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EDITOR'S COMMENTS

Our readers are due an explanation and apology for the late appearance of this January 2007 issue of *Physics and Society*. The January issue is usually completed and sent to the publishers at the American Physical Society, in mid to late November, thus allowing time for printing and mail distribution during the usual end-of-year surface mail glut. At that time, we were still waiting for the Forum elections materials, normally included in the January issue. Unfortunately, the Forum's Nominating Committee was unable to complete its task before I left for a three week mid-winter trip outside of the country. Consequently, the January issue had to wait till I returned, by which time the Nominations Committee had finished its task and had commenced a purely web-based election process. Please vote online at: http://physics.wm.edu/ballot.html. The election is open until March 1, 2007.

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IN THE OCTOBER WEB ISSUE

The Nominations Committee would have been able to finish its task earlier and easier, thus avoiding this publication "snafu" if more of our members had volunteered to serve in the elective positions of the Forum. Please remember that it is your Forum; you make of it what you will, provided that you provide some input into its processes. Please get involved!

In this issue we continue with reports from physicists who have been importantly involved in shaping public policy — in our Physical Society and the more general society: both John Gibbons and Wolfgang Panofsky have rendered important services to physics as well as to societal policy making and serve as role models to all of our members, young and old.

—A.M.S.

NEWS

In the Issues & Events section of the November 2006 issue of *Physics Today*, Jim Dawson describes the formation, in September 2006, of a national political advocacy organization called Scientists and Engineers for America (SEA). The board of advisors of SEA includes 8 Nobel laureates as well as former President Clinton's science advisors, Jack Gibbons and Neal Lane. The impetus for creating SEA was frustration with the marginalization of science issues debate in the recent elections, as well as with the abuse of science by the Bush Administration.

SEA has a long term agenda of focusing more attention on scientific issues during elections (e.g., global warming), as well as challanging scientifically questionable statements by candidates of any political party (e.g., Virginia Senator George Allen's signature of a letter stating that there was little evidence linking global warming to human activity). Mike Brown, SEA's executive director, said, "We can't endorse candidates, but we can challenge statements made by candidates."

In addition to attempting to focus more public attention on scientific issues that affect the public well-being, SEA's organizers have developed a bill of rights for scientists and engineers. It calls for right of intimidation-free debate of non-classified issues, for the prohibition of intentional publication by the federal government of false or misleading scientific information, and the requirement that appointments to federal science advice committees shall be based on scientific qualifications, "…not political affiliation or ideology." The bill of rights also states that the federal government "shall not support any science education program that includes instruction in concepts that are derived from ideology and not science."

—J.M.

Responses to Survey of Women in Physics

A 2005 survey of women working in physics around the world found that most would choose a physics career all over again. Yet at the same time, many had concerns about family and child-rearing responsibilities and feelings of isolation from colleagues, as well as concerns about funding, equipment and lab space.

The survey was conducted by the Statistical Research Center of the American Institute of Physics, in conjunction with the 2005 Second International Conference of Women in Physics. The report, "Women Physicists Speak Again," recounts the responses of 1353 women from over 70 countries, either working in a field of physics or as students.

A large majority (88%) of the respondents received their first undergraduate degree in physics, and 59% indicated that they received positive attention from their undergraduate physics professors. About one-third reported receiving attention that was neither positive nor negative, and less than 10% reported receiving negative attention or no attention at all, the report says.

Of the respondents with a graduate degree, 37% described the relationship with their (current or former) graduate advisor as excellent, and 41% described it as good. "What is surprising," the report states, "is the number of women who reported poor relationships with their advisors, but still persisted in physics."

A majority of respondents said that they made the decision to go into a physics career during secondary school. Many cited teachers and parents, as well as an interest in physics, as influences on their choice of career. Of those women physicists in the workplace, 68% work in academia, 15% in government, 7% in industry, and 10% in other areas of employment. Although the respondents "overwhelmingly said they would choose physics again (86%), a majority (71%) also reported being discouraged by physics." Reasons for being discouraged included: Interaction with Colleagues (55%); Funding(52%);

Research (49%); Personal Life (48%); Climate for Women (43%);and Family Obligations (35%) (respondents could choose more than one answer).

According to the report, “Two-thirds of all respondents said that their marriage affected their work.” When describing whether the effect was positive or negative, “Women in developed countries were much more likely to say that the effect of their marriage was positive (72%) than women from developing countries (58%).” The report goes on to say, “The effect of children on a woman’s career is perhaps stronger even than the effect of marriage.... Many women physicists stated that they had decided not to have children.” The report finds that ”Women over 45 from developing countries are more likely (86%) to have children than women from developed countries,73% of whom have children. Women in developed countries also tend to have their children at a later stage than women from developing countries.... Not surprisingly, almost all respondents said that having children affected their work, and the percentage is higher for women in developed countries.‰ In addition to the responsibility that many women physicists have for children, the report notes that ”20% of the respondents” indicated that they were primarily responsible for taking care of others as well.

In summary, the report says that the women physicists responding to the survey “have many things in common,” and “most spoke passionately about their love of physics.” Yet despite the similarities, it finds that “issues are not the same for women physicists in developing countries as they are in developed countries. Women in developing countries spoke repeatedly of a lack of basic resources (funding, office space, lab space, equipment, travel money, and clerical support). Women in developed countries also found these issues (particularly funding) challenging, but the percentages who said they do not have enough resources for research are higher in the developing countries.”

The complete report, “Women Physicists Speak Again” (AIP Pub. No.R-441) is available, along with other AIP reports on women in physics on AIP’s Statistical Research Center website, http://www.aip.org/statistics/trends/gendertrends.html. The National Academies have just released a report analyzing the barriers to hiring and promotion experienced by women in academia. That report will be highlighted in a forthcoming FYI.

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New Benchmark Report Raises Caution Flag on Future of U.S. S&T Enterprise

“These benchmarks make clear our waning commitment,” warns a new report by The Task Force on the Future of American Innovation. This report, updating an initial 2005 report, charts a range of worrisome trends indicating that components of America’s leadership in research and technology “are at risk.”

Twenty-one months ago, the Task Force issued “The Knowledge Economy: Is America Losing its Competitive Edge: Benchmarks of our Innovation Future.” This 18-page report has been credited with helping to raise the awareness of policymakers about U.S. R&D leadership (seehttp://futureofinnovation.org/PDF/Benchmarks.pdf.) Numerous other reports, including those by the National Academies (“Rising Above the Gathering Storm”), the Council on Competitiveness, and the President’s Council of Advisors on Science and Technology, raise dsimilar concerns. Last February, President Bush sent Congress his American Competitiveness Initiative recommending doubling the aggregate budgets over ten years for the National Science Foundation, Department of Energy Office of Science, and the NIST laboratory research program. The appropriations bills that would provide these agencies with the recommended increases for FY 2007are still on Capitol Hill.

