NUCLEAR ENERGY AND WEAPONS:

- THE CONNECTION

- THE CONTROLS

- CURRENT ISSUES

VICTOR GILINSKY

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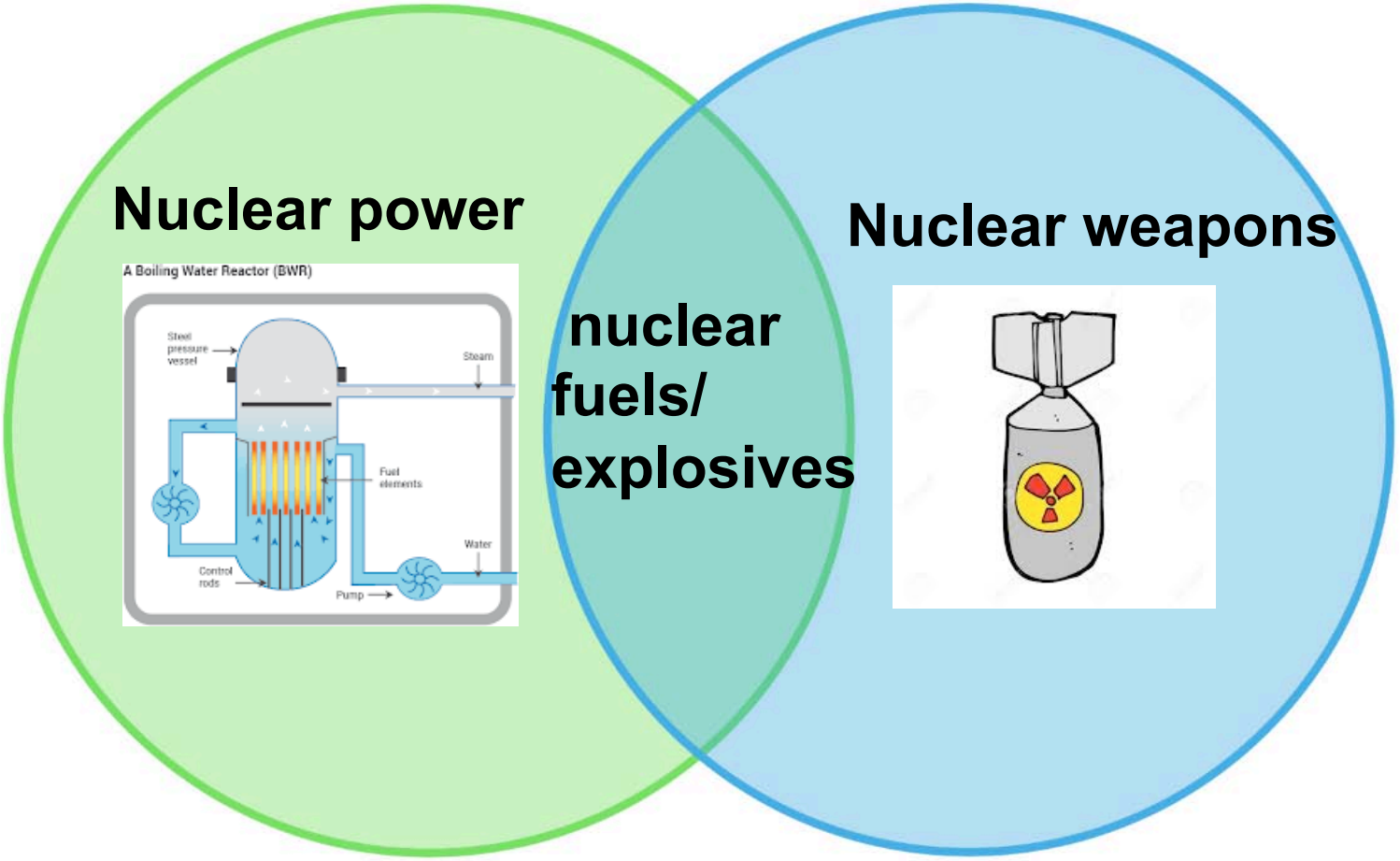
WHY WORRY?
BECAUSE NUCLEAR POWER AND NUCLEAR WEAPONS OVERLAP



NUCLEAR EXPLOSIVES ARE THE KEY TO NUCLEAR WEAPONS

- The fuels that are also nuclear explosives
  - Plutonium (Pu),
  - Uranium 235 in the form of Highly Enriched Uranium (HEU, say, 90% U235)
  - Uranium 233 (so far, only relevant in India)
- You don't need much—several kilograms per warhead
- But it's difficult, and takes years, and so is risky, to produce in plants dedicated to military application
- It's much quicker to access available nuclear explosives used as reactor fuels in "peaceful" nuclear programs
- In some cases, the amounts available are enormous: Japan has 10 tons of Pu, and owns another 30 t in UK.
- Another important ingredient is a pool of trained staff

