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Using Management Techniques to Solve Environmental Problems

Patrick D. Kelly*

Introduction

During the last few years, scientific and mass media warnings of worldwide environmental problems reached new levels of urgency. For example, in the field of ozone depletion, a scientific team led by the National Aeronautics and Space Administration (NASA) issued a report in 1988 showing major declines in upper atmosphere ozone concentrations, not just over the Arctic and Antarctic, but over moderate latitudes as well; wintertime decreases north of 40° N, which covers part of the United States and most of Europe, were nearly five percent.[1] The chairman of that panel, Dr. Robert Watson, said the findings indicate that "draconian" measures may be needed to reduce the emission of chlorofluorocarbon (CFC) molecules into the atmosphere.[2] Most of the mass media warnings tend to focus on increased skin cancer, but skin cancer is one of the lesser worries on a global scale. Increases in ultraviolet radiation (UV) could seriously

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* Mr. Kelly majored in Environmental Engineering at the University of Texas at Austin. He has a J.D. from Harvard and currently practices patent law in St. Louis.

1 The OZONE TRENDS PANEL, REPORT. The report is summarized in Kerr, *Stratospheric Ozone Is Decreasing*, 239 SCIENCE 1489 (1988) and in Shabecoff, *Study Shows Significant Decline in Ozone Layer*, N.Y. Times, Mar. 16, 1988, at A25, col. 3. The Executive Summary of the report is available from NASA in Washington. For a follow-up report indicating that ozone depletions of 5% reached as far south as New Orleans by 1989, *see* Kerr, *Ozone Destruction Closer to Home*, 247 SCIENCE 1297 (1990).

2 Shabecoff, *supra* note 1 at A25.

impair small organisms, such as pollinating insects and the plankton that form the base of the entire oceanic food chain, as well as certain crops that are especially sensitive to UV radiation, such as soybeans. Plants, microbes, and insects are more sensitive than humans to UV radiation, and they cannot modify their behavior the way humans can, by staying indoors or wearing suntan oil or hats. If any of those organisms are seriously affected, the results could trigger a worldwide food catastrophe.[3]

In June 1988, Dr. James Hansen of NASA's Institute for Space Studies testified before Congress that there is no longer any reasonable doubt that increasing temperatures on earth are being caused by carbon dioxide and certain other gases accumulating in the atmosphere.[4] Dr. Hansen and other scientists [5] have warned that:

1. The periodic droughts which occur over most of the temperate and moderate latitudes will grow more severe as greenhouse gases continue to accumulate.

2. Hurricanes, which serve as large scale heat dissipators, will grow more severe, making multibillion dollar coastal devastation more common.

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3 Various summaries of the reports and debates involving CFC's and ozone depletion include L. DOTTO & H. SCHIFF, THE OZONE WAR (1978); Brodeur, *Annals of Chemistry: In the Face of Doubt*, New Yorker, June 9 1986, at 70; J. GRIBBIN, THE HOLE IN THE SKY (1988); and NATIONAL RESEARCH COUNCIL, PROTECTION AGAINST DEPLETION OF STRATOSPHERIC OZONE BY CHLOROFLUOROCARBONS (1979). *See also* Rowland, *Can We Close the Ozone Hole?*, 90 TECH. REV. 50 (1987) and Rowland, *Evidence of Arctic Ozone Destruction*, 240 SCIENCE 1144 (1988) for summaries of the chemical/molecular aspects.

4 Shabecoff, *Global Warming has Begun, Expert Tells Senate*, N.Y. Times, June 24, 1988, at A1, col. 3.

5 Kerr, *Report Urges Greenhouse Action Now*, 241 SCIENCE 23 (1988); Shabecoff, *The Heat is on: Calculating the Consequences of a Warmer Planet Earth*, N.Y. Times, June 26, 1988, at E1, col. 1; Schneider, *The Greenhouse Effect: Science and Policy*, 243 SCIENCE 771 (1989); Roberts, *Is There Life After Climate Change?*, 242 SCIENCE 1010 (1988).

3. Ocean levels will rise from one to four feet by 2050, inflicting massive damage on coastal areas and on every species which depends, either directly or indirectly, on those coastal areas.

4. The global warming rate is likely to be at least ten and perhaps forty times faster than the rate of warming that occurred at the end of the last ice age. At those rates, it will be impossible for many species to gradually adapt or migrate northward, especially since many potential migratory routes have been blocked by humans. Therefore, there will be an enormous increase in the rate at which species are driven to extinction.

5. As the world grows warmer, there will be major increases in parasites and pathogens, especially those carrying tropical diseases that are well suited for warm weather. Weeds will also proliferate, at the expense of crops. In general, parasites, pathogens, and weeds are much better suited to prosper and spread in adverse conditions than pampered, inbred crops and livestock.

