Inherently Risky Design?

The History of Soviet Nuclear Reactors and the Notion of Safety

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The Argument

- The process of choosing reactor designs is often presented in terms of **technical rationality**: the best, safest, most efficient design was selected. I will argue that this is not the case, has never been, and will never be. Instead, these processes are messy and arbitrary, and depend as much on technical functionality as they depend on **social definitions** of "functional," "safe," and "efficient."
- In recent discussions of future nuclear reactor designs, the idea that only **radical, revolutionary innovation** will solve the problem of nuclear energy clashes with the idea that only **standardization** can ensure reliability of operation (and ultimately effective emergency response). I will argue that neither strategy can work on its own. While the dogged pursuit of standardization can hamper safety improvements, the dream of a revolutionary "technological fix" is equally flawed.

Ongoing Controversy

- What is “safe”?
- What is “inherently safe”?
  - When there are redundancies built in for every possible problem?
  - When technology is fully automated?
  - When “tight coupling” and “complex interactions” in technological systems are reduced? (Perrow)
  - When “safety culture” is fully implemented? (Parr, IAEA, INPO)
- Ongoing discussion, e.g. newest French design (EPR, *active* safety features, redundancies) vs. latest US design (AP1000, *passive* safety features)

Safety as a Historical Concept

- "Safety," just like "risk," doesn't mean the same thing to all people in all places at all times
- It is a historically grown, dynamic concept

Why do reactor designers today call their reactors "inherently safe"?
Why did the IAEA (and other organizations) promote a higher, better "safety culture" after Chernobyl?

- "safe" implies "risk free" (or at the very least "accident free")
- "safety" implies mastery of a complex technology

Important, but elusive goal: Do we mean technical artifacts? Human operators? Both?

