Appendix B to the Minutes for the Nuclear Energy Research Advisory Subcommittee Meeting September 30 to October 1, 2002

MEMORANDUM

To: **Chairman, Nuclear Energy Research Advisory Committee (NERAC)**

From: **Thomas B. Cochran, Member of NERAC**

Date: **October 16, 2002**

Subject: **"A Technology Roadmap on Generation IV Nuclear Energy Systems," a report of the NERAC Subcommittee on Generation IV Technology Planning**

Please include these additional remarks in your transmittal of the subject report to DOE's Office of Nuclear Energy, Science and Technology.

Perhaps the greatest security threat to the United States today, and of paramount concern to American citizens since September 11, 2001, is that nuclear weapon-usable materials will be stolen, seized, or secretly diverted from nuclear facilities and then used by terrorists to develop and deliver a crude nuclear explosive device, or by a hostile proliferant state to develop more sophisticated nuclear weapons. This is not the time for the United States to be launching an international research effort to develop advanced nuclear fuel reprocessing technologies to be deployed some 30 to 50 years hence. This research effort will likely expand the availability of weapon-usable materials in other countries in the near-term, result in the training and employment of new cadres of scientist and engineers with expertise in actinide (including plutonium) chemistry and metallurgy, but not result in the deployment of new commercially viable nuclear power technologies.

Over the past decade there have been several cases in which individuals or groups of individuals have sought to steal weapon-usable materials from civil nuclear research institutes and naval fuel facilities in Russia. In some cases the individuals were apprehended after the nuclear material was removed from the facility or institute, and in some cases only after it left Russia. The risk of diversion of plutonium or highly enriched uranium from the civil nuclear fuel cycle facilities and government research facilities represents a greater risk today than the potential diversion of nuclear weapons. Al-Qaeda, Iraq, Libya and North Korea have all sought to acquire nuclear weapon-usable materials and nuclear weapons. The United States believes Iran, a signatory to the Non-Proliferation Treaty, is seeking to develop nuclear weapons and in this pursuit is using its civil nuclear power development program as a cover to train a cadre of nuclear scientists and to import dual purpose nuclear fuel cycle technologies, primarily from Russia. The United States should seek with great urgency the elimination of weapon-usable highly-enriched uranium and plutonium from commerce, and should not be pursuing a research agenda that will inevitably spread dual-purpose nuclear facilities and expertise around the world.

Two years ago DOE's Office of Nuclear Energy, Science and Technology initiated the Generation IV ("Gen IV") program to identify potential nuclear plant designs that in the 2030 time frame and beyond would be economically competitive with fossil-fueled plants, and safer and more proliferation resistant than existing nuclear plants The Office of Nuclear Energy asked the Nuclear Energy Research Advisory Committee (NERAC) to develop a technology roadmap to guide DOE research in this area. NERAC established a Subcommittee on Generation IV Technology Planning to develop the roadmap. In the process of developing the roadmap, the Office of Nuclear Energy organized the Generation IV International Forum (GIF), a consortium of ten countries, to pursue the cooperative development of advanced nuclear reactor and fuel cycle technologies. GIF participants participated in the development of the NERAC subcommittee's Gen IV roadmap. The roadmap identifies six "next generation" reactor technologies, including gas-, sodium- , and lead alloy-cooled fast reactors, and advanced aqueous- and pyro-processing fuel reprocessing technologies. DOE has also transferred management oversight of the Idaho National Engineering and Environmental Laboratory (INEEL) from the Office of Environmental Management to the Office of Nuclear Energy and anointed INEEL as the lead laboratory for developing Gen IV reactor and fuel cycle technologies.

What began as a small conceptual-study research effort has ballooned into a major international research effort focused on the development of a variety of fast reactor concepts and reprocessing technologies. The original goal—to develop a commercially competitive, cheaper, safer and more proliferation resistant nuclear power technology—has been all but abandoned as the entrenched fast reactor and nuclear fuel reprocessing research communities have sought to promote their own research agendas as they developed the Gen IV roadmap in the GIF meetings. The overwhelming majority of GIF participants represent state-owned or heavily state-subsidized institutions and cannot be considered experts in developing or operating commercially competitive energy businesses.

There are four key questions that must be answered satisfactorily before pursuing this research agenda. First, are any of the proposed technologies likely to be economically competitive in the foreseeable future? The answer here is "no," for reasons discussed below. Second, given the low likelihood of commercial deployment, are the ostensible nonproliferation benefits of the new technologies likely to be realized? Third, are the inherent proliferation risks of closed fuel-cycle deployment acceptable even *with* the increased proliferation-resistance supposedly available with GEN IV technologies. And fourth, is the "opportunity cost" of a big GEN IV program acceptable in light of the benefits likely to be forthcoming from alternative energy R&D investments, particularly in advanced solar and fuel cell technologies?

