Historical Perspective on Small Modular Reactors

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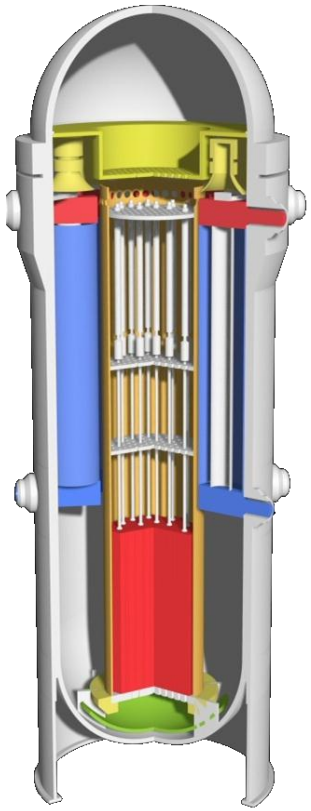
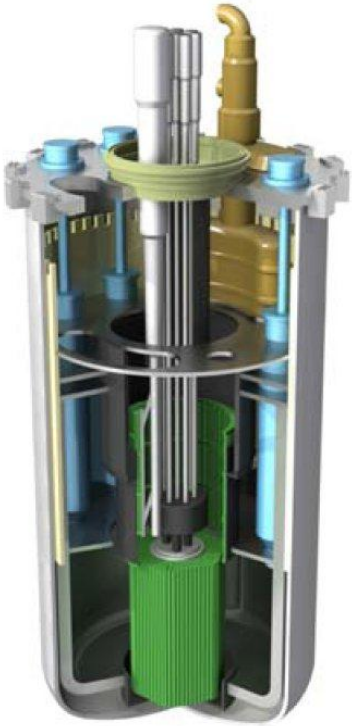
Interest in SMRs is not new

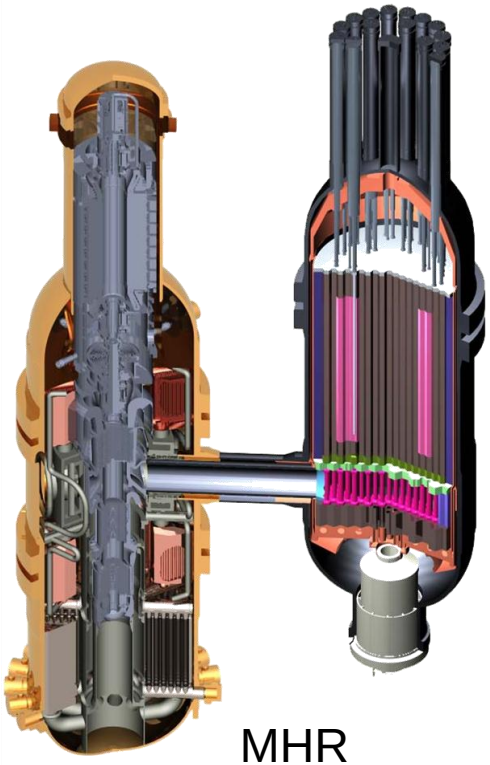
Most contemporary designs have deep roots