Chernobyl Redux

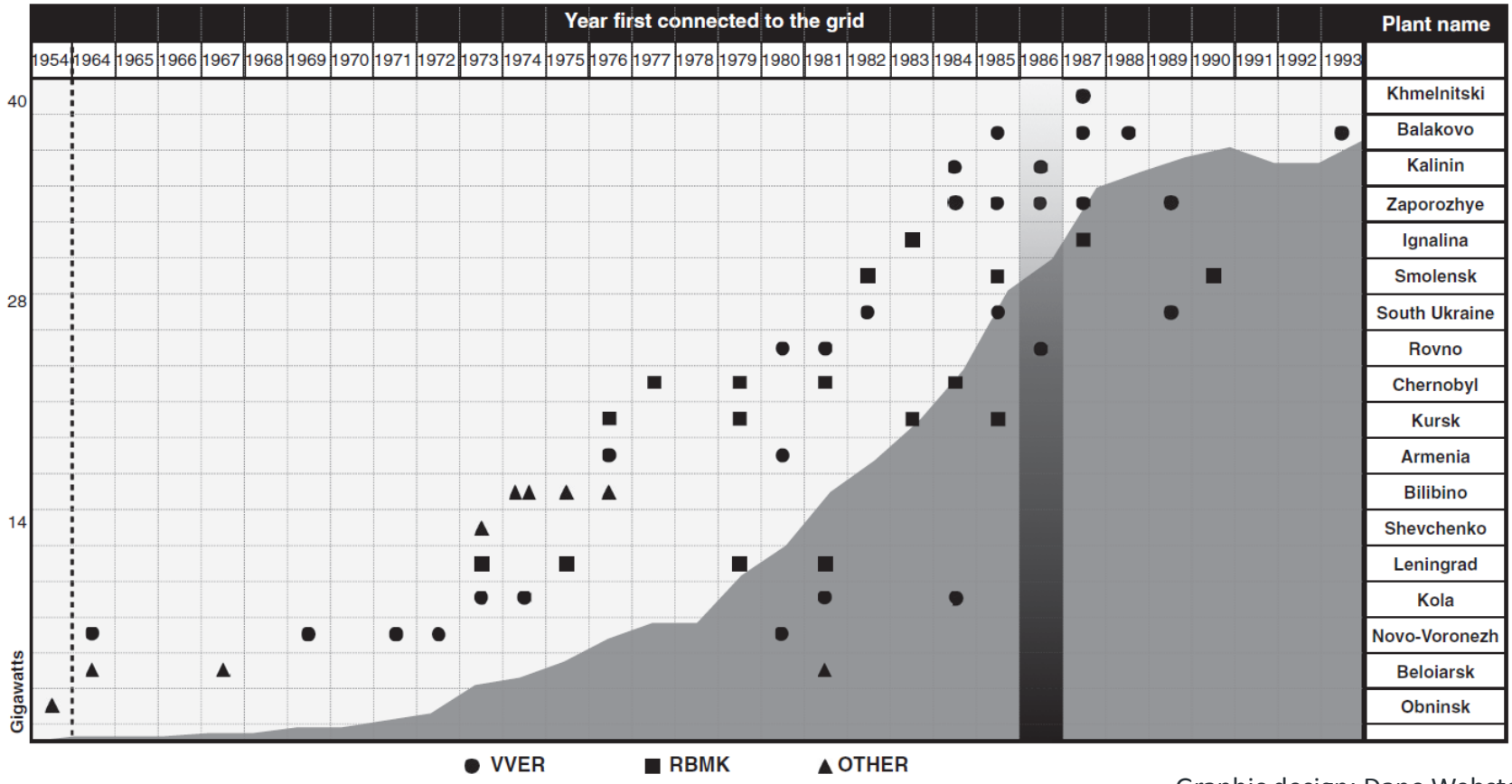
Chernobyl timeline

- Saturday, April 26, 1986, at ca. 1:24 a.m.: Reactor number 4 explodes
- April 27, 1986: Satellite town of Pripyat evacuated, 30km zone created
- April 28, 1986: Scandinavians measure elevated levels of radiation; Soviets admit "incident" and broadcast short announcement on Soviet TV
- Over the next weeks, a radioactive plume wafts across Europe and the world
- August 25-29, 1986: Soviet delegation presents an official report to the IAEA in Vienna
- November 1986: Concrete entombment of the reactor (the "sarcophagus") completed
- July 1987: Chernobyl trial
- 1991: Publication of "Shteinberg Report"

Soviet Civilian Nuclear Program

- Kurchatov turns to power reactors *before* first Soviet A-bomb explodes
- Obninsk ("World's First Nuclear Power Plant") starts up in July 1954
  - Design based on military reactors
  - Other designs ("up to ten") in the works
  - Program funded, defunded, depending on politics (5-Year Plans etc.)
  - Kuchatov lobbies, dies in 1960
- 1962: Civilian nuclear program re-starts
- 1964: Two new power reactors start up

Reactor Startups



Graphic design: Dane Webster

Reactor Design Choices

- Beloiarsk: Design based on Obninsk
- Novo-Voronezh: Design based on submarine propulsion
  - Support from top scientific institutes
  - International argument
  - PWR (VVER) designated as the future design for Soviet nuclear industry