Some people who would prefer to delay any effective response to the greenhouse warnings have tried to emphasize the uncertainties that remain in the studies done to date.[6] Those people take a position that shows up repeatedly when environmental debates mesh with politics; the gist of their argument is that, since more research is needed, the need to act wisely based on what is already known is somehow postponed. That argument is intensely appealing to Congress and the Bush Administration since, instead of facing up to and wrestling with a giant, they can respond at a tiny fraction of the cost, merely by appointing committees to study the problem further. Meanwhile, the latest yearly data show that the warming trend continues, and even appears to be

6 Kerr, *Hansen vs. the World on the Greenhouse Threat,* 244 SCIENCE 1041 (1989), which is rebutted in 245 SCIENCE 451 (1989); Roberts, *Global Warming: Blaming the Sun,* 246 SCIENCE 992 (1989), which is rebutted in 247 SCIENCE 14 (1990).

picking up speed. The year 1989 was one of the warmest years ever measured, despite the presence of a strong "La Nina" cold surface current in the tropical Pacific Ocean.[7] Those two correlated pieces of information should have caused intense public and political concern, but reporters seem to have exhausted their attention span on the greenhouse effect; the only report this author saw or heard about was a short column in SCIENCE, with no fanfare or follow-up.

In 1988, the Government Accounting Office (GAO) and the Department of Energy (DOE) said it will take more than $100 billion to clean up nuclear waste problems at nuclear weapons processing facilities.[8] Those two reports followed a 1986 report from the GAO saying that eight of nine nuclear facilities had caused "high levels" of groundwater contamination with radioactive and/or hazardous wastes,[9] including a huge aquifer that provides drinking water for Georgia, Alabama, Florida, and South Carolina.

In South America, tropical rain forests covering areas roughly as large as Minnesota are being destroyed every year, by slash and burn techniques.[10] Farmland cleared in that manner is agriculturally productive for only a few years, then the thin layer of top soil gives out and the farmers move on to burn down more rain forest. In the past, those rain forests generated roughly forty percent of the world's atmospheric oxygen and sequestered much of the carbon that now

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7 Kerr, *Global Warming Continues in 1989*, 246 SCIENCE 521 (1990).

8 GENERAL ACCOUNTING OFFICE, DEALING WITH PROBLEMS IN THE NUCLEAR WEAPONS COMPLEX, REP. NO. GAO/RCED-88-197BR (1988); DEPARTMENT OF ENERGY, ENVIRONMENTAL SAFETY AND HEALTH REPORT FOR THE DOE DEFENSE COMPLEX (1988) (commonly referred to as "the Glenn Report").

9 GENERAL ACCOUNTING OFFICE, ENVIRONMENTAL ISSUES AT DOE'S NUCLEAR DEFENSE FACILITIES, REP. NO. GAO/RCED-86-192 (1986).

10 Roberts, *Hard Choices Ahead on Biodiversity*, 241 SCIENCE 1760 (1988). The estimate of yearly destruction was 20 million hectares (about 80,000 square miles). It should be viewed with caution, since it came from an official of the Brazilian government. It also does not include forest acreage destroyed by clear-cutting.

pollutes the atmosphere.

The Lack of Progress Toward any Solutions

If people look beyond the warnings and seriously contemplate what they mean, it seems likely that the world environment and the human race will be in serious trouble in the next century. However, virtually no progress is being made toward actually solving any of those problems. While scientists discuss them, issue more warnings, and ask for more money for more studies, the problems grow steadily worse.

For example, companies that emit CFC's are claiming that the so-called "Montreal Protocol," an international treaty, will protect the ozone layer. However, experts estimate that the Montreal Protocol will allow the present concentration of stratospheric chlorine (which is already too high) to *triple*.[11] Environmental groups began warning that the Montreal Protocol was inadequate the day after it was signed, and subsequent findings apparently have proven them correct. Even the EPA Administrator under Ronald Reagan admitted, shortly before the 1988 Presidential election, that the industrial nations need to take another look at the Montreal Treaty and should ban CFC emissions altogether. However, there was no timetable for any action, and there has been no significant action since then (indeed, the CFC issue seems to have disappeared as concern grows over the greenhouse effect). There is no reason to think the EPA's pre-election maneuver was anything more

[11] GRIBBIN, *supra* note 3, at 180. The Montreal Protocol on Substances that Deplete the Ozone Layer: Final Act, United Nations Environment Program (1987) allows CFC emissions to continue at 1986 levels until 1994. After 1994, CFC emissions can continue at 80% of the 1986 levels, and at 50% of the 1986 levels after 1999. In addition, the Montreal Protocol allows emissions of halon (which also contain bromine) to remain at present levels, with no decrease; it allows developing countries to increase their CFC emissions; it calculates allowable Soviet emissions based on 1990 rather than 1986 emission levels; and it prohibits any enforcement action until four years after it took effect.

than pre-election rhetoric.

Meanwhile, lobbyists such as the so-called "Alliance for Responsible CFC Policy" are doing all they can to prolong the right of chemical companies to emit CFC's into the atmosphere, and they have actively promoted the false belief that the Montreal Protocol solved the CFC problem of ozone depletion. The frightening part is, they are succeeding; a number of reporters (including some science reporters) have uncritically praised the Montreal Protocol as the answer to the ozone problem, lulling Congress and the public into a sense of complacency.[12]

There is no reason to hope for faster progress in controlling nuclear waste. DOE recently ordered its nuclear facility managers to begin the process of decontamination, but the DOE estimates it will take until 2045 AD to complete the clean up.[13] Environmental groups say it will probably take even longer, especially in view of the federal budget deficit, and it may be totally impossible to remove all radioactive waste from aquifers we use for drinking water, once those aquifers have been contaminated.