The new report, “Measuring the Moment: Innovation, National Security, and Economic Competitiveness. Benchmarks of our Innovation Future II” was released on November 16 at a Capitol Hill press conference that will be reviewed in FYI #136. The 36-pagereport explains, “The Task Force on the Future of American innovation is a coalition of business, scientific and university organizations that came together in 2004 out of concern that insufficient investment by the federal government in research in the physical sciences and engineering was threatening the nation’s global economic leadership and national security in an increasingly competitive world.” The American Institute of Physics and the American Physical Society are Member Organizations of the Task Force. The report acknowledges: “Special thanks go to Steven Pierson of the American Physical Society as primary editor and to the editing committee of Eric Iverson of the American Society for Engineering Education, Peter Harsha of the Computing Research Association, James Lewis of the Center for Strategic and International Studies, and Tobin Smith and Barry Toiv of the Association of American Universities.” The report may be read at http://futureofinnovation.org/2006report/.

In comparing the two reports, the latest report states: “the problems we described last year — in areas that include federal support for basic research in the physical sciences and engineering, Ph.D.s in the natural sciences and engineering, students' interest in pursuing science and engineering studies, and the trade balance in high-tech products — have not disappeared. They are long term trends that the new figures confirm." Among those indicators are research investments as compared to other nations such as China and India, knowledge creation as measured by U.S. patent applications and the declining U.S. share of S&E publications, high-tech economy benchmarks such as the widening U.S. high-tech trade deficit, various sector benchmarks such as semiconductor and nanotechnology production and research, education benchmarks including the number of S&E graduates, and workforce benchmarks including reverse brain drain. Additional excerpts from the report will be provided in FYI#137.

The report concludes: "Those who stand still will fall behind. The United States has been standing still in basic research in the physical sciences for more than a decade — a decade of immense change and rapid growth in the global economy. The Benchmarks show that if the United States continues to stand still, it faces inevitable decline. Avoiding this outcome does not require huge outlays of federal funds — the research funds in the American Competitive Initiative, if approved, involve only about one-tenth of one percent of federal discretionary spending — but it will require a new attitude and commitment toward sustained investment in basic research. With this commitment, we believe that the United States can continue to prosper and lead in this still-new century."

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Web version: http://www.aip.org/fyi/2006/136.html
Richard M. Jones

Findings from the New S&T Benchmark Report

Earlier this month, The Task Force on the Future of American Innovation released "Measuring the Moment: Innovation, National Security, and Economic Competitiveness. Benchmarks of our Innovation Future II." The following are selections from this report; the complete document can be read athttp://futureofinnovation.org/2006report/.

"This outpouring of [S&T/competitiveness] reports from a broad range of interests has shaped the public debate. Certainly the American people are convinced. A strong majority believes the country needs to invest more in basic research. For example, a national survey conducted by Public Opinion Strategies and commissioned by this taskforce showed that 70 percent of the public supports increasing federal funding by 10 percent a year for the next seven years for university research in science and engineering. The same survey shows that 49 percent of the electorate believes America's ability to compete economically in the world has grown worse over the past few years. This number is up from 38 percent in 1991."

"Economists attribute a significant portion of the extraordinary boom in productivity during the 1990's to technological innovation. Citing innovation as the reason for significant gains in productivity growth since 1995, then Federal Reserve Board Chairman Alan Greenspan told Congress: `Had the innovations of recent decades, especially in information technologies, not come to fruition, productivity growth would have continued to languish at the rate of the preceding twenty years." The energy for this tidal wave of innovation came from basic research, much of which was performed years earlier on university campuses and elsewhere.'"

"While U.S. spending on military R&D is at a record high, recent increases have been devoted to applying existing ideas to the production of new weapons and equipment. We have been underinvesting in the basic research needed for the next generation of military technology. Since the end of the Cold War, the share of the Department of Defense (DOD) investment in science and technology devoted to basic research has declined significantly, from 20 percent in 1980 to less than 12 percent in 2005. . . . over the past five years alone, overall Research, Development, Testing and Evaluation (RDT&E) has grown by over one-third, yet investment in basic research has remained flat."

"The National Research Council and the Defense Sciences Board (DSB)have both sounded alarms concerning our investment in basic research in fields critical to our national defense, such as high performance computing and microchips and semiconductors. The point they make is clear: If the nation does not reinvigorate its investment in the creation of new fundamental knowledge for national security, the United States will not have the most advanced weapons systems and military technologies."

"The benchmarks presented in this paper show that countries such as China and India are increasing their innovative capabilities, fromr esearch investment and science and engineering (S&E) degree production to high-tech products, at a time when, using the same measures, the United States appears to be slowing. They demonstrate that to stay ahead we need to reinvigorate the foundation of our innovation economy."

"We can quibble about specific statistics and metrics used to measure current trends, but the big picture is increasingly clear. If we wait to be absolutely sure these trends are what they appear to be, it will become ever more difficult and expensive to recover."

"Fastest-growing economies continue to increase their R&D investments rapidly, nearly five times the rate of the United States: The countries of China, Ireland, Israel, Singapore, South Korea and Taiwan collectively increased their R&D investments by 214 percent between 1995 and 2004. The United States in that period increased its total R&D investments by 43 percent."

"U.S. physical sciences and engineering research budgets significantly lag economic growth: As a share of GDP, the U.S. federal investment in both physical sciences and engineering research has dropped by half since 1970. In inflation-adjusted dollars, federal funding for physical sciences research has been flat for two decades. ...Support for engineering research is similar."

"Innovators transform new knowledge into products and services. The United States has led the world in innovation and in the creation of knowledge that fuels this progress. Two benchmarks of knowledge creation, journal articles and patents, reveal that change around the world is eroding traditional U.S. leadership in these areas. Other countries are rapidly enlarging their stock of intellectual property assets and are expanding the boundaries of learning and discovery across all fields of science and engineering. Growth in patent applications around the world shows that these countries are also enhancing their abilities to put newly created knowledge to viable commercial uses."

"U.S. share of S&E publications continues to shrink: In the firs Benchmarks report, we reported that the U.S. share of worldwide science had shrunk from 38 percent in 1988 to 31 percent in 2001.The 2003 data reveal that the number continued to decline, due largely to increased Asian output."

"High-Tech trade deficit continues to widen: The annual trade deficit for advanced technology products grew in 2005, for the third straight year. The deficit of $44 billion for 2005 is now larger than the largest surplus of the last 15 years. The 2005 value marks the fourth straight year that the United States has imported more high-tech products than it has exported. While many of those imports come from countries in which U.S. companies own manufacturing facilities, this shift in manufacturing helps build technological capabilities in those countries."

"Across many sectors of the economy, signs of trouble for the United States are showing up in areas important to national security, technological leadership and industrial capacity, showing the ripple effects of lapses in support for research and education."

