seldom hear that the technology for handling the wastes from coal-burning is "yet to be established."

Nuclear Wastes

We now turn to the problem of nuclear waste. In estimating its effects, we use the recommendations agreed to (with small variations) by all prestigious national and international groups charged with responsibility in this area, including the National Academy of Sciences Committee on Biological Effects of Ionizing Radiation (BEIR), the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), the International Commission on Radiological Protection (ICRP), and national bodies in all advanced countries of the world. Incidently these groups, as well as the vast majority of the involved scientific community (which they represent) reject the contention that radiation is more dangerous than it was believed to be a few years ago—this is largely a fabrication of our news media built upon very flimsy "new information" and ignoring the vast bulk of more substantial data, both old and new. The above-named groups give the 50%-lethal level for plutonium in the lung as 10-100 times higher than Winchester's figures, and contrary to her statement, they have never recommended or even suggested a lowering of allowable occupational exposure. EPA's justification for lowering allowable exposure to the public from 170 to 25 mrem/year was done not because of increases in estimated effects of radiation, but because the reduction was deemed technologically achievable and the guiding philosophy is to keep radiation exposure as low as reasonably achievable.

High-Level Waste

The solution to the problem of high-level waste is to convert it into a rock and bury it where the rocks are, deep underground. It is easy to show[1] that if an atom of waste has the same probability of escape as an atom of average rock, and if all U. S. electricity were nuclear-generated for millions of years, all of the accumulated waste would cause *less than one* fatality per year in the United States—compare this with the 10,000 per year from the wastes of coal-burning. There are some ways in which buried radioactive waste would be less secure

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than average rock, especially due to the fact that it will be thermally hot for 100-200 years; while all research to date indicates every reason for optimism, these matters are still under investigation which contributes a grain of truth to the statement that the technology is "yet to be established." However there are alternatives available regardless of how this research turns out—the waste can be diluted or its burial can be delayed to allow the heat source to decay away—so these studies are more for the purpose of optimum waste repository design than for establishment of feasibility. Moreover there are ways in which the buried waste would be more secure than "average" rock; it would be in a carefully selected geological environment virtually free of ground water, and it will probably be in a casing which would give million year protection not available to average rock. All in all, the one fatality per year derived above from average rock seems like a reasonable estimate for buried radioactive waste.

National Campaign for Radioactive Waste Safety

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Even if every nuclear plant in America were shut down tomorrow, we'd still face the terrible question of what to do with 10 million cubic feet of high-level radioactive waste materials that already exist. Poisons that threaten our health and our lives, and will continue to plague future generations for thousands of years.

In the past 35 years, the nuclear industry and the military program have produced millions of gallons of liquid and solid wastes which give off radiation that contaminates our food, our land and the air we breathe—raising risks of cancer, genetic damage and other calamitous effects. A microscopic speck of radioactive waste one-fourth the weight of a grain of salt can, if inhaled, cause lung cancer.

The same government and industry experts who dumped thousands of tons of concrete-encased nuclear waste into the ocean that has now contaminated the sea bed and assured us that the already defective radioactive waste storage tanks at the Hanford Military Facility in Washington State would last 30-50 years, are now trying to cover up the tremendous dangers in implementing their "new" waste disposal plan.

In general, Winchester loses perspective on the dangers from high level waste. She states that it will stay poisonous "forever", but it loses 99.9% of its toxicity after 300 years, and 99.999% after 100,000 years by which time a 50%-lethal dose would be over 6 lbs. converted into digestible form and eaten. There are other substances we dispose of with little control, and there are even natural rocks, for which 1 ounce or less would be lethal, and these truly maintain their toxicity forever. If the waste were dumped in the ocean—no one can claim we don't know how to do that—or buried in the sea bed, and if all of it leaked out immediately, the U.S. waste (if all our power were nuclear) would cause about 60 fatalities per year worldwide[2] through contamination of sea food, still hundreds of times less than the 10,000 fatalities per year from coal burning. Incidently, there would be essentially no harm to ocean eco-systems from such an eventuality.

Low-Level Waste

The low-level waste contains thousands of times less radioactivity than the high-level waste, is therefore less dangerous by a corresponding factor, and is consequently buried with considerably less care in shallow trenches. While there was tremendous publicity about the tiny leakages from the Kentucky and New York State burial grounds, no member of the public was exposed to as much extra radiation from them[3] as he would get from spending two days in a brick house rather than in a wooden house (brick contains more naturally radioactive material than wood), or from spending 8 hours in Colorado or Wyoming where natural radiation levels are higher than average. The chance that a single person will ever die from these past leaks is about one in 100,000. The reason for this low level of damage is that only a very tiny fraction of the buried material leaked out. However, it can be shown[4] that even if *all* of the radioactive material in these burial grounds were to leak out and become distributed through the soil, and if no special attention were paid to it there would still be only about one eventual fatality. The point here is that there is only about one chance in a billion each year for a given atom in the top layers of soil to find its way into a human body, and the vast bulk of the low-level radioactivity has a half life of less than 30 years, so it will decay away long before it can do harm.

Incidently, a large fraction of the low level wastes are from hospitals and from research laboratories, with no relevance to nuclear power.

Mill Tailings

Winchester is a bit behind the times on the issue of radon emission from uranium mill tailings. The Nuclear Regulatory Commission has proposed requirements for operating mills to cover their tailings piles, and the Department of Energy has an active program for taking care of tailings at inoperative mills. The costs of covering tailings will be charged to the electricity consumer, but it will increase his bill for nuclear electricity by less than 0.1%.

On the other hand, little attention has been paid to the fact that coal contains small amounts of uranium, and hence that the ashes from coal burning also emit radon gas. It turns out that if the uranium mill tailings piles are covered, the radon problem from coal burning is considerably worse than from nuclear energy. The radon emitted from one year's production of coal ash will cause about 10 fatalities over the next 500 years.

Another viewpoint on this is that nuclear energy consumes uranium and hence reduces the exposure of future generations to radon. This greatly exceeds the harm done by radon from covered mill tailings so the overall effect of the nuclear industry is to reduce man's exposure to radon.

But if we are to worry about effects of radon, the real culprit is *energy conservation*. In insulating homes to save energy, radon emitted from the building materials and foundations of our houses is trapped inside for twice

as long as it would be without the added insulation.[5] If all homes were insulated to recommended standards, this would cause an extra 5000-10,000 fatalities per year in the U.S.

Intermediate and Transuranic Wastes

The intermediate and transuranic wastes discussed by Winchester are from military and research sources and have no relevance to nuclear power. However, these problems are being taken care of expeditiously and there is no reason to believe that they will even approach in importance the problem of high level waste discussed above.

Airbone Emissions

The technology for controlling airborne emissions of radioactivity from nuclear plants is in place and functioning, so there is no need to speculate on its performance or on the "virtuous intentions" of government programs. Current radiation exposures are such that there is approximately one fatality per year in the U.S. from this source; if all U.S. power were nuclear and if we had a complete fuel reprocessing industry in operation, this number would rise to perhaps 20 fatalities per year, but this is still hardly comparable to the 10,000 fatalities per year from coal-burning air pollution.

Spent Fuel

There has never been a report of significant leakage of radioactivity into the environment from spent fuel storage, and according to all available information, there is no problem expected from this source even if the fuel were stored for 30 years or more. Hopefully the government will allow reprocessing to proceed in less than 30 years, in which case the problem disappears. It is very difficult to see how this problem can be even 1% as great as the problem of airborne emissions discussed above.

Decontamination and Decommissioning

There are now good estimates available on costs for decommissioning of nuclear power plants, and even for the most elaborate procedures, this would be only 10% of the original cost of the plant. This would raise the cost of electricity by only about 2%. The entombment or moth-balling scheme mentioned by Winchester would reduce these costs about three-fold and it would be for only 100 years, which is something less than "forever." The residual material after decommissioning would be "low-level waste" and would represent a minute addition to the low-level waste problem discussed above.

Final Statement

Let me comment on the points in Winchester's last two paragraphs. On her numbered points:

(1) The effects of breach of waste repositories by later generations through drilling, mining, or bombing has been estimated and found to be less than effects of natural releases[1] discussed above.

(2) It is absolutely impossible for high-level waste to get into a configuration that would form a nuclear reactor; there just isn't enough fissile material in it.

(3) By the time ice sheets or other geologic processes could release the waste, its toxicity would be very low, lower than the toxicity of the original uranium ore mined to produce the waste. Thus our use of nuclear power *alleviates* this problem.

(4) The purpose of all the research now going on is to be certain that there are no processes that can lead to very rapid release.

Does the Nuclear Option Make Sense?

The function of a nuclear reactor, like that of any power plant, is to convert energy from the form in which we find it to a form which we can use—in this case from the energy contained in the nuclei of certain atoms into heat and electricity. Energy in the latter form can be used to light and heat our homes and factories and to run our machines. Our goal should be to make energy available in a convenient form at low cost, with little waste, and with minimum danger to human and natural life and minimum consumption of irreplaceable resources

Does nuclear power accomplish this goal well? Regrettably, it does not. The fission of uranium fuel occurs at temperatures in the range of a million degrees Fahrenheit; this heat is used to convert water into pressurized steam at a temperature of six hundred degrees; and this steam is used to drive turbines which produce electricity. Much of the heat produced cannot be used, and elaborate cooling towers and pipes are necessary to dissipate the wasted heat. But even if all of the heat produced could be put to use, the means simply are not fitted to the end: it is enormously wasteful to construct a source of extremely concentrated energy only to dilute it again and again until it reaches a form which we can use. Heating our homes with nuclear power is like candling an egg with a thousand-watt spotlight, putting layer upon layer of masking over the light until it is dim enough to be useful.

A second crucial question is this: What are the political and moral consequences of nuclear power? Like coal- and oil-based energy production, nuclear fission depends on a natural fuel in limited supply. Estimates of the world's stock of fuel-grade uranium deposits vary widely: some say they will be exhausted by the year 2000, others are much more optimistic. Some day, like fossil fuel resources, uranium deposits will be exhausted. Nuclear power cannot shift us from a life which depletes the earth's resources to one which uses replaceable energy sources.

Even more important, because of the relative efficiency of large plants and the high cost of their construction, nuclear power must be produced at relatively few central locations. To shift from fossil fuels to nuclear power would be to commit ourselves to increasing reliance on a small number of centralized power plants and on transportation of energy over great distances. The social cost of such a shift would be great: only a powerful central government could effectively oversee the planning and supply of energy and the safe disposal of waste, and our sources of power would be highly vulnerable both to natural disaster and to military attack. To adopt nuclear power as the basis of our future society is to move in the direction of an even more highly organized, centralized, and technology-dependent society than ours is at present.

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Reprinted from **The Reformed Journal**, *August 1979, pp. 18, 19*

We have many more serious long term waste problems than nuclear waste. For example, the arsenic we import into our country each year has 10,000 times the toxicity of one year's production of nuclear waste after 1000 years of decay. Moreover, the arsenic is not carefully buried 2000 feet underground, but most of it is used as an herbicide and hence is scattered about on the surface in food growing areas. The arsenic, of course, will retain its toxicity forever. But of course this problem can never approach the problem we now have of killing 10,000 people per year from the air pollution of burning coal, our only alternative to nuclear power.

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Benefits of Nuclear Power Outweigh Its Risks

Everett R. Irish

In response to the companion article[1], I asked myself questions about nuclear wastes such as: Why do some people fear them? How should they be viewed in perspective? Could we ever get along without them? Hopefully, in this response these questions are answered and nuclear waste management will be better understood instead of feared.

In order to be both informative and brief, several approaches to responding specifically to the subject article were considered. These ranged from (a) writing a parallel article with a balanced presentation of facts and interpretations, to (b) selecting a few portions of the article for critique in depth, to (c) selecting numerous items for comment. Writing a complete article is not feasible in the allotted space and is also unnecessary; there are numerous publications on the subject in varying degrees of technical detail for interested readers.[2-10] The last approach was selected because of its feasibility, directness, and breadth of coverage. The comments cannot be comprehensive; however, they hopefully are adequate to apprise readers about nuclear waste management and some specific issues raised.

Comments on Winchester Article

The companion article is one of the better articles written in opposition to nuclear power. Many of the facts are summarized satisfactorily; in particular, the description of the types of radiation (i.e., alpha, beta and gamma) and the categorization of the types of wastes (i.e., mill tailings, low-level wastes, transuranic wastes, etc.) are cited. In addition, quite a few of the factual aspects of waste management practices are correct, but there also are numerous misstatements of facts. Incorrect impressions or interpretations all too frequently are given when the article alludes to situations or "explains" information. In addition, the beneficial uses of nuclear power and its waste products are completely omitted from the discussion. The following paragraphs expand on some of these aspects with reference to specific examples from the text of the article.

The companion article arouses fear and anxiety more than it provides understanding about nuclear wastes.

Dr. Irish has spent 24 years in the nuclear field. He is currently on leave-of-absence from Battelle-Northwest, and a Senior Officer in the Waste Management Section, Nuclear Safety and Environmental Protection Division of the United Nations International Atomic Energy Agency, effective November 19, 1979. For a personal statement by Dr. Irish, see the Communications section of this issue.

This paper was prepared in connection with work under Contract No. EY-76-C-06-1830 with the U.S. Department of Energy.

For example, the risk—however small—of radiation causing cancer is presented as the ultimate measure of safety without recognition of many risks of other types. Imagery and associations are also used for this purpose to allude to situations rather than deal with documented facts in perspective. Numerous examples (quotations in italics) can be given:

Radioactive wastes from commercial and military production are already more abundant than all the water in the world's oceans could dilute without risking dangerous reconcentrations of radioactivity in marine organisms and sediments. Possibly true but irrelevant. Even if so, the total toxicity (lethal doses) of nuclear wastes, aged 100 years, which would result from an assumed all-nuclear U.S. electric economy annually would be several orders of magnitude lower than the lethal doses of commonly used chemicals (e.g., arsenic, barium, hydrogen cyanide, et. al.) annually present in the U.S.[6] It has also been shown that the toxicity of the plutonium which would go to waste (projected for the year 2000) is comparable to the toxicity of lead sent to waste in 1973.[11] However, such quantitative representations of potential hazards are virtually meaningless unless one also takes into account the barriers that prevent or retard movement in the environment and the possible pathways that hazardous materials could take to reach man; that is what nuclear waste isolation is all about, as discussed later.

The tragic limit over which human hubris may have tripped is that nuclear waste stays poisonous practically forever. "The tragic limit" of what? The potential of nuclear power to provide a long-term supply of energy is a major step (not trip) toward ameliorating a growing world energy shortage. Furthermore, whereas arsenic, barium and lead are stable and will last forever, radionuclides decay; in fact, after about 500 years of decay, the radiotoxic hazard of high-level waste from the light water reactor industry will be lower than that of the ore that was required to make the fuel.[12] This suggests that isolation time frames of 500 years are most important for isolation of high-level waste.

Alpha-emitters such as polonium and fissile plutonium 239 can be transported in any kind of a sealed container, even pockets' or briefcases, without harming anyone. True but irrelevant and misleading. (Polonium 210 is a radioactive isotope not normally considered a nuclear waste because of its presence in nature.)

. . . gammas penetrate through skin, sinew and bone—as well as through heavy lead, steel and concrete shielding Misleading statement because lead, steel and concrete are very effective shields.

It is worth asking whether the Nevada test-site disposal of liquid wastes could pass the skeptical scrutiny geologists, geochemists and hydrologists are currently giving to concepts for using geologic formations to isolate spent fuel and high-level wastes encased in steel and titanium. Yes, the practice would pass the scrutiny of knowledgeable persons. The wastes about which this allusion is made are estimated to contain less than 1 curie/year and are produced during metabolism and biological transfer rate research on both animal and plant life using radioactive and non-radioactive materials.[13] Certainly the radiological safety of the practice is not in question.

Intermediate-level waste liquids produced at Oak Ridge National Laboratory are injected into a deep underground shale bed after first being mixed with grout. The grout solidifies and is intended to fix wastes into place. Whether it does or not, over the very long periods that some of the waste remains radioactive, will remain in question for many thousands of years. The safety of this practice is well documented[14] and accepted by knowledgeable persons as being entirely satisfactory. Earlier comments are also apropos.

The fact that radioactive particles can travel through the air has been widely known since Hiroshima. It became more immediately apparent at Three Mile Island. Linking Hiroshima and Three Mile Island is technically irrelevant but evidence of scare tactics. Movement of particles through air has been known since before the days of Tyndal's research.

The final (IRG) report, produced by representatives of fourteen federal agencies, further advised the President, who is expected to make the key decision on geologic storage before this article is published . . . The intent of the statement can be implied, but no "key decision"

Congressman Lawrence P. McDonald:

Think of the countless numbers of our fellow citizens who die annually from the belchings of fossil-fuel plants. Nuclear energy is clean.

Think of the damage to our environment from tanker accidents and oil spills in our waterways. Nuclear energy doesn't pollute.

Think of the virtual state of blackmail we face from the Arab and OPEC nations from oil shortages. Nuclear energy is ours and cheap.

Think of the plight of those who die each year from mining diseases, gas explosions, pipeline disasters, oil tanker disruptions and hydro-electric dam failures. Nuclear energy is safe.

Nuclear energy has never killed a single person from an accident in commercial power production in 23 years of reactor operation in America.

Recent severe winters saw entire regions without sufficient energy to warm their homes due to shortages. Hundreds of thousands were thrown out of work in energy intensive industries.

Coal strikers seized the nation's helplessness to grab more for themselves. Schools were closed. People died.

The lesson is clear. The only reliable source of energy during these times was nuclear energy. It saved lives all over America by being there when it was necessary.

To abandon more than 12% of our entire national electric power supply as the anti-nuclear bands demand would be sheer folly. As gas, oil and coal become more and more difficult to use, nuclear energy is there to fill the gap. Ditching nuclear energy would be nothing short of catastrophic.

was made by the President before the article was published. It is neither to be expected nor desirable that all decisions be acted on immediately, but rather that waste management policy evolve in an orderly manner, in consultation with the Congress.

The above examples show how imagery or allusions are used to create anxiety and fear about nuclear waste, in general. The companion article also contains numerous misstatements, misinterpretations or distortions of facts that lead to substantive misunderstanding of the subject. Some of these statements regarding radiation will be commented on as before with the hope of correcting misimpressions.

New information is released almost daily concerning heightened cancer incidence among workers exposed to low-level radiation. The reliability and validity of the information releases must be seriously questioned. Whereas radiation is easy to measure accurately with sensitive instruments, at low radiation levels valid data from which conclusions can be drawn are extremely difficult and time-consuming to achieve. The data on which some claims have been based, and the analyses involved, have been heavily criticized and discredited as is the case for the cited studies of Hanford workers;[15] data from others such as the nuclear shipyard[16] are highly qualified with regard to the interpretation of results.

Recently Ralph Nader's Health Research Group asked President Carter to act on a National Academy of Sciences recommendation that allowable occupational exposures to low-level radiation be reduced ten fold, from 5 rem to 0.5 rem per year. The National Academy of Sciences has not made such a recommendation. Continued study of the radiobiological basis for assessing the risk of radiation exposure per unit of dose equivalent indicates increasingly that the linear, no-threshold assumption represents an upper-limit and conservative estimate. In consideration of the risk now experienced in other "safe" industries, justification for a change is lacking unless a "double standard" were to be accepted by which occupational standards for radiation workers would be more restrictive than are safety standards for other industries.[17]

For 22 years the accepted wisdom has been that annual exposures of 170 mrem above background radiation levels was a permissible level for the general population. However, in 1977 the Environmental Protection Agency suggestd 25 mrem as the annual limit. The Nuclear Regulatory Commission (NRC) has adopted that figure as the permissible dose to the public created by the nuclear fuel cycle. In taking over the role previously held by the Federal Radiation Council, EPA promulgated the lower limit, not on the basis of new knowledge about risk to the health and safety of the public but on what EPA believed the industry could live with.[18] This is consistent with the philosophy of maintaining exposures as low as reasonably achievable and a credit to both government and industry.

Meanwhile cancer mortality is on the rise . . . it seems evident that the release of carcinogens into air, water, or the food chain should be reduced rather than permitted to escalate over time. Nuclear power plants release much lower quantities of radioactivity than coal-fired power plants and also do not release the carcinogen benzo (a)pyrene, the main cancer-causing agent in cigarettes, or large quantities of CO_2, NO_x and SO_2, that have significant environmental health effects.[6] Estimates show the lung cancer risk due to coal-fired power plants orders of magnitude higher than that due to nuclear power stations.[19]

The controversy about low-level radiation is both scientifically and politically complex. For the interested lay person complete understanding is unlikely, but a recent book[20] has been written to provide information and helpful insights about both aspects of the controversy.

Before the isolation of high-level wastes is discussed, some misstatements and distortions of facts related to New York State need to be commented upon:

Waste at West Valley neutralized with an alkaline solution has turned out to be very difficult if not impossible to remove from a carbon steel tank. There is no factual basis for this statement. A key report on the West Valley plant[21] discusses removal of these neutralized wastes, potential difficulties, comparisons with tanks at the Hanford and Savannah River plants and removal methods, predicting more than 99% removal of the sludge. In March 1979, the technique and equipment were very successfully demonstrated at Savannah River.

The United States Department of Energy has proposed placing radioactive wastes 1000 feet below ground in a salt formation in the Finger Lakes region of New York State. This is a false statement. The subsequent statements are thus irrelevant and also gross distortions. However, in this connection mention should be made of the policy of "consultation and concurrence" that involves States at an early date in the repository site selection process.[22] This process involves several years of geological/hydrological exploration combined with environmental impact assessments. The policy implies an ongoing dialogue and cooperative relationship under which the State effectively has a continuing ability to participate in activities throughout the process of evaluation of a potential repository site and, if it deems appropriate, to prevent the continuance of Federal activities.

Following the above allegation the companion article proceeds with a distorted and misleading discussion purportedly to show "why salt is the wrong media for a waste repository." In particular, the author presents an exaggerated conjecture of potential disaster based on an interesting phenomenon of brine migration under thermal gradients toward higher temperatures[23] and potential movements of waste canisters in plastic salt.[24] If brine inclusions were sufficient to reach canisters, the brine would corrode the canisters. However, this phenomenon apparently is a localized one involving relatively small amounts of fluid (e.g., a few liters per canister); therefore, the brine inclusions would be insufficient to corrode the canisters significantly and would also not provide a means of transporting radionuclides away from a salt repository. With regard to potential movement of canisters, the article also conjectures an extreme scenario without factual basis. In reality, appropriately low thermal gradients and tem-

peratures can be established during engineering of a repository system through use of variable parameters such as: (a) the predisposal cooling time for the waste; (b) the geometry of the waste canister; (c) the waste concentration in the canister; and (d) the spacing of the canisters in a repository.

Space does not permit commenting specifically on other numerous mistatements or misinterpretations included in this section; thus, reference is made to a relevant discussion of the subject for a perspective:[25]

> Expectations of extensive, undisturbed beds of dry salt may not have been realized but many researchers believe that the technical questions concerning salt will be resolved at least as promptly as those concerning other media, if not sooner. With its edge in engineering, salt may still be the first geologic environment selected for a repository. But other geologic environments have been under study all along, and their accelerated evaluation recently received a boost from the report of President Carter's Interagency Review Group. Non-salt rocks under consideration include granites and basalts, which cooled in place from molten rock; shales, which are muds turned into rock by high temperature and pressure; and tuffs, which are volcanic ash solidified by its own heat.

