ENGINEERS, BUTTERFLIES, WORLDVIEWS

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ABSTRACT. Taken from three specific environmental decisions involving butterflies in confrontation with development projects, "engineers" becomes a symbol of an anthropocentric, resource-oriented worldview that finds nature to be of instrumental value but without intrinsic value and "butterflies" an instance of wild, pristine nature. Following a contemporary view believed to be justified by both pure and applied science, an engineering outlook can see wild nature as undeveloped raw waste and, as a result of evolutionary theory, judge that natural processes are blind, random, and clumsy.

On the contrary, natural systems, characterized by speciation, are engineering projects worthy of admiring respect—in the sense that they represent inventive, ingenious, trial and error solutions to problems in survival. Butterflies demonstrate engineering principles. Ecosystems are prolific and satisfactory communities in an objective sense.

Culture superimposed on wild nature ought to seek an optimally satisfactory development that maximizes cultural values with minimum loss of natural values. Current environmental policy, though seemingly prohibitive, can liberate environmental professionals from narrow economic constraints and permit them to operate within this more comprehensive worldview. In symbolic as well as specific terms, engineers can and should count butterflies.

The Front Range rivers cut dramatic canyons just before they spill onto the plains, and the South Platte is no exception. The Two Forks area contains a spectacular stretch of river, as well as a spectacular dam site, and Denver is deciding whether to preserve or sacrifice it—that is, how best to value it. The Denver Water Board has spent $36,600,000 on that complex decision, which (some brag and others complain) is the most expensive environmental impact statement in history. The study alone is costing Denver water users a three to five dollar annual increase in their water bills. Coordinated by the U.S. Army Corps of Engineers, the two volume draft environmental impact statement is 1300 pages long (U.S. Army Corps of Engineers, 1986). Though currently still under study, the Environmental Protection Agency has already rejected as inadequate its treatment of the mitigation of environmental damages. One facet of the Two Forks decision is whether and how to protect the Pawnee montane skipper, *Hesperia leornadus montana*, a subspecies of butterfly found only in the environs of the proposed dam site. Under the sponsorship of the Denver Water Board, a task force is meeting monthly to decide whether the skipper is in jeopardy and whether its future is worth a dam.

Outside of San Jose, another butterfly, the Bay checkerspot, *Euphydryas editha bayensis*, proposed to be listed as an endangered species, inhabits the 800-acre local landfill of Waste Management, Inc., the big waste disposal corporation. That corporation set aside 250 acres as critical habitat in a permanent preserve and is spending over $1 million over the next ten years in research and preservation efforts, including eventual reseeding of landfill slopes to make them habitable to new colonies of the checkerspot.

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Waste Management has made the butterfly a mascot, marked "butterfly crossings" at the landfill, and sponsored a contest to name a butterfly logo that will appear on its San Jose garbage trucks.

Nearby, the same butterfly also inhabits peripheral tracts of a 5,200 acre facility owned by United Technologies Corporation. The giant defense contractor is taking an entirely different attitude and has, in effect, declared war on the butterfly. The implication is that the butterfly is a menace to national defense because it might interfere with the company's testing and building of Minuteman and Tomahawk propulsion systems. The company has retained a prestigious San Francisco law firm to raise technical challenges to the butterfly's listing as an endangered species, secured statements of concern from the undersecretaries of the Navy and Air Force, and hired biologists to try to find the butterfly elsewhere and to question its nomenclatural validity (Wells, 1987).

A philosopher would have to be either very learned or foolish to presume to tell environmental managers what they can or cannot do in technical detail about the skipper at the dam or the checkerspots at the defense site and landfill. Philosophers have no expertise about dams, mitigation measures, guided missiles, waste management, or Lepidoptera. Not being learned, hoping not to be foolish, is there anything I can say about engineers and butterflies? Perhaps. Questions within technology belong to environmental professionals, but when questions about technology arise, a philosopher can join the discussion. Science, pure and applied, has to be evaluated to reach a philosophy of nature, of life. Philosophers can locate and examine foundational worldviews that govern human behavior.