IRIS



PRISM



MHR

NuScale

mPower

The U.S. began developing small nuclear reactors for naval propulsion

USS Nautilus

Launched 1954

USS Enterprise

Launched 1960

The U.S. Air Force explored nuclear powered aircraft

Nuclear Test Aircraft
1955-57

Heat Transfer Reactor Experiment

The U.S. Army built 6 small stationary power plants and 2 mobile plants

Ft. Belvoir

Camp Century

USS Sturgis

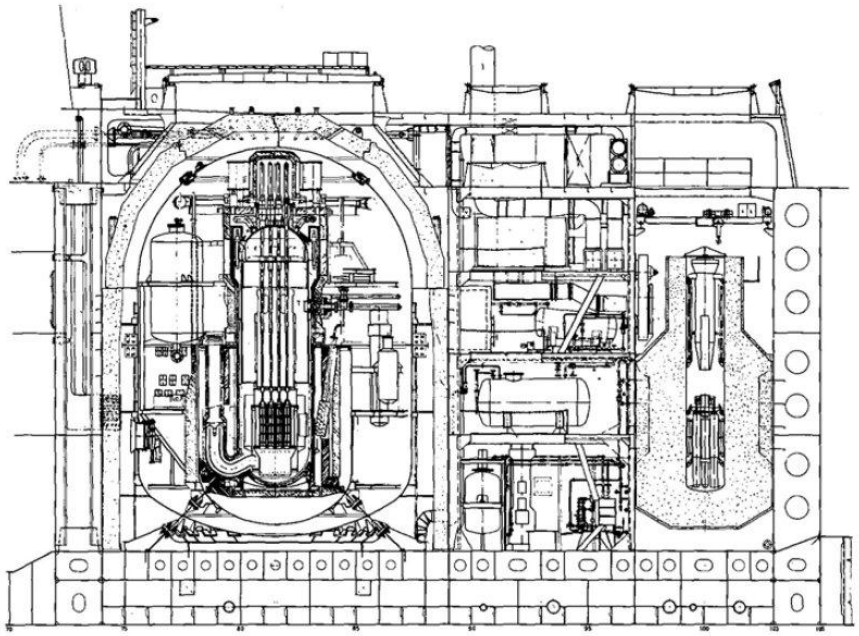
Reactor	Power (MWe)	Type	Location	Startup	Shutdown
SM-1	2	PWR	Fort Belvoir, Virginia	1957	1973
SM-1A	2	PWR	Fort Greely, Alaska	1962	1972
PM-1	1	PWR	Sundance, Wyoming	1962	1968
PM-2A	1	PWR	Camp Century, Greenland	1960	1962
PM-3A	1.5	PWR	McMurdo Station, Antarctica	1962	1972
SL-1	1	BWR	Arco, Idaho	1958	1960
MH-1	10	PWR	Panama Canal (Sturgis)	1967	1976
ML-1	0.5	GCR	Arco, Idaho	1961	1966

N.S. Savannah (1961-71)

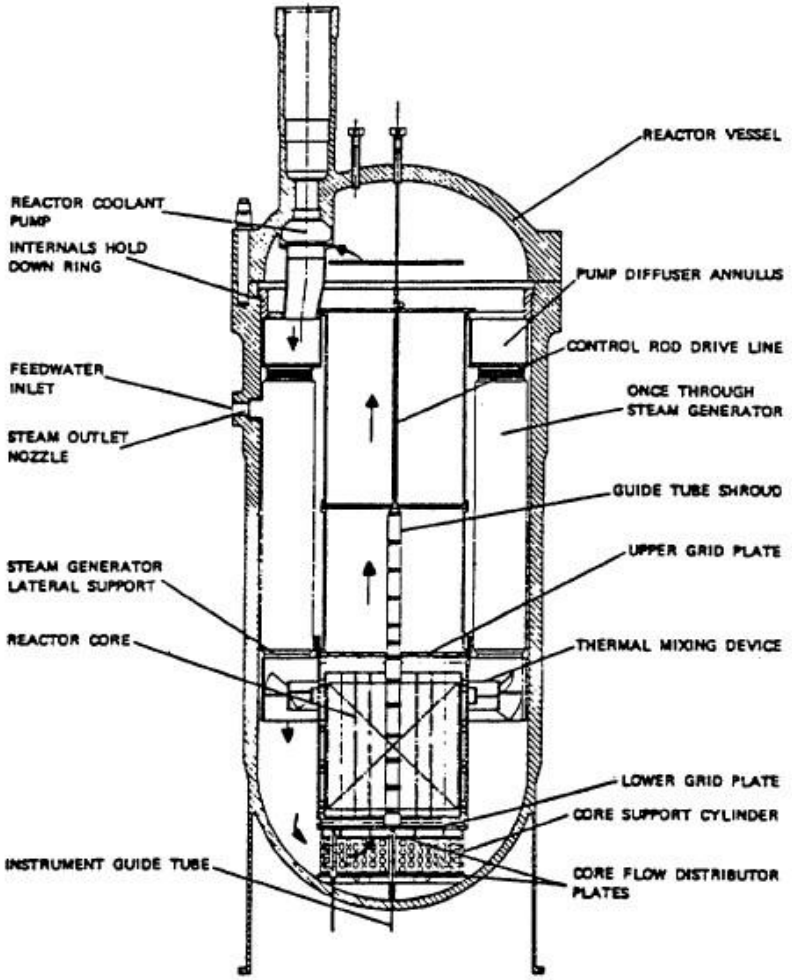
- **Proposed by President Eisenhower in 1955 Atoms for Peace speech**
- **69 MWt reactor; standard PWR design**
- **Visited over 70 domestic and foreign ports**