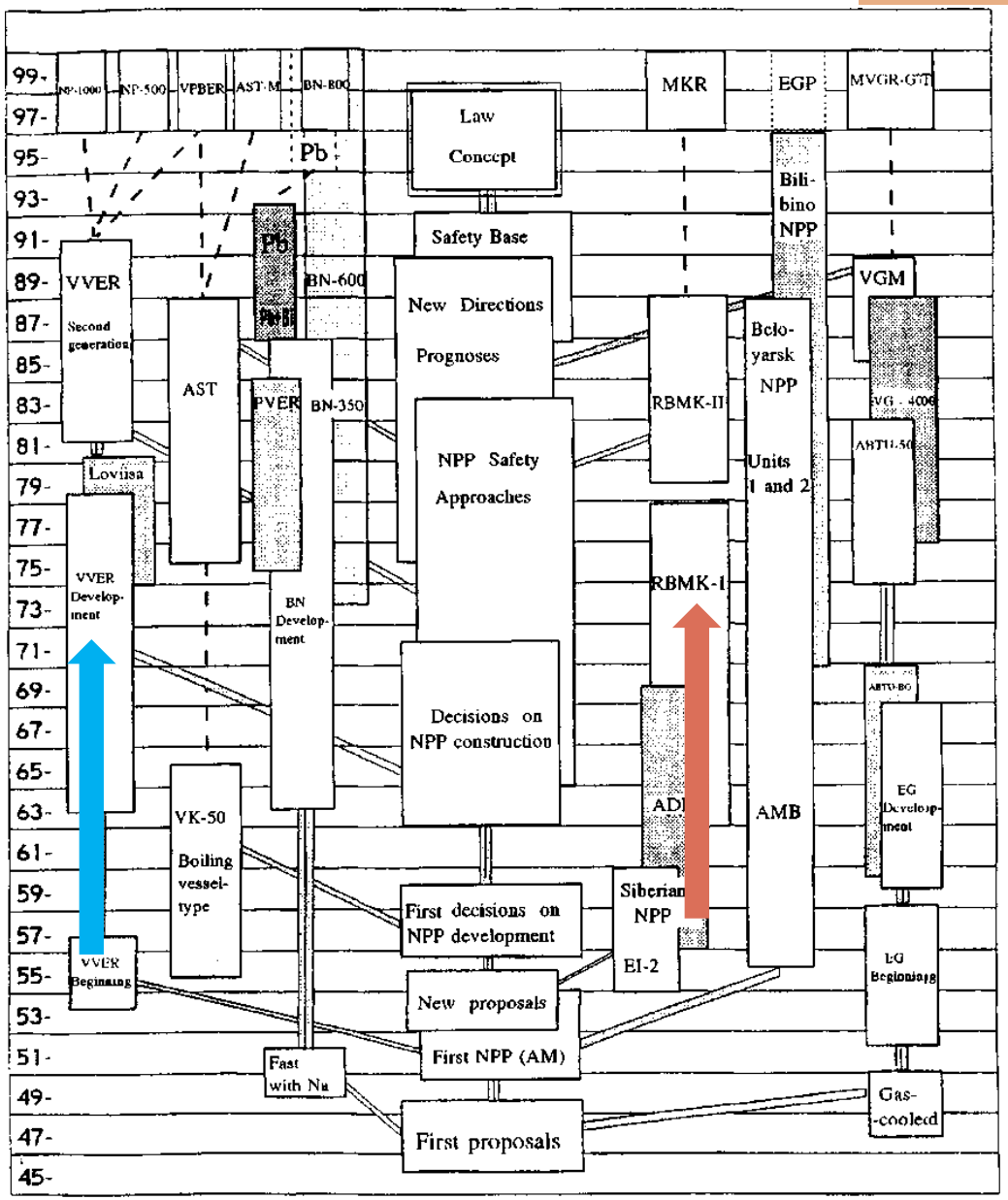
But: Long-term planning and supply *not secured!*

- Domestic supply and manufacturing industry can't handle ambitious expansion of VVER-based nuclear industry
- East European allies want Soviet "Atoms for Peace" (research and power reactors)

Enter the RBMK

- Decorated engineers present a different design
- Design is based on experience with military and dual-use reactors
- Existing cohort of trained operators familiar with similar reactors
- Backed by top scientific institutes and construction bureaus
- 1965: Government approves design before it exists!
- 1973: First Leningrad RBMK starts up, 1000 MW

→ **2 Designs, 2 Paths, 2 Supply Industries = Faster Growth**



Source: Sidorenko 1997

Why the RBMK?

According to some Western experts commenting on the RBMK after Chernobyl, it…

- …is an “inherently unsafe” design, old and flawed;
- …was used primarily for plutonium production;
- …was selected in the USSR because of
  - dysfunctional organizations
  - individual career ambitions
  - deliberate recklessness

Why the RBMK? (cont.)

- If the RBMK was so obviously unsafe, why did the Soviets build them? Lots of them?
  Near large, bustling cities?
- VVER was already operating
- Other available, operational designs