1. PLUTONIUM (PU)

- Pu produced in all uranium-fueled reactors
- Spent (used) fuel from a standard Light Water Reactor (LWR) contains about 1% Pu
- A typical LWR produces about 200 kg Pu/year
- Security problems arise when Pu is separated from the radioactive spent fuel in a ***reprocessing plant***
- The original reason for reprocessing was to accumulate Pu for the next stage of nuclear power.
- This no longer makes any economic sense.
- We could, in fact, eliminate reprocessing entirely without any economic loss to nuclear power, and so eliminate most security concerns about Pu.
- But the nuclear community resists. We'll see why.
- (Japan's Rokkasho nuclear fuel center on next slide)

2. HIGHLY ENRICHED URANIUM (HEU)

- Natural uranium contains ~ 0.7% U235, the fissionable component (the starting point for accessing nuclear energy)
- Most power reactors use more concentrated, or enriched, fuel, about 4% U235
- But the same centrifuge enrichment for producing low enriched uranium (LEU) for LWRs can be used to raise the concentration to bomb levels, say 90%.
- Unlike reprocessing, we can't eliminate enrichment plants entirely because they are essential for preparing LWR fuel.
- It is, however, possible to eliminate HEU, previously widely used to fuel research reactors.
- Most have converted to LEU. Some resist or refuse—most notably: MIT and German FRM-II reactors.

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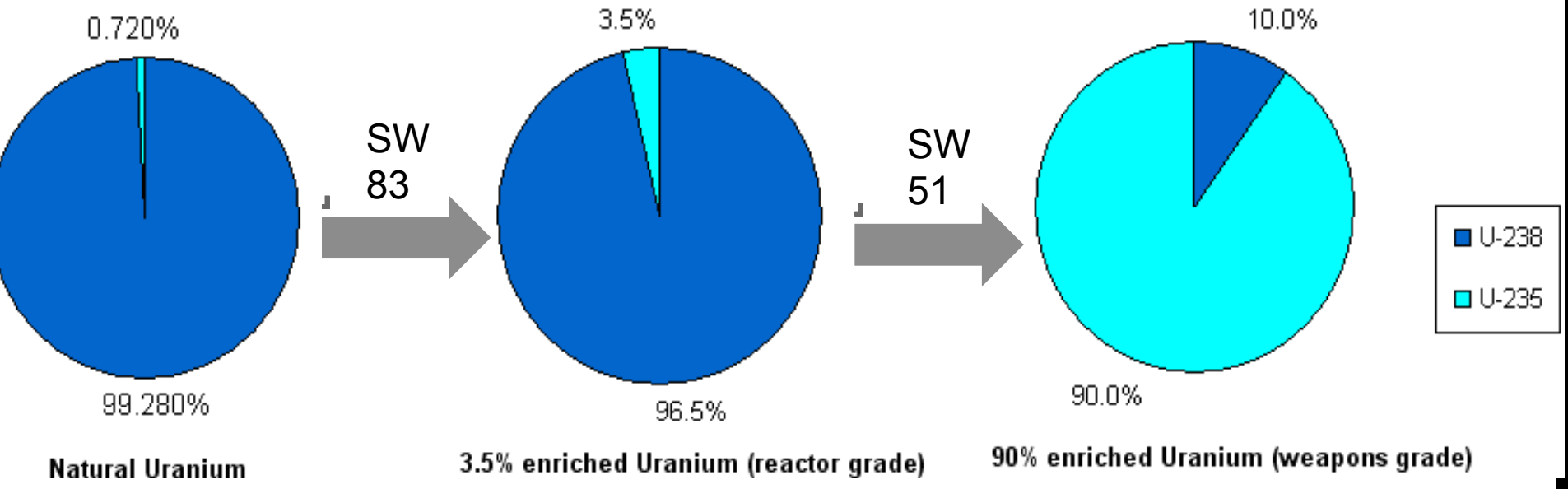
NAT U LEU HEU



~156 tons Nat U

~20 tons LEU, about the annual LWR input

~710 kg HEU

The circles should be shown progressively smaller. Much of the separative work to get to HEU is already done in getting to LEU. If the LEU was 5% instead of 3.5%, nearly ¾ of the SW to get to 90% would have been done.