In that sense, "engineers" as used here serves as a kind of diagnostic symbol, not simply to refer to professional engineers as such, but to managers, executives, investors, citizens who employ professionals to do engineering for them, and to all those who are party to that dramatic rebuilding of the world in which engineers stand as representative agents. "Butterflies" serves as a symbol of wild, spontaneous nature, prior to its being engineered according to human desires. Engineers and butterflies are both instances of more comprehensive principles: science-based, industrial culture and pristine nature.

Environmental management is laden with theories of nature and judgments about human roles in the world. Whether on the Denver Water Board, in Waste Management's corporate offices in Oak Brook, Illinois, in the United Technologies' offices in Connecticut, in the San Francisco law offices of Pillsbury, Madison & Sutro, by federal legislators in Washington reauthorizing the Endangered Species Act, or by biologists and environmentalists defending the butterflies—all professional behavior is directed by social, economic, political, and institutional commitments, as well as by personal commitments, all of which are rooted in a world orientation. Willy-nilly, like everyone else, environmental professionals profess some faith that drives their ethics. By making this clearer we can evaluate—justify or reform—our views about what is and what ought to be. We can find the theory that drives practice in deciding whether to let the skipper be or replace it with a dam, whether the checkerspot puts any constraints on national defense or dumping trash.

VALUING TECHNOLOGY: ENGINEERING VALUE FROM NATURE

Two different convictions mingle here; both are evaluative offspring of science. One involves what we believe about technology, the deliberate management of nature—in a word, beliefs about *resources*. The other prior belief is what we believe about nature itself—in a word, beliefs about the natural *sources* before they become resources. For instance, if we are convinced that the natural world is value-neutral—a conclusion many have thought to reach from the scientific point of view—then we may find that humans are free to assign values to nature in any way they wish. Here scientific knowledge steadily increases our options for managing nature. The skipper is worthless on its own; humans can do as they dam(n) please.

Business and labor use resources resourcefully, and this effort spent transforming nature sometimes leads environmental professionals, following a widespread opinion in technological society, to see nature apart from human occupation as undeveloped and devoid of value. Crude oil in ignorance of technology is wasted, long-dead dinosaurs; add the genius of a petroleum engineer and, presto: we gain energy to fuel a culture. Clever human labor (= engineering) places value on natural resources. Nature assumes instrumental value when human agency harnesses, harvests, transforms it; prior to that nature had no intrinsic value.

Applying this account to Two Forks, humans want dependable water in town; wild nature gives only a sporadic river, a spring runoff, a canyon sprinkled with skippers. It is the engineering that adds the value. In California, defense technology is all important; with rockets and missiles the nation can defend its territorial interests in the world; wild nature offers only ores and fuels and, at San Jose, rolling, rocky grasslands with enough space to hide secret technology from prying eyes. San Jose needs a site big enough to hold its trash for fifty years; the city is so adept in technology that it requires advanced waste management to deal with the leftovers from its consumption. What better place than the wastelands of Kirby Canyon? The natural world provides place, scope, materials, opportunity for human enterprise.

This value added by labor has been universally present in human experience and is prescientific. But in the recent, scientific centuries humans have impressively increased their technological power; labor has become progressively more valuable, raw materials consumed with an ever more voracious appetite, those materials ever more remote from the finished products, so transformed that they are ever harder to recycle back into the native ecosystems, and therefore accumulating at the dump.

But ingenious engineers can find substitutes, can work their will more and more on plastic and recalcitrant nature, can discover technological fixes. We can colonize the moon, or, if that seems outlandish, we can make the desert bloom—as the Two Forks dam will do on the arid plains of Colorado and as has already happened over stretches of California. As knowledge enables humans to escape the constraints of spontaneous nature, engineering skill becomes increasingly valuable; raw nature, though always instrumentally required, becomes decreasingly valuable.