A unique mined geologic repository concept that is not yet being investigated but has considerable merit is the controlled tunnel environment.[26] An alternate to mined geologic repositories, seabed disposal (considered by the Interagency Review Group on Nuclear Waste Management (IRG)), is also discussed in Reference 25. IRG found that disposal in mined geologic repositories is the nearest term option for implementation of the six candidate technologies studied.[22]

Engineering of a Waste Repository

The concept and safety of nuclear waste disposal in mined geologic repositories are discussed in numerous publications from general presentations for the layman[6] to detailed environmental impact statements.[9] The status of relevant technologies[27] is dynamic because of the extensive research, development and demonstration work being performed in many countries of the world. Present scientific and technical knowledge is adequate to support siting and preliminary design activities.

The technical process of site selection can be considered as a set of information screens proceeding from general ideas to specific details, from large areas to small, well-defined ones, and from literature surveys to measurements in the field. The technology for exploration and characterization of repository sites is generally adequate to proceed, particularly because it has been well developed to fulfill other requirements for geologic exploration (e.g., for oil, gas and minerals). The information screening process involves a progressively more stringent investigation of site characteristics and evaluation with reference to specified criteria. Information obtained at each successive step permits reevaluation of uncertainties and the ability of the site and repository to meet regulatory standards. Such reevaluations lead either to a decision to proceed to the next step or to abandonment of the site.

Engineering of a waste repository requires consideration of numerous other factors in addition to those involving site selection. The construction of mined geologic repositories is based on available mining technology resulting from extensive, worldwide experience in mining for minerals and constructing caverns. However, engineering a repository also requires consideration of other aspects. The repository engineering is viewed and analized as a system. That is, the engineering will consider the cumulative effects of the hydrogeologic, geochemical, and tectonic characteristics of the environment and potential future human activities, as well as the physical and chemical properties of the host rock chosen for waste emplacement, the waste form, and other engineered aspects of the repository. Thus, detailed, systematic, site-specific investigations and evaluations of these factors, including multiple barriers to radionuclide migration, are used to engineer a repository.

Why hasn't a repository system yet been demonstrated? There are two major reasons. The first is that the present and projected volume of high-level wastes for tens of

years is so small that it has not created an urgency. The second reason partly stems from the first. From a technical standpoint, the time is being used to perform research and development work in order to determine the best designs of a system. As a consequence, a final system design has not been completed. However, the IRG has concluded that "successful isolation of radioactive wastes from the biosphere appears technically feasible for periods of thousands of years provided that the systems view is utilized rigorously."[22]

Epilogue

Space has not permitted discussion of the outstanding record and benefits of nuclear energy: (a) how it has provided reliable electrical energy for sections of the United States during extreme winter weather or coal strikes;[28] (b) how it has benefited agriculture and reduced use of chemical insecticides;[29] (c) how it can be used for sewage sludge disinfection for fertilizer use;[30] (d) how it has been useful for space, terrestrial and marine power applications; etc. Even though its use has not been completely free of operating problems, I am convinced that the benefits of nuclear power outweigh its risks and that the potential impacts of significant energy shortages without it present greater hazards to humankind than the worst predictions of opponents to the continued and increased use of nuclear power.

Nuclear waste management can be and is being improved. I view waste management, like other aspects of the nuclear fuel cycle, as a set of engineering tasks and a set of political problems. Hopefully, the above will contribute to amelioration of the political problems so that the engineering tasks can be completed in time to provide needed energy for the future.

Chiseled into the monument to the Wright Brothers at Kitty Hawk, N.C. is a challenge for the nuclear age:

> In commemoration of the conquest of air . . . . conceived by genius, achieved by dauntless resolution and unconquerable faith.

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Nuclear Waste: Beyond Faust and Fate

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Ever since Alvin Weinberg's celebrated lament over the "Faustian bargain"[1] made by "we nuclear people," it has become increasingly fashionable to dwell on the hazards of radioactive wastes as the epitome of that reprehensible trafficking with the devil. Otherwise intelligent people simply take it as an unquestioned "given" that the production of nuclear wastes is a unique, unprecedented problem for which there is as yet no technical solution—much less a politically expedient and publicly acceptable solution. Having accepted this "given," the major architects of our current rancorous public dispute over nuclear technology have begun to make an appeal to moral values and ethical principles as if they were substitutes for scientific evidence. Moreover, it is widely believed that in matters of morality and ethical judgment, "everyone is an expert," or to say the same thing, "no one is an expert." The political advantage gained by those who nourish this belief is that neither ethics nor policy-making can escape from a morass of opinion. Unless we reject this belief, ethics will be held hostage by the struggle for political power to mobilize "public opinion" and "popular sentiment." Unless it is based on sound principles and substantiating evidence, a public policy stands only for the prevailing fashion of the times.

Social Justice and Hazard Management

As a fundamental bioethical principle for organizing evidence and dealing with conflicting opinions, I propose this formulation: *Social justice requires an equitable management of potential hazards which might have harmful health effects and unjustifiable social consequences.*

By "equitable management" I mean that policy makers should first be comprehensively informed about the broad spectrum of both natural and ordinary hazards that may have health effects for large segments of the population; then make comparisons of actual costs per capita to reduce these effects; and only then make policies and set standards that will get the most public health protection for the many out of a finite amount of money. Potential hazards management is ethically equitable only if it is proportional in relation to *actual basic harm* that can be identified and reduced by expenditures of human effort, time and money.

Establishing Public Policy

Translating this principle into public policy is by no means straightforward and easy. The fallout generated by the media coverage of Three Mile Island and ensuing public hysteria over radiation foreshadow a period of serious reckoning for a nation which purports to make public policy through democratic processes.[2] Those engaged in writing obituaries and epitaphs for nuclear technology, whether applied in medicine or electricity generation, are well aware that "nuclear wastes" are the kingpin that can bring down an industry.[3] It is understandable that recognizing scientific and technical disagreements is not sufficient. Policy makers must recognize that opponents of nuclear technology in general, and of current waste disposal options in particular, have developed several arguments which appeal to nonscientific moral and ethical premises. Briefly, these can be summed up in two statements.

First, indefinite delay of high-level waste disposal facilities is regarded as morally preferable to a policy of implementing one of several currently available options.

Second, it is claimed that involuntary risks of radiation exposure imposed on present and unconsulted future generations violate ethical principles of social justice and equity.

The Call for an Indefinite Delay

With regard to the first premise, calls for indefinite delay and for more and more thorough geological, seismic, and environmental pathways analyses derive from the perception that the volume and radioactive properties of fission wastes are utterly foreign to human experience. Despite the fact that the volumes and hazardous toxic properties of municipal, industrial, and commercial wastes are far more excessive and accessible to people through multiple environmental pathways, radioactive wastes are being singled out for special treatment because people have been induced to believe there is some-

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thing menacing and sinister about radiation sources. When ordinary people are asked why they have such a nameless fear of radiation and radioactive wastes, the response is that they are "the most toxic substance known to man;" they are not found in nature but are "man-made;" and "they have hazardous lifetimes of a quarter of a million years." The longevity of their hazardous lifetimes makes people leap to the conclusion that the *risks* to unconsulted future generations will last until the wastes are reduced to "harmless levels" by natural radioactive decay processes. From that imaginative leap comes the line of argument that the production of radwastes, and proposed criteria for designing a waste repository, are unethical. The present generation reaps the benefits but exports the hazards into the future—a violation of distributive justice, equity and participation.

Besides the *risk/benefit* argument, there is also the *legacy/longevity* argument. No responsible person would ever rely on the stability and longevity of social institutions or human fallibility in the future. No matter what the cost to present generations, there must be an absolute guarantee provided by engineering technology that there will be permanent *containment* of the wastes in nonleachable receptacles within a selected repository, as well as permanent *isolation* of the wastes from the biosphere. Some even insist that our ethical responsibility to future generations is not fulfilled by sequestering the wastes permanently; we must also assume that there might be some leak or spewing forth from a repository, either as a result of accidental disruptions or intentional intrusions, and therefore set regulatory standards to limit a potential radiological impact on whole populations.

In both arguments, the length of radioactive half-life dictates the problem and undermines proposals for a solution. The common assumption shared by unending arguments about radioactive wastes is that the *mere existence* of that source of radiation is equivalent to an *unacceptable risk*. The risks perceived are measured according to the million-year rate of decay of isotopes and actinides, as well as the number of lethal doses they contain—enough to wipe out a population many times over.

To use this assumption as an ethical basis for formulating arguments about any risk from a potential biohazard, especially radioactive wastes, is absurd. It is totally inconsistent with established legal precedents, scientific evidence, and intellectual integrity. If we actually measure unacceptable risks to our environmental quality by measuring the half-life or rate of decay of toxic elements in common household and industrial use —or their potential for lethal doses to a population— then we would not be talking about spending billions of dollars on burying radwastes. We would demand our Congress to enact legislation for permanent geological burial of lead, mercury, chromium, arsenic, chlorine, cyanide, and many other elements whose half-life is infinite. They are not radioactive. Hence they are not easily detected and monitored in our environment as are radioactive elements. They will never decay to harmless levels. They have been and will continue to remain in our biosphere affecting our environmental quality—not for a thousand or a million years, but forever. This is fortunate, because they are valuable, highly useful, and controllable resources from which we derive countless benefits. If we are to be ethical and equitable, the same yardstick must be applied to radioactive elements. Moreover, "waste" begins only where human ingenuity and inventiveness ends.

It is instructive that our federal government has spent over $1 billion over the past thirty years to research the biological effects of nuclear sources of radiation. But it is only in the last decade that sophisticated instrumentation and refined assay methods for measuring highly toxic *chemical* agents in common industrial use has been developed—and with it an upsurge in public alarm as chemical waste "dumps" (such as the Love Canal) have been discovered and sensationalized by the media. There is a fairly obvious correlation between the massive information flow to the public about radiation hazards, and the mounting public concern to which competing regulatory agencies want to appear responsive, protective and indispensable to the public.

From a bioethical perspective, any risks of adverse health effects from radiation sources, both to present and future generations, must be measured only in relation to *environmental pathways* which determine the degree of likelihood of harmful exposure of and assimilation by the human body. All of the pathways analyses to date have measured those potential risks and found them to be vanishingly small.[4]

Moreover, a geotoxicity calculation has considered only eight toxic elements naturally occurring in the earth's crust and continuously leached into food and water supplies which we daily use. Those elements are mercury, lead, cadmium, chromium, selenium, barium, arsenic and uranium.[5] If our entire electrical supply for 100 years came from nuclear fissioning of uranium, and we buried the wastes, the resulting increase in the toxicity of the earth's crust would be *one ten-millionth of one per cent* (0.0000001%). Those attempting to invalidate that comparison have argued that the other toxic elements are distributed more uniformly, but that the waste would be concentrated in a few repositories. The fact of the matter is that nature has also concentrated toxic minerals in ore bodies. Cohen states:

> It can be shown that in a few hundred years the repository contents become relatively less toxic than typical mercury deposits and in about 1000 years it becomes less than the uranium ore body from which the nuclear fuel was originally derived.
>
> The ore body is at least as available to dissolution and transport as is the waste repository.

The general public seems unaware that the technology exists to meet the most sensible of "performance criteria" for waste disposal facilities. These criteria require that ultimate waste disposal shall be conducted in such a way that there is no net increase in risk of harm by comparison with the typical ore body of natural uranium which yields the energy from which the wastes are derived. In other words, the wastes can be disposed of in a way that returns them to the same (if not better) level of risk than posed by natural uranium ore in the earth's crust. This criterion requires that the waste form have the same stability as the original ore body; that the medium containing the

wastes retains the same integrity as the medium containing the ore; and that geological media surrounding and isolating the wastes retain the same integrity of isolation from the biosphere as that isolating the original ore bodies. If current technology can meet these requirements, then the American public cannot logically demand greater assurance.

The risk-perception and arguments advanced in favor of an indefinite delay and ever more exhaustive study of waste disposal options are insubstantial at best. Under the guise of moral preferability, the pursuit of technical perfection may be either a political instrument of obstructionists who are publicly committed to using any strategy to eliminate nuclear electricity in the United States, or a self-serving strategy of underemployed professionals in geology, seismology, hydrology, etc. In either case, the best has become the enemy of the good. The risks emoted and litigated about are minor when compared with much greater risks of doing nothing about a problem that is not going to go away. The disposition made of radwastes calls attention to the fact that other wastes are becoming even more problematic. Positive, constructive policies of action rather than negative policies of inaction are clearly an ethical imperative.

Involuntary Exposure

Turning to the second premise, it is claimed that involuntary risks of radiation exposure imposed on unconsulted present and future generations violate ethical principles of social justice and equity.

A self-styled public interest group has recently disseminated a critique of criteria for radioactive waste management proposed by the Environmental Protection Agency.[6] The authors of the critique assume that longevity of hazardous lifetimes of radioactive wastes constitutes an unfair imposition of hazards and risks upon unconsulted future generations. Hence, they are of the opinion that the ethical principles of equity and participation require criteria to be *neutral* to future generations. They preface their own proposed criteria by stating that:

> The least unfair way of managing intertemporal relationships is for each generation to try to leave the earth as it was when they arrived. As a goal, the only acceptable distribution of hazards and benefits is the neutral allocation, where no pattern of benefits and hazards is imposed. (p. 28)

By espousing as a fundamental philosophical principle, "non-degradation of the environment," the Natural Resources Defense Council joins with the Sierra Club in defining a "degraded environment" as any place that human actions have affected or changed. Although chastising the EPA for evading what they choose to call "the fundamental mandate of EPA" and "an uncompromisable standard"—namely "non-degradation of the environment"—the NRDC authors commend the EPA at one point for comparing hazards from human activity to hazards from the "pre-existing natural state of the area."[7] Their stated reason for feeling that this is an appropriate standard is that "it emphasizes the role of a trustee as one who maintains the non-renewable environmental as it was originally, to pass on to the next trustee." This fundamental goal is a key consideration, "because if any degradation is allowed (in the name of "allowable radiation exposure") there is no clear bound at which degradation becomes, by anyone's standard, too much."[3, 4]

Formulas such as these conceal two questionable presuppositions:

> *(1) that an untouched "natural environment" by definition manifests a superior, if not sacred order which human interventions violate to some degree;*
>
> *(2) that a trustee of a so-called natural environment can do nothing more nor less than pass it along in its original pristine state; to do otherwise is to be guilty of a moral wrong.*

The philosophy of non-degradation has a long history, as is clear to anyone who has read Book I of Georgius Agricola's *De Re Metallica* published in 1556.[7] This sixteenth century inventory of objections to disturbing the environment makes it abundantly clear that those who are ignorant of history are condemned to repeat it.

Furthermore, a philosophy of non-degradation uncritically assumes the idea that a benign environment is rapidly being ruined by human beings. However, the historical record attests that an untamed environment has repeatedly wrought massive *human degradation* through catastrophic effects of famines, plagues, floods, earthquakes, tornadoes, etc. The fundamental problem about man's interaction with the environment is not to maintain some simplistic ideal of "non-degradation." Rather the problem is a highly complex one of devising appropriate means to protect both life-sustaining and aesthetic qualities of the biosphere, and at the same time develop technologies which provide basic human goods as a necessary condition for maintaining a preferred environmental quality. As a fundamental, meaningful principle for securing that environmental protection, "non-degradation" is vacuous.

In their preoccupation with risks to future generations and a proposed ethical principle of neutrality, the NRDC authors seem committed to perpetuating the specious assumption discussed above, namely, that the hazards of radioactive waste foist unprecedented risks onto unconsulted future generations because the index of their hazard to the future is measured by and equivalent to the longevity of their radioactive half-life. Intellectual honesty should compel those who know better to state as often as necessary that any risks of adverse health effects from radiation sources must be measured only in relation to the *degree of likelihood* of actual harmful exposure.

Our concern for "risks bequeathed to future generations" will be better expressed if we reject two simple-minded notions: (1) that such risks have an existence in splendid isolation from the benefits which justify them; and (2) that such ethical principles as equity and participation require a neutral allocation of risks and benefits to the future (even if that were attainable in actuality.)

The first notion merits rejection because the legacy of any generation to an immediate as well as remote future is not mere "risks" and "hazards." To the contrary, our legacy to the future is an entire social order striving to provide basic material well-being, institutional sta-

bility, and creative freedom for its citizenry. Risks, promises, harms, and benefits are inseparably interdependent within any sustainable social order. If only we could manage to balance our excessive concern and expenditure of public money to reduce risks from but one potential hazard, radioactive wastes, with a concern to reduce the risks we are bequeathing to future generations from the unsolved problems of starvation, poverty and racism—then our legacy would indeed be a spiritually gratifying benefit for our common humanity.

As for the second notion, the ethical principle of *equity* requires a society to provide its citizens with reliable access to those basic goods which sustain material well-being. The principle of *participation* requires a society to provide institutionalized methods of consent for its citizens, who in turn are obligated to contribute to and abide by outcomes of those methods. To reduce the broader content of these ethical principles to a narrow consideration of but one potential biohazard having ill-defined and misconceived risks is an intellectual travesty. It is pretentious for anyone to arrogate to themselves the wisdom either to decide for future generations what is in their best interest in securing basic goods and protection from basic harms, or to suppress—under the guise of "neutrality" to the future"—any method of devising conceptual tools which might enable the present generation to deal constructively with its uncertainties and responsibility toward the living in the present generation. Our primary ethical responsibility is for the living who happen to be the only foundation we have to provide for the well-being of future generations.

Equitable Management

A proper understanding of the ethical principles of social justice and equity should be expressed in the fundamental bioethical principle already noted, namely, the *equitable management* of hazards having a potential for adverse effects on public health and safety.

The disputed question of adequate standards for radiation protection in relation, in this case, to waste disposal facilities has been compounded by a widespread public misconception about "safety"—especially as it relates to risk acceptability. The working assumption of policy makers and regulators has been that safety is an intrinsic, measurable, absolute property that any given system, or product, or activity can and should possess. To the contrary, however, safety is not an intrinsic property measured by approaching zero-risk. Safety is an evolving, relational value-judgment derived from current personal or social priorities on a scale of real possibility. Risks can be scientifically measured, quantified to an extent, and predicted in probabilistic terms. Safety, however, cannot be measured, much less pre-determined by the presence or absence of risks. Judgments of safety are judgments about the *justifiability* or *unjustifiability of harm.*

I concur with my colleague in social ethics, George Pickering, in his observation that "we are going to have to do more than find some level of 'acceptable risk;' we are going to have to come to terms with the question of 'justifiable harm.' There are, after all, some kinds of harm which cannot be avoided; but there are other kinds of harm which any society should not allow and against which it should adopt protective or remedial measures to the best of its ability."[8] Which is which becomes the problem.

The process of reasoning whereby safety policy decisions are made ought to be dictated—not by risk avoidance, an impossible ideal—but by comprehensive *risk/risk* assessments and *cost/risk/benefit* ratios. When these comparisons make it clear that a point of diminishing returns on allocations of money, time and effort has been reached by comparison with other potential hazards in a society, then the particular product or process or facility under scrutiny is "safe enough." If indeed unintended and unwanted harm should occur despite carefully wrought safety-policy decisions, then such harm can be judged "justifiable" because unavoidable and negligible by comparison with other greater harms and essential benefits.

If policy makers were more circumspect about this process of reasoning, there might also be greater clarity about a disputed "threshold concept" in setting radiation protection standards.

Because of increasingly sophisticated measurements in radiobiology, specialists are capable of identifying and extrapolating from even minute effects of exposure to radiation. But it is a qualitatively distinct cognitive leap to make the *value* judgment that a zero-threshold for so-called "safe" radiation exposure ought to be written into regulatory standards. Certain radiobiologists and biostatisticians have sought scientific data that has then enabled them to make such a value judgment. Excessively conservative scientific judgments about putative effects from radiation exposure, however, cannot and ought not to be substituted for an ethically responsible value judgment about "safety." For the policy maker, a practical threshold concept cannot be evaded. There can and must be a *practical threshold below which the possibility of comparatively insignificant unintended and unwanted harm becomes ethically justifiable.* This justification derives from a reasoning process which concludes that such effects are unavoidable and negligible by comparison with other greater radiation exposures—both naturally occurring and applied by human technology—and with other potential hazards against which citizens ought to be protected first and foremost.

Those responsible in society for providing basic goods, methods of informed consent, and an equitable management of biohazards have an ethical obligation to derive value judgments of safety, acceptable risk, and justifiable harm from a philosophy of congruence with a pattern of benefits and harms already established by naturally occurring radiation sources with which human beings have lived and evolved throughout recorded history. That is to say, the philosophy of congruence and logical consistency require a policy maker to form value judgments by first taking account of wide variations in personal exposures and population exposure from naturally occurring background sources.

External sources of exposure include cosmic rays,

together with the radionuclides they produce, and primordial radionuclides in the earth. Variations in natural exposure to thorium in monazite sands along the southeastern coast of India range from 130 mrem to 2,800 mrem; while on the coast of Brazil, exposure ranges from 90 to 2,800 mrem with an average of 550 mrem per year. There is no scientifically established evidence, despite contrived attempts to prove it, that there are *basic harms* to those so exposed.

Human tolerance for, indeed dependence upon, such wide variations in natural radiation sources for several millenia demonstrate that increments from man-made applications of those natural sources can be kept well within the range of those variations without inflicting unjustifiable harm or deprivation of basic goods.

A Bioethical Principle

In view of these reflections, I suggest that the following bioethical principle might better serve as guidance in the formulation of social policies for protecting the health and safety of present and future generations, and for choosing among current options for waste disposal facilities:

> *Any involuntary risks imposed by social policies for radiation protection must be congruent with, must not be in excess of, and may be reasonably less than, those involuntary risks imposed by the wide variations in naturally occurring toxic elements and harmful effects from our natural environment.*

For more than a decade we have been bombarded with "the carcinogen of the week." Because of the media exploitation of the major obstacle to nuclear electricity, waste disposal, we now seem to be entering a protracted period in which we can expect to be bombarded with the "low-level radiation source of the week." We seem bent on becoming a nation of hypochondriacs. We would therefore do well to ponder Max Singer's remarks:

> Safety is one of the reasons it is better to be wealthy than poor. But as we get wealthier and safer, we become more concerned about safety . . . Like most social problems, the death toll from hazards requires a complex, balanced, and limited response. We cannot give ourselves up to eliminating or even reducing hazards. As individuals and as a society we must not become cowardly, fearful or hypochondriacal. The weakening of our character can do us more harm than all the auto accidents and all the fires.[9]

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Nukes or No Nukes? Absolute Thinking in a Relative World

David L. Willis

A public controversy over commercial nuclear power has boiled along throughout the 1970's. Anti-nuclear groups, at first only local, have coalesced into a national movement. Their tactics and rhetoric often appear borrowed from other causes of the 1960's. The nuclear industry, on the other side, lobbies forcefully for the nuclear option as both safe and cheap. A dialogue of the deaf ensues to the confusion of the general public. Scientists have been enlisted on each side. However, few if any authors with appropriate technical expertise have addressed the issues involved in Christian publications prior to this issue of the *Journal ASA*. This article is a small contribution in that direction.

