SAND2011-3382C

Nonproliferation and Research Reactors

Lecture 3

June 6th

Dr. Geoff Forden

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The Nonproliferation Regime

Most nations of the world recognized that **nuclear weapons were a threat to <u>all</u> their security**:

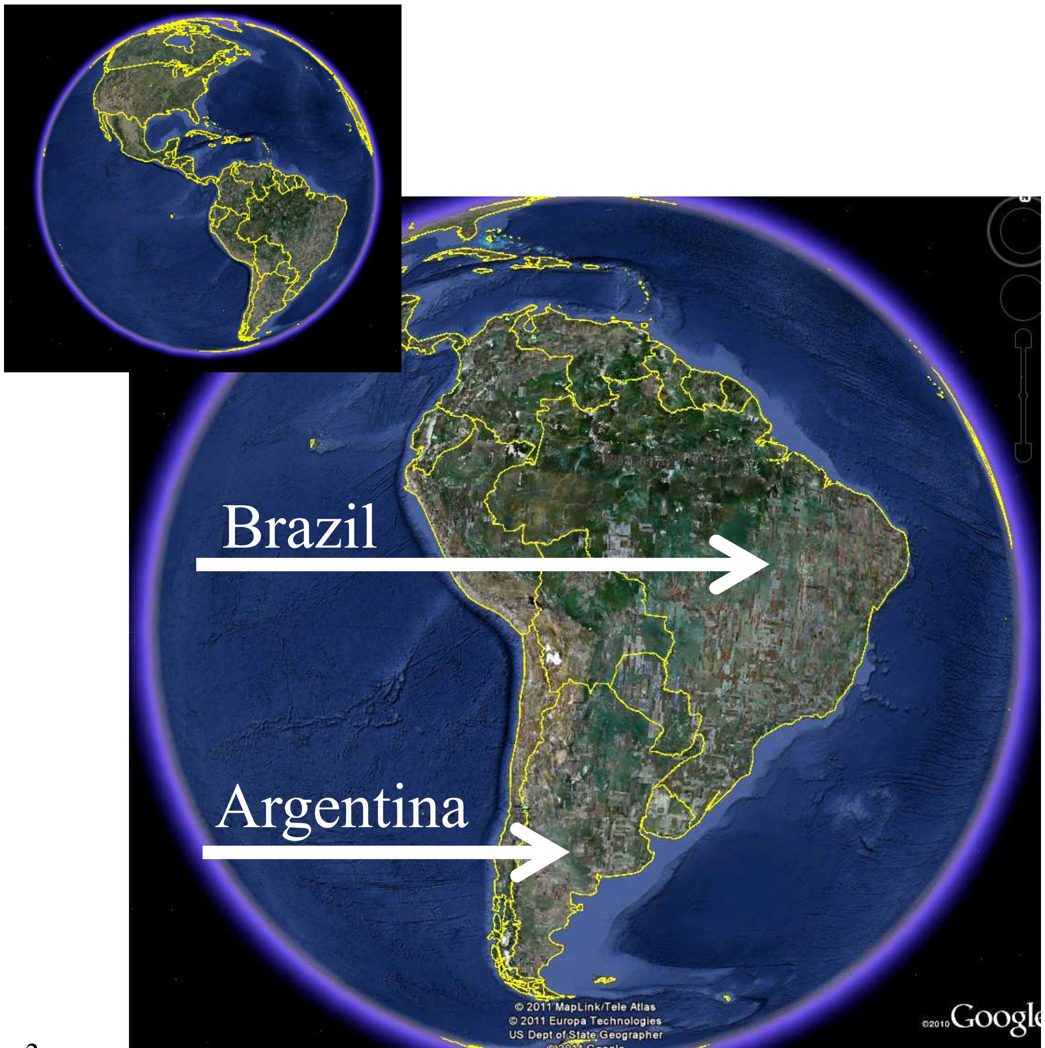
1) **Ireland** first suggested a treaty banning the proliferation of nuclear weapons in October 1958

2) The countries of **Latin America** created the Treaty for the Prohibition of Nuclear Weapons in Latin America in 1967

3) Finally, the **world** approved the Treaty on the Nonproliferation of Nuclear Weapons (known as the NPT) in 1968

From The History of the International Atomic Energy Agency, http://www-pub.iaea.org/mtcd/publications/pdf/pub1032_web.pdf

An example of regional rivalry: Brazil and Argentina



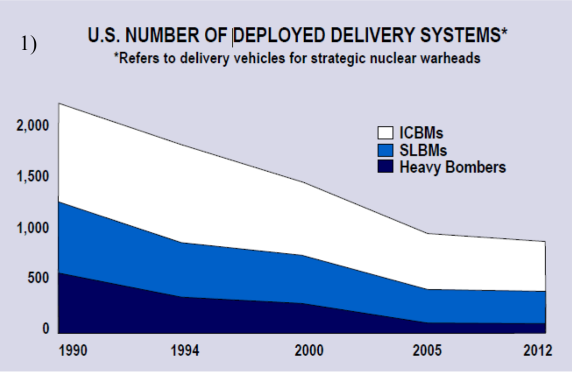
Brazil and Argentina engaged in a "nuclear program race" spurred on, **in part, by their competition in research reactors**. Both had—under military dictatorships—secret nuclear programs that could have developed nuclear weapons.

Sandia National Laboratories

As part of the security arrangements of the NPT:

The International Atomic Energy Agency is given powers to reassure all member states that no new nation is seeking nuclear weapons: This is their safeguarding responsibility.

