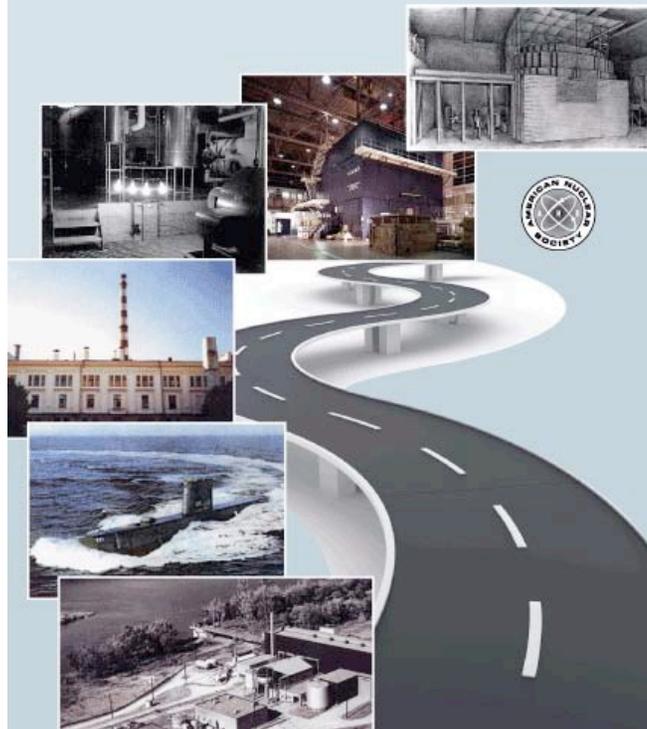


# ***NUCLEAR FIRSTS: MILESTONES ON THE ROAD TO NUCLEAR POWER DEVELOPMENT***

**Nuclear Firsts: Milestones  
on the Road to Nuclear  
Power Development**

Gail H. Marcus



**Gail H. Marcus, Sc. D.**  
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Oak Ridge National Laboratory  
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May 10-11, 2011

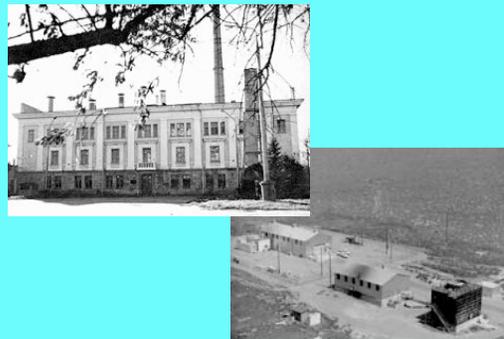
# Classic Nuclear History Timeline

**First controlled fission**



1942

**First electricity to power a town**



1951

1954/5

1957



**First electricity**



**First peaceful reactor**

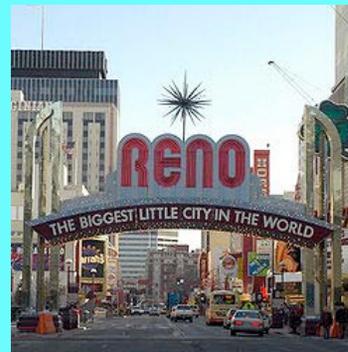
# What's Missing from that History?

- What made Fermi and his cronies assemble a pile of graphite blocks under an old stadium?
- How did we get from a pile of graphite blocks to a system that could generate useful electricity in about a decade?
- What happened after 1957?

*The answers to these questions take a book to tell!*

# What Inspired this Book

- **Conferences commemorating 50th anniversaries of key events in nuclear history (examples):**
  - **1989**, Leningrad, 50th anniversary of nuclear fission (discovery)
  - **1989**, Washington, DC, ANS, 50th anniversary of fission
  - **1992**, Chicago, ANS, 50th anniversary of first controlled fission
  - **2001**, Reno, ANS, 50th anniversary of first nuclear electricity
  - **2004**, Pittsburgh, ANS, 50th anniversary of founding of ANS
  - **2004**, Obninsk, IAEA, 50th anniversary of nuclear power
- **Numerous articles (NN and elsewhere) commemorating major anniversaries**