First, some personal background may reveal at least minimal competence in certain aspects of this controversy. My teaching and research for nearly two decades have centered on radioactivity and radiation in the environment (radioecology). I've coauthored two major textbooks in the field of radioactive tracer techniques.[1,2] A sabbatical leave was spent in the Ecological Sciences Division of Oak Ridge National Laboratory researching the movement of radionuclides in freshwater habitats. I've participated in the three most recent national symposia on radioecology (1967, 1971, 1975), as well as many national and international meetings in this field. Active membership in two major professional societies (Radiation Research Society and Health Physics Society) has provided regular contact with other scientists in this field.

Until 1970 my professional interests in environmental radioactivity were largely within the confines of the academic "ivory tower." In the autumn of that year, I was contacted by the Portland General Electric Company (Portland, OR) to serve as a consultant on environmental radioactivity. The Company was then constructing the first nuclear power station (Trojan) in the state and had run headon into a determined group of environmental opponents. The major concern was over proposed radioactive discharges from Trojan into the lower Columbia River and their possible environmental consequences.

At first I naively assumed that PGE must indeed be planning very large releases of radioactivity to occasion such public opposition. When shown the engineering projections of the specific radionuclides and the annual amounts of each to be discharged, I blurted out, "You must be kidding!" From a radioecological and public health standpoint, the planned effluents represented no cause for concern. The state's universities and hospitals probably put more radioactivity down the sewer each year. How could anyone be worried about this? I was soon to find out in a series of permit hearings, legislative committee appearances and stockholder's meetings, as well as from shouting pickets, biased reporters, and insistent questioners who really didn't seek answers. Eventually I completed the requested report on radioactive releases.[3] This was ultimately incorporated in the final environmental impact statement for Trojan.[4] However, this harsh education in public conflict on technical issues left me deeply troubled.

As an educator since 1952, I instinctively felt that controversy over technical matters would be alleviated by better education of the public. Of course, in the case of nuclear power plants there were the added problems of unfamiliar concepts and units (rems, rads, curies, etc.) and the historical relation to frightening nuclear weapons. For several years subsequently I volunteered to give lectures to teacher and citizen groups around the state in hope of developing a more rational climate. Sad to say, I've lost enthusiasm for that approach. There appear to be too many people who "have their minds made up and don't want to be disturbed by facts," even in religious circles. Hopefully, members of the American Scientific Affiliation and other readers of this *Journal* are exceptions. Thus, in a general and semi-technical manner, I'd like to provide a perspective on environmental radioactivity and radiation in relation to nuclear power plants.

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Much of the difficulty in this area comes from inappropriate and naive absolute thinking. Things are perceived as either good or bad, safe or unsafe, existent or non-existent, either this or that but nothing in between. Thus, my two major points will be: (1) There is no such thing as zero, and (2) There is no such thing as 100%.

There Is No Such Thing as Zero

The anti-nuclear movement has laid great stress on the biologically damaging effects of ionizing radiation, the insidious movement of radioactive isotopes through the environment and the persistence (long half-life) of radioactive wastes. Obviously these are matters of concern. However, the frequent use of half-truths and the presentation of worst case examples as typical, usually project a grossly distorted picture to the uninitiated. A major error is the implication that radioactivity and radiation in the environment are new and sinister phenomena on earth. In fact, just the contrary is true. These are quite natural phenomena that have existed since the time of creation. Moreover, all evidence suggests that natural radiation levels were much higher in past ages. Today we live in a "sea of radiation" as have all living things that preceded us on earth. Any evaluation of possible harmful effects of environmental radiation from nuclear power stations must first consider these natural radiation doses for a proper perspective.

1. *Cosmic Radiation*

High energy particles (protons, alpha particles, etc.) constantly bombard the earth from both the sun and outer space. Only the shielding of the earth's atmosphere prevents the full force of this cosmic radiation from reaching us on the earth's surface. The primary particles are almost totally attenuated by interaction with the upper atmosphere and only less energetic secondary radiation resulting from this interaction penetrates to sea level. This cosmic radiation results in an average dose of 26 millirem per year to individuals living at sea level in the U.S.A.[5]

Since the atmosphere shields us from incoming cosmic rays, people at higher altitudes receive larger radiation doses. For example, the annual cosmic ray dose in Denver, CO, is 50 mrem—twice that at New York City. Furthermore, Leadville, CO, with a population of about 10,000 at 3200 meters altitude, has an annual dose of 125 mrem from cosmic radiation. No rational person would suggest evacuation of Denver and other such cities to reduce radiation exposures to their populations. However, the increased radiation exposure entailed in living there is five times the maximum exposure (5 mrem) allowed by federal regulations for anyone living near a nuclear power station.

2. *Radiation from Cosmogenic Radioactivity*

Cosmic ray interaction with the earth's atmosphere results in the continuous production of a variety of radionuclides. Tritium (hydrogen-3) and carbon-14 are the most important with regard to human concern. These have radioactive half-lives of about 12 years and 5,700 years, respectively. This allows time for them to circulate down to the earth's surface and be incorporated in all plants and animals. (In the case of carbon-14, this is the basis for age-dating of ancient carbon-containing remains.) Every human being carries a body burden of these radionuclides. For example, a 155-lb. man typically has about 77 nCi of carbon-14 in his body,[5] or, put another way, about 170,000 radioactive disintegrations per minute. However, this results in an annual dose of less than one millirem.

3. *Radiation from Primordial Radioactivity*

The decay rate of some radioactive isotopes is so slow that appreciable quantities still exist from the time of creation. In other words, their half-lives are of the order of billions of years. Most of these isotopes occur in connection with decay "chains". A parent radioisotope (such as uranium-238) decays to a daughter (such as thorium-234) which decays further through a series of steps to an eventual non-radioactive end-product—an isotope of lead. These decay chains are restricted to the heavier elements (radium, uranium, thorium, etc.). Such radioisotopes are widely distributed in rock, soil, water and even the human body. One wag has observed that every city in America has unwittingly established a radioactive waste storage facility—its cemetery! Local concentrations of these primordial radionuclides vary greatly (by several orders of magnitude) over the earth.

Rarely are such natural sources of radioactivity considered public health hazards. However, some local populations are exposed to exceptional concentrations. For example, nearly 50,000 people in northern Illinois near Joliet consume drinking water whose radium-226 content approaches the maximum concentration permitted by federal regulations.[6] Populations of many thousands in certain radioactively "hot" spots in eastern Brazil and southern India receive annual radiation doses 5-20 times greater than the average U.S. population from primordial radioactivity.[6] Intensive studies of possible biological damage from such doses to these groups have yielded either negative or statistically equivocal results.

Potassium-40 is another important primordial nuclide. This biologically significant element is quite soluble and, thus, present in freshwater, the oceans and the body fluids of all living things. A 155-lb. man typically has a body content of about 120 nCi of potassium-40. In other words, about 260,000 radioactive disintegrations per minute (dpm) occur in his body continually from potassium-40 alone. For marine organisms the potassium-40 body burden is much greater due to the higher potassium concentration of seawater. This potassium-40 in our bodies delivers an annual radiation dose of about 20 mrem.[5]

The mean annual whole-body radiation dose in the USA from all these natural sources is about 80 mrem.[5] Elevation and local geology lead to variations in this value. For example, residents of the Denver, CO, area receive a dose of about 125 mrem.[5] All concern about added radiation and radioactivity to the environment from nuclear power stations must be viewed in comparison to these natural background levels. Radionuclide releases from nuclear plants are *not* added to zero. Instead, they represent only a very small incremental addition to naturally occurring quantities. Failure to understand (or admit) this has caused foes of nuclear power to

adopt ridiculous positions.

The misplaced concern over projected tritium releases from the Trojan reactor are a case in point. Engineering designs clearly indicated that much larger quantities of tritium would be released during regular operation (about 720 Ci/yr.) than all other radionuclides put together (about 150 micro-Ci/yr.)[4] Critics seized on this value as an indication of the extreme hazard posed by the plant's operation. These tritium releases when diluted by the immense flow of the adjacent Columbia River would result in a mean downstream water concentration of 3.6 pCi/liter (pico Ci/liter = 10^{-12} Ci/liter). Assuming the opponent's good faith, we attempted to set this value in some meaningful perspective as follows:

(1) Since the minimum detection limit for tritium was 200 pCi/liter, river concentrations would be quite undetectable.

(2) The Columbia River and surface waters generally in the Pacific Northwest *already* contained about 500 times this concentration of tritium from fallout and natural sources. Thus, the operation of the Trojan plant would add an increment of only 0.2%.

(3) Seasonal variations in the tritium concentration of the River from high to low water flow were already approximately 1000 times as great as the nuclear plant's projected addition.

(4) The maximum permissible concentration (MPC) of tritium in drinking water set by federal regulations was over 830,000 times the result of the plant's discharges. This MPC level had been established based on the best scientific evidence available.

Did this convince the critics? Sad to say, no. Such figures didn't even seem to faze them in the slightest. They steadily replied, "Any radioactive releases are dangerous."

Their repeated, insistent demand was for "zero release" of radioactivity. This stance evidenced a basic misunderstanding of the concept of zero. The general public is usually comfortable with whole number values, but is quite uneasy when faced with exponents. From the scientific standpoint, exponential expressions are the rule. There is no measured value that cannot be divided by ten. There is no such thing as zero in this case.

With greater and greater dilution of an environmental pollutant we eventually reach a concentration below the minimum detection limit. While we can calculate a value for such a concentration (say 10^{-15} pCi/l), we can in no way measure it. For all practical purposes such radioactivity values can be disregarded as cause for any alarm, but they are not mathematically "zero."

In summary, there is no such thing as zero radiation or radioactivity in the environment. The routine operation of nuclear power plants results in only miniscule incremental releases of radioactivity in relation to natural, pre-existing levels. These effluents are well under established MPC values and are typically far below detection limits. It would appear that those who oppose nuclear power on the basis of public hazard from routine operations are either grossly misinformed or less than honest.

Fortunately, this situation has come to be understood by most responsible critics. Their opposition has more reasonably focused on real or imagined hazards from accidents. Even here, however, a distinct lack of perspective seems evident.

There Is No Such Thing as 100%

"Safe" is probably the most misused word in the current controversy over nuclear power. It is routinely used by advocates and opponents alike as an absolute term. In reality it is strictly relative. It is quantitative, not qualitative. As an example of gross misuse, my local U.S. congressman issued a newsletter to his constituents in July 1979 with the provocative statement, "There are only two kinds of power from which to choose: *safe* power or *unsafe* power" (italics mine). The remainder of his comments were ten reasons for opposing nuclear power.[7] This simplistic approach may win votes, but it shows little understanding of the complex issues involved.

A dictionary definition of "safe" usually reads, "Free from danger or risk." The slightest reflection, however, reveals that no human activity is safe in an absolute sense. Is flying safe? Is driving an automobile safe? Is skiing safe? Is skydiving safe? Is bathing safe? Obviously each of these activities has some degree of hazard or risk. Some are safer than others, but injury or death routinely result from engaging in them. Each of us regards these and other human activities as safer or less safe depending on such factors as our personal experience, physical ability, age, etc. Thus, safety is "a subjective, relativistic, evolving, shifting judgment based on each person's current value priorities.[8] Safety is *not* an absolute or intrinsic property.

A misunderstanding of the relative nature of safety seems to lie at the root of many of the anti-nuclear arguments. This usually takes the form of exaggerating recognized risks and/or conjuring up phantom risks. In all fairness, it should be added that some over-ardent nuclear proponents have often unreasonably dismissed legitimate concerns about nuclear safety. The question is not, "*Is* nuclear power safe?" The essential question is "*How* safe is nuclear power in comparison to other means of generating electricity?" We must clearly recognize that all such technologies (burning coal, hydroelectric dams, etc.) have some degree of risk. It is this author's perception that foes of nuclear power have greatly exaggerated its risks. At the same time, they have chosen to ignore the hazards of the only viable alternatives. These exaggerations fall naturally into several categories.

1. *Confusing Possibility with Probability*

Dramatic doomsday predictions of "possible" accidents at nuclear power plants are frequently made by nuclear power opponents. "The China Syndrome" is representative of this approach. The *possibility* that a serious accident at a nuclear station could seriously harm the nearby population is not really in doubt. It is precisely because

such a possibility exists that the most extreme precautions are exercised in the design and operation of these plants. Major reactor safety studies (such as the Rasmussen Report) have painstakingly attempted to identify and characterize what is termed a "maximum credible accident." The real concern, however, is "What is the *probability* that such an accident will actually occur?" The facile confusion of possibility with probability is a fundamental error in much of the discussion on reactor safety.

A few minutes of morbid reflection can conjure up a legion of frightening natural or industrial disasters. A tidal wave (or *tsunami*) is not an unknown event on many open coastlines. Many thousands of people have been drowned by them in this century alone. Is it possible that a tsunami of unprecedented height *could* strike a large coastal city somewhere and cause the death of over a million people? The answer must be, "Yes, it is *possible*."

Crashes of commercial aircraft carrying several hundred passengers, while not everyday occurrences, are not unknown. Whether these are mid-air collisions or crashes on landing or takeoff, the result is usually a ghastly loss of life. Casualties are usually restricted to the passengers and crew, but persons on the ground may also be victims of falling wreckage. One could conceive of an extreme case in which a fully loaded Boeing 747 jumbo jet crashes in flames into the packed Pasadena Rose Bowl some New Year's Day afternoon. Fatalities could easily run to tens of thousands with nearly all innocent bystanders.

This litany of quite conceivable disasters could go on and on—earthquakes or volcanic eruptions in densely populated areas, large ships suddenly capsizing, dams collapsing, uncontrolled fires sweeping an entire town, a tornado striking a large city, etc. All of these are examples of phenomena which have caused the deaths of hundreds of thousands of people in the past. It would be folly to suggest that such disasters will not occur in the future. However, does the *possibility* of such devastating events really dominate our thinking and affect our everyday living? Do we forsake all coastal areas because a tsunami *could* overwhelm us? Do we avoid either flying or being under commercial flight paths at any time? Do people really abandon all regions where tornados, earthquakes, volcanic eruptions or floods occur? The answer for rational people is, "Obviously not!"

The point here is that we judge risk in such situations based on probabilities, *not* possibilities. We don't ask, "Could such disasters occur?" Instead we inquire, "How *likely* is it that these disasters may happen?" The degree of risk is associated with the probability, not the possibility of a given event. We can never be 100% sure that any possible disaster will not strike. However, the probability may be so small that our assurance greatly exceeds the claimed purity of Ivory soap (99.44%). For all practical purposes, we usually ignore such vanishingly small risks. Who, for example, wears a hard hat whenever venturing outdoors for fear of being struck by a falling meteorite?

My concern is that risks from nuclear power accidents should be reasonably viewed from the same perspective. We could be paralyzed by irrational fears if we fail to apply the same logic to risk from nuclear accidents that we regularly (if unconsciously) apply to other hazards. There is no such thing as 100% safety. We deceive ourselves if we seek such assurance. Thus, the real concern regarding nuclear power should center on the likely as opposed to the conceivable risks. This leads to the second error.

2. *Making Future Predictions Without Considering Past Experience*

Risk determinations in any sphere are based both on actual past experience and best estimates of the future. While the past may be known with a high degree of certainty, future projections are always probability statements. In the early years of any new activity or technology, there is only meager experience on which to base risk estimates. As experience accumulates, the probability of making increasingly more accurate risk predictions improves sharply.

For example, few of us would have volunteered as the first person to use a parachute from an airplane in flight. There was no past experience as a guide and certain death was the penalty for parachute failure. The risks were simply too high and the uncertainties too great. While I'm no skydiver, I wouldn't hesitate to use a parachute now if circumstances required it. The experience of tens of thousands of people over several decades allows us to determine rather closely the degree of risk from parachuting. This is not to say that parachuting is 100% safe, but we now know that it is much closer to 100% than to 0%.

Let's apply this to hazard assessments of nuclear power. Although nuclear reactors still seem quite new to the public, they actually predate such familiar items as jet planes, commercial television and transistor radios. The first nuclear reactor was operated in Chicago on December 2, 1942. Before the end of World War II about a half dozen were in use for military purposes. All these early reactors were under strict government control in the U.S.A. or abroad. The first nuclear-powered submarine, U.S.S. *Nautilus*, was launched in 1954. Nuclear naval vessels numbering in the hundreds have been built and operated by several nations subsequently. By the mid-1950's reactors began to appear on university campuses for research and training. The late 1950's and early 1960's saw the advent of nuclear reactors for generating electricity for civilian purposes. Over 100 of these are now operated by public or private utilities in the U.S.A. and many other nations. In summary, many hundreds of nuclear reactors of different types have been operated for nearly four decades.

What has been the actual operating experience with nuclear reactors? If the doomsday predictions of the nuclear opposition are to be believed, surely the past history must have been grim, indeed. Quite the opposite is true. The actual record is that no civilian in the Free World has ever been killed as a direct result of a nuclear reactor accident. (Since information from the U.S.S.R. and other closed societies is unavailable, this statement is necessarily qualified.) In fact, three military operators of an experimental U.S. Army reactor in Idaho are the only fatalities known.[6] It should be noted that they died from injuries as a result of an explosion, not from radia-

tion itself.

Have other reactor accidents occurred? One might as well ask, "Have any parachutes ever failed to open?" The answer is obviously, "Yes." With parachutes, however, the margin of safety is exceedingly thin. Even a minor malfunction commonly results in death. By contrast, nuclear reactors have multiple and redundant safeguard systems. The other reactor accidents are better described as engineering malfunctions. They certainly could not be construed as major public disasters. A vanishingly small death toll of three (operators, not the general public) over nearly four decades seems amazing in light of the very real potential hazards. How do we account for such a record? The simple answer is that engineering and operating practices in both the military and civilian phases developed from the beginning with unparalleled attention to safety.

It seems ironic that nuclear critics today continue to incite public fears about *possible* nuclear disasters despite this unique safety record. As we have seen, the probable accuracy of future risk estimates improves greatly with accumulated experience. Nuclear power is hardly lacking in such experience. Critics appear to be using a double standard here by insisting that, in this case, the past has little or no relevance to the future. It would be a strange world, indeed, if that logic were applied to other aspects of life.

3. *But What about Three Mile Island?*

The reader may well wonder whether the previous comments were written before the Three Mile Island (TMI) plant accident. The answer is that they were penned in the full light of that situation. The events of TMI No. 2 in the spring of 1979 are acknowledged by all parties as the worst accident in the nation's commercial nuclear power program. We should ask, however, "How many fatalities or even direct injuries resulted?" The stark answer is "None." TMI was a disaster largely from the standpoint of economics and public relations. It was in no way a public hazard of the doomsday variety.

Admittedly, hundreds of nearby residents were temporarily evacuated as a precaution and thousands reputedly suffered "psychological trauma." Unfortunately most of this public impact resulted from the confusion and gross misinformation surrounding the event. TMI might better be regarded as a regulatory and media disaster. There is more than enough blame to go around. The U.S. Nuclear Regulatory Commission appeared confused and fumbling. The utility operators (Metropolitan Edison Co.) were frequently less than candid about the actual situation. The news media were much better at sensationalizing than informing. In perspective, however, how many people annually are evacuated from their homes because of floods, earthquakes, fires, leaking tank cars, etc? How much "psychological trauma" occurs routinely from near accidents in autos and planes, news of impending hurricanes, tornadoes or floods, or even from horror movies?

If the TMI accident is the worst thus far in nuclear power operations, it should give us cause for reassurance for the future rather than unreasoning fear. Would that coal mining, commercial aviation and railroad transportation had the same enviable safety record! The accidents that taught us how to operate these industries with some degree of safety were paid for with far grimmer statistics than from TMI.

Although no immediate deaths resulted from the TMI accident, it was widely publicized that significant amounts of radioactivity were released to the environment. The reader may reasonably wonder what potential for future health hazards these may pose. After some initial confusion, a broadscale radioactive monitoring program was set in motion. Water, milk, air, soil and vegetation in the surrounding area were analyzed. The resulting data give no cause for alarm and responsible safety authorities predict that no measurable public health effects are to be expected in the future. What are the bases for such predictions?

First, the releases were predominantly radioactive gases (isotopes of xenon, krypton, and iodine). These were discharged intermittently from a tall stack on the reactor site. Dilution in the atmosphere quickly reduced resulting off-site air concentrations to minimal levels. More importantly, xenon and krypton are in the group of elements known as "noble gases." This term refers to their chemical inertness in nature. Thus, they remain as elemental gases in the environment and do not bind with other elements to form compounds. Even if inhaled, they do not accumulate or become bound to body tissues like other elements. This greatly reduces their degree of hazard.

Releases of iodine were of greater concern. Radioiodine is readily concentrated in the human thyroid gland following ingestion of radioactively contaminated food or water. The most direct route to man is through deposition of gaseous iodine onto vegetation, its consumption by dairy cows and subsequent appearance in their milk. This pathway has been well characterized from studies of fallout from nuclear weapons testing. Milk supplies in the region surrounding the TMI plant were carefully monitored following the accident. Most milk showed no detectable radioiodine. A few samples revealed iodine-131 in the range of 14 to 40 pCi/l.[9]

How hazardous are such levels? For perspective, the most recent Chinese nuclear test produced fallout around the northern hemisphere. This resulted in an iodine-131 concentration of about 300 pCi/l in milk in this area of Pennsylvania.[10] Note that this was seven times the level from TMI. Furthermore, levels were much higher in the 1950's and 60's before the USA and the USSR agreed to ban aboveground nuclear testing. Federal safety regulations do not require that dairy cows be removed from access to contaminated pasture until the iodine-131 levels reaches 12,000 pCi/l.[9] The magnitude of these differences should offer convincing evidence of the negligible hazard posed by the radioiodine releases from TMI.

More impressive data bearing on this matter come from a reactor accident at Windscale, England, in 1957. There, the core of an air-cooled, plutonium-producing nuclear reactor caught fire and burned for four days. An estimated 20,000 Ci of iodine-131 were released to

the atmosphere as a result. That is 20 quadrillion pCi for comparison. (It should be noted that this type of reactor is not used in the USA.) The Windscale plant is situated along the Irish Sea. Coastal winds scattered the radioactivity both inland and southward for many miles. Health and safety personnel carefully monitored the milk produced in the region for radioiodine content. They initially found iodine-131 levels exceeding 100,000 pCi/l over an area of approximately 200 square miles. Peak concentrations of 1,400,000 pCi/l were noted in a restricted location about ten miles from the reactor.[6,11] Since iodine-131 has a radioactive half-life of only eight days, these levels declined rapidly. The enormity of this environmental contamination compared to that from TMI should be evident. The health status of individuals in the affected region in northwest England has been followed over the 22 years since this accident. What have been the results? No adverse health effects on the exposed individuals have been observed to date.

The TMI incident has brought on another rash of ominous predictions of future "extra" cancer deaths from nuclear power critics. Most radiation health and safety professionals have strongly contested such predictions. The public can be excused for being confused about such matters. This is a classic case of what Alvin Weinberg calls a "trans-scientific" issue.[12] It is well known that high doses of radiation may increase the incidence of cancer in a population. However, even the highest doses from TMI would be trivial in the extreme by comparison. Cancer is already a leading cause of death in this country. Would this high death rate be measurably increased by such infinitesimal added radiation doses from TMI?