On the greenhouse front, President Bush, instead of taking action to require energy conservation or reductions in carbon dioxide emissions, has apparently abandoned his claim to being an environmentalist; to the

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12 As part of its public relations kit, the so-called "Alliance for Responsible CFC Policy" sends out copies of an editorial from the Wash. Post, Sept. 18,1987, at A26, col. 1, which states, "The Reagan administration deserves enormous credit . . . the industry has behaved in exemplary fashion . . . A major environmental threat has apparently been deflected . . .". The early press reports published after the Montreal Protocol was signed quoted various self-congratulatory statements made by the chief U.S. negotiator for the treaty, Richard Benedick; those news reports are also distributed by the CFC Alliance as evidence that the ozone problem has been solved. An example of a science reporter uncritically adopting that line is Kerr, *supra* note 5, which referred to an international movement urging action on the greenhouse effect: "This movement is akin to the one that recently produced agreement on how to deal with destruction of stratospheric ozone."

13 Glenn Report, *supra* note 8.

best of this author's knowledge, he hasn't repeated that claim since he was elected. Judging from news reports of a White House conference on the greenhouse effect in February 1990, he appears to be more concerned with economic growth than with the greenhouse effect.

Indeed, instead of trying to solve long-range problems, the federal government apparently wants to keep the public unaware of them. For example, the Office of Management and Budget has forced scientists working for federal agencies to suppress warnings and recommendations which would require increased federal spending on environmental problems.[14] Other scientists have been sharply critical of the quality of environmental research done by government agencies that are subject to intense political pressure. In the words of Dr. Wallace Broecker of Columbia University, "I believe most scientists would agree with me that the handling of research on greenhouse gases by the Department of Energy and on acid rain by the Environmental Protection Agency has been a disaster".[15]

Somehow, scientists, engineers, and other people who specialize in

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[14] Wilford, *His Bold Statement Transforms Debate on Greenhouse Effect*, N.Y. Times, August 23, 1988, at C4, col. 1. The subject of that story was Dr. James Hansen of NASA (*supra* notes 4 and 6). There was a flap in 1989, when Senator Albert Gore openly accused the Office of Management and Budget (OMB) of suppressing scientific testimony before Congress; however, the OMB had been doing the same thing for years and no one objected. In the words of the reporter (regarding Hansen's 1988 testimony),

> On previous occasions, the OMB, which reviews official statements that have implications for the budget, had forced [Dr. Hansen] to delete from the text of any proposed Congressional testimony any recommendations for increased research spending. Last November [1987], rather than remove such statements, he testified as a private citizen . . . Somehow, the budget office overlooked his proposed statements for this June [1988]. "I understand they were really upset," Dr. Hansen said.

[15] Testimony of Dr. Broecker, *Hearing on Ozone Depletion, Greenhouse Effect, and Climate Change Before the Senate Comm. on Environment and Public Works* 100th Cong., 1st Sess., part 2, at 82, (1987).

technology must do more to help solve the environmental problems that threaten the planet we share. It is not enough to ask for more funding to study the problems; the facts we already know are more than enough to convince any rational person that we had better start solving those problems instead of merely studying them. Certainly, scientists should continue to gather more data; however, they have an obligation to use the data they already have, as wisely as possible.

I once attended a conference organized by the Office of Scientific Freedom and Responsibility, which is part of the American Association for the Advancement of Sciences (AAAS). At the opening of that conference, the host offered a toast: "Here's to peace. May it require more study." At the end of the conference, one of the co-chairmen closed with an impassioned speech, the gist of which was as follows: "It is often said that in real estate, the three most important things are location, location, and location. Science is similar; the three most important things in science are facts, facts, and facts. We need more money so we can continue gathering the facts we need." He made no mention of the fact that during the conference, more facts had been presented than he knew what to do with. It didn't matter how many facts he already had; he wanted more. Or, to be more precise, he wanted a nice salary paid by taxpayers, so he could gather more facts, even though he didn't seem to have any apparent understanding, appreciation, or concern about how anyone would use those facts to accomplish things that couldn't be accomplished with the facts already available.

At one level or another, most scientists deliberately avoid making value-laden assertions about how society should respond to the facts they have gathered, as though they will lose their objectivity and credibility if they are forced to indulge in value judgments. A good example of a scientist struggling to ride both horses is Stephen

Schneider, who published an article entitled, "The Greenhouse Effect: Science and Policy," which contained several rather awkward statements such as, "In my value system, high-leverage tie-in actions are long overdue. Of course, whether to act is not a scientific judgment, but a value-laden political choice that cannot be resolved by scientific methods".[16]

In the minds of scientists, their job is just to gather facts; it's someone else's job to figure out what to do with those facts. I don't bemoan or criticize that attitude; the real problem is that no other qualified profession has stepped forward to do that job. The two professions that openly covet power — lawyers and politicians — are probably the two most unqualified professions that could possibly be chosen for making complex scientific assessments and decisions; however, they are tolerated and even encouraged to gather more power over science and technology by statements such as the one by Schneider, quoted above. If scientific experts openly admit that they are in no position to make value judgments about how to protect the environment, then politicians and lawyers will willingly step in to fill the gap, since they aren't encumbered by scientific expertise or any need for objectivity.