# The Rest of the Story

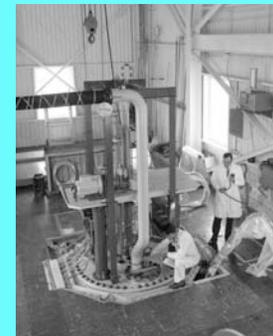
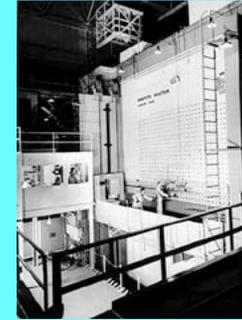
- **Pre-1942**
  - Experiments and theoretical formulations
- **1942-1951**
  - 12 reactor firsts (*out of many more reactors!*)
  - Reprocessing and enrichment
  - Non-power applications (isotopes, neutron beam)
  - Organizations, educational activities
- **1952-1957**
  - 15 reactor firsts, use of thorium
  - Reprocessing and enrichment (centrifuge)
  - Propulsion (submarine)
  - Organizations (AIF, ANS, IAEA)
- **1957-Present**
  - 20 reactor firsts, use of U233, MOX
  - Rocket and satellite applications, ship propulsion
  - District heating and desalination applications
  - Repositories



# Key Role of Oak Ridge

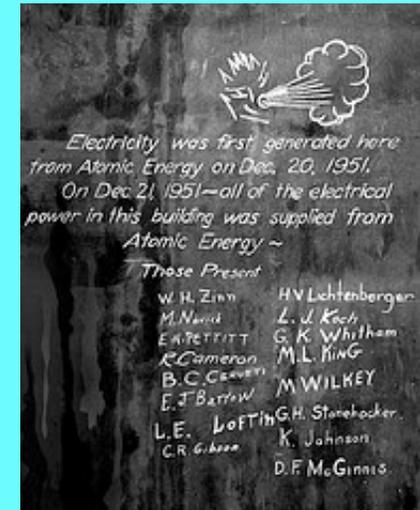
- First Non-Zero Power Reactor
- First Reprocessing Demo
- First Large Scale Enrichment (Y-12, K-25; also S-50 demo)
- First Radioisotope Production
- First Educational Activities
- First Proof of Electricity Generation
- First Zero-Power LWR (LITR)
- First Swimming Pool Reactor
- First Molten Salt Reactor
- First Use of U-233 Fuel

***LONGEST LIST OF FIRSTS FOR ONE INSTITUTION IN THE BOOK***



# Surprises and Puzzles

- First patents registered--**1939!**
- First electricity--**1948!**
- Absence of France in earliest reactor development
- First electricity to power a town
- Several power reactors before Shippingport
- Reactors in Antarctica and Panama Canal
- Early academic training, including universities
- Most “advanced” concepts have already operated
- Involvement of **Kings, Queens, and Presidents**
- Number of countries and states with “firsts”



# First Patents--May 1-4, 1939

**“A device for energy production”**

**France**

**2 patent applications**

- **Frederic Joliot-Curie**
- **Hans Holban**
- **Lew Kowarski**
- **Francis Perrin**



# First Electricity--September 3, 1948

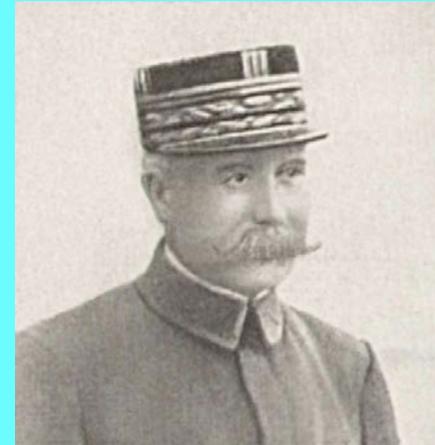
- X-10 Graphite Reactor (Oak Ridge)
- **1/3 Watt!**



# Absence of France from Early Reactor Developments

- France figured heavily in early research:
  - Becquerel
  - Marie and Pierre Curie
  - Irene and Frederic Joliot-Curie
  - Halban, Perrin, Kowarski

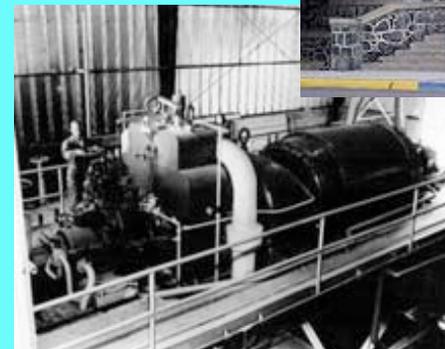
- **1940-1944**
  - France Occupied



- **France today**
  - **highest percent of electricity from nuclear power**
  - **second highest number of reactors**

