Expanding Nuclear Power While Managing the Risks of Accident and Proliferation

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• The Garwin Archive - 2000's

- "Face Masks in Context for Fighting Flu-- Health Care Workers and the General Public," by R.L. Garwin, presentation to the Institute of Medicine Study of Reusable Facemasks for Protection in Pandemic Influenza, March 6, 2006, Washington, DC.
- "The Future of Nuclear Weapons and Nuclear Power," colloquium at the University of New Mexico, March 10, 2006, R.L. Garwin.
- "A conversation with Richard Garwin," with D. Kestenbaum of National Public Radio, and the ensuing Q&A, sponsored by American Association for the Advancement of Science, January 10, 2006. Video and audio available at: http://www.aaas.org/programs/centers/cstsp/Events/Events_2006_0110.shtml
- "Chernobyl's real toll," by R.L. Garwin, revealing the deception in the Chernobyl Forum report. Published as an "outside view" in Europe Features of UPI.com, November 9, 2005.
- "The Future of Nuclear Weapons and Nuclear Power," (Slides) by R.L. Garwin, presented at Argonne National Laboratory, Enrico Fermi lecture, October 6, 2005.
- "The Secret Hans," R.L. Garwin (expanded version; italicized paragraphs of text not presented 09/19/05), Cornell University, Celebrating an Exemplary Life of Hans Bethe, September 19, 2005.

and much more at www.fas.org/RLG/

Market-driven expansion only if economics are favorable:

- Overnight cost
- Operations and maintenance
- Prospective fuel costs and supply
- Cost of disposal of spent fuel
- Cost of implementing nonproliferation measures
- Continued operability
- Assumed $50 /tonC carbon tax

Can operators and analysts have confidence?

- **October 2003 WANO session, "... a terrible disease that originates within the organization..." and can lead to "a major accident..." that could "destroy the entire organization."**
- **Sellafield THORP shut down since April 2005**
- **Chernobyl Forum Report of September 2005 that predicts only 4000 deaths total from Chernobyl—by considering only the exposure of 60,000 person-Sv and not the 600,000 person-Sv established by the 1993 UNSCEAR report. Argue instead that the corresponding 24,000 cancer deaths are much less than those due to 10,000 GWe-yr of coal-fired plants**

Fuel supply and disposal of spent fuel

- **Ten-fold expansion (3000 GWe) of LWR would consume 0.6 million tons natural uranium/yr**
  - **Ultimate recoverable resource:**
    - **Gen-IV: 34 million tons at < $130/kg NU**
    - **Gen-IV: 170 million tons at <$260/kg NU**
    - **Seawater: 4500 million tons NU at unknown cost of recovery—Red Book suggests $300/kg NU. *Governments should invest to learn cost***
- **Operators can well afford to "buy ahead" to obtain assured fuel supply (G.W. Bush and Mohamed ElBaradei)**

Disposition of spent LWR fuel

- **Not a ton of spent LWR fuel in the Yucca Mountain repository**
- **Not a ton of vitrified fission products in the French Underground Laboratory.**
- **Take-back of spent fuel, and then what?**

States should take initiative to change the rules and laws to encourage competitive, commercial, mined geological repositories for spent LWR fuel and packaged vitrified fission products.

Both repositories and fuel forms to be IAEA approved

Global Nuclear Energy Partnership—GNEP announced February 2006 by Pres.G.W.Bush

Garwin comments on GNEP/ABR (1):

- **Of $250 M first-year funding, $155 M for engineering scale demo of UREX+ reprocessing of LWR fuel.** ***Highly premature***
- **Repository benefits from low waste heat only if many tens of ABR are deployed in the U.S. (ABR: Advanced Burner Reactor using fast neutrons to consume transuranics)** ***liquid sodium? molten lead?***

Garwin comments on GNEP/ABR (2)

- ***What fuel form for ABR—metal, MOX, carbide, nitride?***
- ***A 2002 ENA report, 3109ch1-2.pdf, notes for such an ABR a "conversion ratio" of 0.5, so a1-GWe reactor has a net disposal of only about 0.5 ton of TRU/yr. Does GNEP assume "sterile fuel"?***
- ***Recycle of MOX into LWR results in spent MOX fuel element with as much decay heat after 100 years as 4 UOX FE.***

Garwin comments on GNEP/ABR (3)

- ***The ABR is such a large bet that several design approaches should be funded and evaluated, and at least two contractors for the option eventually selected.***

Can we expand the use of nuclear power while managing the risks of accident and proliferation? ***With a greater investment in openness than has been evident.***

Here is the draft text of the talk, to accompany the preceding slides:

March 20, 2006

Expanding Nuclear Power While Managing the
Risks of Accident and Proliferation

Richard L. Garwin

For presentation at Euronuclear ENA2006
Brussels, March 29, 2006.