The answer may best be seen in perspective from an analogy. Auto fatalities and highway speed limits are well recognized to be positively correlated. Higher speed limits and average highway speeds directly result in increased fatalities per mile driven. The federally mandated limit of 55 miles per hour imposed in 1974 is widely acknowledged as the proximate cause for the subsequent sharp decline in highway death rates. That reduction amounted to 10-15 mph from state to state. By contrast, what could be expected if the present 55 mph limit were increased to 55.001 mph? (We will assume that average driving speeds increase proportionately.) Logically one could predict some small increase in highway death rates. Practically this would never be observed. Year-to-year fluctuations in traffic death statistics would greatly exceed any effect of such a trivial increase in speed limit. This is precisely the case for predictions of increased future deaths from low-level radiation doses from TMI or other such accidents. Any theoretical increase would simply be too small to be observed. For all practical purposes it wouldn't occur. (Remember, there is no such thing as zero!)

Conclusions

This has obviously been a somewhat personal and only semi-technical presentation. Some readers may take it as a strongly pro-nuclear statement, but such is not really my intent. Many aspects of the nuclear power controversy have been left undiscussed either for lack of space or sufficient personal expertise. I am altogether too aware of strong differences of opinion on this issue both in the American Scientific Affiliation and the scientific community as a whole. Responsible criticism is healthy and necessary. It is, however, difficult to be charitable to those critics who routinely indulge in demagoguery and distortion. From my necessarily limited experience there seems to be more of this on the anti-, than the pro- side of the discussion. My personal appraisal is that nuclear power is one of the best alternatives available to our nation now to meet our electrical power generation requirements in the near term. Hazards, while well recognized, are quite within reason in comparison to other energy technologies.

My limited personal experience in the public aspects of this controversy has left me with one firm conviction. The real issues are far deeper than the technical and safety matters raised by the opposition. I find Richard Meehan's analysis here to be most appropriate.

> I would go so far as to say that the divisions are deeper and more bitter among the scientifically literate than in the general public. The paradox—that the best informed are the most confused—disappears only if we consider the whole nuclear power issue as merely symbolic of a deeper ideological rift, comparable to, say, the early 19th-century Romantic revolt. One might wonder whether the whole nuclear safety issue even makes sense in the absence of a deeper societal conflict. . . . If, as I am suggesting here, the nuclear safety issue is more of a quasi-religious than a technological conflict, then widespread improvement of scientific literacy is unlikely to improve matters.[13]

The insistent demands for ever higher levels of safety in nuclear power plants leave me perplexed. In a society where very high risk "recreation" is increasingly popular, why is nuclear power singled out to be the only no-risk industry? Surely reason would suggest that we first discourage or abandon sky diving, hang gliding, motorcycle racing, mountaineering and downhill skiing. This nation has spent an estimated one billion dollars over the past 20-25 years characterizing nuclear risks. We now know more about the health and safety aspects of ionizing radiation than about any other environmental hazard. How much is enough? Margaret Maxey puts this most fittingly.

> Zero risks and absolute safety are indeed costly illusions. Man does not live by safety alone. The ultimate challenge is to rediscover what else we live by.[5]

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CONSEQUENCES OF GROWTH: The Prospects for a Limitless Future by Gerald Feinberg, Seabury Press, New York, 1977. 157 pp. $9.95.

This is a book in a fairly classic humanistic optimism mode in which no limits are expected on the future of mankind provided that we proceed with a strong will and a pure heart. The author, Professor of Physics at Columbia University, has written a number of books on physics, philosophy and the future. Here he is at pains to tell us that no technical problems facing us are insurmountable, and although some non-technical issues may arise, they also should not be able to deter us from a glorious future. He makes his position perfectly clear in the words,

> In the natural world outside man, there are no purposes that we know of. In the absence of such purposes, the only ethical criterion we can apply to man's influence on the world is what human beings want. (p. 139)

> We must rid ourselves of the notion that some master plan guides our actions, either providentially or malevolently. Instead, we must recognize that only the human mind, in the known universe, is capable of making the value judgments that underlie all rational action. If we accept this situation and the responsibility that it gives us for deciding our own futures, we can make of the earth, and eventually of the universe, what we wish. (p. 145)

Now Christians are often accused of being too pessimistic about the future and of trying to cop out and leave tough problems in the hands of God rather than accepting personal responsibility. To such an error in the opposite direction, Feinberg's approach may act an an antidote. Except for this, however, Feinberg's approach is clearly non-biblical and fails to include inputs from many real aspects of the universe.

This book is one member of an extensive series called "The Tree of Life," edited by a philosopher with the marvelously euphonious name of Ruth Nanda Anshen. In a Foreword on the series, Anshen sets the tone. She sees us as existing in an "indifferent universe," in an "indifferent eternity," in the midst of "the indifference of nature," and a "badly messed up creation," but seeks to "reaffirm the glory of the human spirit." To this end she urges that science move from simply describing what is, into the realm of establishing and defining human values, admitting "into its orbit, revelation, faith and intuition." Here then is another example of a growing trend to blur the distinction between science and religion, with the result that both authentic science and authentic religion are swallowed up in mystic subjectivism. This approach cannot do without religion completely, of course, and Anshen has her own god: "We bow to the *life force*, to that mysterious energy which creates life." Her poetic yearning bubbles over in one of the longest sentences I've come across in some time:

> The fruit he has eaten from the Tree of Life has carved out for him a difficult but rewarding path: a revolt against traditionally accepted scientific principles and a yearning for that qualitative metamorphosis in which the new stage of consciousness comes into existence as the result of a decisive jolt and is characteristic of a life of the spirit which, when coupled with the organic development, is like the planting of a seed whose successive unfolding has given man the nourishing fruit of the Tree of Life, for man's organism is instinct with the drive toward primal unity. Man is capable of making the world what it is destined to be . . (p. xviii)

In her passionate attempt to have religion without the God of the Bible, Anshen commits herself to a strange course indeed:

> Thus in spite of all evidence to the contrary, we conclude that there is a continuing and permanent energy of that which is not only man but all of life itself. And it is for this reason that we espouse life. For not an atom stirs in matter, organic or inorganic, that does not have its cunning duplicate in Mind. And faith in *life* creates its own verification. (p. xx)

Those who advocate an open embracing of this "new

consciousness" perspective for the Christian, should listen carefully to the commitment being proposed.

Feinberg addresses himself to three technical problems and the resolutions he sees for them in the future: space colonization, control over aging, and materials shortages. Since it is clear that earth's size and resources are finite, optimisms about a limitless future are driven to space. Feinberg, following the suggestion of G. O'Neill, sees space populated by man-made planetoids with controlled atmosphere, each with about 10,000 inhabitants. These colonies would obtain their raw materials from the moon and from the asteroids, and would soon become independent of earth. Such colonization of space would continue the trend "that our species has been following since prehistory," create "a new ecological niche for life," provide insurance for the human race against the day that the earth might become uninhabitable, and allow a significant growth in the human population in the universe. This last is a basic good for Feinberg since "we may expect that when there are more people . . . we will all be better off." This issue is a fundamental one for the Christian to consider: is the universe "better" by having more human beings living in it? Feinberg does not mention that to increase the population in the universe by 1/3 over the present population of the earth would require 100,000 such space colonies!

Feinberg is confident that we will be able to slow the aging process and takes as the basis for a discussion of its effects the situation where aging could be stopped at the physiological age of 20. Eliminating all causes of death except accidents, Feinberg guesses that the human life span would be extended to more than 2000 years. There is a curiously anti-biblical ring to the words,

> We can expect that the removal of the fear of death would act as a liberating force on the human mind, and would result in people much better balanced psychologically than they are now. (p. 49)

There is also a curiously ironic sound to the words,

> Perhaps this activity heralds a new day, when we will become the masters of our life processes, as we have mastered the world outside. (p. 62)

God forbid that we should extend desecration of the physical world to the desecration of the human person.

Feinberg then addresses the possible limit to future growth imposed by the exhaustion of materials through the depletion of high grade ores. He argues that all of the materials needed for far into the future can be obtained simply by processing the top 100 meters of the earth's crust. He is not concerned with the sources of energy to do this job, simply stating, "I shall assume that the problems involved in utilizing at least one of these sources on a large scale will be solved." He admits that

> it may be necessary to process as much as 10 billion tons of rock every year in the U.S. Doing this efficiently will probably require the rather destructive treatment of several square miles of land each year, to a depth of 100 meters or so. (p. 90)

and that there may be some personal objections,

> In the case of strip mining, some people not living near the mines have objected simply because they dislike the looks of the land that has been strip mined. It is not clear to me how widespread such views are in the U.S. population, but if they are held by a large number of people it casts doubt upon whether the whole program of obtaining raw materials from common rock could be carried out. (p. 91)

In the remainder of the book Feinberg treats postmodern science in which he states his conviction that "there is nothing intrinsic in complex systems that differentiates them from simple systems;" long-range goals and environmental problems in which he rejects the common view of a balance of nature and questions the desirability of living in harmony with nature instead of molding nature to fit our desires; and human aspirations and their limitations in which he looks forward to biological and psychological renovation of the human species and expresses the hope that "If there is some specific purpose we wish to accomplish, it would be surprising if we could not accomplish it in some way without producing undesirable changes in the biosphere."

As examples of naive optimism at its best (worst?) I was particularly struck by the following two passages:

Books Received and Available for Review

(Please contact the Book Review Editor if you would like to review one of these books.)

Gladwin, John, *God's People in God's World: Biblical Motives for Social Involvement*, InterVarsity Press

Guenther, Herbert and Kawamura, Leslie, *Mind in Buddhist Psychology*, Dharma

Hammond, Kenneth A. et al., *Sourcebook on the Environment: A Guide to the Literature*, Univ. of Chicago Press

Judson, Horace Freeland, *The Eighth Day of Creation: The Makers of the Revolution in Biology*, Simon & Schuster

Lefever, Ernest W., *Amsterdam to Nairobi: The World Council of Churches and the Third World*, Georgetown Univ.

Koteskey, R. L., *Psychology from a Christian Perspective*, Abingdon

Kraay and Tol, eds., *Hearing and Doing*, Wedge

Lindskoog, Kathryn, *The Gift of Dreams*, Harper & Row

Macaulay, Ranald, and Barrs, Jerram, *Christianity with a Human Face*, InterVarsity Press

Macaulay, Ranald and Barrs, Jerram, *Being Human: The Nature of Spiritual Experience*, InterVarsity Press

Malony, H. Newton, *Living the Answers*, Abingdon

Martin, Charles, *You've Got to Start Somewhere . . . When You Think About Education*, InterVarsity Press

Myers, David G., *The Human Puzzle: Psychological Research & Christian Belief*, Harper & Row

Paul, H. W., *The Edge of Contingency* (French Catholic Reaction to Scientific Change from Darwin to Duhem), Univ. of Florida Press

Ryken, Leland, *Triumphs of the Imagination: Literature in Christian Perspective*, InterVarsity Press

Tulku, Tarthang, *Time, Space and Knowledge: A New Vision of Reality*, Dharma

Vitz, Paul C., *Psychology as Religion: The Cult of Self-Worship*, Eerdmans

Wurthewein, E., *The Text of the Old Testament*, Eerdmans

> When considering choices that will affect the whole human race, it is essential that the widest possible group of people be involved in making the choices. (p. 15)
>
> Ideally, it would be best if the aspirations of different people were sufficiently similar that a world could be made which would satisfy all of us. (p. 142)

Feinberg's book does raise a number of questions that Christians should be considering. Unless Christians grapple with issues like these, and understand the alternatives offered by humanistic optimists, we will not make the contribution to our times for which we are called.

Reviewed by Richard H. Bube, Department of Materials Science and Engineering, Stanford University, Stanford, California 94305.

FAITH, SCIENCE AND THE FUTURE edited by Paul Abrecht, Church and Society, World Council of Churches, Geneva, Switzerland 1978. Paperback. 236 pp.

Subtitled "Preparatory Readings for the 1979 Conference of the World Council of Churches," this volume was intended to be read as source material before the conference held July 12-24, 1979 in Cambridge, Massachusetts. It was put together by an eight-person editorial committee. The first 13 chapters are unsigned, while the final 7 chapters are signed. The book is divided, after an introductory chapter, into five sections: a theological and ethical evaluation of science and technology; energy for the future; food, resources, environment and population; science and technology as power; and economic issues. The keynote phrase of the volume is "a just, participatory and sustainable society;" this is the proposed goal of human efforts.

The major theological input of the book appears in Chapters 2 through 4. Chapter 2 deals with "Faith, Science and Human Understanding," and reflects a sound understanding of the issues. Four characteristics of contemporary science are sketched: an absence of talk about "scientific method," in the sense of some single universal method of science; willingness to use different complementary models; a rethinking of scientific objectivity; and the posing of many intriguing problems by the expanding boundaries of science. Two major changes in common conceptions of faith are outlined: faith is not an explanation in competition with scientific explanations for the working of nature; and faith is not a supernatural tool for manipulating nature and other people.

Chapter 3 deals with the promises and threats of science and technology. It is realized that the power of science and technology can be used for either good or bad, and that even well-intended technological developments often have undesirable and unintended consequences. The overrating of scientific abilities is discussed together with the kinds of frustration and dilemma that result from such unreal expectations. Two temptations awaiting Christians are warned against: making faith irrelevant to ethical decisions on the one hand, and trying to find in the Bible specific answers to questions never before faced by human beings on the other.

The fourth chapter deals explicitly with the topic, "The Biblical Interpretation of Nature and Human Dominion." The richest revelation concerning God and nature comes to us in the Old Testament which emphasizes the immanence of God in the created world as well as the transcendence of God over it. Alienation of God is linked directly to alienation from nature, His creation. The major New Testament contribution to this subject is the assertion that liberation of the created order is at hand in and through Jesus Christ. Human dominion over nature (Gen. 1:28) must be seen only in terms of God's dominion (Gen. 1:27). "Jesus of Nazareth is not the end of the process God started with his creation; he is the anticipation of a new earth and a new relationship between humanity and nature." (p. 43)

The remaining sixteen chapters of the book seldom if ever mention the name of God or involve biblical teaching. This should not be taken as totally critical, for we must not fall into the error of dismissing the "purely practical" as if that were ipso facto non-Christian. In Chapter 5 on "Rethinking the Criteria for Quality of Life," however, one might have expected a biblical analysis. Instead the author writes, "For the effort to define quality inevitably leads to the philosophical-ethical question of the nature of the good, which is a perennial and basically unanswered question in the history of human existence." He follows this sentence with a reference to *Zen and the Art of Motor-Cycle Maintenance* as a source to demonstrate that the question about the good "inevitably leads beyond the limits of critical rationality." The author argues for "social education which will eventually overcome personal greed," and closes with the negative statement, "But there does not seem to be any evidence of the existence of an invisible hand operating to steady and guide the chariot of history." (p. 50)

The book touches on a wide variety of issues, often supplying useful summaries and analyses of the problem and proposed or possible solutions. These issues include biological manipulation of human life, energy prospects either including or excluding nuclear energy, food prospects, limits to resources, environmental deterioration, population growth, technology and the oceans, technology and the structure of government, technology transfer and dependence, quest for appropriate technology, technology and the world economy, a Soviet view of the environment and social production, and a plea for a post-modern society.

Like other treatments of these topics, the book often invokes the necessity for "society" or "the people" to have a direct voice in decisions about science, technology and government. The use of these terms is easy and gives the appearance of a democratic spirit. The determination of exactly what these phrases mean, however, and how to involve the convictions of the informed common man rather than the ideological or demagogic pronouncements of those who exalt themselves in the name of "the people" is an unsolved problem of major proportions.

The authors often lapse into purple rhetoric. The Secretary of State for Industry in the United Kingdom, A. W. Benn, argues that our present needs "must necessarily lead to the strengthening of international and supranational institutions big enough to encompass the totality

of man's needs as he gradually learns that brotherhood has moved from a moral aspiration to an essential prerequisite of survival," (p. 182) and "The groundswell demand for free trade unions or socialized education or socialized medicine . . . bubbled up in the community, lapping around the foundations of the establishment until it acquired sufficient momentum to swamp the opposition in Congress or Parliament." He closes his chapter with the words, "the statesman of today . . . must carry on the struggle until, in God's good time, the people with all their power and might step forth to the rescue and liberation of mankind." (p. 184) He is matched by P. Oldak, Soviet Doctor of Economics, who writes, "Modern man should match the great power which he has acquired with great intelligence. Man is a creator, but not an irresponsible creator. He is predestined to realize the most vivid dreams, but only if he does not destroy the medium of his own habitation 'on his way to the stars.' " (p. 216)

Overall the book is a useful summary of many of the current issues. If the reader can replace some of the liberal humanism and idealism of the text with his own biblical sensitivity, he can put the book to good use.

Reviewed by Richard H. Bube, Department of Materials Science and Engineering, Stanford University, Stanford, CA 94305. This review was originally published in TSF Bulletin.

HUMAN SCIENCE AND HUMAN DIGNITY by Donald MacKay. Hodder and Stoughton, Toronto. 126 pp. $2.95.

Donald MacKay's 1977 London Lectures in Contemporary Christianity present us with some of his broader concerns in the area of humanness. What does it mean to be human? What constitutes human dignity? And, perhaps above all, does the science of human behavior jeopardize a biblical view of man? These are questions with which Donald MacKay, Professor of Communication and Neuroscience at the University of Keele, is well qualified to deal. As in all his writings, he brings his astute logical mind and resolute biblical faith to bear on them.

One of MacKay's basic theses is that a truly scientific approach to the study of man in no way threatens his dignity. According to MacKay, Christians should be seeking a scientific understanding of human nature, rather than running away from it.

For MacKay, man as a phenomenon requires many levels of analysis to do him justice and to reveal the richness of his nature. He is concerned to discover how explanations at these different levels may be correlated; hence his well-known emphasis on their complementarity. This leads him to stress the unity of man, with body, mind and spirit as aspects of this unity.

Human dignity emerges as a reflection of man's capacity for inter-personal relationships, of the way an individual uses his social repertoire, and of his response to God. From this it follows that human dignity should not be defended by denying similarities between man and other species, nor by attacking the positive scientific theory that all physical events are determined by physical causes. MacKay is, nevertheless, at pains to point out that a distinction must be made between this form of positive determinism and its negative form which is nothing more than a metaphysical doctrine.

In extending his discussion to our responsibility for the future, MacKay lays down some very useful basic principles. For instance, he distinguishes between contentment with the unalterable and complacency in face of the alterable, the former being a Christian virtue and the latter a rejection of one aspect of human responsibility. He points out that human engineering may be a means of serving God, while human improvability may be best considered using guidelines based on compassion, obedience to God, and answerability to God. Useful as these principles are, MacKay fails to work out their implications in practical terms, a deficiency which is particularly evident in his sections on genetic engineering and cloning, both of which tend to be superficial. He is on surer ground in his discussion of behavior control, and his consideration of manipulation with emphasis on the role of answerability is especially helpful.

The specific quality distinguishing human conscious experience is that of being treated-as-a-person. Mechanistic analysis cannot therefore destroy personal significance. Indeed, personal identity is closely linked with our priorities, an idea which MacKay applies superbly to our present lives and future eternal prospects.

This book is a testimony to the way in which a courageous biblical faith should be tackling contemporary issues in the scientific (and non-scientific) realm. In places, MacKay fails to apply his ideas as rigorously as he might; but there is no denying their immense stimulation and challenge. As always MacKay has indulged in a ground-clearing exercise. It is for others to take up the challenge and demonstrate how some of these principles can be applied.

Reviewed by D. Gareth Jones, Associate Professor of Anatomy and Human Biology, University of Western Australia.

Perspective on Energy Technology Choices

Introduction

I am concerned that the ASA maintain its credibility through a balanced treatment of energy technology issues. My concern arises from the current polarized situation in our society which jeopardizes the timely availability of needed energy for the future. In this article this concern and its rationale are articulated along with a challenge to ASA members as scientists and engineers working in energy-related fields.

Having worked in the mid-1940's in Boulder, Colorado on one of the first demonstrations of solar house heating, I have a continuing interest in how solar energy can be appropriately used to meet our energy needs. Having spent 24 years in the nuclear field, I have similar interests regarding nuclear energy. And having spent 6 years in seeking to use science for the benefit of humankind in other ways, I gained a perspective about societal problems in general; as a result of this latter experience, my personal credo about research on complex societal problems was developed and articulated.[1] These experiences and beliefs will be reflected as some concepts and ideas from the Scriptures and secular viewpoints on energy technology choices are presented.

Biblical Guidance

A theological view of the relationships of man and nature to God[2] is necessary for a meaningful perspective of the situations that face humankind today. I believe such a view leads to at least three fundamental ethical principles:

1. *Our responsibility to be stewards of the earth's environment and resources that belong to God, not to us.* This responsibility is given in Genesis in the creation (vs. 1:26–30) and garden (vs. 2:15) stories. It is important to recognize the "tending" aspects of the garden story or the "dominion" aspects of the creation story could be incorrectly interpreted to be the cause of a perceived ecological crisis.[3] This stewardship responsibility includes both conserving and using resources prudently, in the interests of both the present and future generations.
2. *Our responsibility to pay special attention to the poor and needy people of the world,* as given in Proverbs 31:9 and many other places in both the Old and New Testaments. History shows that without adequate energy available, the poor and needy of the world suffer the first and most.
3. *Our responsibility to do all things under the Lordship of Jesus Christ,* as given in Colossians 3:17 and elsewhere.

Fulfillment of our individual responsibilities requires us to "seek first the kingdom of God and his righteousness...." (Matthew 6:33). Righteousness in the Bible has at least three dimensions: legal, moral and social.[4] Legal righteousness is justification, a right relationship with God. Moral righteousness is that righteousness of character and conduct which pleases God, an inner righteousness of heart, mind and motive. Social righteousness is concerned with "seeking man's liberation from oppression, together with the promotion of civil rights, justice in the law courts, integrity in business dealings and honor in home and family affairs . . . Christians are committed to hunger for righteousness in the whole human community as something pleasing to a righteous God."

Secular Perspective

We are living at a point in history when the world is rapidly depleting its natural resources. One vital aspect of our society that is being severely affected is that of energy production. Our finite supplies of non-renewable energy-producing fuels (especially petroleum and natural gas) are being depleted at a rapid rate. Humankind must turn to strict energy conservation and other energy sources.[5,6]

The ethic of conservation appropriately is being emphasized throughout our society in order to reduce our energy consumption and resource use. Savings could reach a limit of 30–40% of classic (1972) energy projections.[7] Such significant conservation would require alterations of our lifestyles and practices in generating and using energy. Whereas some of these changes would certainly be salutary, others could result in adverse effects. Even with significant conservation measures, fuels other than petroleum and natural gas will be needed to supply our energy requirements.[8]

Production of energy will likely require the use of all feasible methods, i.e.,

- *Renewable* - Hydroelectric and other solar (direct thermal, wind, biomass, etc.)
- *Fossil fuels* - Coal, natural gas, petroleum and synthetic fuel derivatives.
- *Nuclear* - Fission, geothermal and potentially fusion.

The technologies to assure the availability of needed energy in the future are being developed and/or improved. The challenges we face are to use the above energy sources prudently and in consideration of the overall potentials and limitations of each energy source.