The recognized Nuclear Weapons States (China, France, the Russian Federation, the United Kingdom, and the United States) undertake to eliminate their nuclear weapons. (Article VI)



Dramatic Reductions Since End of Cold War

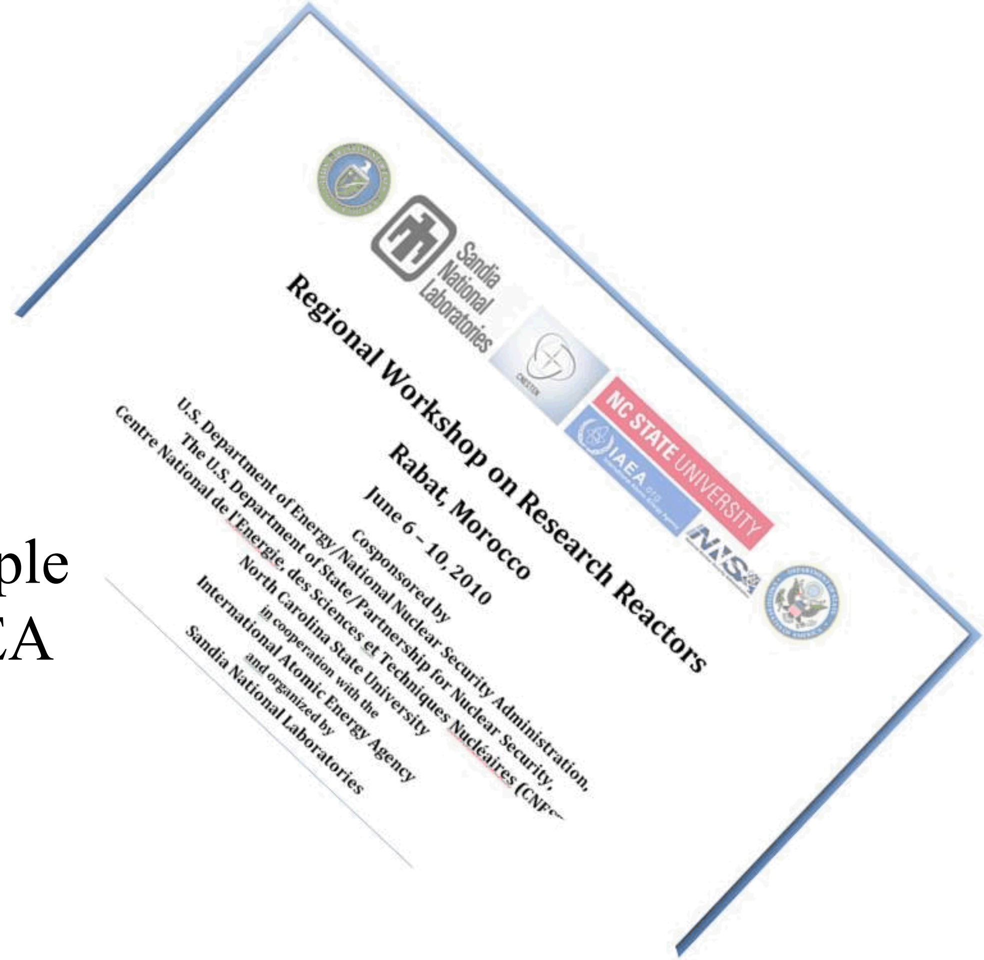
Sandia National Laboratories

1) http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/NPT_Briefing.pdf 2) http://www.iaea.org/newscenter/news/2006/globalpic.html

In fact, the NPT is a set of inter-locking promises and responsibilities:

- **Article I: NWS (Nuclear Weapons States) obligations**
  - Do not transfer nuclear weapons to NNWS (Non-Nuclear Weapons States)
  - Do not "in any way assist, encourage, or induce…" a NNWS to "manufacture or otherwise acquire"
- **Article II: NNWS obligation**
  - Not to receive the transfer of…
  - Not to manufacture or otherwise acquire…
  - Not to seek or receive assistance…
- **Article III: Safeguards**
  - NNWS obligation to accept verification
  - Codified separately in a *Safeguards Agreement*
- **Article IV: Peaceful Nuclear Technology**
  - The carrot: NNWS reward for accepting safeguards
- **Article V: Non-Discrimination for Potential Peaceful Use**
  - Potential benefits from any peaceful applications of nuclear explosions will be made available to non-nuclear-weapon States Party to the Treaty
- **Article VI: Disarmament**
  - All states parties to "pursue negotiations in good faith"

The NPT's Article IV promotes the peaceful use of nuclear energy



Sandia National Laboratories

NC STATE UNIVERSITY

IAEA

Regional Workshop on Research Reactors

Rabat, Morocco

June 6 – 10, 2010

Cosponsored by

U.S. Department of Energy/National Nuclear Security Administration,

The U.S. Department of State/Partnership for Nuclear Security,

Centre National de l'Energie, des Sciences et Techniques Nucléaires (CNE

North Carolina State University

in cooperation with the

International Atomic Energy Agency

and organized by

Sandia National Laboratories

This workshop is just one example of the United States and the IAEA fulfilling their obligations to promote the peaceful use of nuclear energy.

Comprehensive Safeguards Agreements (CSAs)

- Safeguards are applied to all nuclear activities within a State
- All non-nuclear weapons state (NNWS) parties to the NPT are expected to conclude a CSA with the IAEA
- IAEA Safeguards for a CSA are documented in Information Circular (INFCIRC) 153, as corrected:
  - "The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons"
- Technical objective:
  - "…the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by risk of early detection." (*IAEA Information Circular 153)*

Nonproliferation Issues Special to Research Reactors

- **Preventing the theft of Highly Enriched Uranium (HEU):**
  - **Refueling Older Research Reactors—which used HEU—with Low-Enriched Uranium (LEU)**
  - **Transitioning from using HEU targets for medical isotope production to using LEU**
  - **Designing New, High Neutron Flux research reactors that use LEU for fuel**
- **Preventing the production and diversion of Plutonium at research reactors**

The Potential for Theft is Real—and Dangerous!