N.S. Otto Hahn (1968-79)

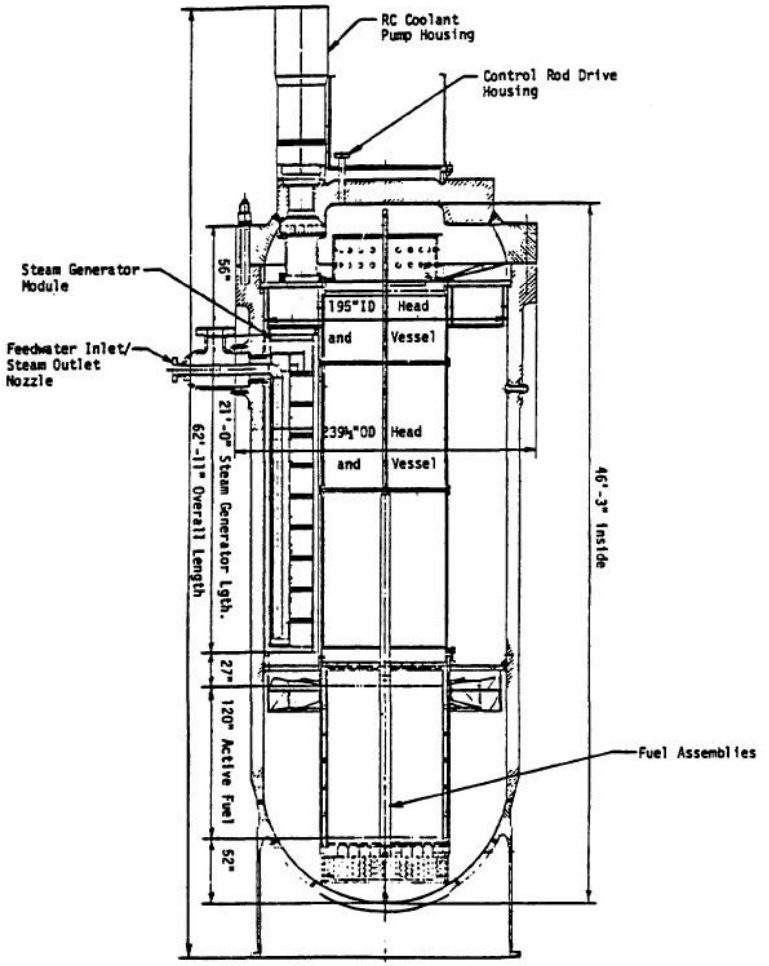
- Configured to carry passengers and ore
- 38 MWt reactor; integral PWR design
- Visited 33 ports in 22 countries