All energy sources have their associated benefits, costs, risks and uncertainties that must be evaluated as objectively as possible, consistent with the amount of information available, so that they can be properly compared for applicability to meet specific needs. Much is known about the energy sources that produce most of our energy today, i.e., hydropower, coal, oil, natural gas and nuclear fission. However, comparatively little is known about the non-conventional sources although the situation is improving. For example, comparative costs for coal and nuclear power systems for generation of electrical energy are quite well understood.[9] Benefit/cost information on solar energy technologies is much less developed; however, at least one significant study comparing environmental effects and benefits of solar energy technologies with coal has been made.[10]

With regard to risks to public health and safety, it must be recognized that all energy sources and production systems have associated risks; none are risk free. In reality, "no-risk thinking" may create the highest risks.[11] Comparisons of risks likewise can be made much better between coal and nuclear power systems[12] than between coal or nuclear and solar because of the advanced state of knowledge and large amount of research on the former systems and the minimal amount on solar systems to date. In risk assessments of various energy sources and comparisons among them it is necessary that entire fuel cycles or systems be considered; otherwise, significant errors can be introduced by the oversights.

The study of risks frequently consider only physical and biological risks. For a complete risk assessment both of these and social, psychological, aesthetic and related risks should be considered to gain an overall perspective. Even though the technology for such a complete risk assessment is lacking, qualitative considerations are important. For example, in the context of this paper, if adequate energy supplies may not be available to meet future needs, the risks of unemployment, deprivation and social unrest need to be evaluated with candor. At the risk of stepping out of my field of expertise, I suggest that the oppression of unemployment and resulting deprivation would lead to increasing gaps between rich and poor, people and nations; the affluent can afford to change lifestyles more than the poor but also are free not to do so. Social unrest from looting during power outages and violence in gas lines to war over resources has been experienced. In the context of a broad discussion of bioethical problems and priorities related to nuclear energy[13] three different options and their respective consequences for the future are described; contemplation of these scenarios, spelled out in greater detail by E. L. Zebroski of the Electric Power Research Institute, reinforces the concerns expressed above. Another publication[14] presents similar ideas on social hazards from a pronuclear viewpoint in a popular format.

Communication among people and sectors of our society is becoming increasingly difficult because of polarizations. Not only is the topic of energy production becoming more political than technical, it is plagued by a moral problem involving dishonesty and deception in communications. There is always a tendency to oversell one's own viewpoint, sometimes with hidden motives. What is needed, in view of the impending crisis society faces, are honest and open dialogues on benefits and risks and uncertainties of all kinds of energy sources so that the choices of the future can be made as well as possible. Evidence of the result of dishonesty and deception, i.e., lack of trust, was gained in a mail-out survey on nuclear knowledge and nuclear attitudes:[15]

> "With respect to four information sources—the news media, government agencies, utility companies, and environmental groups– general sample respondents, on the average, expressed distrust in the four sources more than they expressed trust in them. The least amount of distrust was shown toward government agencies, and the most distrust was shown toward environmental groups. Nuclear neighbors expressed slight trust in government agencies and distrust in other sources, especially environmental groups. Environmentalists expressed strong trust in environmental groups and strong distrust in utility companies."

Another dimension of communications was studied through a comparative analysis of network television news coverage of coal, nuclear power and solar stories from 1972 to 1977.[16]

> "While a large number of the stories presented the pro and con side of the technology story, virtually all one-sided solar stories were pro solar, and virtually all one-sided nuclear power stories were anti nuclear. . . . In terms of the balance of benefit/cost discussions, for solar power the benefit discussion outweighed the cost discussion about ten to one, while for nuclear and coal the cost discussion outweighed the benefit discussion about four to one."

These observations support what many of us have experienced, the optimistic view of a new technology and an associated oversell. The vice versa situation is also familiar to us!

Primary reasons for the polarization over nuclear power are conflicts of values having to do with lifestyles[17] and differences in perceptions regarding desirable social-institutional and political conditions:[13]

> "Pronuclear respondents place significantly more importance than antinuclear respondents (in a mail-out survey) on the values of a comfortable life, family security, and national security. Antinuclear respondents place significantly more importance than pronuclear respondents on the values of a world of beauty and equality. A comparison of the value systems of these respondents with the value systems of the American public indicated that pronuclear respondents have value systems more like the 'average' American, whereas antinuclear respondents . . . have value systems somewhat more like individuals who have been active in other social movements, such as the civil rights movement."

As an individual, I also have conflicts because I value both the pronuclear and antinuclear sets of values summarized above! I wish that the nuclear fuel cycle did not have some of the undesirable features of radioactivity just as I wish that solar energy were not so diffuse and variable. (Except the diffuseness permits me to live and the variability enhances my lifestyle!) But my wishes do not change the realities of the situations. Nicholas Ediger, President of the Canadian Nuclear Association, expressed my sentiments precisely when he said he finds it "unfortunate" that discussions of "policy related to the generation of electricity by utilizing steam from a uranium-fired boiler" are used "by certain individuals as yet another opportunity to engage in a lifestyle debate."[18]

Epilogue

Two prominent solar energy researchers, Margorie and Aden Meinel, "caution us against becoming entrenched within simplistic versions of the multiple problems which surround any energy option. They also urge us to bury the polarized rhetoric—growth vs. no growth, solar energy vs. nuclear energy, soft path vs. hard path, etc. . . . Abandoning the polarized rhetoric is not enough. We must also recognize that the most paralyzing, debilitating, and manipulable human emotion is *fear*—fear begotten from *ignorance*."[13] We would do well to remember Madame Marie Curie's words:

> "Nothing in life is to be feared; it is to be understood."

As scientists and engineers, we have the responsibility and opportunity to help the public understand the complex technical issues of the day, overcome fears of the unknown and face the future with hope, not despair. Clear, balanced, technically-correct communications from us are vital.

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Sociology and the Christian Student: A Statement of the Problem[1]

It appears to be self-evident that a certain amount of antipathy exists between evangelical and fundamentalistic forms of Christianity on the one hand, and the behavioral sciences on the other. Moreover, sociology in particular seems to attract more than its share of attention when this antipathy is recognized and debated publicly. A friend recently attended a Southern Baptist church in Florida and returned with this account of the message: the minister emphatically agrued that college education can—and often does—create real problems for the Christian student. He therefore recommended that parents in the congregation send their sons and daughters to (preferably local) "Bible-believing" colleges. Beyond this, he maintained that under no circumstances should they permit their children—whether they be at a local Christian college or not—to enroll in sociology courses. For, should higher education in general not prove fatal to their faith, sociology surely would.

As a college professor, a sociologist, and as one who would classify himself (should the need arise) as an evangelical Christian, I believe the minister has a point. Of course, I do not think that intellectually capable students should stay out of college or that they should avoid sociology; at the very least, my vested interests in both would urge me to reject that stance. But I do believe that Christian faith and sociology do not easily mix—that is, they do not lend themselves as readily to intellectual synthesis as biology (or, better yet, physics) and Christianity.

Of course, this is not the first time a more general version of this issue has been raised. The question of the incompatability of science and religion is, obviously, one which has received the attention of many scholars.[2] The central question in these essays revolves around the real or apparent intellectual antipathy between faith and reason as the basis for one's world view. While there need be no necessary logical inconsistency between these two perspectives, we find that they are often held to be alternative, rather than merely different, orientations used in making sense out of the world. The apparent 'winner' in this on-going struggle has been science; whereas the Bible claims that the "just shall live by faith," the typical citizen of modern society increasingly seems to prefer living by empirical observation. From the outcome of the famous Scopes trial to the local pastor who now consults psychology texts in order to formulate his moral pronouncements on the effects of TV viewing, science has steadily made inroads into areas previously defined as the exclusive domain of religion.[3]

In addition to the issues arising from science posed as an alternative *Weltanschauung*, the argument has also extended to the more specific subject of the behavioral sciences. Here again there is no shortage of analytical literature. It is when religion (as an individual's belief system or as a bureaucratic organization) becomes the dependent variable in psychological, anthropological, or sociological theories that the otherwise implicit conflict between social science and religious commitment becomes explicit. Here the student is confronted with empirical evidence—not someone's opinion, mind you—demonstrating that religiosity varies with such non-supernatural factors as income, sex, occupational status, education, authoritarianism, anomie, tolerance for ambiguity, peer group pressures, and various forms of psychological complexes. Moreover, the churches which parishioners form in their collective pursuit of organized religion typically turn out to be very similar to non-religious bureaucratic organizations in their financial manipulations, promotional schemes, career motivations, and so forth. In other words, behavioral science has shown religion to be a very human (i.e., "secular") activity indeed, and while this may not provide Christian students with a rationale for pitching their faith, it probably causes many of them to look at religion in a very different (and henceforth critical) light.

The Sociology-Christianity Debate

When we focus more specifically on the role of sociology in this on-going debate, we find that very little has been written—especially when the object is to analyze the effect that the study of sociology has on the religious commitment of the evangelical Christian student.[4]

Rather than attempt a full-scale analysis of all the 'trouble spots,' I briefly discuss two issues in contemporary sociology which pose potential problems for Christian faith—particularly the faith of Christian students studying sociology for the first time. One of these issues deals with the results of empirical studies in the sociology of religion and the other arises from sociological theory as applied to the interpretation of one's daily existence.

Empirical Findings and Faith

There exists within sociology a strong, yet often implicit, theme which Peter Berger and others refer to as the "debunking motif:"

> "The sociological frame of reference, with its built-in procedure of looking for levels of reality other than those given in the official definitions of society, carries with it the logical imperative to unmask the pretensions and the propaganda by which men cloak their actions with each other."[5]

In some cases this unmasking effort is deliberate and therefore obvious. For example, sociologists point out that things are not always as them seem: that the operations of bureaucratic organizations are influenced by informal social controls which are not included on the official tables of organizational authority or that people "fall in love" for many reasons which are not recognized (or, at least not acknowledged publicly) by the lovers themselves. In other words, sociologists often find through their studies of social behavior that there is a lot more going on than what the

people *say* is going on. Moreover, these "unofficial" levels of reality uncovered by sociological analysis involve insights which to many seem threatening. For example, lovers tend to become somewhat disenchanted when it is pointed out to them that many of the factors which play a part in shaping their relationship have absolutely nothing to do with Cupid's arrows.[6]

More to the point, sociology has contributed alternative perspectives on religious interaction which many persons find uncomfortable—perhaps even outrageous. For example, it was the sociologist Max Weber, following the suggested (if somewhat less sophisticated) lead of Karl Marx, who undertook the first full-scale empirical investigation of religious styles and social location, showing that religious world views vary in systematic and consistent ways from one social class to another. More recently, H. Richard Niebuhr has given us a detailed socio-historical analysis of denominational growth and the political and economic forces which, at least in part, generated them.[7]

Empirical studies in the sociology of religion have frequently revealed findings which debunk the image many Christian students have of the church. Liston Pope's analysis of Gastonia, North Carolina, for example, uncovered the blatant ideological functions of local Protestant churches and the role that sermons played in thwarting the union effort in the textile industry.[8] Festinger's study of a millenarian sect reveals that the underlying dynamic in binding a congregation together is based upon social and psychological factors having little, if anything, to do with acknowledged religious goals.[9]

Other studies have also shown that vigorous orthodox commitments often come from persons who represent anything but those who have been profoundly "touched by the love of God." For the most part, these studies have shown that religious orthodoxy and religious commitment are strongest in those persons who are most authoritarian and dogmatic,[10] illiberal and close-minded,[11] socially isolated,[12] ethnocentric,[13] and anti-democratic.[14] Findings such as these are hardly likely to make the Christian student wish to renew his or her commitment to the family of professed believers.[15]

An addition to pointing out that God's people possess feet of clay, (or even perhaps that their feet are dirtier than most), sociological analysis also rests upon the observation that values are relative to the group which endorses them: that is to say, one's perception of the world is more realistically described as an interpretation and one's interpretation varies according to the group in which one is socially located. Thus, the student of sociology inevitably discovers that values are relative. Yet, at the same time, the Christian is, by definition, committed to a set of absolute values —conceptions of how the world ought to operate which are said not to be subject to historical, geographic, or social factors. Even though the value-relativism of the social scientists belongs in the category of empirical claims while the absolute values of the Christian respresent a non-empirical judgment, the possibility of intellectual tension between the two nonetheless exists. For many Christian students, a "belief in" one necessitates rethinking one's "belief in" the other.

There is at least one more reason to suspect that the findings from sociological research tend to run counter to the world-view shared by most Christian students. Most of these students subscribe to the common sense notion that attitudes have causal primacy over behavior. Even though this "attitudes first" thesis is widely held in American culture in general, there is good reason to suspect that evangelical Christians have an even greater attachment to this style of thinking. The basic goal of evangelical Christians is to expand the influence of Christ on earth. The means to this end is some variation of "soul-winning." Here the mind of the non-believer is the basic focus rather than the non-believer's behavior. In other words, the emphasis is on the "heart" rather than superficial externalities of behavior. To express this in biblical terms, the Epistle of James, while not forgotten, takes a back seat to the Epistle of Hebrews: faith is placed first—and changes in behavior follow.

The point here is not to debate the theological issue at hand, but to point out that this sort of reasoning is likely to have an effect on the way in which one generally interprets the world. It is at this point that the student discovers (and, it is my experience that this discovery is accompanied by some degree of discomfort) that conclusions from research studies run counter to this assertion. Although the attitudes-behavior relationship is at least in part reciprocal, the emphasis appears to be on behavior changing attitudes, rather than on the other way around. Thomas Pettigrew puts the matter succinctly: "behaving differently more often precedes thinking differently."[16]

What is at issue here is not merely a matter of revising one's thoughts about a rather abstract relationship. Rather, this intellectual shift has the potential to shift one's theology as well, and it is this shift which brings out the real threat. It must occur to at least some of these students that one's religious commitment is a function of one's typical behavior (as a factor of one's social location, reference groups, etc.). Peter Berger, whose *Invitation To Sociology* is assigned reading in many introductory courses, says as much in the following quote: "Roles carry with them both certain actions and the emotions and attitudes that belong to these actions. . . . The preacher finds himself believing what he preaches . . . In other words, one becomes (a believer) by engaging in activities which presuppose belief."[17] Many students find this notion upsetting not simply because it contradicts the speculations of common sense, but because it threatens to undermine the validity of their spiritual commitment.

Sociological Theory and Religious Faith

As is indicated in the preceding paragraph, underlying all theoretical work in sociology—from functionalistic stratification models to labeling theories of social deviance—is the proposition that reality is socially constructed. This enterprise in reality construction initially takes place as human beings collectively project meanings onto objects and events which confront them. Thus, instead of confronting a chaotic and therefore terrifying world, the average member of society can rest assured that Normal people are going about their Normal affairs.

The crucial point in all this—and one which often goes unnoticed unless sociologists are around to point it out—is that this socially constructed reality is stabilized by the inevitable process of reification, whereby these meanings take on an ontological status they otherwise do not deserve. It is one thing for persons to declare that "little girls are not aggressive," thereby creating (assuming this is a new idea) a predictable and therefore meaningful social world in which to operate; it is quite another thing to assume that little girls *must be* unaggressive. The motive for the first statement is usually nothing more than sheer convenience: the behavior of little girls ought to be at least somewhat predictable; if it were not, social order would be less tenable than it already is. Here it is implied that normal little girls can be anything humanly imaginable and that unaggressiveness is the role we somehow happened to settle on. But the second statement more accurately characterizes the social world in which most of us live most of the time; the issue of normality in little-girl behavior is not ordinarily open for serious debate. Once established as Normal behavior, our roles as traditionally defined tend to become fixed and immutable; in other words, the meanings symbolized by these roles become reified.

Of course, all of these ideas are common to any introductory sociology course.[18] It is my experience that ideas such as these tend to transform the consciousness of students; what was previously seen as ordinary (and rather dull) everyday social behavior now becomes a fascinating if not consciously-planned conspiracy to maintain an artificial, socially imposed set of meanings. But the Christian student is likely to react with shock when he or she learns of the part which religion has historically played in this conspiracy.

This is neither the time nor the place to go into a detailed empirical account of how religious movements have involved themselves in reality-maintenance enterprises throughout history.[19] More to the point of this paper, it should be emphatically underscored that this sort of intellectual revelation can, and often does, have a profound effect upon Christian students. Quite often these students have previously been encouraged to think of religion as a purely personal affair—not in the sense that it is "private," but in the sense that religion has not been perceived as a collective social enterprise subject to the same institutional factors as are other spheres of collective action. When seen as just one more institutionalized activity, religious faith can become (to use Max Weber's famous concept) disenchanted: i.e., it can lose its distinctive character. When the realm of the sacred falls within the analytical purview of the social scientist, the phenomenon itself must inevitably be transformed from a unique aspect of human experience into just another mundane human activity. The point here is to acknowledge that the Christian student of social behavior is likely to find him or herself in a difficult position; the detached sardonic observer is a tough role to integrate with that of committed believer. The result is quite often either anxiety and tension or an alteration of one or both of the roles, so that they can be played without enduring the cognitive dissonance involved. When the second option is exercised, the result will be a poor grasp of sociology's analytical purpose, the loss of some measure of religious commitment, or perhaps an alteration of the original religious world view.

Closely related to this problem is the collectivistic orientation of sociology and the typically individualistic nature of contemporary Christian faith. One of the distinct traits of Christianity-Protestantism in particular, and its evangelical wings even more so—is its individualistic character. Christ may indeed have "died for the sins of the world" but evangelicals stress that the atonement must take on a distinctly personal significance for the individual believer. Throughout the conversation of the typical Christian one notes an orientation focused on the individual and not the corporate nature of social life; for example, the concept of sin is normally thought of in individualistic terms. As God commands us to love our neighbor, so those who hate are sinning—and are doing it individually. Similarly, the sinner is seen as reconciled to God through Christ as an individual and not in any corporate sense. (The "old dispensation" may have stressed the social covenant, but the "new dispensation" does not). As a result, the idea that the church represents something more than the total number of individual saints is certainly an uncommon notion for evangelical Christians today. Yet this "something more" thesis lies at the heart of what is known as the "sociological perspective." Society represents something over and above the sum total of all the individuals —a social force not reducible to its component parts. This "something more" is, of course, its institutionalized system of interaction which operates as an independent variable in its own right.

Arthur Holmes, philosopher and evangelical Christian, claims that "Christians believe that the source of evil is ultimately within a man, not without" and that "the nature of man undergirds his behavior and his institutions."[20] But the sociological theories on criminal behavior, suicide, marital instability, economic inequality, prejudice, and so on all stress causal variables which lie outside the individual. The image of the individual given in such "Durkheimian" theories is of a leaf before the wind—unaware of the causes of his behavior and therefore not responsible for them. Thus, it is the social institutions which shape the "nature of man" and not, as Holmes would have us believe, the other way around. This is the message which sociology is likely to leave with the Christian student.

The basic pedagogical purpose behind every sociology course is to clarify the analytical connection between the students' individual biography and the social system of which he or she is a member. It is therefore apparent that insofar as the professor succeeds in doing just this, he or she threatens the epistemological foundations of evangelical Christianity.[21] What, for example, is to be the conclusion of the student of sociology who discovers that American racism represents something more than merely the sum total of prejudiced individuals: that racism represents an institutionalized system distributing the economic surplus unequally according to skin color—a system which continues to operate despite our "best" intentions and equalitarian laws? The student is either forced to compartmentalize his or her thoughts into "sociological" and "Christian" areas, refuse to internalize the findings of sociology, or reformulate his or her religious faith—often with far-reaching and rather unsettling consequences.[22]

Summary and Conclusion

Before any argument can provide an adequate explanation, the component parts of that argument must be fully explicated. While there have been numerous previous attempts to explicate a "Christian sociology" or (more modestly) to demonstrate how Christianity and sociology can be intellectually integrated, there have been few, if any, attempts to outline the specific areas in which Christianity and sociology contribute to the construction of mutually antagonistic world views.

As we have noted, at least part of this incompatibility is due to the status of sociology vis-a-vis the scientific method of inquiry. Other problems are due to sociological issues which arise from both its empirical findings and from its general theoretical approach. Both of these areas are introduced in most basic sociology courses and it is here where we typically see the most apparent (as well as the first) evidence of the sociology-Christianity debate.

Several points must be carefully noted before this discussion is closed. First, the intensity of this "debate" will vary, depending upon the nature of both the students' faith and the presentation of sociology by the course instructor. For the student whose faith has been closely examined, or who is enrolled in a sociology course in which the unique sociological perspective is not clearly presented in an integrated manner, this encounter is not likely to be traumatic. But for the student whose Christian faith is naive, and who encounters a rigorous and well-integrated sociology course, this encounter can sometimes reach crisis proportions.

Furthermore, the encounter—should it occur—is not likely to be a public event. More typically, the Christian student's struggle is a private affair; he or she engages in the debate as a solitary combatant without the immediate aid of sympathetic peers. Furthermore, the private nature of this situation undoubtedly accentuates the conflict; not only does the responsibility for an adequate apologetic fall squarely on his or her (normally unprepared) shoulders, but the social situation of the classroom typically exacerbates the tension: everyone else seems so unmoved by all this apparent contradiction. Thus the issue of deviance and intellectual abnormality is sometimes added to the pressure already felt. To be troubled when everyone else is troubled is one thing; to be the only troubled soul within a sea of complacency is quite another. Finally, the teacher may turn out to be quite unsympathetic to any student's question if it appears to be based upon any epistemological foundation other than relativistic empiricism.

This scenario, of course, can be easily worked into a defense of Christian education. But the intent of those who participate in and defend the purpose of Christian higher education must not be to simply remove the cause of all the anxiety. A deliberately sociology-less Christian educational curriculum is deficient and pays no respect to either Christianity or education. Furthermore, constructing a sociology program around faculty who evidently lack the sociological imagination—regardless of the purity and vigor of their faith—contributes nothing towards the goal of liberal education which most Christian colleges claim to support. In the words of Arthur Holmes, Christian higher education ". . . shuns tacked-on moralizing and applications, stale and superficial approaches that fail to penetrate the real intellectual issues."[23] Our

task as Christians involved in higher education is to seek a synthesis of faith and knowledge. But this task cannot be successfully undertaken as long as "the real intellectual issues" remain improperly outlined and misunderstood.

[1]I would like to thank Gerry Fuller and Dale Hess of Westminster College for their assistance in reading the first draft of this paper.

[2]Of the empirical studies, perhaps the best known is Charles Y. Glock and Rodney Stark's in *Religion and Society in Tension* (Chicago: Rand McNally, 1965); cf. Chapter 14, "On the incompatability of religion and science." While the Glock and Stark essay is useful in observing the effects of the religion-science clash it does not provide us with very many insights into why this clash develops. Nor does the essay take a peculiar position vis-a-vis theology; their measurement of "religion" remains rather general throughout. The purpose of this essay will be to examine probable causes of the antipathy and to consider evangelical Christian presuppositions in particular. This is a task which has not as yet received very much attention.

[3]Even if we take into consideration the current meditation fad, the presumed growth of "Consciousness III," and the formation of Americanized eastern cults, the same general conclusion has to be drawn for our society taken as a whole.