"U.S. leads world in nanotechnology but competition is fierce: Two recent reports, one by Lux Research and one by the President's Council of Advisors on Science and Technology, confirm that the United States leads the world in nanotechnology, but that future leadership is not assured. Despite doubled spending on nanotechnology between 2001 and 2004, the U.S. share of the global investment in this field decreased from 30.3 percent to 26.2percent."

"U.S. teenagers lag most developed countries in math and science literacy: In the 2003 OECD ranking of the mathematics and science performance of 15-year-olds in the 30 OECD countries, the United States ranked 18th and 24th, respectively, scoring below the OECD average for each. The rankings are similarly poor when the list is narrowed to the countries of the G8. To quote the 2005 OECD report, Education at a Glance, `With its relatively high expenditure and its relatively low student achievements at the school level, the United States education system is clearly inefficient.'"

"The United States falls behind in the ratio of undergraduate natural science and engineering (NS&E) degrees to broader populations: While U.S. NS&E degrees as a percentage of the population of U.S. 24-year-olds increased from 4 percent in 1975 to 5.7 percent in 2000, this country fell below the OECD average of roughly 6.8 percent. In 1975, only two countries had higher ratios than the United States. By 2000, 25 countries had higher ratios."

"U.S. universities are still best in the world: In its rankings of the top universities in the world, researchers at the Shanghai Jiao Tong University found that the United States had 8 of the top 10 and 35 of the top 50. A report from the Center for European Reform found that the United States has 18 of the world's top 20 universities, and 37 of the top 50."

"Asian production of natural science and engineering (NS&E) Ph.D.s is on a steep trajectory; U.S. figure stagnant: The number of NS&E Ph.D.s granted in several Asian countries is climbing quickly and shows no sign of slowing. Their production surpassed the flat figure of the United States in 1998 and the gap has been quickly widening. Three European countries collectively have more than the United States but show a similar flat to declining trend in recent years."

". . . U.S. student interest in science and math has waned so much since the Sputnik days that there are now fewer Americans studying science and engineering in U.S. graduate schools than foreigners. Luring America's young talent to science and engineering is essential to our future competitiveness, especially as more and more research and development opportunities develop in other parts of the world."

"These benchmarks demonstrate America's historical strength in science and technology, but they also reveal the impact of earlier decisions about the federal investment in basic research in physics, mathematics, engineering, chemistry and computing. The bench marks help us see how inadequate investment has helped to set in motion an erosion of American leadership in science, in turn jeopardizing the foundation upon which our future economic and national security will be built.

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Richard M. Jones

ARTICLES

Reflections of a Science Advisor: II. Approaches to Science Advice and Policy Formulation, and a Few Vignettes

John H.Gibbons

Part I of my tale of science and governance (Physics and Society, October, 2006) offered some general reflections on the two interdependent but disparate worlds of science and politics with a brief discussion of the Superconducting Supercollider (SSC) and Space Station decisions. In Part II, I offer a few examples of approaching policy-making from a comprehensive perspective rather than from isolated considerations.

I suspect that my experience as a physicist (to think in terms of comprehensive solutions and in terms of cause and effect) and my responsibilities as Science Advisor (to work on very broad issues of national scope) strongly nudged me to approach challenges from a "systems" perspective rather than taking isolated actions. I offer here four examples of such an approach:

(1) Energy/Climate/Transportation: The Partnership for a New Generation of Vehicles (PNGV)

During the 1992 presidential campaign, Bill Clinton and Al Gore emphasized the importance of government's role in trying to solve the knotty, related problems of air pollution, climate change, and dependence on foreign oil. It was clear to us that governmental analysis was necessary, but by no means sufficient, for addressing these problems. We consequently devised an integrated action strategy for a public-private partnership. Within a month after Clinton's inauguration we created a public-private research and engineering partnership to develop, within a decade, a new generation of cars that would have much greater fuel efficiency, would be safe and economically competitive, would have low emissions, and could be manufactured and sold at a competitive price. Such an advance would require forming a working, cost-sharing, decades-long partnership among federal agencies, industry, and academia. The resulting "Partnership for a New Generation of Vehicles" (PNGV) advanced U.S. capabilities in part because of the sustained interest and support from the President, and especially the Vice President. This initiative was ably steered at OSTP by Henry Kelly, and it was also aided by annual independent reviews and critiques carried out under a special committee of The National Academies. Sadly, some of the technical advances (especially hybrid systems) that resulted were not capitalized upon by U.S. industry. Subsequently, Japanese manufacturers passed us by. Still, as one auto industry executive confided in me in 1999, the PNGV work helped advance the U.S. auto industry's technical capability (in cutting fuel requirements and air pollution) ahead by several years.

(2) Florida's Challenge: The Everglades

My second example is also national in scope but regional in focus. Owing to decades of actions by the U.S. Army Corps of Engineers, highway construction, agricultural industry practices, and urbanization, the southern half of Florida is beset with water pollution (mostly salt water intrusion and agriculture run-off) and a drying up of the Everglades. There has been an associated loss of the invisible but vital underground flow of fresh water down the Florida peninsula. We tackled the challenge from a systems perspective out of which came several complementary changes in public policy, including elimination of canals and dikes, tougher pollution standards (especially for sugar production), and more conservative pumping of groundwater.

(3) Mississippi River Basin Flooding

In pre-historic times, this great river basin nourished the land through periodic flooding. Because of continuing abuses associated with various public policies, the river system has lost its capability to replenish the land along its banks and offshore below the Delta. Huge areas are so poisoned by the gunk brought downstream that a large area of the once biologically rich Gulf waters are anoxic and barren. To contain floods, dikes and levees were built to compress the river and deny it an opportunity to spread its floods and silt more gently over the land. The effects of these and other ill-conceived human actions are increasingly devastating. Yet effective technical solutions lie largely fallow for want of sound state and federal policy decisions. The Administration's work led by OSTP through its National Science and Technology Council focused on integrating the talents in multiple federal agencies with regional and local jurisdictions. For example, following the floods in the mid-1990's, we helped develop viable policies for small towns to relocate beyond the flood plain and dedicate the flood-prone areas to pastures and woodlands that were more flood-tolerant.

(4) The Pacific Northwest Challenges

Uncoordinated attempts to use natural resources of forests, fresh water (flood control, irrigation, electricity generation), and fish (especially salmon), have led to degradation of the land and depletion of highly valued fish (again, especially salmon). Over-harvesting of timber has threatened wildlife and degraded spawning grounds, and impoundments have caused devastating losses of migrating fish. Again, with active engagement of the President and Vice President, we helped broaden awareness of the related issues and the practical opportunities. Through cooperation, we applied best scientific practices and integrated the agency resources of agriculture, energy, and forestry across a multi-state region with the goal of more sustainable development.