’73 Oil embargo spawned interest in small iPWRs for industrial applications

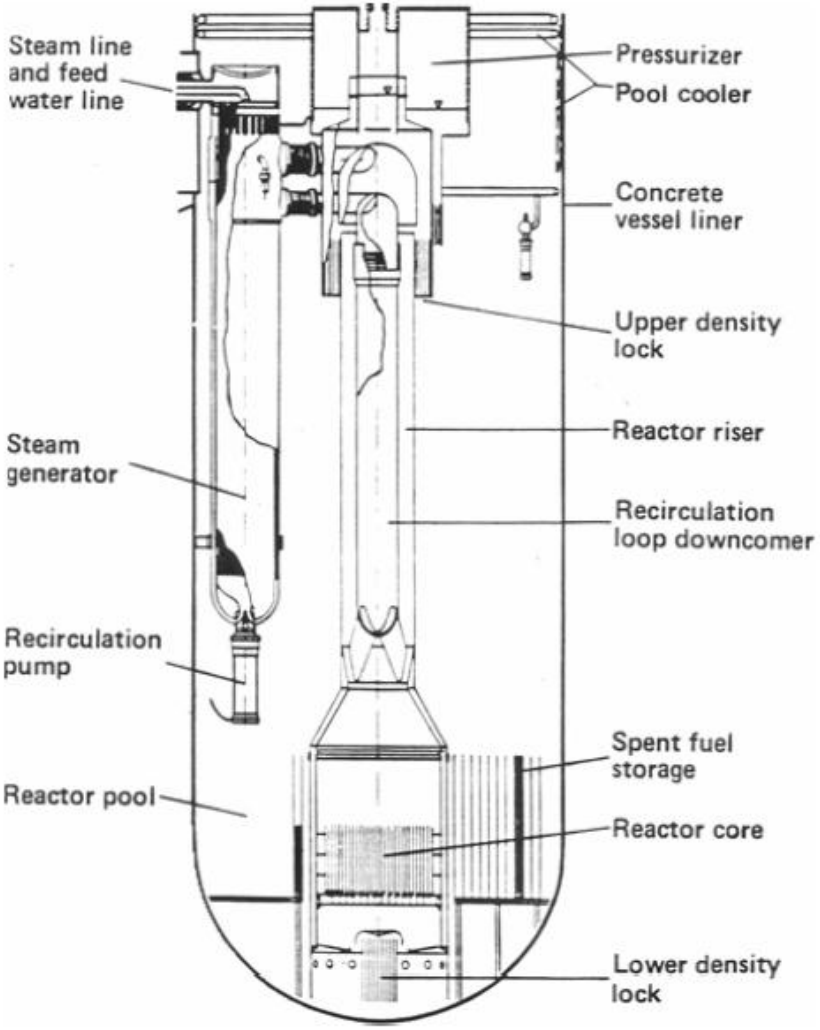


91 MWe Consolidated Nuclear Steam Generator (CNSG)

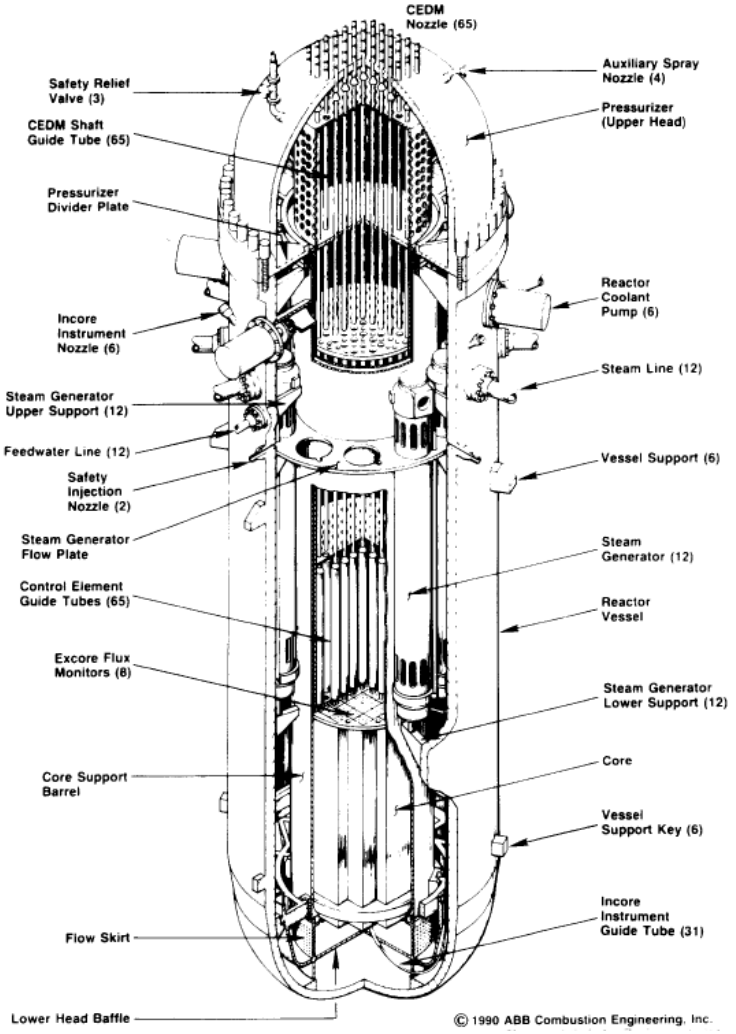