DEVALUING NATURAL HISTORY: ACCIDENTAL, BLIND NATURE

The companion belief is that wild nature is intrinsically value-free. This conclusion is thought to be sound because it is supported by pure science, rather as the labor-adds-value conviction is intensified when coupled with applied science. Prior to the age of science, prior really to the industrial revolution and the Darwinian revolution, our forebears did not ordinarily think of raw nature as being value-free. Often religiously inclined, they thought the world was engineered by the Creator, who had pronounced each species good. Or, if philosophically inclined, they thought the world bore the impress of the Platonic Form of the Good or tended toward Aristotelian goals as form impressed matter.

Today, scientific discoveries can seem to converge on the intrinsic valuelessness of nature. The world is a jungle where every living organism survives by outcompeting its competitors. An ecosystem is a loose collection of externally related parts, the antithesis of anything engineered. It is chaos and happenstance, the intermingling of unrelated lines, contingent juxtapositions, the conflict of individuals each aggressively pushing to wedge itself into place. By that account, the skipper resides in Two Forks Canyon as a Pleistocene relict, there by accident. Likewise, some whim of nature has adapted the checkerspot to the nutrient-poor vegetation of a few plots of serpentine soil around San Jose and the San Francisco peninsula. Both survive by luck and struggle; neither is all that impressively biologically competent, else both would be more common.

If a person were to enter the offices of Denver consulting engineers and find them throwing dice and thereby designing the Two Forks dam, he would be dismayed at their stupidity. But that is what is going on in nature; there is dice throwing at the innovative core. Random mutations are tossed up without reference to any needs of the organism; and on rare occasions, some of these are preserved when they accidentally convey a survival benefit. From genes to species, at macroscopic and microscopic levels, evolutionary natural history is a random walk.

Jacques Monod in a celebrated conclusion found that natural history, humans included, is the "product of an enormous lottery presided over by natural selection, blindly picking the rare winners from among numbers drawn at utter random" (1972, p. 138). Stephen Jay Gould agrees: "We are the accidental (and) fragile result of an enormous concatenation of improbabilities" (1983, pp. 101-02). Darwin exclaimed that the evolutionary process was "clumsy, wasteful, blundering, low, and horribly cruel" (quoted in de Beer, 1962, p. 43).

None of these words have much intelligibility or value in them. They leave the world absurd, inelegant, and doubtfully aesthetic. That makes it all the more imperative for humans to engineer values in an otherwise valueless world. The historical, evolutionary past producing the Two Forks ecosystem is as erratic as the flight of a moth circling about a candle flame. The essence of engineering is intelligent design; the essence of nature is blind luck.

Homo sapiens is the professional manager of an otherwise drifting, valueless world; man is the engineer in an unengineered world. Humans couple the technological power of brain with hand and go about their business resourcefully, aggressively defending their interests, assigning values as they please. Humans are on top of the scale of values, and insects are near the bottom. Those are the value commitments that routinely orient engineers and those who employ them as they encounter butterflies. Can this world picture be painted in a different light?

REVALUING NATURE: NATURE AS ENGINEER

The randomness at the innovative core that first seems so senseless is really a form of creativity. Mutation, crossing-over, and related permutations represent the capacity of life to experiment, to proceed by trial and error methods. The mutation is a trial "idea" (Greek: *idea*, form, type), most often neutral or detrimental, but sometimes beneficial in function because it enables the organism to handle itself better in relation to the environment or even to invade and exploit a new environment. This groping, blind character strikes many as being wasteful and dumb; but we have now to notice something more. The capacity for mutation has exploratory value. Mutation forms the context of discovery; natural selection is the context of justification. The editing pressure is of value because from many trials, the beneficial inventions are preserved and the rest eliminated.