A Few Other Vignettes

Within the Clinton Administration the science advisor's role was sometimes ad hoc, direct and personal (e.g., my recommendations to the President on high-level S&T appointments; my representing the United States in international meetings of science ministers) and sometimes more formal (such as my membership on the President's National Science and Technology Council, my co-chairing of the President's Committee of Advisors on Science and Technology, and my helping to establish the National Bioethics Advisory Commission). These more formal entities enabled our Administration access to a rich source of public and private sector national wisdom on critical issues. I note here that this kind of help works best when the political leaders recognize that the sharing of information and concerns, not the sequestering of the same, can be a great source of power and influence. Here are a few examples of such activities:

(1) Nuclear Testing

A moratorium had been placed on testing for several years, but proposals to resume nuclear testing soon came from within the new Administration. Two reasons were proffered: first, to make existing warheads less susceptible to fire, and second, to gain more confidence in reliability as warheads aged. Subsequent discussions in which I was engaged concluded that the alleged fire safety hazard could be resolved without nuclear explosions, and also that there were alternative ways to assure non-degradation of aging warheads. After considerable negotiations and technical discussion, we worked out a consensus at the cabinet level (National Security Council), easing the burden of the President's decision to halt further efforts to resume testing. I did not realize at the time that our proposed "stockpile stewardship" program later would be transformed into such an expensive activity. Some forms of institutional momentum are exceedingly resilient!

(2) U.S.-Russian Cooperation on Disposition of Fissile Materials

I asked John Holdren (a member of the President's Advisory Committee on Science and Technology (PCAST)) to lead an analysis for the President on the most promising ways for U.S. and Russia to cooperate on protection and disposition of fissile nuclear weapons materials.

The challenge of plutonium disposition is more complex than that for uranium, but the two most plausible options are (a) to mix oxides of plutonium and uranium in the right proportion to be fuel for reactors (MOX); or (b) blend the weapons plutonium into high-level waste from power reactors to make it irretrievable. We suggested to the President that he keep both options on the table since at that time we favored option (a), but Russia favored option (b). The analysis took several months to complete. Less than two weeks after John Holdren briefed the President and Vice President (an hour in the Oval Office), President Clinton met with President Yeltsin, and the plutonium issue was successfully addressed by the two. If we had pushed exclusively for our favored option and/or the Russians for theirs, the issue could have been frozen. Through agreement to proceed with disposition with either one or the other options as national choices, progress on plutonium sequestration/disposition continues. In the succeeding months of our Administration we had an opportunity to purchase from Kazakhstan about a half-ton of weapons-grade uranium (U-235). In the fall of 1994 it was airlifted to Oak Ridge, denatured with U-238 to become reactor-grade, and transformed into fuel elements for power reactors—a universally agreed method of disposition of enriched uranium. My task was to help arrange for the interstate transfer, quietly, of the material into Tennessee.

(3) Cooperative Research and Development Foundation

Reflecting the Administration's interest in fostering progress in American-Russian relations in the wake of the Cold War, the Vice President co-chaired discussions with his counterpart in Russia (and later with other countries) and then inaugurated a series of bilateral cooperative activities. I chaired the U.S. side on S&T cooperation, and many fruitful projects emerged. We soon recognized that the desperate state of support for science in Russia could be aided greatly through very modest funding support. Our aim was to seek funds to support Russian scientists who sought to change their work from defense-related to basic and civilian research focused on cooperation with U.S. scientists. At OSTP we were able to scrounge support from the DOD (Nunn-Lugar), the National Science Foundation, and George Soros (private citizen) to create an ad hoc pool to support multi-national, non-defense-related R&D. The concept, the Cooperative Research and Development Foundation, has proven to be much more successful than we anticipated—another example of the encouragement by the President and the Vice President for the science advisor's office to integrate resources from multiple agencies and the private sector. CRDF remains active and productive today.[1]

(4) National Bioethics Advisory Commission (NBAC)

At OSTP we saw the rapid advances in biology and genetics coming fast. However, there was insufficient expertise within OSTP for the Administration and Congress to tap for clear understanding and thoughtful response of not only the technical, but also the societal, implications for public policy. With bipartisan support from the Senate and at the request of the President and Vice President, I put together a charter and nominees for the President, modeled after PCAST. A year later in 1996 NBAC was up and running—only a few months before "Dolly", and the age of cloning, was born. NBAC's first task was to report to and advise President Clinton on the matter. The Commission still exists in the Bush Administration, albeit with a different name and membership.

(5) Global Climate Change: The Kyoto Protocol

From the start of the Clinton-Gore Administration, we recognized global climate change (GCC) as a massive looming issue. At OSTP I used one of my four available Associate Director positions for "Environment," recruited Bob Watson for that post, and also Rosina Bierbaum who had led the GCC assessment at OTA in the late 1980's. We worked closely with other Executive offices and agencies on improving knowledge of the dynamics and likely consequences of GCC—technical, economic, political and social. Bob Watson undertook leadership on intergovernmental cooperation in research and analysis of climate change, and Rosina Bierbaum helped pull the work together into a coherent, policy-relevant framework for key people in the Administration and Congress. When the group briefed Clinton and Gore prior to the meeting in Kyoto, I argued for a multi-decade time frame for action, reflecting the long-time required for an orderly infrastructure and technological change. Others pushed for action on a shorter time scale. The President agreed with my technical logic but decided on a 10-15 year target because he knew that a longer-term goal, however logical, would be fully discounted in political decision-making. I believe that he and I were both correct!

These vignettes are but a few of the myriad activities that flooded our agenda during my tenure of about five and a half years. Due to time and space constraints, I omitted in this article discussion of other major responsibilities that I had, such as S&T budgets, arbitration of interagency disputes over proposed regulations, and selection of key technical personnel for sub-cabinet positions and members of commissions (e.g., NIH, NSF, Energy, Commerce, DOD, Interior, State). Very few days passed in which my planned activities schedule wasn't changed! I found myself constantly stretched to the limit in technical knowledge and political wisdom. As I told a university president and friend of mine, my former experience in both physics and federal service were invaluable aids.

Finally, one of my best moves was to recommend my esteemed friend and colleague, Neal Lane, to succeed me. A flow of capable people is the lifeblood of good government!

Dr. John H. "Jack" Gibbons, President, Resource Strategies, and Chairman of the Board, Population Action International, is a member of advisory and working committees of The National Academies, the U.S. Department of Energy, and the Massachusetts Institute of Technology, among others. Following White House tenure (1993-1998) served as the Karl T. Compton Lecturer, MIT; Senior Advisor, U.S. Department of State, and Senior Fellow, National Academy of Engineering. Before he served in the Clinton Administration as Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy (OSTP), Dr. Gibbons was Director of the U.S. Congressional Office of Technology Assessment (OTA)(1979-1993). During the early 1970's "energy crisis" he initiated and directed the first work on energy conservation and policy for the federal government. See also johnhgibbons.org.