400 MWe Consolidated Nuclear Steam Supply (CNSS)

Additional iPWR designs evolved in the 80s

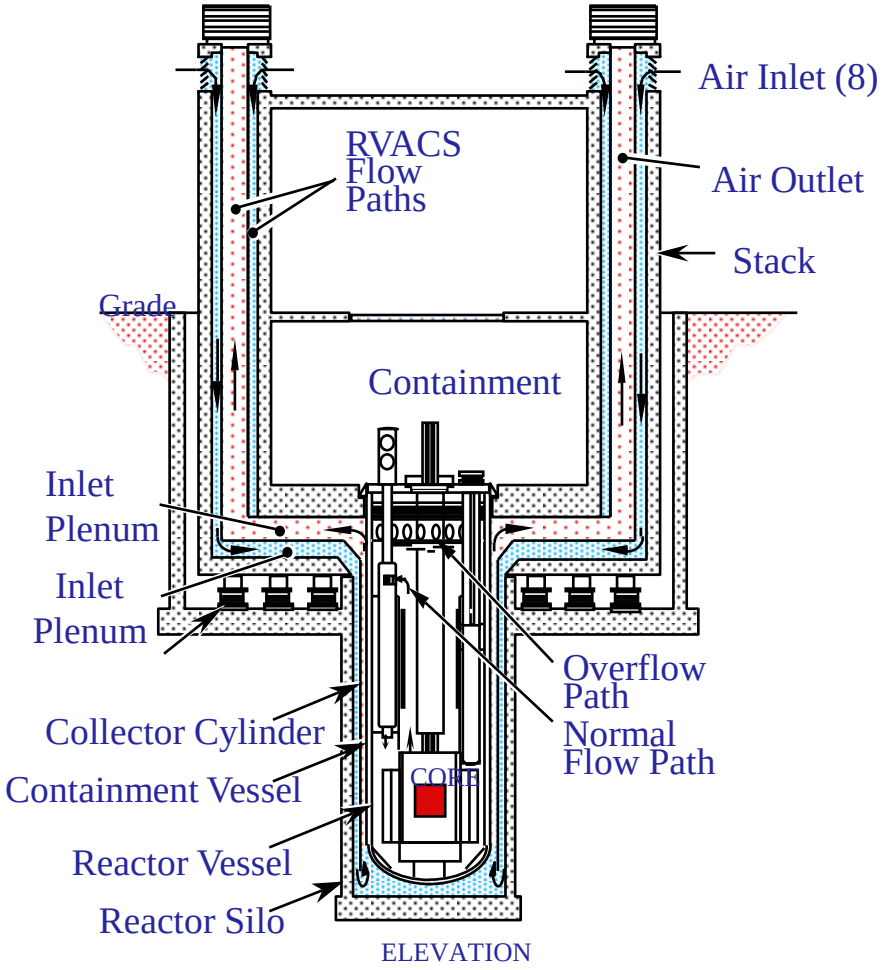


Process Inherent Ultimate Safety (PIUS)