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CENTRIFUGE ENRICHMENT POSES SPECIAL DIFFICULTY

- In terms of control, the essential difficulty posed by centrifuge technology is that it lends itself to small scale, flexible operation, and uses little power.
- A small clandestine plant is hard to find.
- It is important to understand that a plant small in commercial terms can be large in military terms.*
  - A plant to supply LEU for a single LWR could also produce HEU for dozens of bombs per year.
- Lots of countries have this technology
- (Next slide shows scale of Iranian centrifuges)

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3. URANIUM 233—SIMILAR TO PU

- U233 is produced in a reactor by irradiating thorium 232 with neutrons.
- (similar to the way Pu239 is produced by irradiating U238)
- U233 is separated by reprocessing
- Can then be used as reactor fuel, or explosive
- (Often misnamed as “thorium reactors,” but thorium is not the fuel, U233 is.)
- Only India has a significant interest in this fuel cycle.

NONPROLIFERATION CONTROLS

1946 ACHESON-LILIENTHAL REPORT > 1954 ATOMS FOR PEACE > 1970 NPT

- The dual nature of nuclear energy was understood from the beginning.
- 1946 A-L Report was post-WWII US statement proposing international control of nuclear energy.
- A-L conclusion: "If nations . . . carry on intrinsically dangerous activities [e.g., reprocessing, enrichment] it seems to us that the chances for safeguarding the future are hopeless."
- After Pres. Eisenhower's 1953 Atoms for Peace speech, US switched gears to spread technology and rely on peaceful use pledges, and inspection (the approach A-L said wouldn't work).
- 1957 IAEA created. US efforts for IAEA to control Pu blocked.
- 1970 New approach formalized in Nonproliferation Treaty.

1970 NPT APPROACH

- **NPT now central to controls, in principle**
- **Security rationale is that IAEA inspection—"safeguards"—will deter diversion by "the risk of early detection"—in time to prevent bomb manufacture.**
- **This makes sense in warning about suspicious activities still far from bombmaking (such as reactor operation), or catching small, slow diversions of explosives.**
- **But it's less believable that it can be counted on to provide adequate warning if a country with *Pu* or *HEU*, or *reprocessing* and *enrichment facilities*, suddenly abandons compliance completely, as North Korea did.**
- **NPT has no significant system for enforcement. Every response to a violation requires improvisation by the "big dogs" of the Treaty, which takes time. A lot depends on whether the violator is a friend of the powerful.**

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WHY NPT HAD LIMITATIONS FROM THE START

- IAEA was set up and NPT was adopted when the nuclear community was convinced Pu-fueled reactors would take over electricity production, and that large flows of plutonium fuel were inevitable.
- NPT Article III requires IAEA inspection (with limitations)
- But Article IV talks of "the inalienable right of all the Parties" to peaceful nuclear technology--basically referred to future plutonium technology (at insistence of future purveyors)
- "Peaceful" basically meant that an activity was subject to IAEA inspection, even if it involved nuclear explosives
- This inconsistency with the NPT's nonproliferation objective was largely overlooked or rationalized

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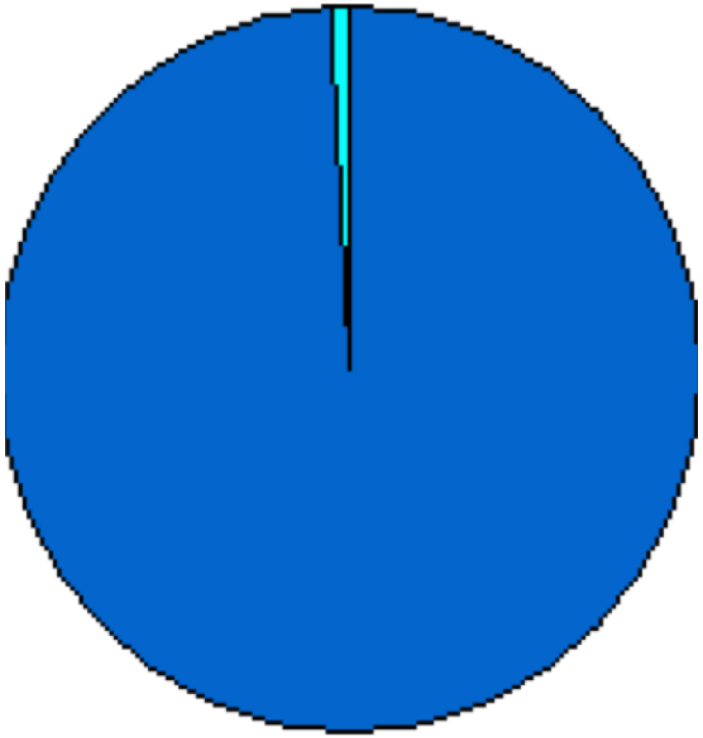
DIGRESSION: WHY PU-FUELED FAST REACTORS WERE SO ATTRACTIVE