In an era of high oil prices and apparent global warming due to the accumulation of carbon dioxide in the atmosphere, nuclear power offers the option for large amounts of substantially carbon-free energy.

The expansion of nuclear power will occur in market economies only if the economics look favorable, and that includes notably overnight cost, operations and maintenance, prospective fuel costs and supply, and the cost of waste disposal.

Furthermore, critical to an investment decision is the confidence of the investor that the asset will continue to be viable and to produce a revenue stream. This requires the absence of substantial accidents in the worldwide nuclear industry.

The cost of reducing proliferation hazard to an acceptable level also figures in the economics, since there should be effective standards of protection of the nuclear fuel cycle against diversion of enriched uranium or of spent fuel or reprocessed nuclear materials to the production of nuclear weapons.

The economics of nuclear power will be helped by the assumption of a substantial carbon tax, on the order of $50 per ton, whether it is actually imposed or not. But the acceptability of nuclear power depends on the confidence that careful analysts can have in the overall system, and in the information they are supplied from the nuclear regulatory organizations and from the industry. Here there are problems.

In October 2005 I published with Georges Charpak and Venance Journe, "De Tchernobyl en tchernobyls," which treats both nuclear weapons and nuclear power. Although the book provides our conclusions and recommendations, it is primarily a resource for understanding the fundamentals of nuclear weapons and the options for nuclear power.

Our book emphasizes the October 14, 2003 conference of the World Association of Nuclear Operators-- WANO-- in which leaders of the nuclear operating community follow one another in expressing their concerns that the profit pressures in the marketplace are driving the industry to sacrifice safety. At that biennial general meeting, participants heard WANO Chairman Hajimu Maedae say that "a terrible disease" threatens nuclear operating organizations from within, and that it begins with "loss of motivation to learn from others ... overconfidence ... (and) negligence occurs in cultivating a safety culture due to severe pressure to reduce costs following the deregulation of the power market." Maedae warned that these troubles can, unless they are acknowledged, be "like a terrible disease that originates within the organization ..." and can lead to "a major accident ..." that could "destroy the whole organization." They are acknowledged, but what is the response?

One hears also that certain elements of the industry feel confident that they are much better protected against terrorist theft of separated plutonium, for instance, than are other elements of the industry. But such assertions have not yet been reflected in standards promulgated by IAEA or in overall security measures adopted as "good practice" by the industry.

Another problem of confidence is the tendency to bury bad news as if it did not exist. Try to find in the French press the information that the BNFL reprocessing facility at Sellafield has been shut down since April, 2005 because of the loss of some 83 cubic meters of process liquid (containing some 23 tons of dissolved spent reactor fuel (including a ton of fission products, 20+ tons of uranium, 250 kg of plutonium and transuranics) fortunately into a stainless-steel-lined concrete space. This loss had taken place undetected over a period of many months.

In my opinion, the lack of confidence is heightened by the September 2005 Report of the Chernobyl Forum, whose summary conclusion was picked up by the world press, that the ultimate deaths due to the Chernobyl disaster of 1986 would total about 4000, deriving from a total exposure listed in the Chernobyl Forum report as 60,000 person-sieverts. In reality, as the Forum reports states, this 60,000 p-Sv is the total for the most heavily exposed population. It ignores the 600,000 p-Sv established in UNSCEAR 1993 (p. 23) and that no longer appears in the UNSCEAR 2000 report, where there is no overall collective dose estimated -- only (vol. II, p. 486) that the 'estimated lifetime effective dose' for Belarus, the Russian Federation, and Ukraine totals about 60,000 man-Sv. Understand that the Chernobyl Forum does not dismiss the influence of the 600,000 p-Sv as negligible because they judge that low doses of radiation do not contribute to cancer; it simply ignores the exposure itself-- to my mind an unacceptable act.

Evidently the early expansion of nuclear power can take place only by the deployment of large numbers of nuclear plants of existing type-- that is LWR, such as the European Pressurized Reactor-- EPR. Would-be reactor operators should buy from established manufacturers, perhaps in consortium with others, but there will be needed a vast expenditure and a vast expansion of manufacturing capability. If the current 20% of electricity provided by nuclear plants is to be expanded to provide not only electricity but the four-fold larger amount of non-electric energy, some 9000 reactors of 1-GWe class will need to be deployed in the next 20 years. This is probably an infeasible goal, but in any case a straight-line projection of 450 per year (more than one per day) could in no way be realized in the early years. So one might hope to ramp up the deployment rate, as reactor manufacturing and siting capability increase.