Somehow, someone needs to convince engineers (who are supposedly trained to use science and technology to solve problems, rather than just to look for more facts) to step forth and take on a full share of the responsibility. Alternately or additionally, someone needs to convince at least *some* scientists that the time has come for them to abandon their claims of impartial, objective neutrality, and put their shoulders to the task of helping humanity avoid the disasters lurching toward us (for example, atomic physicists or polymer chemists could preserve their professional objectivity and credentials in physics and

16 Schneider, *supra* note 5, at 778.

polymer chemistry even if they start working to help solve ozone depletion and the greenhouse effect). And someone needs to convince business managers who can organize and motivate people and analyze numbers and plan budgets that they must use those skills to help humanity avoid a fate that, according to the warnings of environmental scientists, looks like a rather persuasive vision of genuine hell.

This article proposes a two-pronged strategy for solving environmental problems. It is not a panacea, and it will not be enough by itself to solve the environmental problems facing the world today. However, it is a powerful and effective management technique used in many successful companies, and it has already been adapted to several large-scale scientific problems with good results, as described below. Therefore, it holds good promise as a logical and effective way to begin solving environmental problems that defy other efforts.

The "Chunking" Strategy

The name "chunking" comes from IN SEARCH OF EXCELLENCE,[17] the 1982 book on business management by Tom Peters and Bob Waterman. It refers to two steps which are carried out in coordination: (1) a specific problem is selected and designated as the highest priority problem facing a company or other organization; and, (2) a small "chunk" in the organization is created (if necessary) and assigned to identify a solution which can be adopted by the management of the entire organization.

Peters and Waterman offered the following as an example of the chunking strategy at work:[18]

> The line officer who has headed one of Exxon's Asian affiliates for the last ten years made a presentation on

[17] T. PETERS & R. WATERMAN, IN SEARCH OF EXCELLENCE: LESSONS FROM AMERICA'S BEST-RUN COMPANIES (1982). The section entitled "Chunking" is in ch. 5, *A Bias for Action.*

[18] *Id.* at 125–126.

> "strategy" at a recent top management meeting. He reported a remarkable tale of improvement. Was it a tale of shrewd foresight and bold strategic moves? Not in our view. It was a story, instead, of a series of pragmatic actions. In almost every one of the ten years, some single problem had been knocked off . . . the key success factor in business is simply getting one's arms around almost any practical problem and knocking it off — now. Exxon in Japan simply executed (to near perfection) a series of practical maneuvers. They made each problem manageable. Then they blitzed it. The time associated with each problem was fairly short. That it was the *real* number one priority for that short period of time was unquestioned. It sounded like strategic foresight, but we would argue that it was a much more remarkable trait: they had just gotten a string of practical tasks done right.

Peters and Waterman then described how various small "chunks" in an organization (such as task forces, czars, project centers, skunk works, etc.) are the most effective agents to encourage action in a large organization. A chunk assigned to solve a problem works on only one problem at a time, until that problem is solved.

Chunking doesn't mean ignoring every problem except the number one problem; instead, it means keeping top priority on one major problem, and solving that problem, before people and resources get distracted and diverted by other problems. The key word is *solve*, which means *actually implementing an effective solution.* Thinking up a solution and writing memos and reports don't qualify as solving a problem, unless those steps lead to actual implementation of an effective solution.

To some people, this strategy might seem simple and obvious. But in business and government, managers surrounded by dozens of problems often lose sight of this strategy and try to solve too many problems at once. If they succeed, fine. But they usually don't. Managers who actually solve five or ten major problems in five or ten years are rare and valuable. Far more common are managers who

accumulate reports analyzing and setting forth recommendations on dozens of problems, but who never really solve any of those problems. That is exactly what is happening to the efforts of thousands of people who are trying to solve environmental problems today. They are diluting their efforts by trying to tackle too many problems at the same time. Perhaps they are making some progress on every problem, but the painful and dangerous fact is that very few large-scale environmental problems are actually being solved at anything near the rate that needs to be accomplished.

The science and engineering communities should consider using the chunking technique. Rather than trying to solve dozens of environmental problems all at once, they should ask their organizations, such as the AAAS, the American Chemical Society, the National Society for Professional Engineers, the American Institute of Chemical Engineers, and the American Society of Civil Engineers to work together and choose one problem that poses the most urgent threat to humanity and the environment. Once that problem has been chosen and designated, the members of those organizations should concentrate on solving it, and on making sure politicians and the public realize it has been chosen by thousands of scientists and engineers as the single most urgent problem facing America and the world today.