[4]See, for example, David Lyon's *Christians and Sociology* (Downers Grove: Inter-Varsity Press, 1976); Jack Balswick and Dawn Ward, "The nature of man and scientific models of society," *Journal of the American Scientific Affiliation*, 28 (1976), 181–185. Most essays such as these center on the "nature of man" issue—a "heavy" philosophical problem which does (and should) concern intellectuals, but one which does not concern very many undergraduate students (except in superficial ways) at least at the introductory level, where most students come in contact with sociology. Therefore, the distinction between the essays cited above and the one in hand is that this one is attempting to center on a few prominent issues which inevitably crop up in most introductory sociology courses—ones which are likely to pose problems to the uninitiated Christian student. Since few of these students are expected to read this essay, it is being directed at sociologists who teach at Christian colleges where an integration of faith and learning is desired and expected. As such, it constitutes a warning to undergraduate teachers of sociology of potential problems between Christian faith and sociology rather than an attempted integration of the two.

[5]Peter Berger, *Invitation to Sociology* (Garden City, New York: Anchor, 1965), p. 38.

[6]Peter Berger, *ibid.*, p. 35.

[7]Cf. *The Social Sources of Denominationalism*. Of course, Niebuhr acknowledged (as did Max Weber) that the causal schema runs both ways: that religious faith influences, as well as is influenced by, one's social location and social structure in general. See Neibuhr's *Kingdom of God in America*, and Weber's *The Protestant Ethic and the Spirit of Capitalism*.

To a certain extent, this mode of analysis coincides with common sense; even the most fanatical advocate of religious determinism would have to concede that "religion" *per se* had very little to do with the original nineteenth century separation of southern and northern brands of Methodists, Presbyterians, or Baptists. Why would one nineteenth century Baptist group have asserted with full sincerity that slavery was ordained by God while another, equally sincere and emphatic, maintained that slavery represented an absolute evil? It does not take a particularly sophisticated observer to conclude that in a case such as this we must overlook all the pious rhetoric and investigate certain prominent economic and political forces—forces that neither group of true believers in the above example would wish to acknowledge as pertinent.

[8]*Millhands and Preachers*, (New Haven: Yale University Press, 1942).

[9]Festinger, *et al.*, *When Prophecy Fails* (New York: Harper Torchbooks, 1956).

[10]J. D. Photiadis and A. Johnson, "Orthodoxy, church participation, and authoritarianism," *American Journal of Sociology*, 69 (1963), 111–128.

[11]Milton Rokeach, *The Open and Closed Mind* (New York: Basic Books, 1960).

[12]R. Stark and Charles Y. Glock, *American Piety: The Nature of Religious Commitment* (Berkeley: University of California Press, 1968); Glock, Ringer, and Babbie, *To Comfort and Challenge* (Berkeley: University of California Press, 1967).

[13]Gordon Allport, *The Nature of Prejudice* (Garden City: Doubleday and Co., 1954); R. L. Gorsuch and D. Aleshire, "Christian faith and prejudice: a review of research," *Journal for the Scientific Study of Religion*, 13 (September, 1974), 281–300.

[14]E. L. Struening, "Antidemocratic attitudes in a midwestern University," in *Antidemocratic Attitudes in American Schools*, edited by H. H. Remmers (Evanston, Illinois: Northwestern University Press, 1963).

[15]The point here is that findings such as those reported in the previously mentioned studies are those which the student is likely to confront in a sociology class; the point is *not* that these studies represent all there is to say on the matter, or that they are free from any methodological defect.

[16]Thomas Pettigrew, *Racially Separate or Together?* McGraw-Hill (1971), p. 279.

[17]Peter Berger, *op. cit.*, p. 96.

[18]Every sociology course, that is, which is worthy of the designation. It is recognized that some "sociologists" lack what Mills called the "sociological imagination" and whose courses, as a result, constitute nothing more theoretically rigorous than lectures on current events or "problems of democracy," and whose discussions rarely go beyond what one could otherwise find on the six o'clock news. In addition, I have the sneaking suspicion that such nonsociological sociologists have a way of finding their way into the faculties of Christian colleges at a rate which exceeds what would exist were recruitment due solely to chance. In other words, Christian sociologists—when taken as a group—appear to be less oriented towards theoretical sociology than others in that their courses tend to substitute a discussion of otherwise unrelated concrete events for abstract systems theory, as well as typically substituting a normative for an impirical basis of discussion.

I readily admit that these conclusions are based on nothing more substantial than impressionistic observations. I would be greatly relieved to find out that they are, in fact, untrue.

[19]The interested but intellectually uninitiated reader would do well to read Peter Berger's *The Sacred Canopy* (Garden City, New York: 1969), especially Chapter 2, "Religion and world maintenance."

[20]*The Idea of a Christian College* (Grand Rapids, Michigan: E. Erdman's, 1975), p. 47 and p. 52. The word "ultimately" in the sentence quoted obscures the issue somewhat. Even so, there is a tension between the "interior" causes proposed by conservative theology and the "exterior" causes proposed by the social sciences, especially sociology.

[21]I say this knowing that Christian behavioral and social scientists are dedicated to the task of integrating the scientific perspective with that of Christianity (or vice versa). But the question we are addressing here concerns the tensions inherent between sociology and Christianity, and not how successful Christian behavioral scientists are in handling this tension in the classroom. This pedagogical issue is, of course, quite important

and hopefully this and other essays on the subject will sponsor some comment in future publications on how various members of A.S.A. deal with this problem in the classroom.

[22]There is, of course, one additional reason which typically creates tension between Christian students and sociology relating neither to research nor theory. Sociologists are, as a group, more politically liberal and radical than any other group of their academic colleagues. It is very likely that elements of this world-view become evident to their students, who come to college with political views considerably to the right of those they meet in introductory sociology. Whether these liberal political values are somehow inherent to sociology itself is a debatable point, but one which will not be taken up here. We are concerned in this paper with less subtle sources of tension between Christianity and sociology.

On the political liberality of sociologists, cf. Seymour Lipset and Everett Ladd, Jr., "The Politics of American Sociologists," *American Journal of Sociology*, 78 (1972), pp. 67–104. On the inherent liberal (and, simultaneously, conservative) political bias in sociology, cf. Peter Berger, "Freedom and Sociology", *The American Sociologist*, 6 (1971), pp. 1–5.

[23]Arthur Holmes, *op. cit.*, p. 17.

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Genes and Grace: A Christian Looks at Sociobiology

"In the beginning God created the heavens and the earth." So begins the first chapter of Genesis which Christians believe to be the revealed Word of God. The biblical record continues with an account of the creation of the inanimate and animate components of the universe, concluding with the creation of human beings "in God's image". Infused by the divine "breath of life", man became a living soul. Adam, the first man, named the animals, and thus completed his unique relation to the Creator and the remainder of creation.

While interpretations of the origin and meaning of the biblical account differ greatly, the Genesis story is in sharp contrast to the primal mass of incredible density which is the source of the currently popular "big bang" theory of the origin of the universe. According to this view, the entire "material" of the universe was compacted into a single mass of energy and matter that erupted with a bang of prodigious proportions. This "bang", occurring some 15–20 billion years ago, set in motion forces that are believed to remain at work in the expanding universe of today.

From the dust clouds of the exploding cosmos orderly systems evolved as stars, planets, moons, and asteroids took the places appointed them by the laws of physics and chemistry. On at least one small planet, the primeval soup developed in a manner that made life possible. It was into this inorganic aggregation of chemicals that a stimulating force produced new organization and an essential "spark" forged living matter. And once begun, life followed life into ever more complex forms, until some millions of years ago a new genus emerged—*Homo*.

Of all the details of these accounts of origins which have provoked controversy, the emergence of *Homo* has provided the most emotional debate. Ever since Charles Darwin published his research on the probable relationships between species, many believers in the Christian religion have followed their interpretation of creation and rejected the "Godless" evolution of Darwin. Christians recoil at the thought of finding their heritage in monkeys, apes, and even "lower" species of animal life. (It must be recognized that creation and evolution are no longer perceived as mutually exclusive by many Christians who acknowledge that evolutionary processes operate in nature, and may be incorporated in various ways into a creationist position. The focus in this paper is not the origin and interpretation of Genesis but on the character and predispositions which produce human behavior.)

Recently, the tensions between science and religion have been reformulated and intensified with the emergence of a self-defined "new synthesis" which calls itself sociobiology. Starting with evolutionary assumptions, sociobiology seeks to account for mankind's biology, sociology and psychology through analysis of animal and human behavior (Wilson, 1975).

In the remainder of this paper, focus is on the human portion of the debate generated by recent findings in the social and natural sciences, particularly as interpreted by contemporary sociobiology. While it is clearly impossible to resolve the complex philosophical and scientific issues separating sociobiology and Christian faith, an attempt is made to detail the path a Christian might take in facing the claims of the "new synthesis". It is further hoped that perceptive Christian thinkers will find creative ways to resolve these issues, both from the perspective of reasoned debate and from the workbench of the scientist. It is only as Christians accept this task that the challenge of theories contrary to faith can be confronted.

Perhaps it is the Christian scientist who should provide the "instance" called for by Gregory (1978). He writes:

> "One of the problems sociobiology encounters in seeking genetic determinants of behavior is that it must explain everything or else it explains nothing. If there exists in a single species a single behavior that is intrinsically incapable of explanation on genetic ground, sociobiology drops from a universal to a limited hypothesis." (p. 286)

The Human Character

Let us examine first the type of human being expected by the sociobiologists. Several writers, in books oriented to a popular audience, have made strong statements concerning this topic. Ardrey (1961) suggests that human beings bear the violent legacy of "killer apes" who are our immediate predecessors. Dawkins (1976) suggests we are opportunistic "survival machines" designed to perpetuate our "selfish genes". And most recently, in a widely acclaimed book, Edward Wilson (1978) writes:

> "the essence of the arguments, then, is that the brain exists because it promotes the survival and multiplication of the genes that direct its assembly. The human mind is a device for survival and reproduction, and reason is just one of its various techniques." (p. 2)

Furthermore,

> ". . . no species, ours included, possesses a purpose beyond the imperatives created by its genetic history. Species may have vast potential for material and mental progress but they lack any immanent purpose or guidance from agents beyond their immediate environment or even an evolutionary goal toward which their molecular architecture automatically steers them." (p. 2)

Thus, while they may differ in emphasis and detail, sociobiologists clearly believe that humans are genetically programmed to "selfishness" in the interests of their own (genes') survival. Genetic success requires adaptability, competitive advantage, deceit, aggression, territorial control, and reproductive success, if these characteristics are not countermanded by the situational superiority of kin

dynamics and/or reciprocity. Perhaps even more significant for the Christian is the assumption that the unfolding of the genetic drama occurs without any "immanent purpose" or "agents beyond their immediate environment." This self-reliant and survival-oriented individual perceived by the sociobiologists exhibits remarkable similarity to the scriptural description of unredeemed humanity.

In the Old Testament, human character is shaped by the sin of Adam and Eve, an event motivated by their selfish desire to be "like God". The history of God's people following that event is one of constant yielding to the sins of pride, greed, and self-interest. The Ten Commandments are directed against these human propensities and the Old Testament Scriptures promise a saviour who will provide a way of redeeming fallen humanity.

In the New Testament, consider Paul's scriptural concept of the "old nature." In Colossians 3, Paul notes deceit, anger, wrath, and coveteousness as aspects of the "old man", and in Ephesians 4 he lists vice, indecency, anger, bitterness, evil speakings, and theft. He then admonishes his readers to "put on the new man" (v. 24 KJV) which will "put away" these traits which destroy kindness and forgiveness.

"Putting away" the old nature is a key element of the "immanent purpose" that Christians call the Gospel. Human beings who respond to this message are to bring the old nature of pride, self-interest, deceit, and anger to the cross and thereby experience conversion. The "new creature" created by this experience is to demonstrate characteristics substantially opposed to the genetic predispositions of the "old nature". This "new creature" will exhibit attributes making possible a community of human beings which exhibit the fruits God's Spirit makes possible.

Reciprocity

In order to explain helping behavior between organisms, the sociobiologists suggest that self-interest may be risked in the pursuit of reciprocity, with the "faith" that such behavior will result in "cost effective" benefits at some future time. Reciprocity defined in this behavioral manner reminds the Christian of the "eye for an eye and tooth for a tooth" doctrine upon which Christ commented in the Sermon on the Mount. In response to this formulation of the reciprocity ethic, Christ's words were "But I say unto you, that you resist not evil; but whosoever shall smite thee on thy right cheek, turn to him the other also." (Matthew 5:39) In further examples Christ requires going the extra mile, and providing for persons in need regardless of their ability to reciprocate. Finally, even enemies are not to be feared or hated. "But I say unto you, love your enemies, bless them that curse you, do good to them that hate you." (Matthew 5:44ab)

The call to behavior which contrasts with self-concerned reciprocity is elaborated in a passage recorded in Luke.

> "If you love those who love you, what credit is that to you? Even 'sinners' love those who love them. And if you do good to those who are good to you, what credit is that to you? Even 'sinners' do that. And if you lend to those from whom you expect repayment, what credit is that to you? Even 'sinners' lend to 'sinners' expecting to be repaid in full. But love your enemies, do good to them, and lend to them without expecting to get anything back." (6: 32-35a NIV)

The unavoidable conclusion is that the follower of Christ is to extend love and assistance to others, without requiring the sociobiological assumption that such help may ultimately benefit one's own genes. The result of this behavior is the spreading of Christ's love, and reward in heaven, whatever may be the cost to one's biological survival.

Clearly, if genetic forces are programmed to "equivalent" reciprocity, the Christian is called to violate his "genes" in the pursuit of a higher goal. Similar implications may be derived from analysis of equally important sociobiological constructs.

Kinship Altruism

The theory of kinship altruism has been developed to account for the assistance animals, and humans, provide for members of the same species. Honeybees demonstrate this principle well, since the workers, in caring for the young, are in fact caring for offspring with whom they share ¾ of the same genes. Parents who care for their children are providing for individuals who carry ½ of their genes. Through similar argument, if providing for cousins, eight persons must benefit according to this theory, since cousins carry only ⅛ of the genes of the helper.

It need not be denied that humans concern themselves with their relatives, although the concern may not be as carefully calculated as kin altrusim would lead us to believe. Family breakdown patterns, the rising abortion rate, and shrinking family size are facts which cause difficulty for the sociobiologists' concept of kin altruism.

The life of the Christian is based on different ties. While the welfare of every human individual is a concern of the Christian, the "family" for the Christian transcends genetic ties. The "family" is the church, where "kin" are based not on chemical DNA, but on common faith. The Christian is called to support, suffer, and even die, not necessarily for biological kin, but for his or her faith or fellow believers.

The best example of this redefined kinship pattern is Christ, whose death was for humanity, even though many reject his costly sacrifice (a violation of reciprocity!). Christ's death, which Christians reciprocate with a response of acceptance and belief, was in the interest of creating a community of faith which transcends the sociobiologists' genetic conception of altruism.

The family created by Christ's death breaks down the barriers, both genetic and cultural, which separate people in cubicles of self-interested preservation. The New Testament stresses that for human beings biological and sociological subspecies have been transcended. Paul expresses this truth in these words: "For as many of you have been baptized into Christ have part of Christ. There is neither Jew nor Greek, there is neither bond nor free, there is neither male nor female: for ye are all one in Christ Jesus." (Galations 3: 27, 28)

The implications which accompany the formation of this universal body of believers are also of considerable interest. For if the Christian life requires conversion from the old biological/cultural nature to a new life, it must be possible to transcend the genetic and social forces which sociobiologists feel are determinants of behavior. Indeed if humans are to be held personally responsible for their behavior at the time of judgment, provision needs to be made for achieving acceptance before God. Christians believe that Christ's power makes this possible. His power, exercised by His Spirit, makes achievable the redefined kinship and the revised reciprocity principles.

Selfish Gene or Jubilee

Sociobiologists and evolutionary biologists have devoted extensive attention to concepts of competitive advantage through acquisition of status and/or territory. Data from animal genera demonstrate the numerous ways in which territory affects the struggle for food, furnishes safety from predators, and provides access to mates. Strength and strategy accumulate these necessities to the genetically most "fit".

The Old Testament proposes a model at variance with competitive striving and the accumulation of property. This program is called the year of Jubilee (Leviticus 25). During this time (every 50 years) debts are to be forgiven, lands are to be returned to their

rightful heirs, and slaves are to be given their freedom. Although this doctrine is little taught or followed by contemporary Christians, it serves as a benchmark against which New Testament teachings on wealth and property might be understood.

In the New Testament, money and possessions are repeatedly named as temptations to the believer and the Christian is instructed to use them in God's service, not for power, ease, self-interest, or exploitation. In place of the human propensity to seek territory and wealth the Scriptures outline the necessity for Christians to choose a servant role. In this role Christians are to serve the needs of others and avoid the temptation to "lord" it over their fellowman.

The year of Jubilee and the servant stance are in stark contrast to the notions of dominance and acquisition common in animal data. A successful return to a biblical view of wealth, position, and justice might lead to human behavior quite discontinuous with sociobiological predictions.

In Whose Defense

Discussion of the year of Jubilee suggests another doctrine followed by few contemporary Christians (a fact which the sociobiologists may help us understand). While the New Testament teaches quite plainly the need to love one's enemies, and appears to teach nonviolence, few Christians find this interpretation. Thus Christians have frequently, even eagerly, been participants in warfare, particularly wars to protect freedom of religion and democracy.

This paper is not the place to reargue the voluminous literature on war and nonresistance. It will be sufficient to note that conflict leading to aggression is readily predicted from animal data. For Christians to choose the way of peace, and seek their security in a God who guarantees eternal life, would provide a rebuttal of the proponents of war's "natural" causation. Furthermore the renunciation of war implies the rejection of tribalism (read nationalism), the repudiation of wealth, power and territory as purposes of human life, and the discarding of "fitness" as an inviolable motive of human being. In renouncing these sociobiological drives, the Christian affirms the servant stance and the non-biological character of the believing community.

Unfortunately, the fractured and fractious characteristics of the church, and the self-interested behavior of individual Christians, serve to support the position of the sociobiologists. Examples abound. Agape love is denied by personal competitiveness, gossip, and conditional relationships (a form of sociobiological reciprocity). Materialism and economic gain contradict professions of the servant role. Denominational territorialism belies a common faith in the power of love and the unity of the Spirit. Indeed, one might suggest that the church family is split into tribes seeking their own "genetic" preservation, in denial of the biblical instructions that it is necessary to lose life in order to find it. In short, if the church is to transcend sociobiological determinism, therapeutic efforts are urgently needed. I have sometimes speculated that if Christians were really being Christian, much less of their behavior could be understood psychologically, sociologically, or sociobiologically. Until Christians demonstrate the power of love and the servant stance, the "selfish gene" (and theories of like emphasis) will not have been displaced by the power of the divine Spirit.

[1]Ardrey, Robert. *African Genesis*. New York: Dell Publishing, 1961.

[2]Dawkins, Richard. *The Selfish Gene*. New York: Oxford University Press, 1976.

[3]Gregory, Michael. "Epilogue". In Gregory, Michael; Silvers, Anita; and Satch, Diane (eds) *Sociobiology and Human Nature*. San Francisco: Jossey-Bass, 1978.

[4]Wilson, Edward. *Sociobiology*. Cambridge: Harvard University Press, 1975.

[5]Wilson, Edward. *On Human Nature*. Cambridge: Harvard University Press, 1978.

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Paradigm Shifting and the Apologetics Debate

Of late, a new piece of jargon has intruded itself into discussions of theological and religious language. The newcomer is the "paradigm." One may find this concept, borrowed from the philosophy of science, in theological works as far removed from each other as Thomas Torrance's *Theological Science* and Charles Kraft's *Christianity in Culture*. It seems safe to suggest that the recent currency of this term and its attendant concept is in large part due to the efforts of Thomas H. Kuhn. Though Kuhn himself is a philosopher of science, the relevance of his work for other fields such as theology has become apparent. We would like to suggest the utility of his theory for the field of evangelical apologetics. More specifically, his schema of "paradigm-shifting" will be shown to provide the key for grasping the differences in the evidentialist *vs.* presuppositionalist debate in apologetics.

In his *The Structure of Scientific Revolutions*, Kuhn takes issue with the common conception that scientific advancement has proceeded mainly by way of "new discoveries." In fact, really new data are relatively seldom discovered. Scientific progress has more to do with scientists coming to formulate new ways of construing the same old information, new keys to solve the puzzles presented by the data. One such paradigm will be accepted by scientists as long as it seems to make plausible sense of most of the evidence. Only when the paradigm starts to appear inadequate to the task of explaining this or that phenomenon do scientists begin looking for an alternate *gestalt*. The new paradigm will seek to incorporate much of the explicative power of the old, yet starting from at least a slightly different point, so as to deal plausibly with more of the hitherto-troublesome data. When the cogency and comprehensiveness of a newly proffered paradigm becomes evident, a "paradigm-shift" occurs. The new model for construing the data becomes the basis for the next stage of theorizing and research. Of course the likelihood is that it, too, will be superseded in time.

Copernicus and Super-paradigms

To give a famous example seen through the lenses provided by Kuhn, we will look at the contest between the geocentric paradigm of Ptolemy and the heliocentric paradigm of Copernicus. Ptolemy's model of the planetary system functioned well enough to predict the motion of the (apparently earth-orbiting) planets, but it ran into trouble when it came to the mysterious retrograde motion of the planets. In order for the geocentric model to predict accurately these erratic movements (hitherto considered to be the "free will" of the planets!), Ptolemaic astronomers had to postulate myriad series of "epicycles," or wheels within hypothetical wheels on which the planets turned. Copernicus found that the whole system might be simplified by postulating that the sun, not the earth, was the center of planetary orbit. This way all the epicycles disappeared. Eventually Copernicus' view became dominant. It wasn't that Copernicus had somehow "discovered" the earth to be orbiting the sun instead of the other way around. Such a thing would have been (and probably still is) incapable of observation. Rather, he merely formulated a new *gestalt* for the data which made its explanation less

problematic, more natural, than before. And this is basically the way all scientific progress comes about, by a "conversion"[1] from one paradigm to another.

But there is an important tension, often unnoticed, in Kuhn's schema. Are paradigms self-sealing? That is, do they carry their own criteria of plausibility of explanation? Mustn't they, if they are truly comprehensive systems for understanding data (so that only in light of them is the data "data for" anything)? But if they do, then how is any shift from one paradigm to another ever possible? In terms of our example, why should Ptolemaists have felt ashamed of all those epicycles? Given the fundamental postulate, geocentricity, there could be nothing embarrassing or implausible about the resulting complexities. Why should not things be complex? If the paradigm itself carries its own criteria of plausibility, then any explanation assigned to "problematic" data must *ipso facto* be plausible.

But of course, the shift did occur. This implies that paradigms do not contain within themselves their own criteria of plausibility. And if they do not, they must be seen as sub-paradigms, or subsets of a larger, all-comprehensive paradigm. This super-paradigm will be the field of presuppositions in which scientific thought occurs. It will include criteria by which given sub-paradigms (geocentricity or heliocentricity, Einsteinian or Newtonian physics, Big Bang or steady-state cosmologies) can be preferred to one another. Included among these criteria would probably be something like "economy and inductiveness of explicability of the data." Such criteria will be the arbiters of which paradigm makes "better sense" of the evidence. They will tell which sense is the "better" sense.