During the night of 8 November, 2007, two teams of armed men raided the Pelindaba nuclear facility in South Africa and shot the employee in the emergency control center in the chest (he lived)

Pelindaba had 130 kg of spent HEU fuel from its SAFARI-1 research reactor. 3)

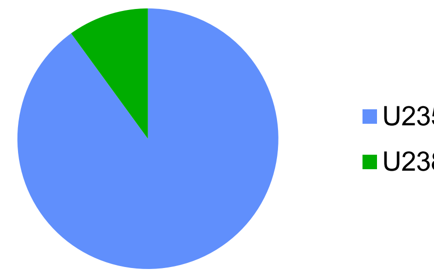
1) http://southafrica.usembassy.gov/press090903.html
2) http://www2.fbi.gov/publications/leb/2005/feb2005/feb2005.htm
3) http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

Why are we worried about *spent* HEU fuel?

Consider a research reactor that started with 90% U235

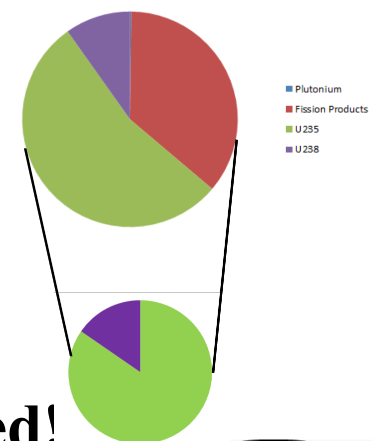
→ 10% is U238



or for each kilogram of Uranium,

0.9 kg is U235 and

0.1 kg is U238



After a 40% burn up of the U235 we are left with

0.54 kg U235 from the 0.9 kg we started with

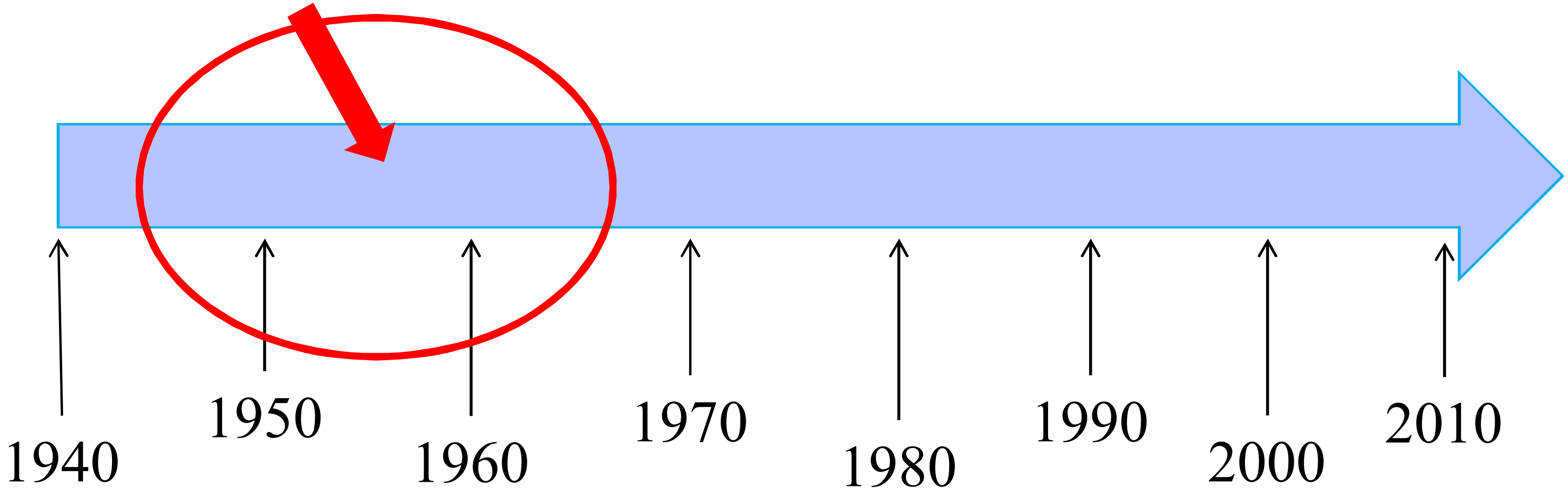
the new enrichment level of the *spent* fuel is

over 80% U235. Which is still highly enriched!

Source for images: G. Forden, based on physical laws

The designs of research reactors have changed over the years with changing nonproliferation implications:

Most Research Reactors were built using uranium with 20% or less U235



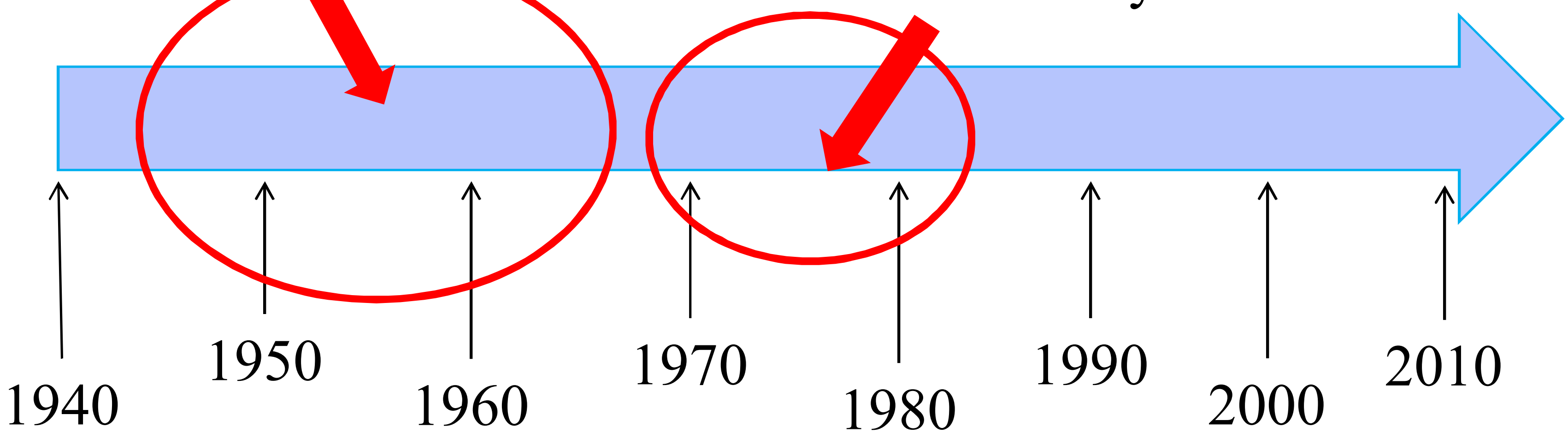
Information from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

The designs of research reactors have changed over the years with changing nonproliferation implications:

Most Research Reactors were built using uranium with 20% or less U235

In the 1970's, research reactors started to be made with HEU as the fuel to maximize neutron density



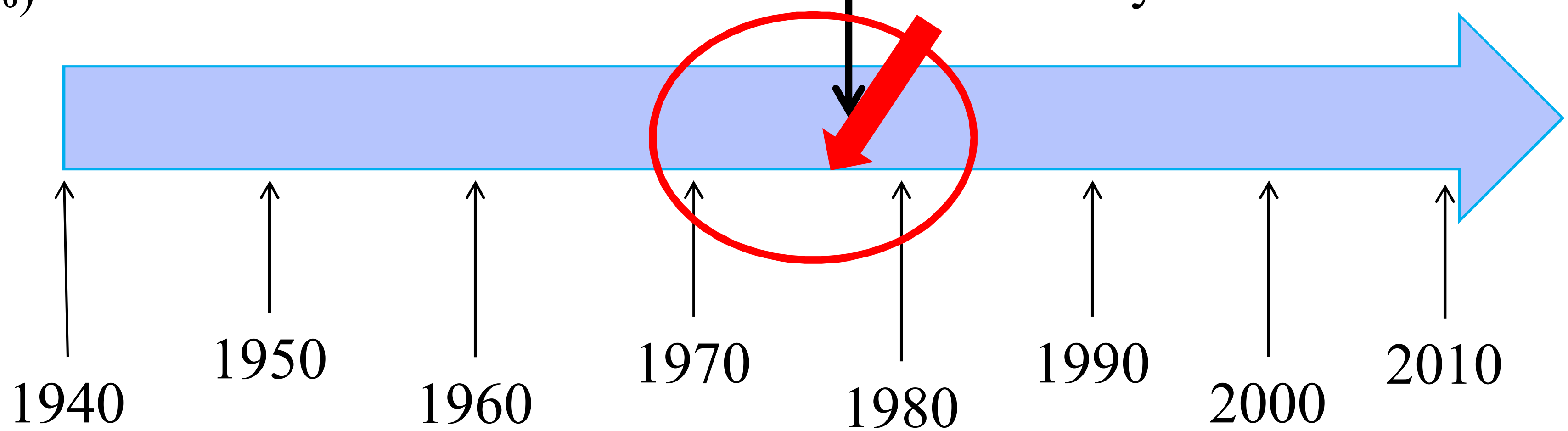
Information from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

The designs of research reactors have changed over the years with changing nonproliferation implications:

In 1978, the United States and the Soviet Union started independent programs to design reactors using lower enrichment fuel. (The US's goal was < 20%, while the Soviet Union's was 36%)

In the 1970's, research reactors started to be made with HEU as the fuel to maximize neutron density