Nuclear Proliferation: Capability versus Intent

W.K.H. Panofsky

Since the beginning of the nuclear age, a new state has emerged as a nuclear weapons power roughly once every 5 years, as indicated in Figure 1. This growth has been slower than predicted by some experts familiar with the situation but such growth is still unacceptable considering that stopping proliferation of nuclear weapons remains the primary policy objective of the countries of the world. The reason why this growth is considerably slower than has been predicted, for example by President Kennedy in 1963, is the entry into force of the Nonproliferation Treaty (NPT) in 1970. This Treaty sealed a complex bargain which divides the world into Nuclear Weapons States (NWS) and Non-Nuclear Weapons States (NNWS) and imposes obligations on each. In this note, I will address only the obligations imposed on Non-Nuclear Weapons States. They are not to acquire nuclear weapons, while at the same time having an "inalienable right" to enjoy the benefits of nuclear energy, including generation of power and medical applications; the NNWS are to negotiate an agreement with the International Atomic Energy Agency (IAEA) to provide safeguards against diversion of relevant material to military purposes. Addressing this separate topic here does not signal the diminished importance of the obligations of Nuclear Weapons States to deemphasize the role of nuclear weapons in international relations. Working towards their eventual elimination must remain an inseparable component of the nonproliferation regime.

Acquisition of nuclear weapons by Non-Nuclear Weapons States can be categorized into "breakup," "breakdown" and "breakout." *Breakup* led to proliferation when the Soviet Union disintegrated leaving nuclear weapons in the hands of the Ukraine, Kazakhstan and Belarus, in addition to the Russian Federation. It took a major diplomatic effort to persuade the new States to give up their nuclear weapons and ship them back to the Russian Federation. *Breakdown* is the highly justified concern that States such as Pakistan, whose government was established by military takeover, may suffer further upheavals with the result that control over their nuclear weapons stockpile might prove inadequate to prevent their dispersal into irresponsible hands. *Breakout* is the problem associated with the ease of withdrawal from the Nonproliferation Treaty: the non-weapons programs of countries can accumulate many of the technologies whose attainment would shorten the acquisition time of nuclear weapons, and they can then withdraw from the Treaty. As written now, the NPT provides that three months advance notice be given for such withdrawal but does not require that a "just cause" for such withdrawal be given. North Korea is a case in point: after the so-called "framework agreement" was negotiated by the Clinton administration with North Korea, arranging for the cessation of nuclear reprocessing activities in exchange for major material benefits, that agreement deteriorated under charges of North Korean evasion by enriching uranium, and through the United States and its allies defaulting on their commitments to supply fuel oil and to assist North Korea in building a light water reactor.

North Korea has now tested a nuclear explosive, although their supply of plutonium for nuclear weapons construction is limited to probably less than one dozen warheads; the evidence of North Korea having succeeded in enriching uranium is unpersuasive. Iran is being accused of having a clandestine nuclear weapons program but maintains that its nascent uranium enrichment activities are to serve a civilian power program.

In encouraging the inalienable right of NNWS to civilian nuclear power, the NPT does not differentiate among the different elements of the nuclear fuel cycle, starting from uranium mining through ore processing, conversion into gaseous form, isotope enrichment, fuel fabrication, the use of fuel in nuclear reactors and ultimately either reprocessing of spent fuel by separating plutonium or alternately disposal of spent fuel in deep geological formations. Yet, two stages of the fuel cycle, namely isotope enrichment and plutonium reprocessing, also provide pathways to nuclear weapons and greatly shorten the lead time towards their acquisition. It is this potential for ambiguity in the NPT which produces latency towards acquisition of nuclear weapons by those NNWS who are including one or both of these elements in the pursuit of nuclear energy.

The problem of latency is that it is, in essence, the product of two dissimilar factors: *technical capability* in pursuing critical elements of the fuel cycle, and *intent*, that is, the perceived goal of the NNWS to produce nuclear weapons. This combination of capability and intent is shown in Figure 2. Latency is inherent in the nature of the NPT as enacted. To counteract this latency in an enduring manner, it would be necessary to amend or complement the Treaty. Instead, the administration has chosen the course of *selective enforcement*, that is, taking action to prevent those States it considers hostile or "evil" from engaging in either enrichment or reprocessing activities. In my view, this selective enforcement mechanism is bound to fail for a number of reasons. Firstly, the selection of targets for enforcement will change as the perception of friends and foes shift, and as governmental or societal changes occur in the countries in question. Secondly, such selective enforcement breeds disrespect for the NPT itself and thereby lessens the pressure on the Nuclear Weapons States to deemphasize the use of nuclear weapons in their international pursuits.

Let me illustrate this unsatisfactory situation by three examples: Iran, Brazil and Japan, starting with Iran:

Iran

Iran signed a nuclear cooperation agreement with the United States in 1957 and signed the NPT in 1958. It subsequently developed ambitious plans to construct 23 nuclear power plants by 2001 and contracted for construction of the Bushehr reactor with a German supplier. But then came the Revolution of 1979 which put the present Islamic clerically dominated regime in place. The European contracts were cancelled. The Bushehr reactor was damaged through bombardment by Iraq during the Iran-Iraq war; several years later Pakistan and China signed agreements of nuclear cooperation with Iran and it is likely that numerous technological transfers from the Pakistani Khan organization occurred thereafter. Russia has contracted with Iran to finish the Bushehr reactor with the current arrangement being that Russia will furnish the reactor fuel and take back the spent fuel for reprocessing or geological disposition. As provided for under the NPT, Iran has submitted its declared facilities to International Atomic Energy Agency inspection, but its disclosures to the IAEA have not been fully candid. In fact in 2002, a group of Iranian dissidents revealed Iran's progress in the construction of a uranium enrichment facility at Natanz which eventually could house as many as 50,000 centrifuges. Of these, only two "cascades" of 164 centrifuges each have been put into intermittent operation; while uranium hexafluoride gas has been introduced into these cascades, it is likely that no separated low-enriched, let alone high-enriched, uranium has been generated for use. Under external pressure, enrichment was suspended in 2003, but the resulting negotiations, intended to lead to permanent cessation of enrichment in exchange for a series of benefits, have thus far proven fruitless.

American administration spokesmen continue to claim that Iran has a nuclear *weapons* program while the International Atomic Energy Agency maintains that no evidence for such a program exists at this time. To put these facts into perspective, I note that perhaps 50,000 centrifuges will be required to supply fuel for a single one gigawatt reactor such as the one in Bushehr, and that if this total number was operational it could also serve to supply perhaps enough highly enriched uranium for 5 to 10 uranium weapons per year. Thus Iranian capability derived from its fuel cycle activities is very moderate today and the goal of Iran's program is debatable. The proclaimed *intent* is to serve an at-present nonexistent but planned large nuclear power program, and Iranian officials emphasize the *prestige* value of a complete indigenous fuel cycle. Thus the judgments of *latency* for weapons of Iran's program remain in the eyes of the beholder, but it does not constitute a clear and present danger.