Natural selection tends to conserve the best of nature's constructions within a particular ecological niche. Almost axiomatically within the theory, each life form has to have a comprehensive situated fitness. Evolutionary pressures will tend to adjust toward a maximally favorable blending of retention and variation. The usual case is that each organism is mostly *hit* and a little *miss*, and the miss is really an experiment. The old "hit" is when the cumulative know-how of that species is successfully inherited, but also with a new shot gambling to see what else there is to hit.

Consider the results in butterflies. Butterflies must fly, an energetically expensive form of locomotion, fueled by high-energy nectar (or other sources such as fruit juices). In refueling, they suck nectar up a long, thin proboscis. Nectar with the highest sugar content is too viscous to draw up the slim tube, and the proboscis has to be structured and flowers selected that optimize sucking pressures against sugar content and viscosity of the nectar. Butterflies must warm up to fly, and the wings serve as solar energy panels both conducting and reflecting heat to abdomen and thorax and raising temperatures to functional levels. Wing colors, dark and light, are adjusted for optimal absorption and reflection, as also is the angle at which the resting wings are held. The fluttering flight of butterflies uses a flap and glide in which the wing, controlled by muscles at the base, has a structure with a stiff leading edge and great flexibility among the wing chords—from an engineering point of view, the best compromise among several crucial flight functions. In some cases the aerodynamic factors are so delicately balanced that if a butterfly is transplanted 1,000 meters in elevation, it can no longer fly (Kingsolver, 1983, 1985a, 1985b, 1987 and references there; Kingsolver and Wiernasz, 1987).

Deliberate thought also requires the launching of many trial ideas, with the selective testing of these in experience. The vastest number of these innovations are abandoned; very few prove to add to our know-how and are worthy to be transmitted to posterity. Looking at the invention and engineering of the internal combustion engine or the aircraft, one sees abandoned a thousand dreams and attempts for every component that we now inherit, as there were eliminated a thousand mutations for each one now preserved in the Pawnee skipper. There is relentless pruning back by a cost-effective editing process so that only the best-adapted survive. Detroit engineers do a lot of this sort of tinkering, pressed toward efficiency, defeated if their trials are structurally or functionally unsound.

It will be objected with some justification that spontaneous natural evolution is devoid of consciousness and therefore wholly unlike deliberate engineering—a crucial difference. The one kind of creativity takes place in the genes, the other in the mind. That is true; there are important cognitive and moral consequences. But a crucial difference does not mean there are not also significant similarities.

We first think that engineers and those who direct them know what they want (a dam) and how to get it (with blueprints). Butterflies, knowing nothing at all, flutter erratically about. But neither extreme is entirely true. Denver citizens, their leaders, with their engineers, are figuring out what they want—a dam? a skipper? a wild trout stream? bluegrass lawns? What will be the shape of society alongside or replacing wildlands and wildlife? What are the now unknown means to obtain what they choose?

In that sense engineering technology and the social development that directs it moves by formulating hypotheses on the forefront of experience, by testing these, and preserving only those few that succeed. A think tank of consulting engineers in Denver, groping to meet Denver's water needs with the least environmental disruption, does cast up random trial variations on what has worked before and select the fittest. In terms of human imagination and logic, it is not always a waste but sometimes an index of creativity to cast forth a thousand ideas so as to sort out the single best one. From this perspective, the evolutionary process, far from being irrational, is a prototype of the only kind of rationality that we know. It is not babel; there is a logic to it, not only to its information conservation, but to its random exploration and problem-solving. It might at first seem that evolutionary processes only simulate rationality. They are in fact a genetic form of cognition.