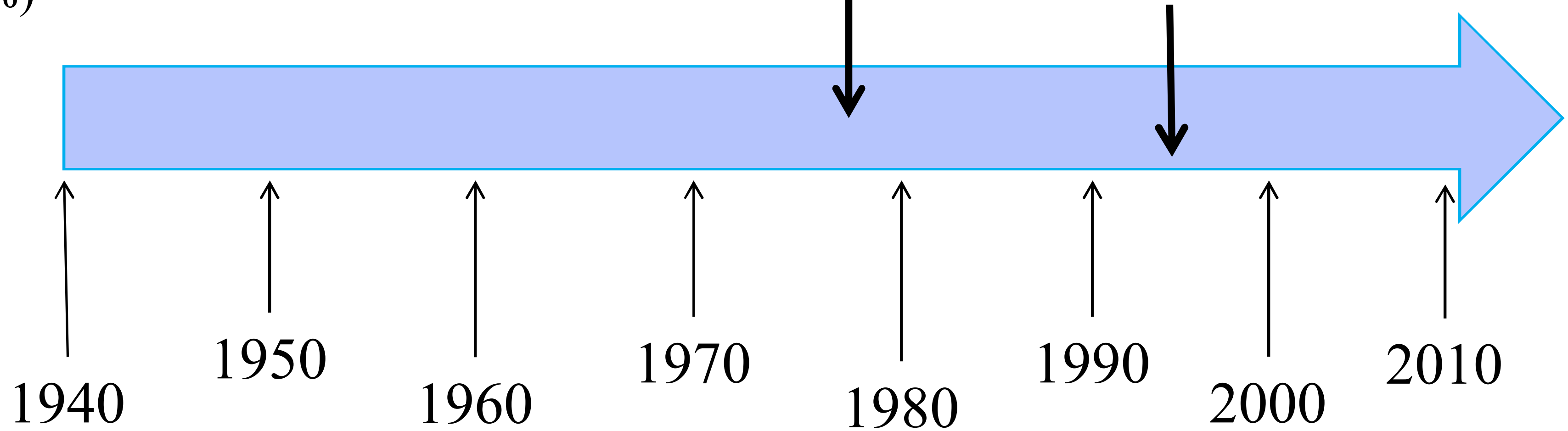


Information from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

The designs of research reactors have changed over the years with changing nonproliferation implications:

In 1978, the United States and the Soviet Union started independent programs to design reactors using lower enrichment fuel. (The US's goal was < 20%, while the Soviet Union's was 36%)

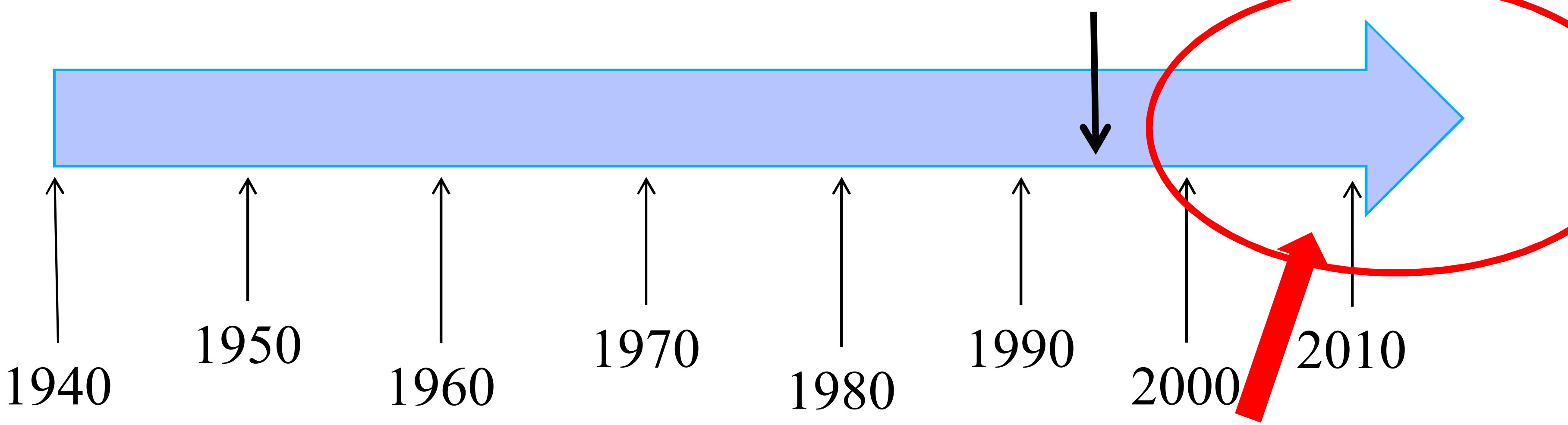
In 1994, the United States and the Soviet Union signed a protocol to cooperate in the development of research reactors with enrichment levels at most of 19.75% U235



Information from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

The designs of research reactors have changed over the years with changing nonproliferation implications:

In 1994, the United States and the Soviet Union signed a protocol to cooperate in the development of research reactors with enrichment levels at most of 19.75% U235



The United State, the IAEA, and the Russian Federation are cooperating to “repatriate” HEU fuel (spent and fresh) from around the world.

Information from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Redesigning the Fuel for Research Reactors

What is the right level of enrichment?

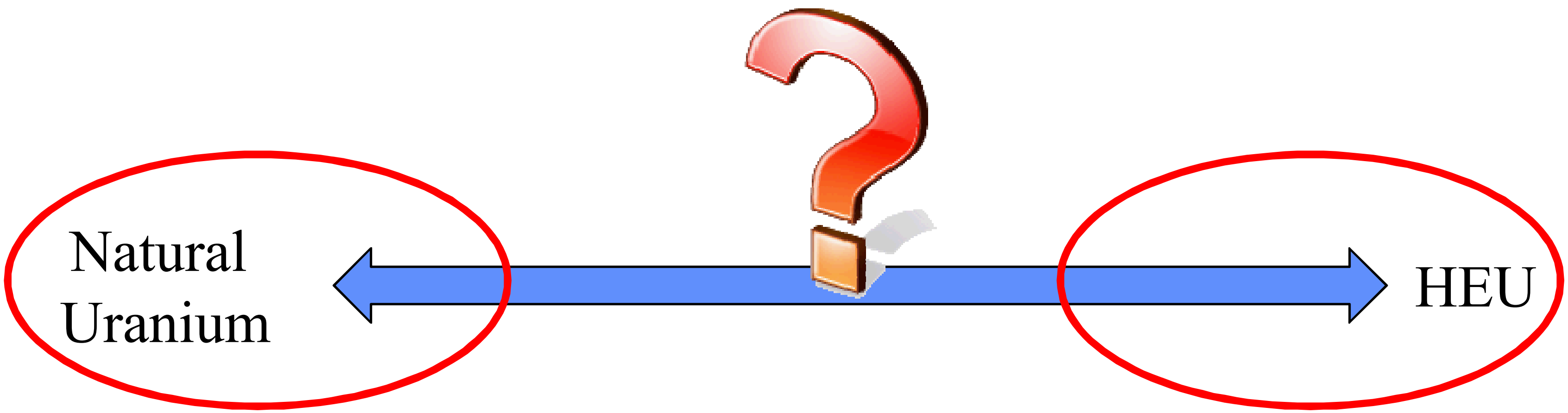
Redesigning the Fuel for Research Reactors

What is the right level of enrichment?