Brazil

In 1951, Brazil established a National Council of Scientific Research and bought a complete 625 megawatt turnkey reactor from Europe. In 1970, a military government planned six reactors, each producing 1.3 gigawatt of electric power by 1998 and attempted to import foreign centrifuges. By 1980, the Brazilian Air Force, Army and Navy each pursued independent nuclear weapons military programs. All this changed when in 1988 Brazil approved a new constitution, ruling out the acquisition of nuclear weapons. Both Argentina and Brazil elected civilian presidents and terminated their weapons programs. The two countries signed a peaceful uses treaty and established a bilateral monitoring agency. That agency, together with the IAEA, negotiated a quadrilateral agreement with Argentina and Brazil for monitoring any civilian nuclear power activities. Nevertheless, Brazil has continued its centrifuge program and has developed domestic designs for advanced centrifuge technology. The claimed intent of this program, which technologically appears more advanced than Iran's program, is largely prestige and energy independence. The latter is not fully credible in view of the very large hydropower resources available to Brazil. Also Brazil has not permitted complete access of its centrifuges to the inspecting authorities, claiming the need to protect proprietary information.

In summary, the *technological capability* of Brazil seems to be ahead of that possessed by Iran. While its *intent* towards acquiring nuclear weapons is generally believed to be nonexistent, the prestige believed to be inherent in a complete fuel cycle may be a primary motivator. In contrast to that of Iran, Brazil's program has hardly been in the news.

Japan

The situation in Japan in respect to intent versus capability is quite different. Japan has an extensive nuclear power program and is pursuing a "closed" fuel cycle "burning" plutonium which is recovered from spent fuel. At this time, Japan has contracted with European suppliers to provide reprocessing services for its spent fuel; over four tons of reprocessed plutonium have been shipped back to Japan with a quantity about ten times as much owned by Japan but still stored in Europe. For reference, one can assume that 4 kilograms of plutonium might be adequate for a nuclear weapon. It should also be noted that while the isotopic mixture of the reprocessed plutonium is reactor grade, that is, it contains large quantities of isotopes other than the dominant 239, nuclear weapons can definitely be designed based on reactor grade plutonium. The official rationale for the accumulation of such a large plutonium stockpile is to provide for a closed fuel cycle which would burn the plutonium as Mixed Oxide Fuel (MOX) in light water reactors and for use of the stockpile to supply a breeder reactor. Both of these programs are real, but have been beset by failures and setbacks. Therefore, the availability of separated plutonium has run far ahead of Japan's ability to use it. Thus the *technical capability* of Japan to produce nuclear weapons is large and could be almost immediate since Japan has large industrial and human resources. However, *intent* to produce a nuclear weapon is contradicted by the Japanese constitution. Nevertheless, discussion of the need for nuclear weapons by Japan continues to resurface occasionally, particularly in view of the recent North Korean nuclear test. Also, some Chinese officials continue to express concern about Japan's nuclear weapons potential.

Technical Capability of NNWS

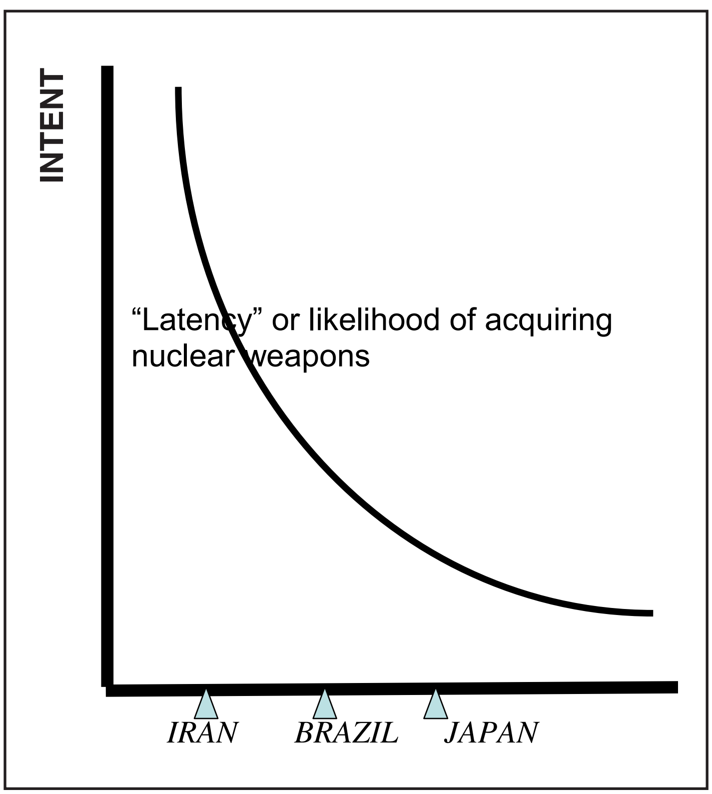

Figure 2

The above is a brief summary of the latency situation as it applies to three countries (Iran, Brazil and Japan). Clearly such latency by these three states, as well as that by other countries to varying degrees, constitutes a threat to the Nonproliferation regime. The extent of this threat is a matter of judgment, but the selective enforcement policies pursued by the current Bush administration are doomed to failure in the long run.

Worldwide, a great excess of weapons useable plutonium, as well as low and highly enriched uranium, exists for civilian and military purposes. Thus there is no economic excuse for additional NNWS to pursue enrichment. However, concern about assured supply of low-enriched uranium for civilian purposes, national prestige, in addition to the option or definite intent to acquire nuclear weapons can be the real drivers. There exist about 20 enrichment facilities worldwide including those operated by the States possessing nuclear weapons as well as the Non-Nuclear Weapons States indicated above, and Germany and the Netherlands. All the States possessing nuclear weapons operate spent fuel reprocessing facilities, but at this time Japan is the only NNWS possessing such plants. *Amendment* of the Nonproliferation Treaty to control reprocessing and enrichment is extremely difficult considering the onerous conditions for such an amendment. As has been pointed out by many advocates, the principal enduring solution would be to *complement* the NPT with international binding agreements assuring supply of low-enriched uranium for civilian purposes from an internationally managed source. The establishment of an internationally owned and operated "Fuel Bank" for low-enriched uranium would serve such a purpose. A variety of specific proposals towards this end have been put forward but at this time real initiatives towards that end have been lacking. We must do better lest the latency for nuclear weapons acquisition will undermine the world's nonproliferation regime.