Imagination is as necessary as is logic for rationality. Mutation scans for new "ideas," and natural selection throws out the trash and saves the gems. This innovative exploration is of great value as it accumulates into the drama of natural history. The mutants and reshufflings first seem to be mistakes, but seen again are the key to the entire evolutionary growth. Skippers and checkerspots are not intentionally crafted and inserted into Colorado canyons or California hills, not as human engineers insert dams or missile facilities there. Still their way of living is a fit form experimentally crafted for a niche. A two volume report, comparable to the 1300 pages of the draft EIS, could as easily be written on engineering principles spontaneously at work in the Two Forks ecosystem, its fauna and flora. The fossil record is no more evidence of the chaotic unintelligibility of natural history than a trash heap outside an engineer's office is evidence of the unintelligibility of events in that office.

The word "engineer" comes from the root *ingenium*, an innate genius, an inventive power, and hence our word *ingenious*, "characterized by original construction." In that sense there is ample inventive and engineering power in nature, which has built the skipper—more impressive in many ways than that of the engineers who build the dam. The skipper in the Two Forks ecosystem is neither accidental nor clumsy, though it is not designed in the human sense. It is an ingenious natural achievement. With that, we have reversed our paradigms. Nature is not the antithesis of engineering; it is the prototypical engineer.

OPTIMALLY SATISFACTORY DEVELOPMENT

Recent biology has emphasized not so much aggression, struggle, or chance as efficiency, habitat fitness, and coaction. The paradigm is not survival of the fittest in a chaotic jungle, but of the well-adapted in a biotic community. Each life form is specialized for a niche, limited to its own sector and woven into a web, so that it depends on many other species in a pyramidal, dynamic biomass. If not checked from within, a species' genetic impulses are checked from without by the natural incorporation that keeps every living thing in community. An ecosystem is an economy in which the many components have been naturally selected for efficient fitness in a prolific system. There is little waste of materials and energy. Wherever there is available free energy and biomass, a life form typically evolves to fill that niche and exploit those resources.

The natural ecologies humans invade are durable; they have worked about as they do for tens, or even hundreds of thousand of years. Though there is species turnover, some communities have persisted, migrating before changing climates, over many millions of years (Axelrod, 1959), and some specific lepidoptera-plant associations have persisted from the Miocene to the present (Opler, 1973). In that sense, ecosystems and their associations are classics.

Alternately put, an ecosystem is a quite satisfactory place, in the objective sense that there is a sufficient but contained place for all the members, each with a situated environmental fitness, coupled and coordinated with the welfare of many others. Individuals are short-lived, and organismic needs are not all satisfied, of course. Individual organisms flourish but are also eaten, starved, become diseased, and die. Other organisms flourish in result. But the sacrificed individuals are replaced, and species survive for millions of years, as long as they remain adapted to their environments. Any species that, like the Pawnee skipper, has a home (*oikos*, the root of ecology, a niche) occupied since before Pleistocene times has a satisfactory place.

There is an engineering worldview that overlooks the Two Forks ecosystem and thinks, "The gorge is wild now; it will be good to develop it." Subjectively speaking, such development might be a good thing from the point of view of human preference satisfaction. (On the other hand, it well might be the case that more and higher quality human preferences can be satisfied with the gorge left wild.) But from an objective point of view, were humans to "develop" the gorge with inadequate environmental mitigation, we would be replacing greater with lesser elegance, complexity, beauty, stability.

Complexity is not in every case a good thing; in engineering the simpler mechanism is to be preferred, provided that it is adequately functional; it will be cheaper and more reliable. But complexity in nature and often in culture is a key to richness, diversity, individuality, uniqueness, integrity, and stability. There is more integration of parts in whole in a skipper than in a dam, more organismic, "organized" unity. The skipper is a self-replicating kind, spontaneously reproducing itself for several million years, uniquely adapted to this habitat since Pleistocene times; the dam is a mere machine, good for fifty years, perhaps with daily outside maintenance.