HEU can be diverted directly into a weapons program: Iraq had a "crash program" plan for diverting its HEU (from a research reactor) to its weapons program.

Redesigning the Fuel for Research Reactors

What is the right level of enrichment?



Natural uranium rectors are ideal for producing weapons grade plutonium. If 1 gram of plutonium is produced in a 20% reactor, then 3 to 4 grams is produced in a natural uranium reactor.[1]

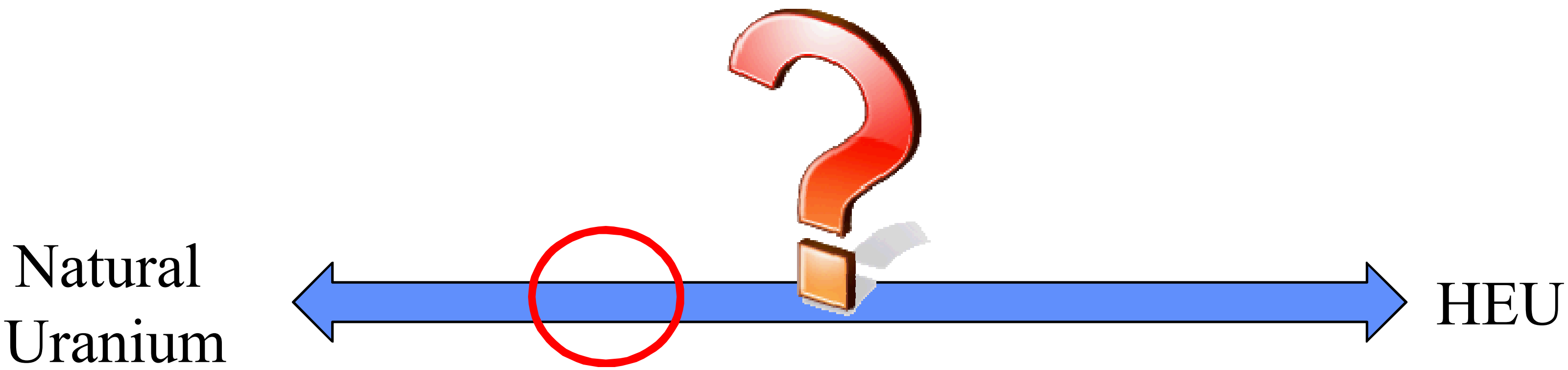
HEU can be diverted directly into a weapons program: Iraq had a “crash program” plan for diverting its HEU (from a research reactor) to its weapons program.

Sandia National Laboratories

1) From http://www.iaea.org/Publications/Magazines/Bulletin/Bull251/25105381821.pdf

Redesigning the Fuel for Research Reactors

What is the right level of enrichment?



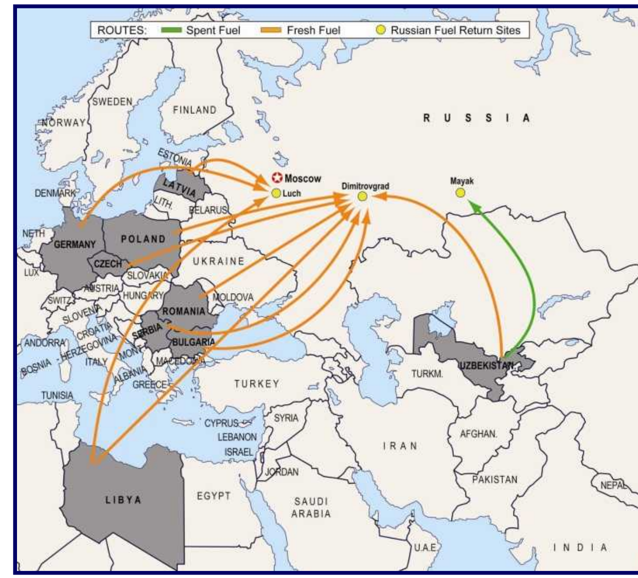
Up to 20% U235 fuel produces less plutonium, is still considered low enriched uranium, and can, by increasing the fuel density, produce high neutron fluxes.

What is the world doing about Spent HEU Fuel?

The US part of the program is under the Global Threat Reduction Initiative (GTRI):

Accomplishments with Russian-origin HEU:

- To date, over 765 kilograms of HEU fuel have been repatriated from 10 countries



- **FY07 – Germany, Poland, Vietnam**
- **FY08 - Czech Republic, Latvia*, Bulgaria***
- **FY09 – Hungary**

Latvia and Bulgaria are now HEU-free

The program goal is to complete repatriation of eligible Russian-origin HEU spent fuel currently stored outside of research reactors by 2010.