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Number of States with Nuclear Weapons

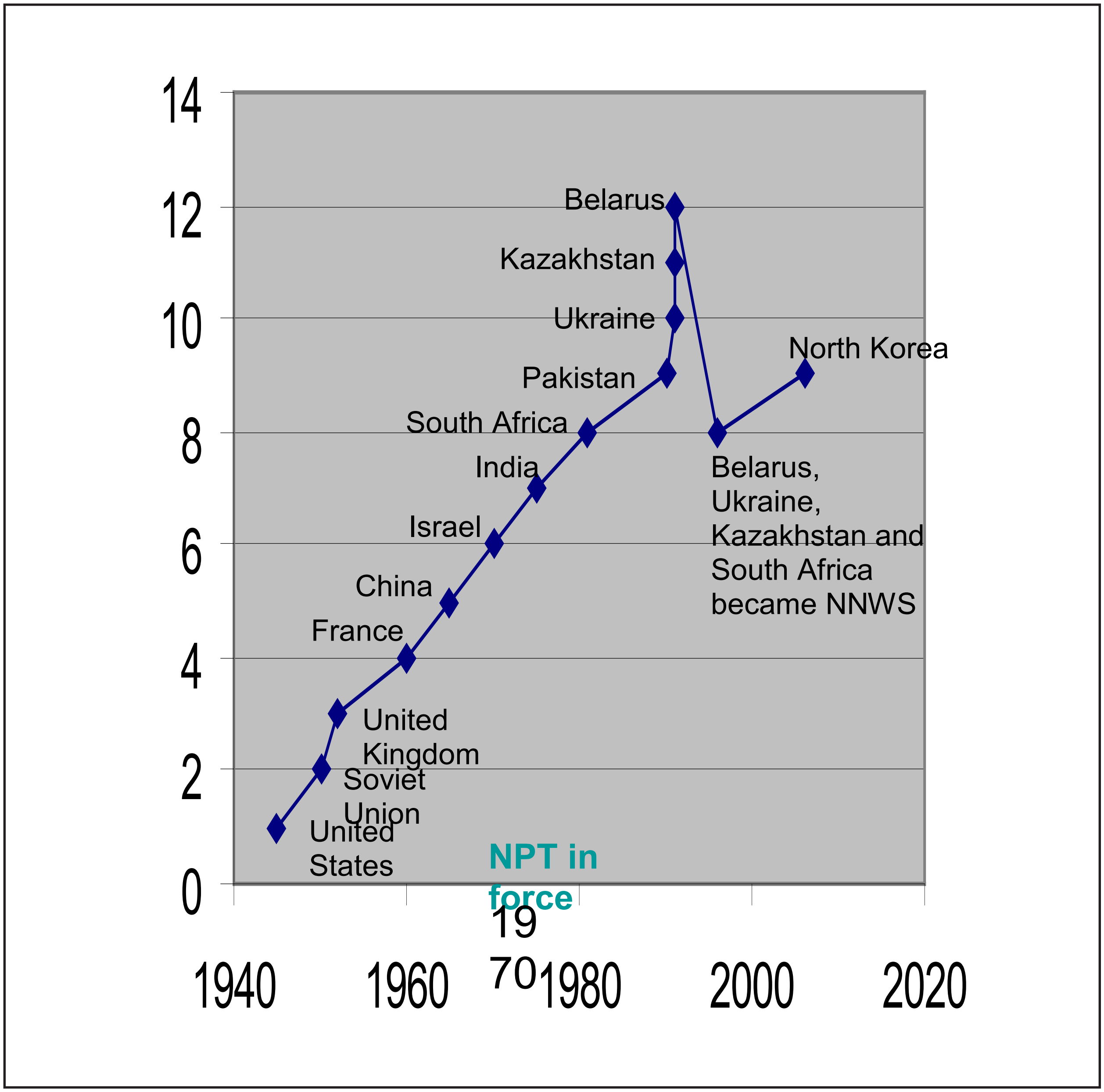

Figure 1

"I am haunted by the feeling that by 1970, unless we are successful, there may be 10 nuclear powers instead of 4, and by 1975, 15 or 20."

—John Kennedy, 1963

REVIEWS

An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It

By Al Gore (Rodale, Emmaus, 2006) ISBN 1-59486-567-1. $21.95 (paper). 328 pp.

Before seeing the movie of *An Inconvenient Truth*, Al Gore's film about the dangers of global warming, I had caught a fleeting glance at the book version. Noting that the graphical displays I had espied in the book were also shown in the movie, it occurred to me that the book would provide opportunity for greater reflection on the movie, so I bought a copy of the book the next day. There I learned that profits from both the book and the film are being contributed "to a nonprofit, bipartisan effort to move public opinion in the United States to support bold action to confront global warming."

The book indeed gave me a wonderful opportunity to reflect further on the film. The graphics of the film are colorfully displayed in the book, and this makes it a quick read. In fact, it would be ideally published in an enlarged, hardbound, cocktail table version. I was particularly struck by how Gore framed the issue: "Global warming is not just about science and..not just a political issue," he writes in his introduction. "It is really a moral issue."

"The relationship we have to the natural world is not a relationship between 'us' and 'it.' It is us and we are of it. Our capacity for consciousness and abstract thought in no way separates us from nature. Our capacity for analysis sometimes leads us to an arrogant illusion that we're so special and unique that nature isn't connected to us." (p. 161) "We have a moral obligation to take into account . . . the relationship between our species and the planet." (p. 216)

"The fundamental relationship between our civilization and the ecological system of the Earth has been utterly and radically transformed due to the powerful convergence of three factors," Gore points out (p. 216): (1) the population explosion, (2) the scientific and technological revolution, and (3) our fundamental way of thinking about the climate crisis.

"Many of our new technologies confer upon us new power without automatically giving us new wisdom" he adds, "and those with the most technology have the greatest moral obligation to use it wisely." Gore notes that the U.S. accounts for 30.3% of global greenhouse gas emissions.

Using his sister's death from cigarette smoking-related lung cancer as an example, Gore likens coal and oil company "hype" about uncertainty about the relationship between carbon dioxide emission and global warming to hype from tobacco companies about uncertainty between smoking and lung cancer. He uses this to deflate the first of the 10 most common misconceptions about global warming, namely the notion that scientists disagree about whether humans are causing the Earth's climate to change.

He acknowledges the following problems in thinking about the climate crisis:

1. It seems easier not to think about it at all, like a frog in water that is gradually heating up.
2. There is a disconnect between the consensus of scientists according to peer-reviewed journals, and the publicly-perceived uncertainty (according to newspapers) which give skeptics equal coverage in reporting of a science story as if it's a "debate."
3. "We have a false belief that we have to choose between a healthy economy and a healthy environment."
4. We feel that we're helpless, so that we might as well throw up our hands-- a feeling which Gore cites as moving directly from the denial in problem #1 (which he notes is "not a river in Egypt") to despair (which he notes is "not a tire in the trunk").

In spite of all these problems, he also acknowledges the basis for the title of his book: "The truth about the climate crisis is an inconvenient one that means we are going to have to change the way we live our lives. ...There's already enough data, enough damage, to know without question that we're in trouble. ...There is only one Earth, and all of us who live on it share a common future. Right now we are facing a planetary emergency and it is time for action."

The last pages are headed "What you personally can do to help solve the climate crisis," with many suggestions listed under the headings of "Save energy at home," "Get around on less," "Consume less, conserve more," and "Be a catalyst for change." This advice clearly shows that the key to controlling global warming is changing our present energy diet of fossil fuels.