- At start of the nuclear age, it was widely assumed uranium was scarce.
- For nuclear power to become important, the fuel supply had to expand beyond U235--from green to blue)

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1970 BROADLY ACCEPTED PLAN FOR NUCLEAR ENERGY FUTURE

1. "Converter" stage: use LWRs to convert some U238 into Pu, extract Pu by reprocessing, use it to start FBRs
2. "Fast Breeder" stage: produce ("breed") more Pu from U238 than they burn to start more FBRs—unlimited cheap fuel supply.

- A captivating idea, but all the forecasts proved wrong so the whole idea doesn't make economic sense.
  - U is not scarce,
  - Fewer power reactors are consuming it,
  - Reprocessing is much more expensive than forecast
  - FBRs are significantly more expensive to build than LWRs,
- *Plus it would create a near impossible safeguards problem*
- Nevertheless, the belief in the ultimate need for Pu-fueled fast reactors entered the nuclear community's DNA, and has remained there.

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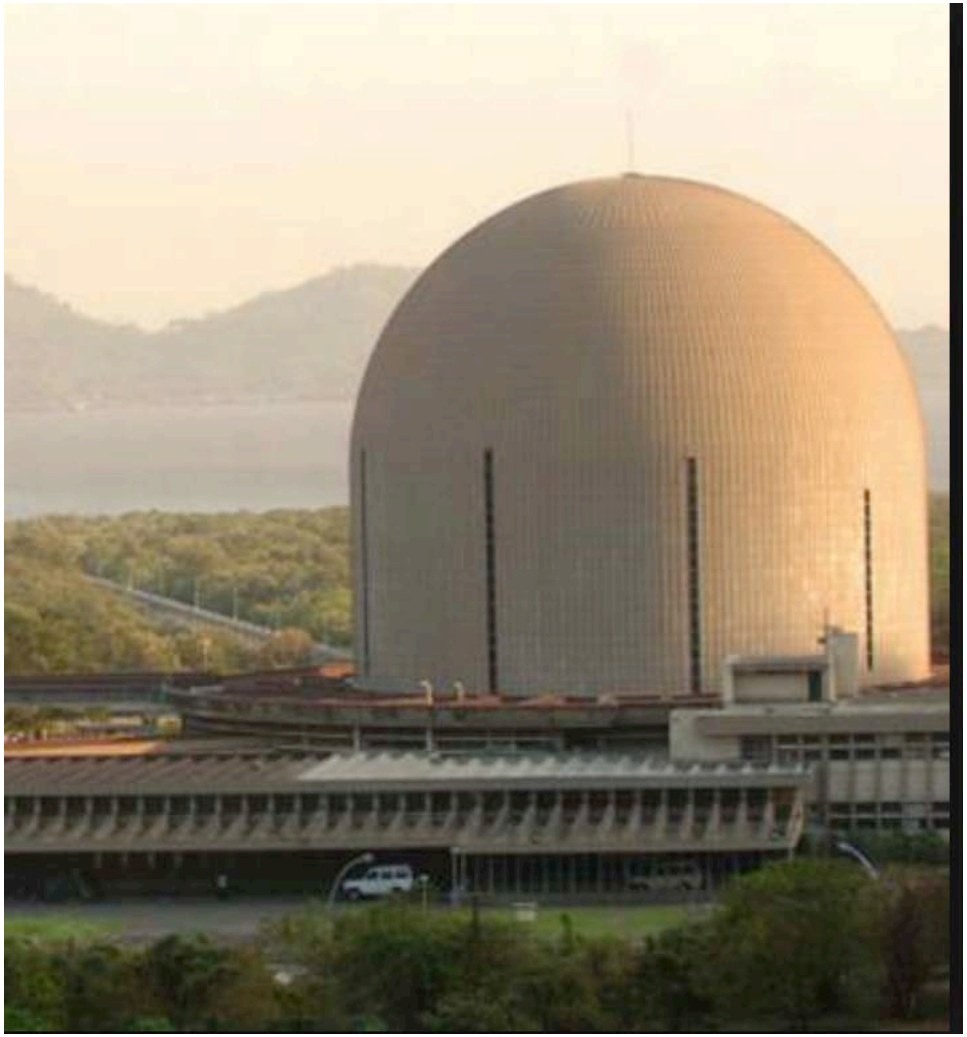
TURNING POINT: INDIA USED "PEACEFUL" CIRUS REACTOR TO MAKE PU FOR 1974 BOMB

- CIRUS not subject to IAEA inspection, but covered by "peaceful uses" pledges to Canada and US.
- When called to account, India said the bomb was peaceful.