There will need to be also an assured fuel supply. Those states and operators serious about nuclear power should for the most part forget assertions that they need their own domestic enrichment capacity, and should rely on a market that is nascent and inherent in the proposals by Mohamed ElBaradei and President George W. Bush to provide at advantageous prices an assured supply of LEU (perhaps 4.4% U-235) for members of the NPT. Those concerned about just-in-time delivery of LEU could "buy ahead," either raw LEU or fabricated fuel, since the cost of fuel for a reactor is a small part of the total cost of electrical energy. This LEU fuel would, of course, need to be safeguarded and an irrevocable commitment made that it will remain under IAEA safeguard and in the civil sector.

Unfortunately, neither France nor Japan, although arguing lack of native resources, ever seriously considered such buy-ahead in order to assure a fuel supply-- opting instead for highly uneconomic reprocessing of LWR fuel and recycle in LWRs.

Similarly, although the disposal of spent nuclear fuel is eminently affordable-- on the order of $0.001 per kWh, not a ton of spent fuel has been committed to a mined geologic repository in the United States, and not a ton of reprocessed spent fuel fission products has been committed to a repository in France.

These states should take the lead in changing national and international regulations to permit and encourage the use of competitive, commercial, mined geologic repositories that would accept appropriate spent fuel packages or reprocessed waste packages. The repositories should be regulated by the IAEA in order to avoid a "race to the bottom," and the packages for spent fuel and for vitrified fission products should likewise be approved by the IAEA. With that basis, the market should provide minimal cost disposal to repositories that might be sited in Russia, China, the United States, Australia, and even Sweden and many other countries. In addition to the IAEA safeguards, there should be a limited ceding of sovereignty, so that such repositories would be subject to protection by international military forces operating under the United Nations.

Enrichment is eminently affordable and expandable, but 9000 reactors would use on the order of two million tons of natural uranium per year of a finite fuel resource. According to the Red Book there exists 16 million tons of terrestrial uranium at prices below $130/kg, but it is also known that there is 4500 million tons of uranium in seawater. The Generation-IV working group identifies 34 million tons of uranium ultimately recoverable at prices below $130/kgU, and 170 million tons at $260/kgH; Thu Uranium Information Centre (Australia) quotes 500 million tons at the $260/kgU price. The Red Book very tentatively suggests a cost of $300/kg to extract uranium from seawater, and it is of the utmost importance for the world to know whether this cost can be capped at $300 or $500/kg, in comparison with the $1000/kg that it costs to save uranium by recycle of plutonium and uranium into LWRs.

The February 2006 announcement by President Bush of the Global Nuclear Energy Partnership-- GNEP-- provides an obligation to look farther out. GNEP incorporates assured fuel supply and fuel take-back, although with no details. It proposes also the provision of packaged reactors to many states for modular generation of electricity, with the reactor being taken back for reloading or disposal of the spent fuel. But the main first-year element of GNEP for the United States is the engineering scale demonstration program for UREX+ reprocessing of LWR fuel, with the promise that this will be a proliferation-resistant approach to saving fuel and to saving space in the repository.

Unfortunately, that happy result absolutely depends upon the deployment of large numbers of Advanced Burner Reactors-- ABR-- which are fast-neutron reactors to consume the plutonium and other transuranics to be removed from the spent LWR fuel.

To my mind, this UREX+ demonstration program is absolutely premature. The goal of deploying large numbers of ABRs is laudable, but these must be safe and technically capable of carrying out their function. There is no reason to believe that these should be liquid-sodium cooled, rather than molten lead, as advocated by Russian experts. There is also absolute uncertainty as to whether the fuel should be metallic, oxide, or nitride, or carbide.

A 2002 ENA report: http://www.nea.fr/html/ndd/reports/2002/3109/nea3109ch1-2.pdf, notes many of the problems of such an ABR, among which is that its conversion ratio with MOX or Pu-U fuel would be on the order of 0.5, so that only half of the fission power goes to destroying the initial load of transuranics-- thus doubling the number of ABRs required compared with an ABR that might run on sterile fuel rather than fertile fuel.

It seems to me that this dream of reducing the heat load in the repository by burning TRU productively in ABRs depends so critically on a large and early deployment of ABRs that multiple design approaches to the ABR should be supported, and that even for a particular design approach several independent groups should be contracted for their design, so that the best might be selected in an international competition.

Expanding nuclear power while managing the risks of accident and proliferation? Maybe, but it will require an investment in openness and technology from the industry that is not at present evident.

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