Evidentialists vs. Presuppositionalists

This issue, merely implicit in Kuhn's discussion, is raised explicitly (albeit in different terminology) in the long-standing debate between "evidentialist" apologists (Clark Pinnock, John Warwick Montgomery, Josh McDowell, etc.) on the one hand, and their "presuppositionalist" rivals (Cornelius Van Til, Gordon Clark, etc.) on the other. In this context, the issue is that of "common ground," i.e., does any exist between believers and non-believers? Evidentialists build their whole enterprise on a positive answer to this question. Indeed, they say, there can properly be no apologetics at all unless some commonly-acknowledged criteria exist, whereby the evangelical position may be rendered probable or compelling to the fair-minded non-believer. Before examining the presuppositionalist objection to this belief, let us analyze the evidentialist position further in the light of Kuhn's categories. In effect, the evidentialists assume that both they and their imagined non-Christian partners in dialogue assent to a "super-paradigm" of shared criteria for plausibility and explicability. The same kinds of grounds will determine which is the "better" sense made of the evidence. By their amassing of evidence, what McDowell, Montgomery, Pinnock, et al., seek to do is to show that the secular naturalists' paradigm cannot adequately (plausibly) explain "troublesome data" like, e.g., the empty tomb. Of course, this is the point of the stock rehearsals of how "no explanation fits the facts of Easter Morning as well as the Resurrection does." The naturalists' explanations "demand more faith than the Resurrection itself" (Montgomery).[2] That is, the "swoon theory," the "wrong tomb theory," etc., are like epicycles. They are implausible. What makes them implausible? A common set of criteria including the notion that eyewitness reporting is valid, that crucified but surviving men are not likely to be able to roll away stones and stagger into Jerusalem, etc. So no matter how much the skeptic cherishes his naturalistic paradigm, he really should admit its inadequacy to explain the evidence of Easter Morning. He should convert his paradigm (and with it, in this case, his eternal destiny).

Presuppositionalists, of whom we may take Van Til as the paramount example, repudiate this whole approach. There can be no common ground, he insists, because of the "noetic effects of the fall." It is a fundamental mistake to imagine that (Christ-rejecting) unregenerate persons can perceive enough of the facts correctly to be led from them (the common ground) to faith in Christ.[3] No, "all things hold together in Him" (Colossians 1:17). Since every single fact is to be construed properly in the light of faith in Christ, then *any* perception by a Christ-rejecting (or Christ-blind) person is a misapprehension, even a delusion. Leaving aside the fact that this is pretty much the same rationale that has led historically to the branding and treatment of religious dissidents as insane, we will proceed to develop our interpretation of this view in Kuhn's terms. Van Til is essentially arguing that paradigms are self-sealing. They must carry their own criteria for plausibility within themselves, so that whatever explanation assigned to a datum is *ipso facto* plausible and natural. The apologetical/epistemological meaning of this is that religious certainty may be achieved only if it is defined into the system from the start. One can never reason his way to certain faith in Christ; he may have certainty only if he begins by defining Christ (the Logos) as the ground of reason. They *by definition* faith in Christ is not only "a reasonable option," it becomes the *only rational option.* The evidentialist approach is unsatisfactory at least partially because it makes the Christ-Logos posterior rather than anterior to the reasoning process. In Kuhn's terms, evidential apologetics makes the evangelical Christian subparadigm subordinate to the larger paradigm of neutral, common criteria. And if it does this, then the same bridge from one subparadigm to the evangelical one, could as easily one day be the bridge to still a third sub-paradigm. Theoretically, this possibility must be left open. And what kind of faith-certitude would this be?

Evidentialists like Pinnock reply that such absolute theoretical certainty is neither available nor necessary to live any other area of life, so why here? We can have practical certainty. As Gordon Allport observes,

> "The believer is often closer to the agnostic than we think. Both, with equal candor, may concede that the nature of Being cannot be known [with absolute certainty]; but the believer, banking on a probability . . . finds that the energy engendered and the values conserved prove the superiority of affirmation over indecisiveness."[4]

However, as full of common sense as the evidentialist position seems to be, the presuppositionalist critique is still a good one. Acquaintance with the literature of evidentialist apologetics makes it clear that their religious faith is more certain than is allowed by their common-ground approach with its inherent provisionality. For instance, John Warwick Montgomery writes of the doctrine of the Trinity, "I believe it with all my heart. I believe it because . . . it offers the best available 'construct' or 'model' for interpreting the biblical descriptions of God as Creator, Redeemer, and Sanctifier."[5] Can one appropriately cling to a (mere) "model" or paradigm with "all one's heart"? Or to put it another way, can anyone reading such a statement really envision any other interpretation of the evidence changing Montgomery's mind? Along the same lines, it is clear from a reading of much evidentialist literature that facts have been amassed to buttress beliefs already held on other grounds, and by willpower.[6] A subtle shifting of ground occurs. The apologist's faith causes him to deem "best" the reading of the data most in accord with his beliefs, even if it must be harmonized. But he proceeds to offer this reading to the non-believer as if it were the best reading of the facts *in and of themselves.* He claims to appeal to "common ground" (e.g., "economy and inductiveness of explanation") but actually appeals to partisan criteria (e.g., "which reading of biblical criticism conforms with evangelical beliefs?"). This results in what James Barr has called "maximal conservatism," the serving of a hidden dogmatic agenda.[7] The presuppositionalists on the other hand, are quite open about their dogmatic agenda. They drop the pretense of a "common ground" and admit that the paradigm is self-sealing.

We have just suggested that, like their presuppositionalist rivals, the evidentialists actually seem to place their faith anterior to argumentation, though their principles call for the placing of it posterior to argumentation. (Both then are really in effect "presuppositionalists" though one side doesn't realize it.) And this

inconsistency is no accident. Indeed if one thinks to use a truly evidentialist approach, he is dooming his apologetics from the start. There is something inherent in the common-criteria approach that makes its use in apologetics fundamentally wrong-headed.

The Principles of Analogy

Basically the trouble is that the only common ground is contemporary human experience of the world. (In terms of our discussion of paradigms, this is the same as "economic and inductive explanation" of the data at hand, without recourse to extraneous hypotheses.) Historical critics have a term for this: "the principle of analogy," as formulated by Ernst Troeltsch.[8] This principle, the basis of the historical-critical method's "denial of the miraculous," is a red flag to evangelicals. Yet they use exactly the same principle, only with a different name and applied to different cases. This is the famous "empirical fit" argument used by Francis Schaeffer and Os Guiness to write off Eastern religions as failing to ring true to the depths of human experience.[9] In both cases, the idea is that though theoretically anything (ancient miracle stories or modern philosophical worldviews) is quite *possibly* true, there is no available criterion for *plausibility* except present, shared human experience. This is why users of electric lights and radio may have trouble accepting the miracles of the New Testament. This is why those who know suffering or love may find it difficult to accept the Eastern denial of the reality of these things. If the "common-ground" or "empirical fit" argument works at all, it works too well. Consistently pursued, such an inductive approach could of course lead only to some kind of natural theology, not to a "revealed religion" like evangelical Christianity.

Now if "common ground" is a chimera for apologetics, on what basis may the outsider opt for revealed religion? The evangelistic appeal of a consistent presuppositionalist must seem (from the human side) as a "leap of faith." And what the prospective convert sees, that the apologist-evangelist may not, is that this is only one of several invitations to leap in several directions. And the leap is known to be the right one *after* the choice has been made ("I once was blind, but now I see"). How is he to decide which faith to leap into? Walter Kaufmann said it well a few years ago:

> "They say their doctrine is infallible and true, but ignore the fact that there is no dearth whatsoever of pretenders to infallibility and truth. . . scores of other doctrines, scriptures, and apostles, sects and parties, cranks and sages make the same claim. . . . Those who have no such exalted notion of themselves have no way of deciding between dozens of pretenders if reason is proscribed" [i.e., if common ground criteria are disallowed because of the "noetic effects of the fall"].[10]

Quite a dilemma! The common ground approach can never lead to conviction, but the presuppositionalist "leap of faith" could lead to Jim Jones as easily as to Jesus Christ! How could one decide? "Revolutionary suicide" in a Guyana rainforest is quite reasonable once one accepts the proper presuppositions. If one flinches because "obviously that's pathological," isn't he holding out on his piece of common ground, just like the unbelieving skeptic who judges the cross to be foolishness? If we cast away everyday experience as our standard of judgment, there can be no standard of judgment until *after* we make the leap of faith. But we could make that leap in any direction. And after we made it, it would seem right. The paradigm would carry with it its own criteria.

The upshot of all this is that the evidentialist apologetic with its common ground approach finally backfires. A really inductive approach to this-worldly evidence can lead one only to this-worldly (i.e., non-revealed) religion. The presuppositionalist apologetic is consistent but not at all compelling, since the immunity from doubt that it wins for those inside the circle of faith simultaneously cancels its attraction to those outside. It can look neither more nor less plausible since there is no standard with which it may be compared. And the same approach is amenable to every sect. But the evangelical Christian (or believer in any sect) does not need to trouble himself about this. If he is safely within the circle of the truth himself, he can dismiss the other sects. And as for the outsider, doesn't the believer trust in the Spirit's conviction —if not actual predestination, then at least prevenient grace?[11] Then why worry about common ground, or for that matter about apologetics at all? Believers may plant the seed, but isn't it up to God to give the harvest (I Corinthians 3:6–7)? Shouldn't faith rest on God's Spirit, not the persuasive words of man's wisdom (I Corinthians 2:4)? Shouldn't it be revealed by the Father in heaven, not by flesh and blood (Matthew 16:17)?

And finally, seen from the outsider's perspective, it would have to be said that the way to certain faith is an overwhelming "final experience," an enlightenment. Though the question of rational certitude is not theoretically *solved*, it is psychologically *settled*, since the new believer will no longer care to ask it. Now he *knows*.

Summary

By raising the question of the structure of paradigm-shifts and how they are possible, Thomas H. Kuhn has provided a set of categories with which better to understand the long-standing apologetics debate. When seen in terms of his theory, the two apologetical strategies presently dominant in evangelical circles, the evidentialist and the presuppositionalist, seem to be beset with surprising difficulties. In fact, these difficulties run so deep as to indicate that the only consistent apologetic is fideistic presuppositionalism, which is in a sense no apologetic at all, since on principle it removes any external standards by which its faith might be "vindicated" or "defended."

[1]Thomas H. Kuhn, *The Structure of Scientific Revolutions* (Chicago: The University of Chicago Press, 1969), p. 150.

[2]John Warwick Montgomery, *The Suicide of Christian Theology* (Minneapolis: Bethany Fellowship Inc., 1975), p. 39.
This line of reasoning is to be found in a large number of books, and with very little variation. See, for example, John Stott's *Basic Christianity*; J. N. D. Anderson's *The Evidence for the Resurrection*; Michael Green's *Man Alive!*; Josh McDowell's *Evidence That Demands A Verdict*, Vol. I; Clark Pinnock's *Set Forth Your Case*.

[3]Among his many works, see for example *The Protestant Doctrine of Scripture* ([n.p.] den Dulk Christian Foundation, 1967), p. 11. ". . . one must be a believing Christian to study nature in the proper frame of mind and with proper procedure."

[4]Gordon Allport, *The Individual and his Religion* (New York: Macmillan Publishing Company, Inc., 1974), p. 83.

[5]Montgomery in Robert Campbell (ed.), *Spectrum of Protestant Beliefs* (Milwaukee: The Bruce Publishing Company, 1968), p. 20.

[6]This assertion, I realize, invites a full-scale demonstration for which there is no space here. Basically, let me say that much apologetic argumentation for, e.g., the total reliability of the gospels as historical records, and for the historicity of the resurrection, are totally out of date and do not come to grips realistically with modern biblical criticism. This is true even of such recent works as Josh McDowell's *Evidence That Demands A Verdict*, Vol. II; and Buell and Hyder's *Jesus—God, Ghost or Guru?* The interested reader may find a full-scale treatment of these questions in my forthcoming book *Beyond Born Again*.

[7]See his incisive work *Fundamentalism* (Philadelphia: The Westminster Press, 1978).

[8]For two clear and sympathetic treatments of the principle of analogy, see Van A. Harvey, *The Historian & The Believer* (New York: The Macmillan Company, 1972); and F. H. Brad-

ley, *The Presuppositions of Critical History* (Chicago: Quadrange Books, 1968).

[9]See, for example, Francis Schaeffer's *The God Who is There* (Downer's Grove, Illinois: InterVarsity Press, 1968); *Escape from Reason* (Downer's Grove, Illinois: InterVarsity Press, 1968); and Os Guiness, *The Dust of Death* (Downer's Grove, Illinois: InterVarsity Press, 1973). Shaeffer's and Guiness' use of this argument, incidentally, shows them to be less consistently presuppositionalist than, e.g., Van Til.

[10]Walter Kaufmann, *The Faith of a Heretic* (Garden City, New York: Doubleday & Company, Inc., 1963), p. 86.

[11]Van Til certainly does: "And it is only when the Holy Spirit gives man a new heart that he will accept the evidence of Scripture about itself and about nature for what it really is. The Holy Spirit's regenerating power enables man to place all things in true perspective." (Ibid., pp. 10–11).

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Thermal Consequences of a Short Time Scale for Sea-Floor Spreading

Introduction

The concepts of sea floor spreading, plate tectonics and continental drift have revolutionized and revitalized the geological sciences during the past 15 years. Stated simply, these concepts suggest that the earth's outer shell (lithosphere) consists of a number of relatively rigid plates that are moving with respect to each other at velocities on the order of a few cm/yr. Plates are moving away from each other along the crests of mid-ocean ridges; a series of branching, interconnected, underwater mountain ranges that extend for more than 40,000 miles through all the world's oceans. As these plates move away from each other at the ridges, new ocean crust is created between the plates by volcanic activity. If the earth's surface is not growing larger, then an amount of crust equal to that generated at the mid-ocean ridges must be consumed elsewhere. This occurs mainly at the ocean trenches surrounding the Pacific Ocean where one plate slides under another, creating a topographic depression (ocean trench) with accompanying volcanic and seismic activity. This process is called *subduction*. The continents are part of various lithospheric plates and move passively with the larger plate of which they are a part.

The purpose of this paper is not to explain these new ideas in detail or to critically examine the evidences pro and con. Such publications are readily available.[1-5] Assuming that sea floor spreading may have occurred in the earth's history, I would like to examine some of the consequences of such activity from the viewpoint of a short time scale Flood geology model that assumes that most of the fossiliferous stratigraphic record was developed in a few years during the global Genesis Flood and its immediate aftereffects. Specifically I develop a simple model to examine the thermal consequences of creating the present ocean crust by magna injection and cooling this new crust to near its present temperatures all within a few years.

Time Constraints on Model

Geologists have suggested that the present phase of sea floor spreading began in the Late Triassic or Early Jurassic period and continues to the present day. This process broke up one or two large super-continents and created the Atlantic, Indian and Arctic ocean basins, at the expense of the Pacific Ocean.

The oldest known ocean basin sediments are Late Jurassic and are found in the northeast Pacific and the western North Atlantic Oceans at the greatest distances from ridge spreading centers in these two ocean basins. These sediments have been dated biostratigraphically from Deep Sea Drilling Project cores from these areas.[6-8] Ocean crust existing previous to this time plus a large amount of newer crust has been subducted at present and ancient trenches or lies buried beneath thick continental margin sediments in the Atlantic Ocean. The relative timing of this sea floor spreading is deduced from an examination of the sedimentary and tectonic history of the ocean basins and continental margins and from the polar wandering curve for the various continents determined from the remanent geomagnetism of terrestrial volcanic rocks.[2,3,9,10]

Based on these evidences, the correlation of sea floor spreading history to classical continental stratigraphic geology appears to be well established in its broad outlines. There are features of the earth's sedimentary and tectonic record that suggest episodes of sea floor spreading prior to the most recent break-up of the supercontinents in the Triassic. However, the primary evidence for such activity (the geomagnetic, tectonic, and sedimentary record of the appropriately aged ocean basin crust) has been lost presumably by subduction, relegating any pre-Mesozoic sea floor spreading to the realm of geological speculation at this time.

Under a short timescale Flood geology model, the constraints of historical and archeological chronology and of the presumed character of the ante-Diluvian earth suggest that most of the fossiliferous sedimentary rocks from at least mid-Paleozoic up to Pliocene were deposited during the Noachian Flood and at most a few years after.[11] The Pleistocene "ice age" epoch commenced almost immediately after the waning of the Flood and lasted, at most, several hundred years until the start of the post Pleistocene archeological period.[12] Pleistocene and recent ocean floor is represented by a narrow strip about 100 km or less wide along the mid-ocean ridges, only a few percent of the total ocean basin area.[13]

These chronologies, of sea floor spreading and of Flood geology, suggest that almost all of the present ocean floor was created during a few years at the time of the Flood, since the history of the ocean floor is correlated stratigraphically with the continental fossiliferous rock sequence as mentioned above.

In addition, a significant amount of ocean crust created during this time has already been subducted, so that the total amount of sea floor created during sea-floor spreading is significantly greater than that presently in existence. If we assume that ocean crust equal in area to the present ocean basins was created by sea floor spreading during the Flood event, this should underestimate the total volume of crust produced.

Sea Floor Spreading Model

The model used for calculating the thermal consequences of a short chronology sea floor spreading event uses numerical data that are the best estimates or actual calculations, and can be considered reliable for the purposes of this paper.[14]

Ocean crust averaging 6.5 km in thickness exclusive of sedimentary cover and equal in area to the present ocean basins is created in a period of a few years by intrusion and extrusion of rock magma at ocean ridge spreading centers. This rock is created at an assumed temperature of 1100°C and must cool to its present average temperature of 100°C within this same short period of a few years

since there is no evidence of a significant warm thermal anomaly in Pleisotocene and recent sediments and fossils.

I am not considering a detailed calculation of the actual escape of heat from the newly created crust; this would be a complex and difficult calculation. Instead, assuming that the heat can be removed from the crust by some mechanism, I ask what are the consequences of this heat release to the ocean and atmosphere of the earth?

Our first calculation is the total heat released by cooling of this new ocean crust: $Q_T = 2.1 \times 10^{27}$ calories. We can compare this with the total radiant energy absorbed by the earth from the sun in one year: $Q_T/Q_S \simeq 2400$. The first consequence of this heat release from the ocean crust would be to heat the oceans to the boiling point of water assuming one atmosphere of pressure at the ocean surface: $Q_B = 1.05 \times 10^{26}$ calories. The oceans will proceed to boil since the heat required is only 5% of the total heat released from the new crust. The excess crustal heat is sufficient to boil away all the water at the earth's surface 2.8 times.

The final consideration of this thermal model is the escape of this heat from the earth's atmosphere into space. The temperature structure of the present earth's atmosphere is in equilibrium with the present heat budget of the earth. The escape of thermal radiant energy from the earth's upper atmosphere balances the absorption of radiant energy from the sun. The present contribution of crustal heat to the atmospheric heat balance is insignificant ($\sim$0.1% of absorbed solar radiation).

The Stefan-Boltzmann Law states that the total radiant energy emitted by an ideal radiator is proportional to the fourth power of the absolute temperature. The effective radiation temperature of the earth's present atmosphere is about 218 K (-55° C). For our purposes, we can neglect compositional and structural changes in the atmosphere due to boiling of the oceans and simply calculate the effective radiant temperature needed to remove the heat of formation of the new ocean crust. The calculations are as follows: T (1 yr.) = 1252°C; T (10 yr.) = 585°C; T (100 yr.) = 209°C; T (250 yr.) = 110°C; T (1000 yr.) = -1.6°C.

The first two figures for 1 to 10 years would represent time periods of first choice for Flood geology. However, we can see that time periods in excess of 250 years are needed to lower the effective atmospheric radiating temperature to below 100°C. Temperatures at the earth's surface would be even higher than these radiating temperatures because the atmospheric temperature must decrease with altitude until one reaches an atmospheric density where most of the emitted thermal radiation can escape directly into space (effective radiant temperature of the earth).

Discussion

From the viewpoint of Flood geology, one is forced to compress the warm thermal anomaly into a time span of a few years. (1) The Pleistocene epoch (ice ages) must have occupied most of the time between the waning of the Flood waters and the start of the historical period, but the existence of ice caps and the isotopic temperature record allow temperature variations of only a few degrees in this period.[15,16] (2) The generation of the Pleistocene ocean floor at ridge crests ($\sim$100 km wide strip) within a few hundred years would have added a yearly heat load to the atmosphere approximately equal to the energy presently absorbed from the sun with very significant thermal consequences for which there is no evidence (see item 1 above). (3) The time constant for cooling of the ocean crust is on the order of 10^5 to 10^6 years,[17] but the present thermal and bathymetric structure of ocean basins does not suggest a recent episode of very fast sea-floor spreading. In fact, the thermal and bathymetric structure of ocean basins supports the current concepts of geological chronology.[3,18]

Acceptance of an intermediate chronology for Genesis history that allows "tens of thousands of years for combined pre- and post-Flood events" does little to alleviate the time problem for the sea-floor spreading thermal anomaly. Flood events are still compressed into a few years and the "extra time" is used to accommodate the development of extensive ante-Diluvian fossiliferous sediments and to allow more time for post-Flood "ice ages" and archeological pre-history.

However, it is obvious that dissipation of ocean crustal heat within a few years produces thermal effects in the ocean and atmosphere that are not compatible with the continuity of organic life through the Flood event or with the hydraulic evidence for conditions prevailing during the deposition of the sedimentary rocks.

The model used for the calculations is somewhat crude in many respects but it is sufficient to show the magnitude of the thermal effects. More realistic (and complex) calculations would produce similar overall results.

The sea-floor spreading thermal problem can be resolved in three ways. (1) Sea-floor spreading has not occurred, or the fast Flood geology spreading proceeded by some unknown mechanism quite different from the "normal" slow spreading process currently envisaged by geologists. (2) Sea-floor spreading and the events producing the correlated sedimentary record from Mesozoic to Recent occurred over a period of time comparable to the presently accepted ideas of geological chronology. (3) Physical "laws" were suspended or altered in some way during the "Flood event" so that the purposes of God were accomplished but the environmental conditions remained within acceptable limits.

It is noteworthy that the application of simple physical principles to well defined "short-time scale geological events" often leads to alternatives similar to the three listed above. Two of these areas are radiometric geochronology and the thermal cooling history of batholiths or large intrusive bodies.[17] The latter problem was ignored in the present paper (how the heat was initially removed from the newly created ocean crust). The long geological ages calculated from radiometric dating are based on the assumed constancy of radioactive decay rates, an unprovable though reasonable assumption from a scientist's point of view. Thermal modeling on the other hand, simply assumes constancy in the physical interactions of matter and energy, and of atomic and molecular properties. It is significant that thermal modeling of the earth's crust leads to calculated ages comparable to radiometric geochronology. Considering alternative (3) above, the required "alterations" in the interactions of matter and energy during the "Flood event" extend beyond a mere change in radioactive decay rates and must include the laws of conductive, convective and radiant heat exchange and the atomic and molecular interactions of matter.

[1]Marvin, V. B. (1973), *Continental Drift: The Evolution of a Concept*. Washington, D. C. (Smithsonian Institution Press) 239 pp. Presents the historical development of modern concepts.

[2]Tarling, D. H., and M. Tarling (1971), *Continental Drift, A Study of the Earth's Moving Surface*. Garden City, N.Y. (Doubleday) 140 pp. A popular level exposition.

[3]Le Pichon, X., J. Francheteau and J. Bonnin (1973), *Plate Tectonics*. Amsterdam (Elsevier) 300 pp. A more technical presentation.