# First Electricity on Grid

- **AM-I Reactor, Obninsk, USSR**
  - June 27, 1954
  - 6 MWe
  
- **BORAX-III Reactor, Arco, Idaho**
  - July 17, 1955
  - 2 MWe
  - **First in US**
  - **First for 100% of power to town (but at midnight!)**



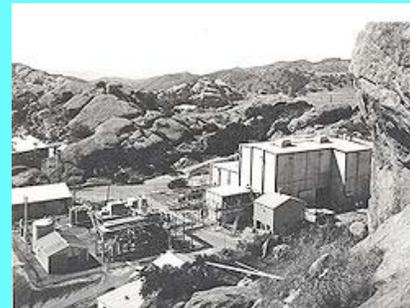
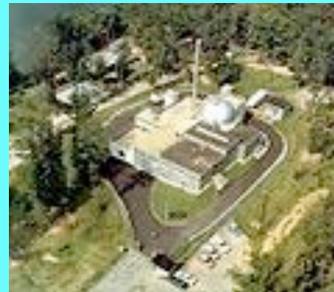
# Power Reactors Before Shippingport--1

- **Calder Hall in UK**
  - August 1956
  - 50 MWe
  - Production reactor



# Power Reactors Before Shippingport--2

- **Four small reactors in US (~2-5MWe)**
  - EBWR, Argonne, IL (December 1956)
  - SM-1, Ft. Belvoir, VA (April 1957)
  - SRE, Santa Susana, CA (July 1957)
  - VBWR, Pleasanton, CA (October 1957)
    - **AEC Operating License #1 (power reactor)**



# Reactors in Antarctica and Panama Canal

- **Antarctica**

- July 1962-September 1972
- 1.75 MWe
- First nuclear desalination



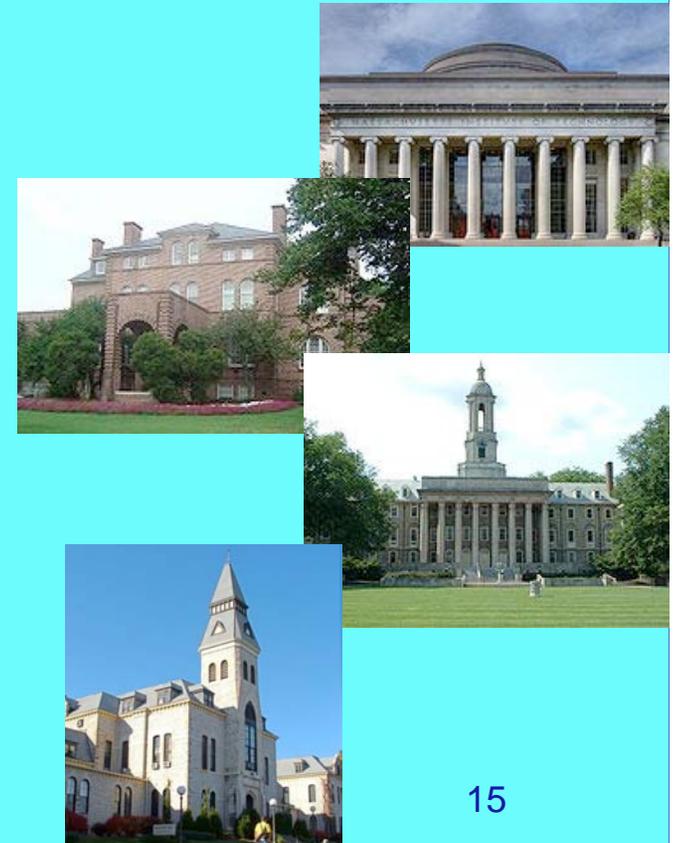
- **Panama Canal**

- July 1968-1976
- 10MWe
- First floating nuclear power plant



# Early Educational Involvement

- **Clinton Training School, Oak Ridge (1946)**
- **Pioneering Universities**
  - First courses (1946)
  - First academic program (1950)
  - First degrees (1951, 52, 54)
  - First reactors (1953, 55)
  - First departments (1958)
  - First accreditation (1964)



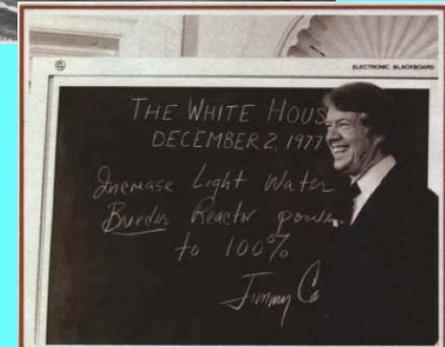
# Many Reactor Concepts Already Used to Produce Electricity