In *The World is Flat*, Thomas Friedman writes that by changing our energy diet, President Bush could "dry up revenue for terrorism, force Iran, Russia, Venezuela, and Saudi Arabia onto the path of reform — which they will never do with $50-a-barrel oil — strengthen the dollar, and improve his own standing in Europe by doing something huge to reduce global warming." If President Bush doesn't do it, Friedman has clearly spelled out a platform of important political issues for 2008, and in *An Inconvenient Truth* Al Gore has clearly placed his feet firmly on that platform.

[This review was originally written for the Fall 2006 issue of the Teachers Clearinghouse for Science and Society Education Newsletter. It is reprinted here with permission.]

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The Revenge of Gaia: Earth's Climate Crisis & the Fate of Humanity

By James Lovelock, Basic Books,2006, xvii + 177pp., hard cover, $25, ISBN-13:978-0-465-04168-8

The very word Gaia may be sufficient to scare away prospective readers of this book. To me it conveyed a mystical entity which would be used by New Agers and not by respectable scientists. So my first task is to dispel such illusions and point out that the Gaia theory is the product of scientific observation, and like good scientific theories is subject to test and also bears predictive fruit. It comes from a scientist who is the author of about 200 scientific papers distributed almost equally among topics in Medicine, Biology, Instrument Science and Geophysiology. He has filed more than 50 patents mostly in detectors for chemical analysis. These have been important in pesticide research, the presence of PCBs in the natural environment, the global distribution of nitrous oxide and the chlorofluorocarbons and their application to the stratospheric chemistry of ozone. Some have been adopted by NASA in planetary exploration. He is a Fellow of the Royal Society and received numerous awards and prizes.

Dr Lovelock's latest book summarizes his life's work, primarily on global warming, but including many other environmental subjects. He is an excellent writer and the intelligent lay man or woman will find the book a very readable introduction to climate change and more incidentally to several other environmental problems. Considering the breadth of material covered, it is a short book and it cannot be expected to delve into the detail that a more specialized mind will demand. But, for these people there are novel ideas which will act as a great stimulus for further understanding.

After an introductory chapter titled the State of the Earth, Dr. Lovelock follows with two chapters explaining what Gaia is and the history of its evolution. An important step in the latter is the recognition that there are severe constraints on the conditions for life. Notably among these are temperature and the ambient chemical composition. What amazed Dr. Lovelock was that the Earth system had the capacity to stay close to the right temperature and the right chemical composition for life to thrive for over three billion years. From this came the Gaian hypothesis that views the biosphere as an active, adaptive control system able to maintain Earth in homeostasis. Next was the recognition that Gaia was the whole system — organisms (including humans) and material environment coupled together — and it was this huge Earth system that evolved self-regulation, not life or the material environment alone. It works through a system of feedback mechanisms between the living and the non-living environment.

There is another aspect of the Gaia nomenclature which results from Dr. Lovelock's first experience in serious science as a graduate student in physiology followed by twenty-three years of medical research. This taught him to think like a physician or a surgeon and from this it was easy and fruitful to think of the Earth system, Gaia, metaphorically as a patient. The message is that the patient is ill and in urgent need of care. So ill, that unless we cease abusing Earth it may revert to the hot state it was in fifty-five million years ago, resulting in the death of most of us and our descendants.

Dr. Lovelock estimates that this will happen when the CO_2 concentration in the atmosphere reaches ~500ppm, as it did 55 million years ago when similar CO_2 concentrations were present. Drastic action is called for *now* if we are not to inherit disaster. However Dr. Lovelock declares that he is not a pessimist and constantly imagines that good will ultimately prevail. His analysis will no doubt be hotly debated as it has been in the past. However many prominent climatologists are now making similar predictions. Articles in the September (2006) issue of *Scientific American* are accepting a critical CO_2 concentration ~500ppm and suggesting ways in which this may be averted. And even the political world is waking up as witnessed by Tony Blair's call to action stating that "We must pay more to avoid climate disaster," and headlines such as "Major Warning Sounded on Climate change," both stimulated by the recent *Stern Report on the Economics of Climate Change*.

Is there hope in the alternative sources of energy? In Chapter 5, he analyzes critically the situation for many systems. He comes to the conclusion that all the non-carbon sources are essential but insufficient unless nuclear energy plays a *major* role in the mix. This nuclear contribution could be temporary as more advanced green sources come into existence. His insistence on nuclear energy is a most controversial item and where he departs company with many environmentalists. To set the nuclear waste situation in a different perspective he notes that burning fossil fuels produces 27,000 million tons of CO_2 yearly — enough, if solidified, to make a mountain nearly one mile high and with a base 12 miles in circumference. This he compares with the 16 meter cube of waste accumulating from nuclear fission giving the equivalent energy. The danger associated with nuclear waste is firmly established in the public mind. Not so the invisible CO_2 which is deadly if its emissions go unchecked. Furthermore if his homeland, the United Kingdom, closed down all its commercial nuclear reactors and replaced them with one-megawatt wind turbines, 56,000 of them would be required and they would need to be backed up by 10 gigawatts of fossil fuel generators (~10 major power stations) for the occasions when the wind was too weak or too strong.

A chapter titled Chemicals, Food and Raw Materials looks at some of the blunders and successes made in the name of environmentalism during the 40 years since Rachel Carson's book *Silent Spring*. This is an interlude in the general theme of global warming, with many novel (to me anyway) and controversial ideas. For example his assertions that natural carcinogens made by vegetable life are present at thousands of times higher abundances than were those from the chemical industry, or that the oxygen of the air is the dominant carcinogen of our environment, or that the all-pervading European atmospheric haze is a sulfate aerosol which reflects sunlight back into space thereby producing a substantial cooling effect on Earth. Overall he emphasizes that Gaia is an intricately complex system which cannot be grossly manipulated to feed an ever-increasing burden of humans without consequences.

The next chapter on the technology for a sustainable retreat discusses some conceivable technical fixes in the future. Nuclear fusion is treated in an earlier chapter, and here he discusses the possibility of putting a sunshade between sun and Earth. This would decrease the amount of energy from the sun reaching Earth, but would not decrease the build up of the atmospheric abundance of CO_2 which eventually would increase the acidity of the oceans. There is evidence that this would be disastrous to ocean productivity. Then the problem is the sequestration of CO_2 which is difficult and very expensive because of its vast quantity. He envisages dense compact cities reducing the use of fuels for traveling, and for longer distances high-tech automatic sailing vessels and giant sailing airships riding on the trade winds. He also speculates on the possibility that we could synthesize all the food needed by eight million people and thereby abandon agriculture, giving a third of Earth's surface entirely to Gaia, to be left to evolve wholly without interference or management.

He ends his book with his personal views of Environmentalism and what must be done to nurse Gaia to health. His whole book is bubbling over with exciting ideas. I have only been able to select a few. The reader will find many more.

James Lovelock has long been a voice crying in the wilderness. His genius and the general validity of his message are clearly evident in this highly recommended book.

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