This prioritizing approach has already been used successfully in several fields of science. For example, America cannot afford to build more than one huge high-energy accelerator at a time, so physicists working in that field set aside their differences and drew up a request for one accelerator. People can argue about the problems that arose during the site selection process, but the fact remains that Congress agreed to fund that accelerator, and construction may begin before long.[19]

Similarly, the European Southern Observatory, an eight-nation

[19] Crawford, 242 SCIENCE 1004 (1988).

consortium, obtained approval in December 1987 to build a $240 million telescope complex in South America. By contrast, numerous competing groups in America are all clamoring for money to build their own large telescopes, and none of the American groups are getting what they want.[20]

The simple and logical conclusion is that when groups with similar but potentially competing interests need to tackle a very large problem, they should work in coordination, and they should focus on one goal at a time.

Suggested Procedures

If any science or engineering organizations agree to work on this project, they will need to work out the exact procedures. The following steps are proposed as a first draft to help any planners focus on what needs to be done:

1. The participating organizations could create a task force to be in charge of the project, made up of officials or other designees chosen by each organization.

2. In published articles in various science and engineering journals, and in a press release to the mass media, the task force could announce that it is working on the project. That announcement can set forth dates and locations for a series of conferences to discuss the candidate problems. It could set forth several obvious candidates, such as ozone depletion and the greenhouse effect, and it could invite members of the participating organizations to nominate any other major problems as candidates.

3. The task force could select three to six environmental problems as the main candidates, and it could ask one or more experts in each field to write a preliminary report analyzing each problem and setting forth the

20 Waldrop, 240 SCIENCE 28 (1988).

known facts, the unanswered questions, and arguments for and against tighter controls on any specific activities. Those reports could be published in science and engineering journals, and anyone would be free to write to the authors and the task force with comments or additional information.

4. The task force could hold a series of conferences across the nation to provide a forum to debate the preliminary report. Following the conferences, the task force could publish a follow-up article on each problem, summarizing the problem, any new information that came to light after the preliminary report was published, recommendations for action, and any dissenting viewpoints.

5. The memberships of the organizations could vote and choose the line of technology which should be regarded as the most dangerous and urgent environmental problem facing America and/or the rest of the world. To eliminate the need for a separate mailing, the organizations could publish the ballot in their journals. Members could mail it in, or they could even use Reader Service Cards in certain journals to cast their votes.

6. The organizations, or their members, could follow up on the selection in various ways, using the recommendations of the task force as a starting point. Although the specific course of action will depend on which problem is chosen, scientists and engineers should make sure the press, the public, Congress, and the administration understand the seriousness of the problem, and they should ask Congress to pass a law enacting the recommended control measures.

Repeating the Process

One of the inherent rules of this proposed project is this: it cannot become an annual chore, like electing new officers or holding a fund-raising drive. If an environmental problem is chosen as the single most

urgent and threatening problem facing the world, it should be solved or at least effectively addressed before anyone repeats the process and chooses some other problem to focus upon. Anything else would violate the strategy and render it ineffective.

It will not be possible to "solve" major environmental problems any time soon. For example, even if everyone stopped emitting CFC's, the CFC molecules already in the upper atmosphere will remain there for decades. They will continue to release chlorine atoms, which will continue to destroy ozone molecules. As another example, even if we could reduce the worldwide burning of oil, gas, and coal by more than half, which is highly unlikely unless a major depression arrives, the surplus of greenhouse gases will remain in the atmosphere for quite a while, and temperatures will increase accordingly.

Therefore, if this project is started, people will need to settle for effectively addressing one problem at a time. For example, suppose scientists and engineers decide that ozone depletion is the most urgent problem facing the world today, partly because of the risk of UV radiation damage to plankton and insects, and partly because highly effective steps to reduce CFC emissions can be adopted within a period of a few years without massive economic disruptions. Suppose also that Congress passes and the President signs a law that extends beyond any provisions likely to be adopted in the 1990 Clean Air Act and contains the following provisions: (1) it outlaws disposable products such as food containers which contain CFC's; (2) it requires companies that sell air conditioners, refrigerators, etc. to establish or support recovery centers to remove CFC's from units that are no longer in use; (3) it offers tax incentives for companies that reduce their CFC emission levels on an accelerated schedule; (4) it requires manufacturers which use CFC's as solvents to use CFC recovery systems, and (5) it imposes an escalating import fee on products made in other countries using

processes which violate American laws controlling CFC emissions, and converts that fee to an outright ban after a few years. If such a law were to be passed, the task force that coordinated the project could decide whether the law is adequate to get things moving at an adequate pace in the right direction. If so, it will be time to address the next problem. If not, the task force will need to make sure Congress, the administration, the press, and the public realize that the law is not enough, and more needs to be done.

A Potential Objection

One of the objections commonly raised against any effort to take a simple, straightforward approach to solving problems can generally be paraphrased as follows: "But these problems are extremely complex and interrelated. You can't solve just one part of the problem without understanding the entire network of interrelated problems."

I'd like to offer several responses to that objection.