Existing nuclear plants in the United States can produce electricity at competitive prices—since the forward cost of these plants is limited to fuel and operating and maintenance costs—but there have been no new nuclear power plant orders in the United States since the early 1970s, and this is likely to be the case into the foreseeable future. New nuclear plants are not competitive with gas- or coal-fired plants in the United States, because the fully amortized capital cost of new nuclear plants more than offsets the higher fuel cost of fossil–fueled plants. These higher capital costs of nuclear plants are due to a combination of higher "overnight" construction costs, longer construction times which must be financed, and higher interest rates for debt financing of nuclear plants. It is widely recognized that for nuclear to be competitive a combinations of events must occur, for example, some combination of a large carbon tax or limits on CO_2 emissions from fossil-fueled plants, a 25 percent, or so, reduction in "overnight" construction costs of nuclear plant, and a significant increase in the cost of natural gas over a prolonged period. It appears unlikely that such a combination of events will occur anytime soon.

We have considerable evidence from the failed attempt to develop plutonium breeding fast reactors in the United States, France, United Kingdom, Germany and Japan, that it costs more to construct a commercial-size fast reactor than a conventional thermal reactors—considerably more I would suggest. The cost of a new fast reactor is likely to be at least twice that of new light-water reactor—a pressurized or boiling water reactor. We also have over two decades of data from Europe and Japan related to the cost of aqueous reprocessing of irradiated nuclear fuel and the cost of fabricating mixed-oxide (MOX) fuel assemblies. These data indicate that the cost of reprocessing and fabricating MOX fuel is several times the cost of mining and enriching uranium and fabricating low-enriched uranium fuel. In the past thirty years uranium and enrichment costs have gone down, not up, and there is no reason to believe this trend will not continue for decades into the future, particularly when so few nuclear plants are being built. Certainly, there is no reason to believe that uranium costs will ever increase to the point that fast reactors and a closed fuel cycle will be economically competitive with new conventional nuclear plants, which are not now competitive with fossil-fueled plants in the United States.

Since these new fast reactors and reprocessing technologies are not likely to be competitive in the foreseeable future, they will not be deployed, and we will see no non-proliferation benefits even if there were net benefits to be realized.

Aqueous reprocessing and MOX fuel fabrication have resulting in huge stockpiles of weapon-usable plutonium and availability of weapon-usable plutonium and plutonium dioxide at reprocessing and fuel fabricating facilities. It is true that the deployment of new fuel cycles in theory could eliminate *the need* for separating plutonium entirely from radioactive fission products or actinides, but the various integral fast reactor concepts that have been proposed would nevertheless provide the inherent *capabilities* for making such separations if the owner were sufficiently motivated to do so. And the supposed benefit would occur only if the reactors and fuel cycles are deployed, and since there is virtually no chance that they will be competitive, there is little likelihood that this benefit will be realized, In the meantime—over the next 30 to 50 years, and even beyond—the research programs will spread hot cells and other dual purpose technologies around the world and encourage currently non-nuclear-weapon countries like Iran, South Korea, and Japan to pursue research in these advanced fuel cycle technologies and train cadres of experts in nuclear weapon related technologies.

While they have no weapon development intentions today, it should give one pause to reflect on the fact that of the ten member states of the Generation IV International Forum, four, South Africa, Brazil, South Korea, and Argentina, had clandestine nuclear weapon programs in the recent past, and one, South Africa, fabricated half a dozen atomic bombs. Switzerland has also dabbled in nuclear weapon design work, ostensibly to better understand the effects of nuclear weapons. It makes no sense for the international community to expend billions on an effort (KEDO) to limit North Korea's future access to plutonium while the GIF facilitates and promotes such future access in South Korea.

Pursuit of the GIF international research effort will increase U.S. national security risks, and it stands essentially no chance of reaping any energy security or economic rewards. In contrast, the world energy market is poised on the cusp of a major revolution in commercially competitive, distributed power generation, based on accelerating commercialization of solar and hydrogen sources. A billion dollars of public expenditure in this area is likely to have a far greater near- and long-term public benefit than a billion dollars expended on trying to resurrect highly-capital intensive, central-station nuclear power alternatives with serious (and costly) nuclear safety, security and safeguards requirements. The United States should withdraw its support for GIF, and the Gen IV program should be redirected to focus on improving existing reactors operating on the once-through fuel cycle, and on the potential optimization of LWR plants for hydrogen production via electrolysis.