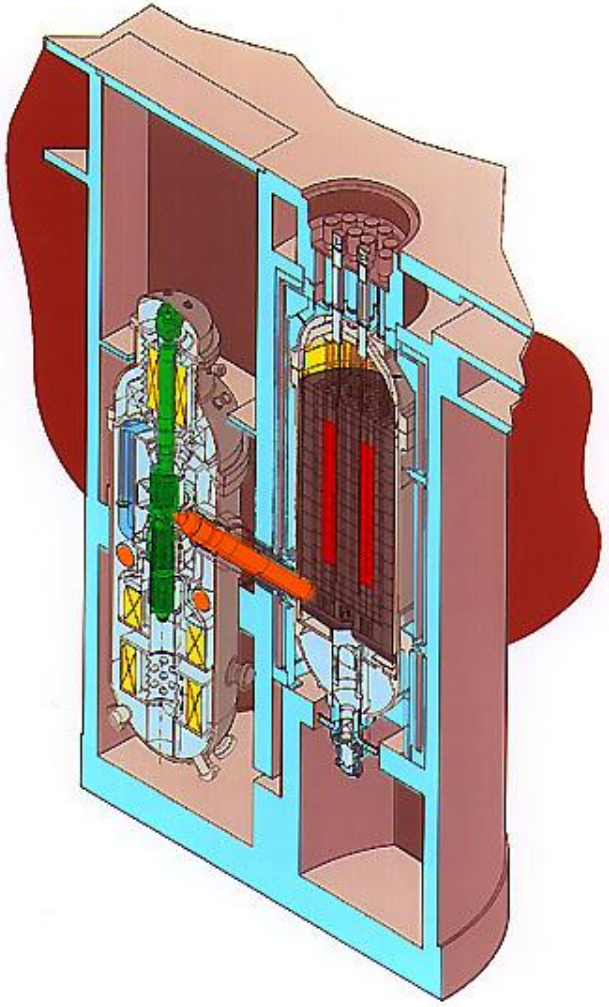


Safe Integral Reactor (SIR)