[4]Kahle, C. F., ed. (1974), *Plate Tectonics-assessments and Reassessments*. American Assoc. of Petrol. Geologists Memoir #23. A collection of papers pro and con.

[5]The most prolific anti-drifter has been A. A. Meyerhoff. For an amazing array of anti-drift evidence (some good, some indifferent, some bad) see the series of articles by Meyerhoff and others (1970–1974) in: *Journal of Geology 78*; 1-51, 406–444;

79, 285-321; *80*, 34-60, 663-692; *American Assoc. of Petroleum Geologists, Bulletin 56*, 269-336, 337-359; and in Kahle, C. F., ed. *op. cit.*

[6]Ewing, J., C. Hollister, et al. (1970), "Deep Sea Drilling Project: Leg 11," *Geotimes, 15*, no. 7, 14-16.

[7]Heezen, B. C., I. D. MacGregor, et al. (1972), "Deep Sea Drilling Project; Leg 20," *Geotimes, 17*, no. 4, 10-14.

[8]Benson, W. E., R. E. Sheridan (1976), "In the North Atlantic: Deep Sea Drilling." *Geotimes, 21*, no. 2, 23-26.
For more detail than above, see respective volumes of: *Initial Reports of the Deep Sea Drilling Project*, Washington, D. C. (U.S. Government Printing Office).

[9]Van der Voo, R., and R. B. French (1974), "Apparent Polar Wandering for the Atlantic-bordering Continents: Late Carboniferous to Eocene," *Earth-Science Reviews, 10*, 99-119.

[10]Jurdy, D. M., and R. Van der Voo (1975), "True Polar Wandering Since the Early Cretaceous," *Science, 187*, 1193-1196.

[11]Coffin, H. G. (1969), *Creation-Accident or Design*. Washington, D. C. (Review & Herald Publishing Assoc.) see Chapter 10, pp. 108-114.

[12]This "accordianed" chronology is necessitated by well accepted dating of the historical period to within a few hundred years of the Ussher date for the Genesis flood of 2350 B.C.

[13]See map by Pitman, W. C., R. L. Larson and E. M. Herron (1974) The age of the ocean basins, determined from magnetic anomaly lineations. Geological Society of America, map & chart series MC-G.

[14]The author will gladly supply information on the model and details of the calculations upon request.

[15]Savin, S. M., R. G. Douglas and F. G. Stehli (1975), "Tertiary Marine Paleotemperatures," *Geological Society of America Bulletin, 86*, 1499-1510.

[16]Emiliani, C. (1970), "Pleistocene Paleotemperatures," *Science, 168*, 822-825.

[17]Barnes, R. O. (1971), "Time-and Earth's History," *Spectrum, 3*, No. 1, 29-46 (see page 41).

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In Defense Of Pure Science

An article with a title like this may seem absurd in the *Journal ASA*, but I mean well as I hope will be evident. My intent is to accentuate the core of similarity that exists between all pursuits of mankind. At college I found myself between two friends with opposite interests. One was a pre-med student with attention given to the field of psychology and the other was a practicing musician, poet, philosophy and literature major. The tensions between them surfaced often enough for me to begin pondering some of the causes of their dislike. To the one, the arts were meaningless, subjective garbage; to the other, science (pure science more accurately) was a total waste of time. In certain particulars they were both right, but fundamentally their motivation was essentially the same.

Pure science (as opposed to applied science or technology) is that field of endeavor which corresponds to the pursuit of the fine arts, mathematics, philosophy, and religion. In its attempt to disclose the mysteries of the universe and the life within it, pure science exposes man's need to know something—anything that will satisfy his empty understanding. To discover that substance which permeates all matter, space, time, and energy, and explains the reason for the onward flow of the universe, is the fundamental drive of pure science.

Let's examine each of these areas of interest in their pure form. The fine arts reveal a vibrant world centered on creativity. Including painting, sculpture, architecture, music, and many forms of literature, the fine arts explore and express the magical world of the mind. Somewhere in the cranial cavity, in the noodled symmetry of gray matter, comes thoughts and imaginations filled with the wonder of surreality. These creations from the subconscious are known to everyone but are taken seriously by the practicing artist. Through study and experiment with the realm of surreality, the artist brings into being, into reality, the depths of the mind. In whatever form the artist uses, he is seeking to discover what lies within. By making the depths surface, the artist hopes to strike a resounding chord with the mass of mankind. A successful artist usually hears quite an echo. We observe from the fine arts a fundamental drive to find that common element which fills man's empty understanding of life itself.

The second area of interest mentioned was mathematics. Pure mathematics is an intriguing field as it attempts to discover the relationships that exist between universal, numeric principles. Finding equations which describe form and change can be fascinating. Although much of the work done in mathematics has carry-overs into other fields, pure mathematics itself is another attempt by man to discover that all-encompassing formula which fills the void and enables us to understand the secrets of life.

Philosophy, as the third area of interest, is also a rich field of dimensions of the reasoning mind. Human logic (and oftimes imagination) coupled with anthropology has yielded a macrocosm of philosophical viewpoints, each with an air of truth. Philosophers throughout history have devoted their lifetimes to the discovery of truth and most have found agreeable followers. These various schools of thought have one thing in common, however: their search for that substance which gives meaning and purpose (or non-meaning and lack of purpose) and fills the indigenous void in the essence of man.

The fourth area of interest mentioned was religion. This area too strives for an answer: what is to be defined as God? As St. Anselm put it, "God is A Being than which no greater being can be conceived." Religious endeavors have created gods of many sorts; through the art of hermeneutics, theologians have devised numerous systems. The religious systems in practice today range from thousands of years old to merely months, and their diversity is unending. They all, however, have the fundamental drive to fill the vacuum in the human soul.

As we return to pure science, we see how it is like the others. In the study of the DNA molecule, the scientist is hunting for the secret to life. In the search for a unified field theory, the scientist is looking for the answer to the universe. In the overall study of matter, energy, space, and time, from quasars to neutrinos, man is looking for knowledge of ultimate significance. What is that substance which is over all, through all, and in all? What was before all things and what holds all things together? It is this pervasive desire which unites these major fields of human endeavor, and one is no better or worse than the other. Whether in the depths

of the mind, the universality of mathematics, the logic of philosophy, the systems of theology, or in the mystery of the universe, mankind searches for the reason, the substance, the answer, the Truth.

To complete the picture, this author believes man will continue to search, to devise his schools of thought, and to formulate his theories of nature, but unfortunately he will never find the answer he wants save the revelation of God in Jesus Christ!

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Communication: The Leaven that Holds the Church and the Scientific Community Together

The theme of communication has always been a central tenet of Christian theology. The communication of love between Father, Son, and Holy Spirit existed in the Christian Trinity before the universe was formed. The properly functioning church, as Figure 1 portrays, is held together by communication linkages. As you harmoniously communicate with God and He communicates His purposes to you, you are able to harmoniously communicate with your Family and other church members thereby establishing a working fellowship and a unity of purpose. Note that for a true unity and fellowship to develop in the church, all must maintain an ongoing dialogue with our creator-God. Remember also that even when we are not making the effort to communicate with God, God in His love, is always seeking us out for His loving purposes, even though we may not be aware of His communicating acts. Lastly, each person thinks and communicates through his or her own matrix of personal commitments concerning the nature of reality; all communication between individuals and God is filtered through these matrices. These individual faith matrices are in turn embedded in the matrix of presuppositions of the general culture (The Metasystem of culture).

This model of the church and its relationship to God is seen to be strikingly analogous to the scientific community in its exploratory relationship to physical reality, as Figure 2 indicates. Figure 2 views scientific exploration as continual communication of scientists between themselves and reality. Michael Polanyi[1] sees science as a model of a free society engaged in a collective exploration. Communication between scientists is essential so that each may know what progress others have made and accordingly may build upon and extend the work of others. Scientific understanding thereby expands due to such collective, freely communicating efforts. Each scientist chooses what particular research path to follow but by constant communication they all are aware of each other's work; thus communication between them has enabled each to utilize the insights of others and avoid unnecessary duplication. Furthermore constant communication with physical reality is the only means by which insight can be gained as to its true law-structure as contrasted to a priori speculations concerning it. To describe such behavior Polanyi uses the analogy of a group of people attempting to solve a jigsaw puzzle in a free, collective effort. Each participant is aware of what the others have done in fitting pieces together and he or she moves accordingly. Note that there is a key presupposition that all the participants tacitly hold: The jigsaw pieces really fit together to form a coherent picture. From this model Polanyi draws an important implication. Attempts to extensively

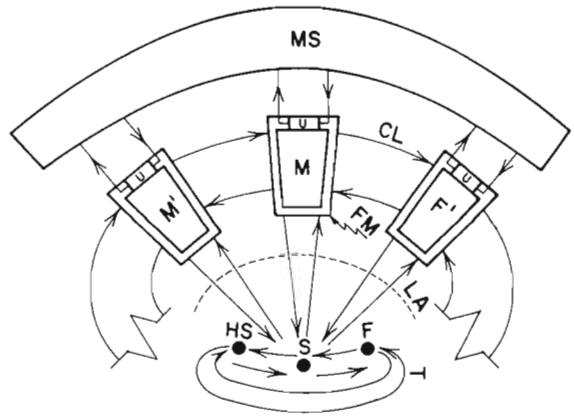

Figure 1. The Church in Ongoing Communication with Triune God.

Nomenclature: MS - Metasystem of culture, general human values; U - undecidability, basic questions that are not decidable from within an individual person's world view; T - the Triune God; F - the Father; S - the Son; HS - the Holy Spirit; LA - line of anthropology; M - me; F' - my family; M' - other church members; FM - the faith-matrices of the individuals shown; CL - communication linkages between the Triune God, the individuals shown, and the individuals themselves—these linkages are filtered through the respective faith-matrices.

plan scientific activity will hinder rather than help scientific progress.

As Polanyi has shown, this communication model of the scientific enterprise can be extended to answer a key question often asked of the scientific community:

> "How can we confidently speak of science as a systematic body of knowledge and assume that the degree of reliability and intrinsic interest of each of its branches can be judged by the same standards of scientific merit? Can we possibly be assured that the new contributions will be accepted in all

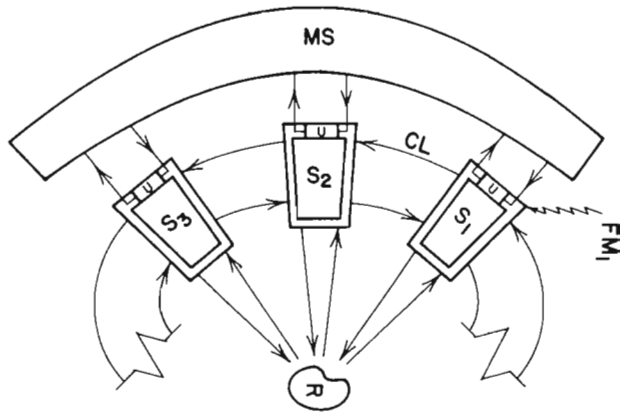

Figure 2. Scientific Exploration as Continual Communication of Scientists between Themselves and Reality.

Nomenclature: MS - Metasystem of culture, general human values; U - undecidability, basic questions of science that are not decidable from within Science; S_1, S_2, S_3 - three scientists of a common discipline; FM_1 - the faith-matrix of the first scientist; R - reality; CL - communication linkages between the scientists of the common discipline—these linkages are filtered through the respective faith-matrices.

areas by the same standards of plausibility and be rewarded by the same standards of accuracy and originality and interest?"[2]

The fact that contributions in science can be evaluated by the scientific community as a whole, even comparing the values of topics of marginal interest in such diverse fields as astronomy or biology, is due to a *principle of mutual control* in which fields of scientific specialties *form chains of overlapping neighborhoods*. By the *principle of mutual control* one means that scientists keep watch on each other's work.

> "Each scientist is both subject to criticism by all other scientists and encouraged by their appreciation of him. This is how the scientific opinion is formed which enforces scientific standards and regulates the distribution of professional opportunities. It is clear that only fellow scientists working in closely related fields are competent to exercise direct authority over one another; but their personal fields will *form chains of overlapping neighborhoods* extending over the entire range of science. It is enough, of course, that the standards of plausibility and worthwhileness be equal at every single point at which the sciences overlap to keep them equal over all. Even those in the most widely separated branches of science will then rely on one another's results and support one another against any laymen seriously challenging their authority. Such mutual control produces a mediated consensus among scientists even when they cannot understand more than a vague outline of one another's subjects."[3]

Figure 3 depicts the spectrum of scientific disciplines envisioned by Polanyi. The chains of overlapping neighborhoods are formed by communication linkages between scientists in the different disciplines as the diagram indicates. All such communication linkages work through the faith-matrices of the respective individual scientists in the differing disciplines. These faith-matrices in turn are embedded in a wider matrix of general presuppositions of the metasystem of general culture. Indeed the whole structure of scientific authority as we have envisioned it would collapse if separated from such basic societial trusts as:

(a) Truth can be obtained by free discussion and free inquiry. "This manner of settling disputes and establishing consensus is a heritage common to our general democratic institutions."[4]

(b) Human beings have the capacity to discover truth; we can recognize and share a rational and universal standard.

A striking analogy exists between the structure of the church with its relationship to its object of study and worship—the Triune God, and the structure of the scientific community with its relationship to its object of study—all physical reality. Indeed both community structures reflect that which is at the very heart of the nature of the Triune God, for communicative acts are central to the relationship between the three Persons of the one Godhead. At the core of the structure of both communities is the concept of communication, both to and from the respective realities under investigation or worship and communication between members of the respective communities. Of course to study the nature of God requires communication methods and types of questioning very different from those used in the study of physical reality.

When we study inert nature we pose our questions in such a way as to manipulate and deform physical reality so that hidden features are revealed and new phenomena observed. When we study the objects of attention in the human sciences we are faced with a much more open dialogue where we often find our own motives are probed by their questions and it is only when openness prevails on both sides of the encounter that real understanding

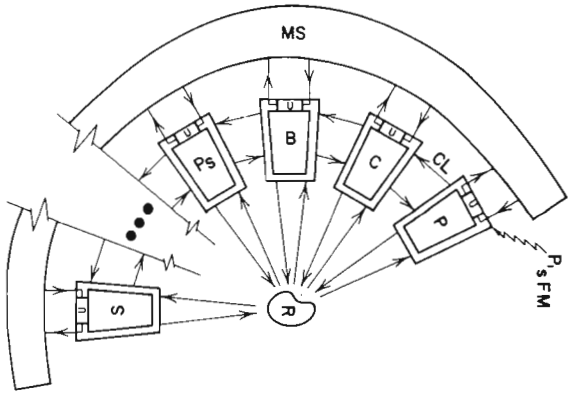

Figure 3. The Spectrum of the Scientific Disciplines Considered to Represent a Systematic and Reliable Body of Knowledge due to a System of Mutual Control.

Nomenclature: MS - Metasystem of culture, general human values; U - undecidability, basic questions of science that are not decidable from within science; P - physics; P's FM - the physicist's faith-matrix; C - chemistry, B - biology, P_S - psychology; S - sociology; R - reality; CL - communication linkages between workers in the various disciplines—these linkages are filtered through the respective faith-matrices and establish the overlapping neighborhoods essential for the system of mutual control.

through communication results. And when we as church members encounter God, it is He that always initiates a true dialogue probing the very core of our rebellious nature as He sweeps away any attempt on our part to manipulate Him, also by His very nature as love refusing to manipulate us in any way but always seeking an open and truthful dialogue from which we may understand the clarity of His ultimate love toward all His creation that He continually sustains in being. To best communicate with God, we should open our hearts and minds and first listen to His revealing Word rather than attempting to question manipulatively as when dealing with inert nature.

Lastly note that communication with physical reality or the Triune God presupposes that the reality we encounter is ultimately rational in its nature and, secondly, that we as humans possess means of communication (either experimental and theoretical techniques of questioning or intelligible human languages) that are also rational in their nature.

The second main idea of the analogy is that for understanding of the Triune God or physical reality to take place communication is essential between members of the respective communities. With respect to the church, the Christian community, Jesus and Paul both pointed out many times that only when a person is in loving communication with his or her fellow believers will God accept a person's worship and petitions and reveal Himself to that particular person. To put it in another way, if a person cannot experience loving communications with his or her neighbors he or she is not capable of experiencing communication with God whose very nature is love. Communication experiences with imperfect human love prepare a person to experience communication with perfect divine love. Similarly with respect to the scientific community, if a scientist isolates himself from the rest of the scientific community he has become isolated from many creative sources of rational understanding; even if the particular scientist is a genius, this isolation will eventually deprive him of the insights and techniques necessary to successfully probe a physical reality that is ultimately rational in structure but whose rationality is at an inner level not immediately perceived from the phenomena observed in direct experience. Thus, both in theology and the other sciences communication as open dialogue among the respective communities members is essential to even the most gifted person if he or she is to gain true understanding.

It is instructive to carry this analogy further by comparing the manner in which the spectrum of scientific disciplines explore all facets of a many-sided reality to the manner in which the spectrum of denominations of the church attempt to achieve greater understanding of the nature of God and His redemptive acts toward His creation. The scientific community makes progress and upholds universal standards by maintaining constant communication with physical reality and between scientists of the spectrum of neighboring disciplines. As physical reality is many-faceted it requires the insights and techniques of many differing points of view (the different scientific disciplines) to gain understanding of reality as a whole. In this there is a fundamental unity to all science though it is composed of many different subdivisions. Such principles as conservation of energy and the inevitable increase of disorder in isolated systems play a vital role in many different scientific specialties. The scientific subdivisions maintain progress toward greater understanding by preserving open communications between themselves; often a new development or technique in one field is found to be very useful to workers in other fields (sometimes quite different). Only by maintaining communication linkages between fields is this type of useful information flow established.

With respect to the denominations that compose one true Church: a diversity of viewpoints that are continually exploring and worshipping the many different aspects of God can be quite helpful in acquiring greater true understanding. Differing denominations have grasped differing aspects of the nature of the one God; the resulting theologies can ideally complement one another in attempting to describe the inexhaustible depths of God's nature. But a core of truth can be maintained and one-sided distorted theologies avoided only if the denominations actively attempt to understand, test, and utilize the insights of the other denominations. Accordingly communication linkages must be actively maintained between members of the spectrum of neighboring denominations for theological progress to be made. (This is analogous to what is done by the scientific community in communicating across the spectrum of scientific disciplines.) In my opinion, the church as a whole lags far behind the scientific community in maintaining communication ties between neighboring communities (denominations), thereby hindering the growth of theological understanding. By better establishing and maintaining such communication ties greater understanding and true unity of fundamental issues could be obtained in the one true Church. Note that in establishing such communication linkages the individual denominations are in no way committed to yielding their own distinctive understandings or agreeing with every thing that another denomination believes; rather the denominations together will seek to find and preserve the central core of Christian belief as C. S. Lewis so forcefully accomplished in his own work.

[1]Michael Polanyi, *The Logic of Liberty*, The University of Chicago Press, Chicago, 1951, pp. 34–38.

[2]Michael Polanyi and Harry Prosch, *Meaning*, University of Chicago Press, Chicago, 1975, p. 191.

[3]M. Polanyi and H. Prosch, *Ibid.*, pp. 191–192.

[4]Richard Gelwick, *The Way of Discovery*, Oxford University Press, New York, 1977, pp. 45–46.

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Letters

A Challenge to ASA Members

May I respectfully register my protest against the propaganda featuring Dr. Ramm and his book. Twenty years ago, after reading it extensively, I put it in the garbage pail. I refused to put it in the waste basket from which it would be put in the incinerator and given an honorable cremation. However my conscience bothers me a little bit and I think I owe Dr. Ramm an apology for putting his book in the garbage pail.

I tried to get my pastor (Nazarene) to destroy his copy but he refused.

Since them I've written and had published *Earth's Most Challenging Mysteries*, in which I have marshalled a mass of hard scientific facts against modern geology and its theories. May I gently ask the question, "Why did you not publish a review when it first came out?"

Here's a challenge to A.S.A. members. A copy will be mailed to you on request. You pay nothing. And you don't have to even return the book, or acknowledge receipt of it, if *in your opinion* it fails to demolish the "Geologic Column." But if, in your opinion, it effectively refutes the basic principles and theories on which modern geology rests, then you pay $5.95, provided you want to. But you pay nothing; and you keep the book and *no bill will ever be sent to you* if you decide to pay nothing.

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The Straightest Thinking

I just read your editorial, "The Relationship between Christian Truth and the Natural Sciences," in the June 1979 issue of the *Journal ASA*. It was excellent and surely the basis for freedom of understanding and thought. I liked it—it is the truth. Your simple definition of truth as "that which conforms to reality" is also very good.

Thomas Merton provided some of his thoughts about truth in the chapter on Sincerity in *No Man Is an Island*. Here he states, "Truth, in things, is their validity. In our minds, it is the conformity or our knowledge with the things known. In our words, it is the conformity of our words to what we think. In our conduct, it is the conformity of our acts to what we are supposed to be."

Later he states, "Objective truth is a reality that is found both within and outside ourselves, to which our minds can be conformed." and still later, "Truth is the life of our intelligence. The mind does not fully live unless it thinks straight."

Your editorial is the straightest thinking I have seen on the subject for some time. God bless you and your work.

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Founded in 1941 out of a concern for the relationship between science and Christian faith, the **American Scientific Affiliation** is an association of men and women who have made a personal commitment of themselves and their lives to Jesus Christ as Lord and Savior, and who have made a personal commitment of themselves and their lives to a scientific description of the world. The purpose of the Affiliation is to explore any and every area relating Christian faith and science. The *Journal ASA* is one of the means by which the results of such exploration are made known for the benefit and criticism of the Christian community and of the scientific community.

A closely affiliated organization, the **Canadian Christian and Scientific Affiliation**, was formed in 1973 with a distinctively Canadian orientation. The **CSCA** and the **ASA** share sponsorship of this publication. **CSCA** subscribes to the same statement of faith as the **ASA** and has the same general structure. However, it has its own governing body with a separate annual meeting in Canada.

Members of both organizations endorse the following statement of faith: (1) *The Holy Scriptures are the inspired Word of God, the only unerring guide of faith and conduct.* (2) *Jesus Christ is the Son of God and through His Atonement is the one and only Mediator between God and man.* (3) *God is the Creator of the physical universe. Certain laws are discernible in the manner in which God upholds the universe. The scientific approach is capable of giving reliable information about the natural world.*

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INDICES to back issues of the *Journal ASA* are published as follows: Vol. 1-15 (1949-1963), *Journal ASA* 15, 126-132 (1963); Vol. 16-19 (1964-1967), *Journal ASA* 19, 126-128 (1967); Vol. 20-22 (1968-1970), *Journal ASA* 22, 157-160 (1970); Vol. 23-25 (1971-1973), *Journal ASA* 25, 173-176 (1973); Vol. 26-28 (1974-1976), *Journal ASA* 28, 189-192 (1976). *The Journal ASA* is indexed in the CHRISTIAN PERIODICAL INDEX. Present and past issues of the *Journal ASA* are available in microfilm at nominal cost. For information write University Microfilms, Inc. 300 North Zeeb Road, Ann Arbor, Michigan 48106.

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VOLUME 32, NUMBER 2 JUNE 1980