Information and images from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

The US part of the program is under the Global Threat Reduction Initiative (GTRI):

Accomplishments with U.S.-origin HEU:

- GTRI has repatriated 1,200 kilograms of HEU spent fuel and 3,153 kilograms of LEU spent nuclear fuel from 27 countries in 46 shipments
- 16 countries have returned all of their eligible U.S.-origin HEU fuel

Information and images from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

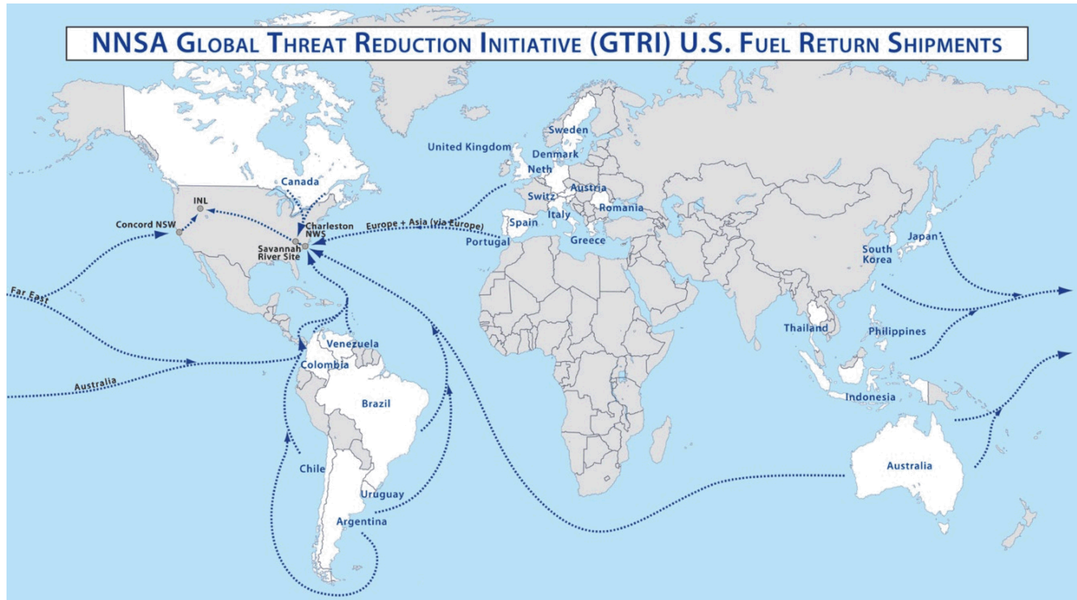
U.S. Origin HEU Shipments (from all over the world):

2 Shipments to Y-12

1. Argentina
2. South Korea

8 Shipments to INL

1. South Korea
2. Romania, Slovenia, Italy and Germany
3. United Kingdom
4. Germany
5. Japan
6. Indonesia
7. Japan
8. Romania



36 shipments to SRS

1. Sweden, Switzerland, Germany, Colombia, and Chile
2. Canada
3. Germany, Switzerland, Spain and Italy
4. Japan, Sweden, Germany, and Spain
5. Denmark, Italy, Germany, Sweden, and Greece
6. Australia
7. Venezuela, Uruguay, Japan, Sweden, and Spain
8. Thailand, Philippines, Indonesia, and Taiwan
9. Germany, Denmark, and Sweden
10. Portugal and Denmark
11. Japan (via Europe)
12. Brazil and Venezuela
13. Canada
14. Italy and Germany
15. Japan
16. Chile and Argentina
17. Austria, Germany, and Netherlands
18. Germany, Sweden, and Japan
19. Denmark
20. Denmark, Germany, and Sweden

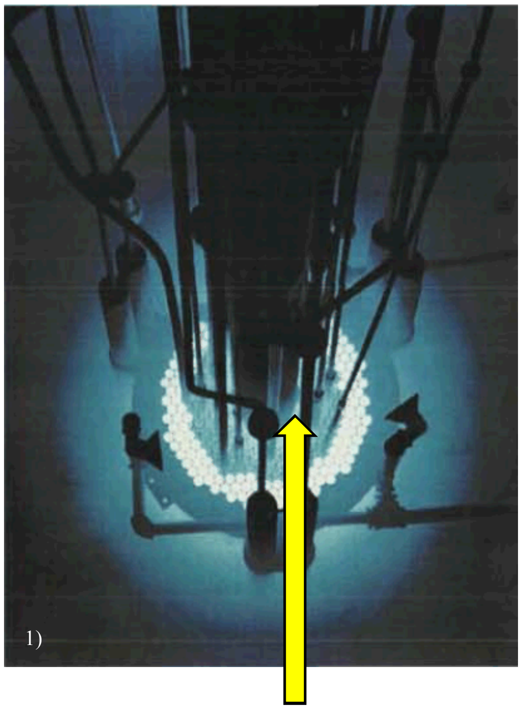
21 &22. Japan

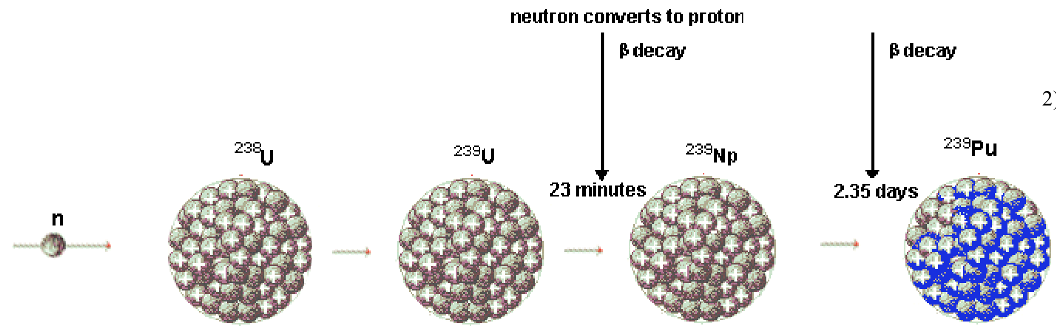
23. Indonesia
24. Germany
25. Japan
26. Netherlands and Sweden
27. Austria and Greece
28. Netherlands and Germany
29. Australia
30. Japan
31. Sweden
32. Argentina and Brazil
33. Sweden, Germany and Japan
34. Portugal
35. Germany and Japan
36. Canada

Information and images from http://nsnfp.inel.gov/program/strategymtg/2009-apr/21%20Chamberlain%20for%20Bieniawski&Cummins.ppt

Sandia National Laboratories

Preventing the Production of Plutonium at Research Reactors





Causing a U238 nucleus to absorb a neutron produces plutonium.