- Pressurized Water Reactor
- Boiling Water Reactor
- Heavy Water Reactor
- Organically Moderated and Cooled Reactor
- **Liquid Metal Reactor**
- **High-Temperature Gas-Cooled Reactor**
  - **Pebble Bed Reactor**
  
- Thorium-Fueled Reactor
- MOX-Fueled Reactor
  
- Other concepts tested  
(but to date not used to put power on the grid)
  - Molten Salt Reactor



# Kings, Queens and Presidents

- **President Dwight D. Eisenhower (1954, 55, 58)**
- **Queen Elizabeth II (1956)**
- **King Olav V (1959)**
- **Pope John XXIII (1959)**
- **King Baudouin (1966)**
- **President Jimmy Carter (1977)**



# Countries with “Firsts”

## Research

France  
Canada  
Switzerland  
England  
Scotland  
Italy  
Germany  
Denmark  
Sweden  
US

## Other Researchers

Poland  
New Zealand  
Hungary  
Serbia

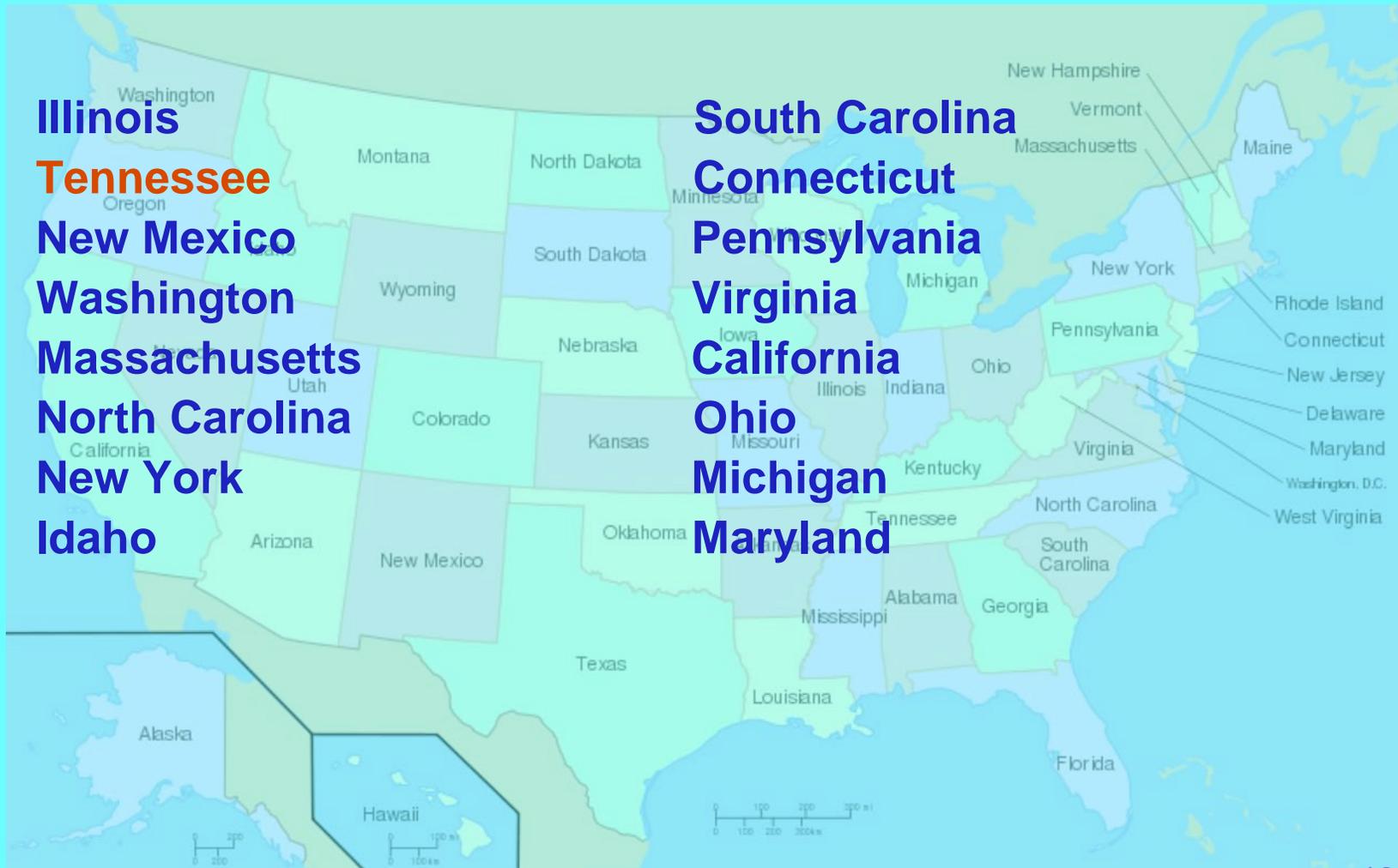
## Reactor-Related Development

US  
Canada  
France  
USSR (Russia, Kazakhstan)  
UK  
Norway  
Belgium  
Italy  
Sweden  
Japan/(India)  
Germany  
Argentina/(Brazil)  
South Africa/(Egypt)

## Other locations

Panama Canal  
Antarctica

# US States with “Firsts”



# Fukushima and Future Firsts



As a great American philosopher  
once said:



*“It is hard to make  
predictions, especially  
about the future”*

Yogi Berra

# Immediate Impacts of Fukushima

- **Operating Reactors**

- Reviews of all operating plants worldwide
- Statements of **continued commitment to nuclear power**
- Permanent loss of multiple units at Fukushima 1 station
- Temporary shutdown of several other plants in Japan
- Shutdown of oldest plants in Germany (temporary?)
- Delay in extending operation of other German plants (temporary?)

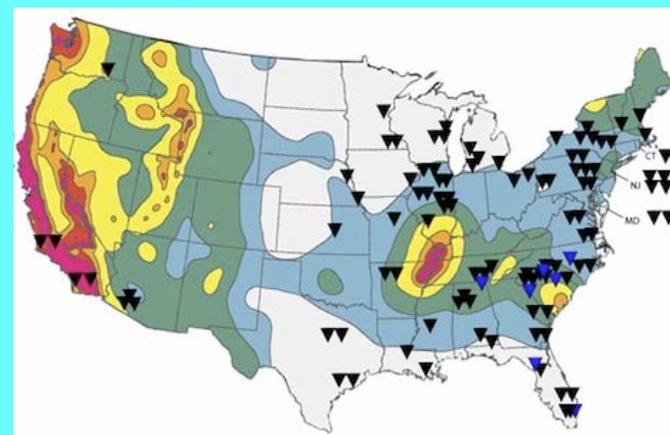
- **Reactors Planned or Under Construction**

- Reviews of design/siting of all planned plants worldwide
- Delays in planned activities aimed at building new reactors (Italy, other)