First: it isn't always necessary to understand a problem in order to begin solving it. For example, the British scientists and doctors who finally began testing Alexander Fleming's penicillin mold against bacterial infections in humans didn't have the foggiest notion of how the beta-lactam ring structure in the penicillin molecule interfered with the synthesis of bacterial cell walls. All they could tell at that level of technology was that some sort of fluid extract from the mold cultures could kill certain types of bacteria. That was all they needed to know to convert penicillin into a practical tool that saved hundreds of thousands of lives. The research that followed led to improved forms of penicillin, which are undoubtedly more useful than the first version; but there was no need to wait for that research to be completed before using penicillin as an antibiotic. Indeed, if the practical use of penicillin hadn't started first, that research might never have been done.

Second: some problems require prompt action, even though the

person who finds himself at the center of the problem isn't thoroughly qualified to solve it. If you come home and find your basement flooded, you don't think, "I need to study fluid mechanics and piping networks before I can do anything." You grab a flashlight, turn off the electricity, and shut off a water valve. After you've taken those steps as quickly as possible, it's time to consider the problem further. If you see an auto accident and stop to help, and you discover the driver isn't breathing, you don't get back in your car and drive for miles to a telephone to call an ambulance first; you try to give him CPR, doing the best you can even though you're not an expert. And you certainly don't tell yourself, "I should go to medical school to become a doctor first, and if this guy is still here and still warm but he still isn't breathing when I get back, that's when I'll try to help."

Third: even though a certain symptom or problem is just one part of a complex and interrelated network of problems, that's not a valid reason to stall and delay instead of taking reasonable, practical steps to solve that particular symptom or problem. Quite frequently, a doctor must treat an immediate symptom before he or she can treat the underlying disease that caused the symptom. If a patient is suffering from several different sources of stress, then removing any one of those stresses can help the patient move closer to a healthy and stable condition.

Fourth: the same interrelatedness that makes some scientists want to stall and delay would actually help them gather useful data, if they would find the courage to start taking practical action instead of waiting for more data. If problems are interrelated, solving part of the problem and then studying subsequent beneficial effects triggered by the partial solution will give scientists some of the best data they could gather about how the entire system works.

Fifth: the argument that we need to understand an entire network of

problems before we can solve any of the component problems is contradicted by the process of scientific research. In a laboratory, the most common way to assess the effects of any variable is to hold other variables constant while manipulating that variable. That process often creates artificial and potentially misleading conditions that never exist in nature, but scientists continue to use that approach. They rely on it heavily, not because they want to, but because it is often the best they can do.

Sixth: the benefit that can come from a partial solution is often worth the cost, all by itself, regardless of whether it helps any other part of the problem. Energy conservation is a perfect example. Even if everyone could completely ignore the greenhouse effect, the simple and obvious fact is that if America would do more to conserve energy, we would reduce our trade deficit and our vulnerability to being held hostage again by petroleum-exporting countries. If the advocates of "We need more studies before we take any action" can overcome any of the six points above, I'd like to hear their reasoning. In the meantime, any complaints or arguments that I don't adequately understand the complexity or interrelatedness of environmental problems are misguided and misleading; my point is that we don't need to fully understand some problems before we begin solving them. By way of analogy, a chess player doesn't need to be able to foresee quadrillions of potential moves in order to be a competent player. He only needs to make one good move at a time, which really is the essence of facing any challenge and solving any problem. It's a good idea to have an overall strategy, but first and foremost, you need to protect your major pieces. Any player who gets so wrapped up in expansive thoughts about the complexity or the interdisciplinary aspects of chess that he loses a knight, a bishop, a rook, and a queen to straight-on attacks is going to lose the game.

Potential Benefits

If done properly, this project outlined above could accomplish at least three goals.

First, it would help political leaders and the public understand the seriousness of dangers they are ignoring today. In the past, our political leaders have given plenty of lip service to the problems; most people who read the words of Senators Mitchell, Chaffee, and Gore during the January 1987 Senate hearings on CFC emissions would heave a sigh of relief, thinking that key players in Congress had finally realized the depth of the problem and had resolved to take effective action. However, the only action taken since then was the Senate's ratification of the Montreal Protocol, which is woefully inadequate to solve the problem.

One of the great problems of democratic government is that elected officials are under intense pressure to give nothing more than lip service to steadily growing problems until a major crisis arrives which can no longer be put off by words alone. World War II offers an example. By the time Nazi Germany invaded Poland in 1939, most Congressmen knew America wouldn't be able to stay out of the war forever, but they continued to stall until America was attacked. That way, they could blame the crisis on someone else, and they could claim to be leading America through its hour of need. By contrast, if they had acted wisely to avoid the crisis, they would have been criticized for imposing hardships on the public. The Japanese openly stated that the reason they attacked Pearl Harbor is that Congress very nearly refused to adopt a draft; the bill that created a draft passed Congress by only one vote, after bitter argument by dozens and dozens of Congressmen who passionately argued that America didn't want or need a draft. The Japanese honestly thought America, or at least Congress, simply didn't have the willpower to fight a real war.