The Two Forks ecosystem is a prolific place, a prime wildlife habitat for deer, elk, bighorn sheep, beaver, and turkeys. The north abutment of the dam is to be placed at a significant bighorn lambing site. A Colorado Division of Wildlife study found that the productivity of the trout stream to be inundated "is one of the highest known anywhere in the world" (Goettl, 1984, p. 13; 1987). The U.S. Fish and Wildlife Service has designated it to be in Resource Category 1, its highest designation for identifying valuable ecosystems, and said that the river canyon "represents a uniqueness seldom found on a national basis and unparalleled in the state of Colorado" (U.S. Fish and Wildlife, 1986). The dam would trade 10,244 acres of wildlife habitat and 60% of surrounding wetlands for a large bathtub in the mountains. It is difficult to find an objective perspective from which, after the dam, there would be greater diversity, richness, productivity than before. Development, so-called from a subjective human viewpoint, would objectively degrade the canyon. "A thing is right," said Aldo Leopold, "when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (1969, pp. 224-25). Apply that criterion here, and there will be no dam.

Well, comes the reply, of course dams and generators are less diverse and complex than butterflies and ecosystems, but that is an incomplete comparison. Fit the dam into a culture and the picture will change. Two Forks water will support urban

Denver and its suburbs, and humans outrank butterflies in the elegance, beauty, complexity, significance of their affairs. A thing is right, say the utilitarians, when it produces the greatest good for the greatest number of people. Surely a bustling metropolis is a better thing than a semiarid canyon. Leopold's criterion can be overridden by the integrity of the cultural community.

There is some truth in such a reply, but it is certainly no foregone conclusion that anything in city life trumps everything wild. Nothing directly correlates the excellence of human culture with an ever escalating thirst. Denver citizens use 221 gallons of water per day per person; in the summer months 80% of this is for watering lawns. Are there any good arguments, objective ones, that make it plausible that satisfying a human thirst for bluegrass lawns in arid Colorado is more noble than leaving wild a quite satisfactory, prolific ecosystem? Perhaps what Denverites need is development of their perceptive capacity, not their consumptive capacity. There lies before Denver and its water engineers a canyon full of ingenuity. Could they see this, a decision to swap this wildness for the cultured simplicity of suburban lawns might seem philistine.

There is an engineering worldview that overlooks the hills outside San Jose and finds it airy and frivolous that a butterfly should slow the delivery of warhead missile propulsion systems. Operating with such a view, presumably, United Technologies recently went ahead and dug a water pipeline through a butterfly patch. But there is a more objective mood. The Bay checkerspot, much studied by Stanford University biologists, is one of the best known natural populations of invertebrates and really a more marvelous phenomenon than the missiles United Technology builds.

Humans who can make rockets are certainly more sophisticated than butterflies who cannot, but it does not follow that human products—even sophisticated high technology products—are more elegant than what they replace in spontaneous nature. At first, the diminutive checkerspots can seem trivial beside the giant rockets; but then again, just the miniaturization is impressive. Space-age engineers, with their computer guided missiles, know about that; they have been steadily driven down to the microscopic levels by design requirements for efficiency, economy, light weight, calculating speed, memory storage, and information processing. Inside exoskeletons, insects did it first. They have external structures that are often more complicated than those of birds or bats, controlled by internal systems that are quite sophisticated and more miniaturized. About the size of a microchip, a ptiliid beetle has six legs, a pair of wings, a digestive tract, reproductive organs, a nervous system, and genetic information that, translated into a code of English words printed in letters of standard size, would stretch 1,000 miles.

Engineers (with their managers) who can and do make rockets simultaneously with a concern for preserving butterflies are more sensitive to the comprehensive ingenuity in their world than engineers who cannot or will not. If humans are to build their cities, waste managers must sacrifice some sites. The San Jose dump will be less complex than the Kirby Canyon ecosystem it replaces, but that tradeoff seems justified for life in San Jose. Nevertheless, Waste Management has resolved to keep the butterfly there if it can. The trash managers have proved more sensitive than space-age engineers to an optimally satisfactory development. What Denver, its politicians, and its environmental professionals will do remains to be seen.