- Most countries indicating intention of continuing nuclear deployment plans
  - **UAE groundbreaking held March 14**



# Concerns About Current Plants Raised by Fukushima Accident

- **Plants in earthquake zones**
- **Plants in areas vulnerable to tsunamis**
- **Plants of the Fukushima type**  
(early BWRs - but US plants had many upgrades, unclear if all had been adopted in Japan)
- **Multi-plant vulnerabilities**  
(including flooding)
- **Spent fuel pool vulnerabilities**
- **Potential for loss of cooling water**
- **Potential for loss of backup power**  
(diesel generators, batteries, off-site power)



***Are we back again to 1986?***

# Probable Longer-Term Impacts of Fukushima

- Some early shutdowns of current operating plants, **but continued operation of most**
- Some cancellations or slowing of plans for new plants, **but continued deployment in most countries**
- Upgrades to operating plants & sites
- Enhanced measures to respond to emergencies
- Improvements to new plant designs
- **Accelerated move to new designs with more inherent safety features**
- Renewed attention to used fuel disposal
- Possibly greater role for international safety standards



# Possible Future “Firsts”?

- Long-term used fuel disposal  
**Finland may lead the way**
- Centralized interim storage (US)
- Advanced reactor fuels
- Advanced reprocessing technologies
- Advanced enrichment technologies (ex., laser)
- Advanced reactor concepts
- Fission-fusion hybrid designs



# Other Histories

- **To those interested in history, there are many fascinating stories that tell other parts of the story:**
  - Early research, researchers
  - Manhattan project
  - Individual national laboratories
  - DOE history
  - NRC regulatory history
  - Army reactor program
  - Submarine program
  - Different country histories
  - ANS history
  - IAEA and NEA histories
- <http://www.marcus-spectrum.com/NEAHist.pdf>