The desire to substitute rhetoric for unpleasant decisions is pervasive among elected officials, who feel trapped by the need to get reelected. It is reinforced by the attitude that America can and will respond to crises. After Pearl Harbor, when America found itself with no choice but to fight back, it won the war, didn't it?

If anyone thinks it is an exaggeration to compare ozone depletion or the greenhouse effect to World War II, consider the following. Many people think World War II was a Malthusian war, which served the brutal but necessary purpose of reducing human overpopulation. But despite all the killing and suffering, World War II didn't reduce the number of people imposing demands on the environment. At the end of World War II, in 1945, there were more people alive than in 1939, at the start of the war. By contrast, if the oceanic food chain is crippled because plankton are being killed by UV radiation, and if the world's agriculture drops because bees and other pollinating insects are being killed or disrupted, the number of humans will have to drop, somehow, by some fraction. Fifteen to twenty percent, perhaps? That would be more than twenty times the number of people who died in World War II.

My comments above are a suggestion that the human population may be decreased by some reasonably small fraction. That seems inevitable, somehow or another, sooner or later. To place that possibility in perspective, consider that a number of scientists have warned that the total extinction of the human race may be approaching unless we solve our environmental problems.[21] After reviewing the mass extinctions that occurred at the ends of the Ordovician, Devonian, Permian, Triassic, and Cretaceous periods during the last 600 million

[21] *See, e.g.*, P. EHRLICH & A. EHRLICH, EXTINCTION: THE CAUSES AND CONSEQUENCES OF THE DISAPPEARANCE OF SPECIES (1981); GRIBBEN, *supra* note 3 at Ch. 7, *Global Implications;* comments by James Lovelock in Cowley, *The Earth is One Big System,* Newsweek, November 7, 1988, at 98.

years, Douglas Futuyma, the author of the most highly regarded comprehensive text on evolution, concluded, "tropical forests with their richness of species face almost complete annihilation, temperate zone forests and prairies have been eliminated in much of the world, and even marine communities suffer pollution and over-exploitation. In the next several hundred years one of the greatest mass extinctions of all time will come to pass unless we act now to prevent it".[22] In the words of Thomas Lovejoy of the Smithsonian Institute, "I am utterly convinced that most of the great environmental struggles will be either won or lost in the 1990's, and that by the next century it will be too late".[23] In the words of Lester Brown of the Worldwatch Institute, "We do not have generations, we only have years in which to attempt to turn things around".[24] Anyone accustomed to thinking hope is never lost should contemplate what Lovejoy and Brown mean by phrases such as "won or lost," "too late," and "we only have years." They aren't saying that unless we act, we will have to live with nagging annoyances; instead, they are warning us that most of the species that currently exist on this planet are being rapidly driven extinct. Even if the human race is somehow clever enough to survive the catastrophe it caused, there can be little doubt that the number of humans that could be supported by a crippled ecosystem will decrease; the only question is how large that decrease will be. All of the national news magazines and TV networks have run feature stories which talk in complete seriousness about worldwide catastrophe and the possible extinction of humans unless we solve the greenhouse effect and ozone depletion.[25] Even magazines

22 D. FUTUYMA, EVOLUTIONARY BIOLOGY 343 (1986).

23 Roberts, *supra* note 10.

24 Sancton, *What on Earth are we Doing? Destruction of the Earth's Environment*, Time, January 2, 1989, at 26.

25 *See, e.g.*, Begley, S. et al, *The Endless Summer*, Newsweek, July 11, 1988, at 18. An example of a statement by a national television network is from ABC

such as Reader's Digest, Sports Illustrated, and TV Guide have run feature articles warning of dire catastrophe unless we begin solving those two problems.[26] Surely, everyone has heard the warnings by now . . . we just haven't done anything about them.

The public may be starting to understand; a 1988 study found that two-thirds of Americans believe that the greenhouse effect presents a danger. However, it was ranked as thirteenth on a list of sixteen dangers; the only dangers ranked lower were Xrays, indoor radon, and radiation from microwave ovens.[27] Somehow, scientists and engineers must do more; we must make people realize this isn't some TV show, and there isn't going to be a happy ending. The future is coming at us like a locomotive, and we're trapped in a tunnel with nowhere to run and no scriptwriters or stuntmen to save us.

The second potential advantage of the chunking project is that it can lead to solid, beneficial results. By giving the press and the public one specific problem to focus on, it would greatly increase the political pressure on Congress to take action on that problem. Regardless of whether the public or Congress understand the chemistry of the upper atmosphere or the UV sensitivity of insects and microbes, a federal law which would effectively reduce CFC emissions would help reduce a major threat to our health and welfare.

Most scientists disdain one issue voters and political "litmus tests,"

World News Tonight, July 27, 1988 (transcribed from videotape on file with author):

> It's what scientists call the greenhouse effect, and in the long run it could mean devastating changes to all life on earth . . . The habitability of the planet is really in doubt [quoting Michael Oppenheiner of the Environmental Defense Fund] . . . Experts guess we have a window of about twenty years to undo the atmospheric damage. After that, they say, the planet could slowly turn uninhabitable.