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1975 NUCLEAR SUPPLIERS GROUP

- Supplier states realized a country with a reactor and a reprocessing plant can easily and quickly make bombs. Nonproliferation required technology control.
- A world with lots of countries having access to nuclear explosives is a dangerous one
- IAEA goal of timely warning can't be met in dealing with materials (Pu) that can be put to weapons use quickly.
- Nuclear Suppliers Group formed to agree on export controls, especially, exports of reprocessing plants and enrichment.
- Several reprocessing projects in Asia and South America were stopped
- The NSG consultations were handled confidentially at first because technology control seemed to conflict with the NPT's "inalienable . . ."
- Conflict between NPT and technology control never resolved.

1976 US URGED A HALT TO PU USE:

President Ford 1976 Nuclear Policy Statement:

- **The United States would no longer regard reprocessing of used nuclear fuel to produce plutonium as a necessary and inevitable step in the nuclear fuel cycle [as was the case before],**
- **We should not pursue reprocessing and recycle until "*the world community can effectively overcome the associated risks of proliferation*."**
- **The US would not export reprocessing or enrichment technology**
- **Non-proliferation objectives would take precedence in the United States over economic and energy benefits.**
- **We can pursue nuclear power perfectly well without using Pu.**

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INDUSTRY AND BUREAUCRACY OPPOSED CONTROLS ON PU

- World nuclear industry and nuclear bureaucracies argued fiercely against Ford (and later, Carter) restrictions on Pu
- Where the nuclear bureaucracy was especially strong—France, Japan, Russia—the nuclear programs supported reprocessing of LWR fuel and development of FBRs
- When FBR programs ran into problems, the bureaucracies switched to recycling Pu in LWRs, even though this was uneconomic, because it kept the Pu programs alive.
- The Pu advocates argued that
  - Reprocessing helps to manage waste—a complicated issue but I believe the opposite is true.
  - There is no security problem because Pu from commercial reactors is unusable for weapons.

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LWR PU IS USEFUL FOR BOMBS

- **It is a myth that Pu produced in power reactors—which irradiate the fuel longer than military reactors and thus obtain a larger mixture of plutonium isotopes—is intrinsically unusable for powerful bombs.**
- **This thinking reflects how such additional Pu isotopes would reduce yield in a 1945 design bomb. Even then, an exaggeration (unfortunately begun in the A-L Report)**
- **But no one would start today with a 50-year old design**
- **US DOE 1997 statement:**
  - **"*Advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapons-grade plutonium*."**

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WHAT NOW?

- Talked a good deal about Pu because it's important for understanding the historical context, and
- Nuclear establishments in East Asia—Japan, South Korea, and China—are still wedded to a Pu fueled future.
  - Japan still plans commercial operation of Rokkasho reprocessing plant even though it already owns 40 tons of Pu
  - ROK seeks US approval for a greater role in reprocessing
  - China has a fast reactor program and is negotiating with France for a large reprocessing plant like Rokkasho
  - And, of course, North Korea started its weapon program with Pu
- But probably the greater concern today is centrifuge enrichment.
- That is how the DPRK is expanding its bomb program.
- Centrifuge enrichment is at the center of concerns about Iran.
- The Saudis want to emulate Iran's enrichment, and openly talk of getting bombs—if Iran does, but I wouldn't count on them waiting.
- Despite this, the Trump administration is eager to supply KSA with nuclear technology. Fits in with Middle East scheme to create an anti-Iran alliance—Israel and Arab states led by KSA. A big mistake.
- That's where we are today. How this story ends is unclear.

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SOME ISSUES FOR DISCUSSION

2020 NPT CONFERENCE COMING UP

- **It would be useful to clarify which nuclear power activities are inconsistent with NPT Articles I and II, e.g., Pu separation (reprocessing)? Needless to say, a tough sell.**
- **Current nuclear power needs LEU. Can countries agree to limit national enrichment (despite "inalienable right . . .")?**
- **Nuclear economic prospects have diminished. Should IAEA continue to encourage nuclear installations?**
- **Is it prudent to put *any* additional nuclear plants in volatile areas, for example, the Middle East?**
- **Do we think we can reliably separate nuclear power from nuclear weapons? Indefinitely? If not, what then?**

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