Non-LWR SMR designs also developed during the 80s

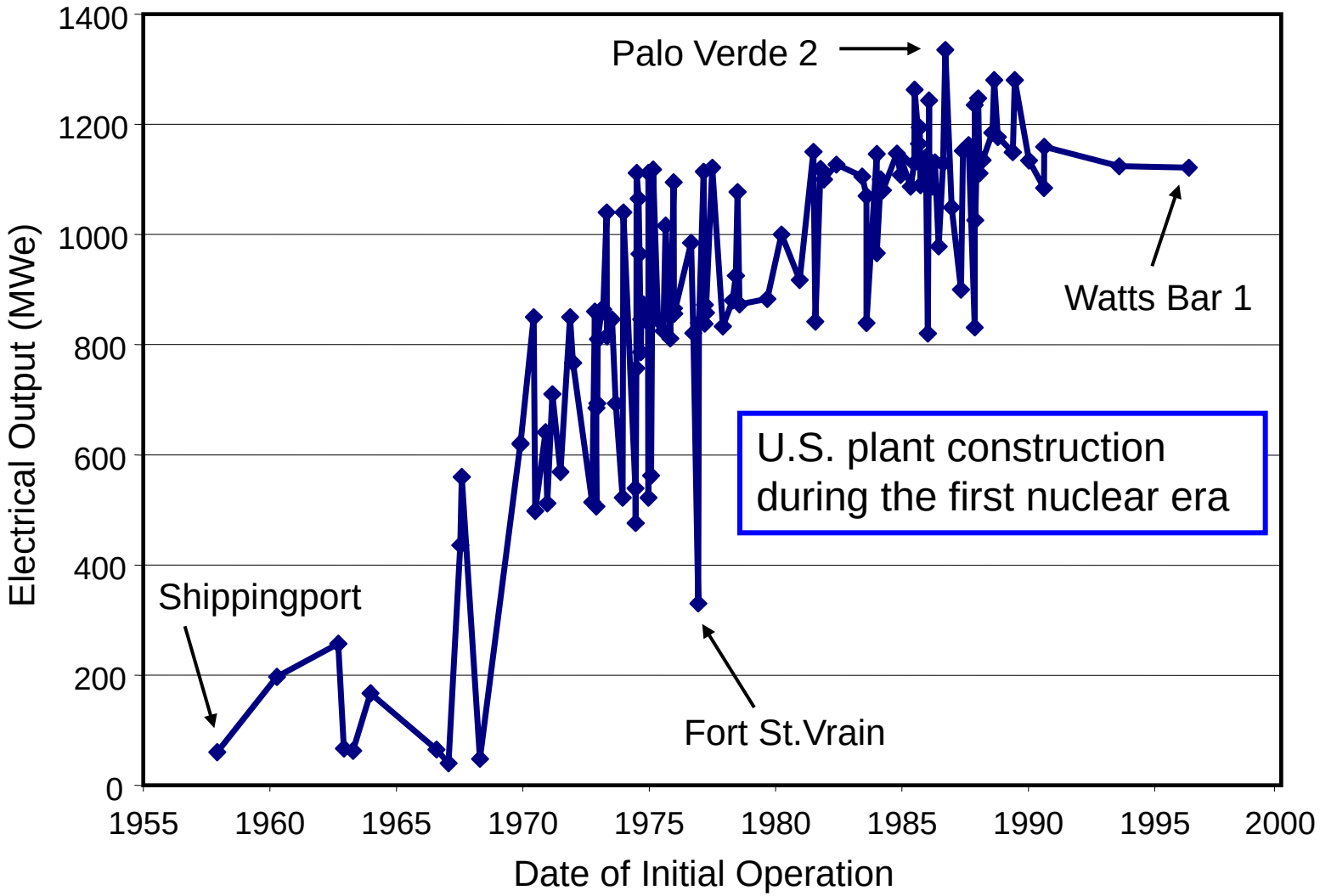


Power Reactor Inherently Safe Module (PRISM)

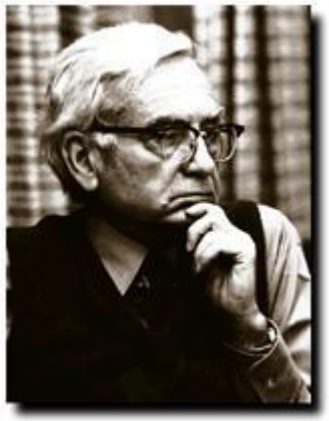


Modular High-Temperature Gas-cooled Reactor (MHTGR)

Meanwhile, commercial nuclear power plants escalated rapidly in size



Weinberg study* (1985) explored merits of smaller, simpler, safer reactors



Motivated by the dismal performance of the large plants (at that time)

Main findings:

- **Large light-water reactors pose very low risk to the public but high risk to the investor**
- **Large reactors are difficult to operate: complex and finicky**
- **Small inherently safe (highly forgiving) designs are possible if they can be made economically**
- **Two designs were especially promising:**
  - **The Process Inherent Ultimately Safe (PIUS) reactor**
  - **The Modular High-Temperature Gas-Cooled Reactor (MHTGR)**

*A. M. Weinberg, et al, *The Second Nuclear Era*, Praeger Publishers, 1985

Interest in SMRs is reemerging

- Enabled by excellent performance of existing fleet of large nuclear plants
- Motivated by carbon emission, energy security, and financing concerns
- Key Benefits
  - Reduced capital cost
  - Competitive power costs (hopefully)
  - Smaller incremental capacity addition to match power demand and growth rate
  - Domestic supply chain
  - Enhanced safety and robustness from simplified designs
  - Enhanced security from below-grade siting
  - Adaptable to a broader range of energy needs
  - More flexible siting (access, water impacts, seismic, etc.)

Summary

- **Small sized reactors got their start in the military and had a brief excursion into merchant ship propulsion.**
- **After being rapidly super-sized for commercial electricity production, new interest in SMRs began in the mid-70s and has continued ever since.**
- **Their anticipated merits haven't changed, but also haven't been realized.**
  - **Design robustness**
  - **Favorable economics**
  - **Diversity of application**

It is time to put up or shut up!