THE CHALLENGE: RESPONSIBLE ENGINEERING IN NATURE AND CULTURE

Cultural progress ought to complement biotic process. When culture is superimposed on nature, optimally satisfactory development should count values in both culture and nature, and ingeniously engineer the maximum development of the one consistent with the minimum disruption of the other—a "maximin" principle. A related corollary is that we spend as much effort asking what a place is (an ecosystem) as we do asking what it is not (a dam, a missile site, a landfill). We need to know what we are undoing before we can really know what we are doing and if the scope of our destruction is not greater than the scope of our construction.

Still another corollary is that, while renewable biological products may (and must) be consumed by human development, irreversibly shutting down biological processes puts a strong burden of justification on those who purchase culture at such cost to nature. Alternately said, we ought not to spend biological capital without a resolute effort to engineer an alternative. One more corollary is that environmental decisions are to be made politically, philosophically, and scientifically, as well as economically and technically.

Something like this "maximin" policy underlies much environmental legislation in the last quarter century. Consider, for example: the National Environmental Policy Act with its requirement for major federal policy projects a detailed statement of expected environmental impacts and of alternatives to the proposed action; the Endangered Species Act, with its requirement of a no jeopardy opinion for listed species; the Wilderness Acts, setting aside regions where the earth and its community of life are untrammeled by man; and the recent Food Security Act, with its provisions to discourage swampbusters and sodbusters and to encourage conservation reserves and easements. Without NEPA and ESA to regulate what is happening in Denver and San Jose, the course of events there would be radically different. This legislation reflects a national will that engineers and environmental professionals give butterflies a place in their worldviews.

In a pluralist, capitalist democracy, the will of society is not always, perhaps not often coherent, and engineers are often caught in social contradictions. Decisions are made elsewhere, by developers, industrialists, speculators, financial institutions, legislators; engineers are hired to execute decisions at the lowest possible cost. There is little room left for creative approaches and environmental sensitivity. There is an understandable tendency at this point for engineers (those with professional careers as engineers) to shrug their shoulders and pass the responsibility elsewhere in the society that purchases their engineering skills. Yet, like those atomic scientists who waked up to ethics when bombs were dropped on Hiroshima, engineers are waking up to the destructive as well as the positive results of their engineering powers. Over the long term, the threatened loss of biotic diversity is comparable to the threat of nuclear war. Anyone who releases power in the world has an ethical responsibility.

Environmental regulation has arisen to protect by national will environmental values whose protection cannot be left to economic interests alone. In that sense, for an ingenious engineer, regulation brings freedom. By insisting on a specification, consideration, testing of alternatives in the full view of environmental and social impacts (as NEPA does), or by insisting on a no jeopardy solution if this is at all possible (as ESA does), environmental policy enlarges the context of discovery of ideas and the context of their justification. It allows a wider scope of imagination, more opportunity, a broader generation of trial ideas. Seen at the right level, regulation is not prohibitive policy, not policy that tells you what you cannot do. Rather it is liberating policy, because it pushes back economic constraints to allow a larger perspective, permitting sensitivity to environmental and cultural values. It allows engineers to operate within a more inclusive worldview and requires them to think about optimizing satisfactory development as culture is set within nature, not simply to submit to criteria of economic efficiency. Aphoristically put, environmental policy permits engineers to be gentlemen, gentler persons when they walk over the earth.

Sometimes it is said that for engineers the numerator can be a public or environmental good, but the denominator must be a dollar mark. Perhaps that is true if one is left to business pressures alone on any particular job, but when we add the policy imperatives it is truer to say that, while the numerator can be a dollar mark, the denominator must be, and ought to be, an ecosystem. Earth carries humans most gloriously, but it cannot and ought not carry humans alone. The best of worlds is not one entirely engineered by humans, but one that has place for natural ingenuity. The best of engineers count butterflies in their worldviews.

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