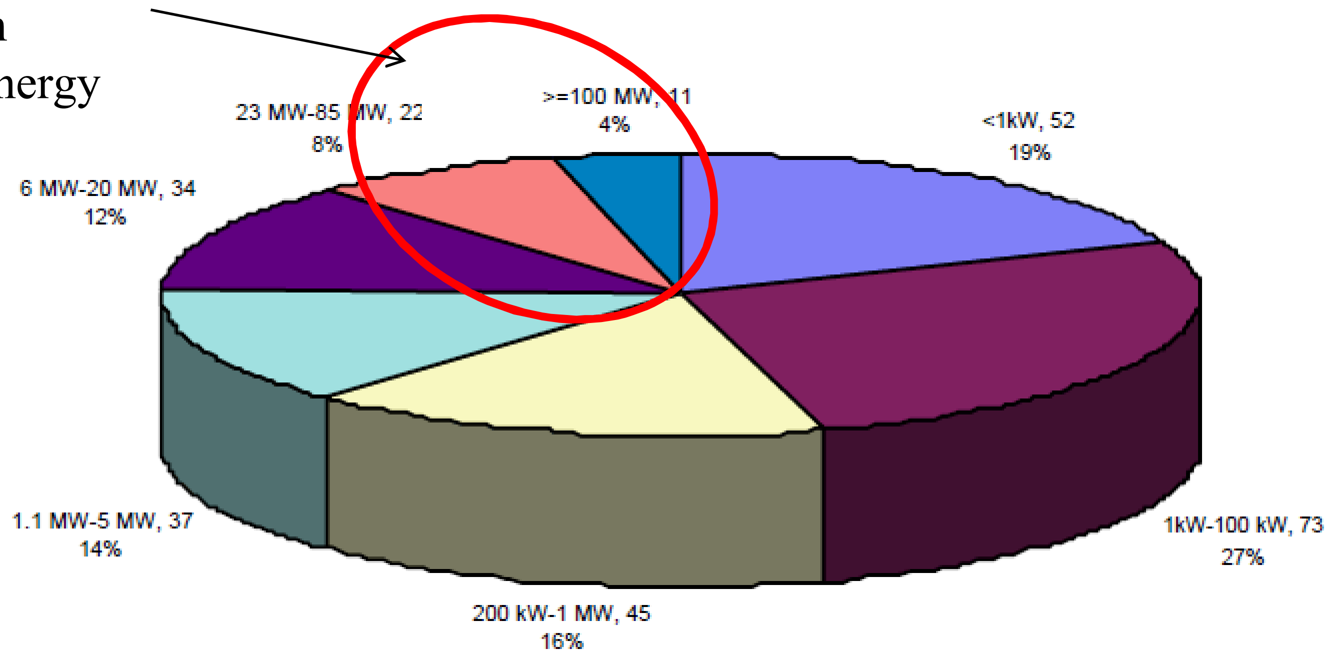
Natural uranium can be introduced into a research reactor's core through an irradiation channel.

1) http://www.iaea.org/Publications/Magazines/Bulletin/Bull384/38402082024.pdf
2) UCRL-PRES-233695

Preventing the Production of Plutonium at Research Reactors (con't)

The IAEA, in cooperation with member states, has determined that only those reactors with powers greater than 25 MW(t) pose a serious potential for producing plutonium for weapons:

Less than 12% of the worlds research reactors have energy greater than 25 MW(t)



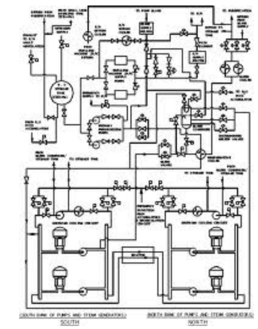
www.rertr.anl.gov/IAEA197/ark136.pdf

Power distribution of operational research reactors.

All reactors (outside of nuclear weapons states) are under safeguards

- These include:
  - Annual physical inventory verification
    - Of fresh (unirradiated) fuel
    - Fuel still in the core
    - Spent fuel (which is often stored in the same pool)
  - Auditing records and reports
  - Verification of specific types of fuel transfers
  - Verification of the absence of clandestine irradiation of fertile material

Additional safeguards at high energy ($> 25\ MW_t$) could include:



1)

- **Additional analysis of the facility design and operations (to ensure there are no secret passages etc.)**
- **Containment and Surveillance (C/S)**
  - **Could include monitoring the power of the reactor over time**
  - **To ensure that there no unrecorded introductions of fertile material**

2)

- **Environmental sampling**
- **Unannounced routine inspections**
- **Unattended monitoring and remote transmissions of safeguards information**

1) http://aris.iaea.org/ARIS/reactors.cgi?requested_doc=report&doc_id=74&type_of_output=html 2) http://www.iaea.org/OurWork/ST/NA/NAAL/sal/salCLmain.php

Questions?

Thank you for your attention!