26 Ponte, *What's Wrong with our Weather*, Reader's Dig., November 1988, at 71; Boyle, *Forecast for Disaster*, Sports Illustrated, November 16, 1987, at 78; Asimov, *Danger: We're Losing our Shield of Life*, TV Guide, February 21, 1987, at 36.

27 Kerr, *supra* note 5, at 24.

with good reason. However, our ability to actually solve environmental problems may be a litmus test that determines whether the human race survives over the long run. That's not cheap-shot, opportunist politics; it's a matter of survival. The only way to make voters and Congress understand how much is at stake may be to focus on one problem at a time and emphasize the seriousness of that problem.

Too many reporters (even science reporters) focus on tidbits such as changes in the sex ratios of alligators, and they give their articles cutesy titles,[28] as though the catastrophes that threaten the ecosystem are amusing. Too many scientists couch their warnings about parasites and pathogens in dense, academic language that only scientists can understand.

To make things even worse, they play right into the hands of people who want to stall and delay, by admitting that science doesn't yet have all the answers and then failing to emphasize that despite our uncertainty over the details, we understand the basic problem. As pointed out by William C. Clark of the Science, Technology and Public Policy Program at Harvard University, "Management is not the same as prediction. The distinction is an important one, for management can be improved despite the enormous uncertainties. . . that will continue to make detailed predictions illusory." [29]

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[28] Barinaga, *Where Have All the Froggies Gone?*, 247 SCIENCE 1033 (1990). That supposedly cute title distracts from an intensely serious fact: the number of amphibians around the world seems to be declining drastically. Because of physiological factors (they are uniquely exposed to pollutants in both terrestrial and aquatic environments, and their skins are permeable to airborne gases), amphibians appear to be highly sensitive to environmental disruption. Therefore, they may provide a very useful warning, comparable to canaries in coal mines (which were used to warn miners of poison gases). But despite their sensitivity, amphibians are highly adaptable; in the words of one scientist, "They were here when the dinosaurs were here, and they survived the age of mammals. They are tough survivors. If they are [dying off] now, I think it is significant."

[29] Clark, *Visions of the 21st Century: Conventional Wisdom and Other Surprises in the Global Interactions of Population, Technology, and Environment* (Discussion

The time for obfuscation is over; the only way we can solve the problems facing us is through careful strategy and concerted action, by hammering as hard as we can on one problem at a time until the governments of the world face up to that problem with more than just words.

The third advantage of the chunking project is that it would encourage everyone to think hard about the long term future of America and the planet we live on, and about the role of science and engineering in society and in the future. Many people outside the scientific community have an impression that too many scientists and engineers are narrow-minded nerds who, either willingly or naively, allow their work to be turned into weapons against the helpless, the innocent, and the environment by rapacious businessmen who couldn't care less about ethics. A project which leads to actual, effective solutions for worldwide environmental problems would encourage every scientist and engineer to realize that they have responsibilities that extend beyond their daily jobs. In addition, it would encourage more young people to choose careers in science and engineering, and it would increase the number of ties and interactions between science and engineering, on one side, and business, law, and politics on the other side. As an effort that began within the science and engineering community rather than being imposed on it from outside, it will encourage Congress, the public, and antitechnologists to take another look at what is happening within the technical community.

But unless and until scientists and engineers prove that they can and will solve the problems technology is creating, the public has every right and reason to regard them with intense skepticism and mistrust. If technologists are destroying the world's ozone layer, annihilating most

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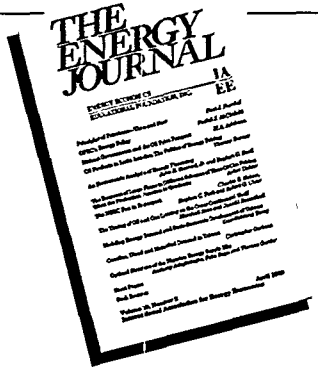
Paper 89–09, J.F.K. School of Government, Harvard U., June 1989); *see also,* WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, OUR COMMON FUTURE (1987) (commonly referred to as "the Brundtland Commission Report").

other species on earth, and dumping nuclear waste into the nation's drinking water, then technologists are more dangerous to peace and freedom than any band of terrorists.

In the science fiction novel A CANTICLE FOR LIEBOWITZ[30], there was some interesting speculation that if a nuclear war ever occurs, there will be an intense backlash against science and technology; the survivors will hunt down and kill any scientists and engineers left alive, to repay them for what they did in creating nuclear weapons. To anyone who has studied the greenhouse effect or ozone depletion, it is not too difficult to imagine a similar scenario actually occurring. If the greenhouse effect disrupts worldwide agriculture as much as predicted and UV radiation begins to kill off plankton and insects, there will be more suffering, starvation, and killing than anyone can imagine today. Whether the human race survives in shrunken numbers, or whether it is driven to extinction, anyone who is still alive after a billion people have died may decide that scientists and engineers were responsible for their suffering. Rather than looking to us for salvation, they may look to us for revenge.

30 W. MILLER, A CANTICLE FOR LIEBOWITZ (1959).



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