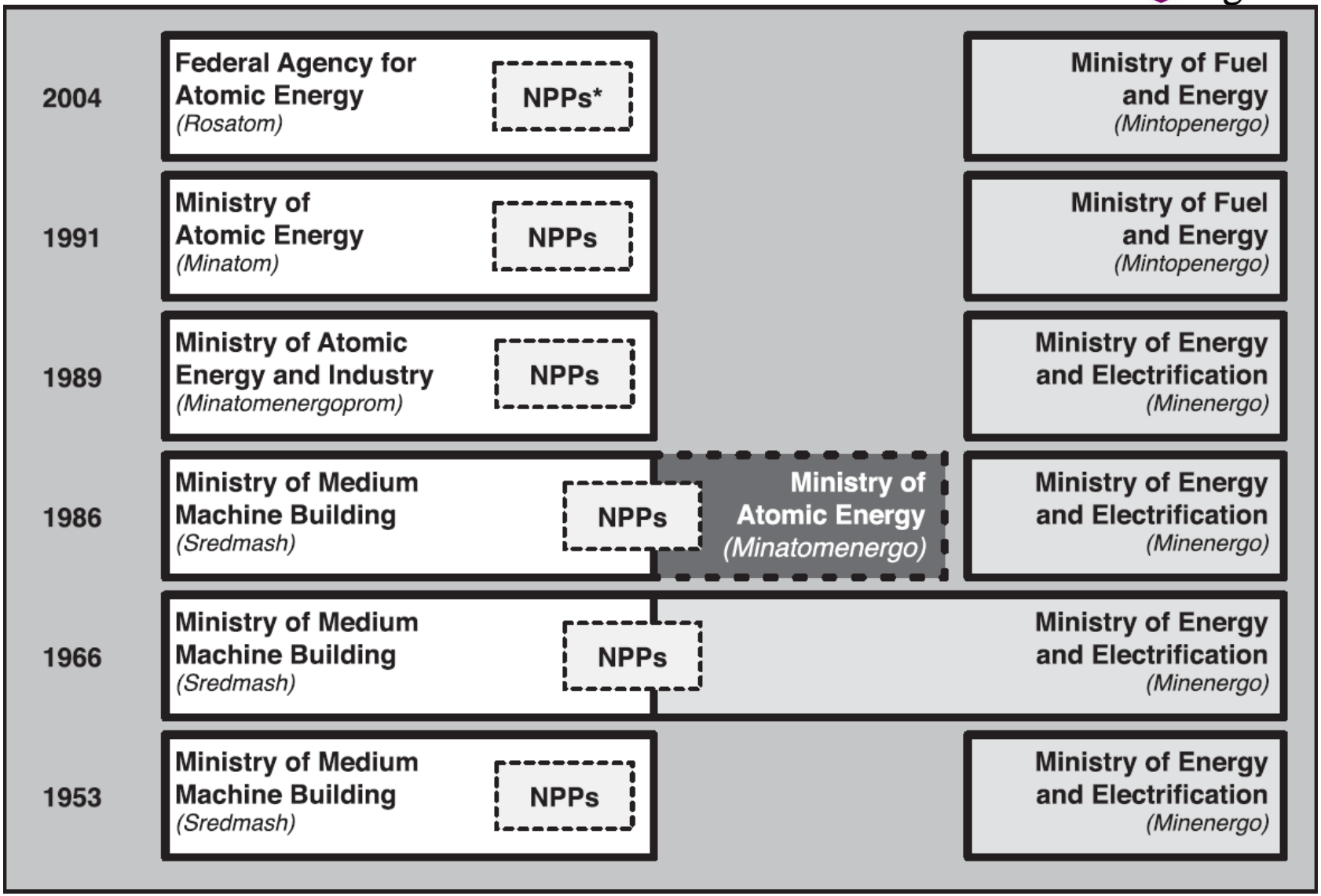
The wide adoption of the RBMK suggests that Soviet scientists and engineers thought the RBMK design was safe and efficient.

RBMK reactor hall, Kursk NPP

Why the RBMK? (cont.)

- This reactor would technologically and economically surpass the graphite-water reactors already operating
- A reactor designed to produce plutonium could be converted into a power reactor relatively easily
- Enough new civilian reactors could be produced to fulfill the plan of rapidly expanding the nuclear industry

- Existing supply industry, on-site assembly
- International considerations: "American" vs. "Soviet" design
- Security dimension (at least rhetorically successful)
- Organizational dimension



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What Makes a Design "Safe"?

- Standardization: "Holy Grail" of nuclear industry
  - Standardizing artifacts
  - Standardizing people (training: from on-the-job to formal curricula; how the "human factor" is envisioned; rule-following and wider social norms)
  - Standardizing organizations (how best to manage nuclear industry)

vs.

- Continuous improvement
  - Design generations
  - Operators knew their job (salaries depended on passing regular exams), and which systems were introduced when

RMBK “Generations”

Generations	1	2	3	4	5	6	7
Leningrad	Units 1&2		Units 3&4				
Kursk		Units 1&2		Units 3&4			Unit 5
Chernobyl		Units 1&2		Units 3&4			
Smolensk				Units 1&2	Unit 3		
Ignalina						Units 1&2	

The RBMK: A Safe Design?

- **Political** arguments: "unique" Soviet design, relatively easy conversion to Pu production
- **Economic** arguments: 1,000 MW prototype, online refueling, existing supply industry, on-site assembly
- **Technical** arguments: "proven" design, operational experience, safer than PWR

Severe Accidents

- Operator error
- Design flaws
- Corrupt system

- **Resist the temptation of “obvious” causes**
- **Encourage more contextualized understandings**

Conclusions (1)

- Designs are chosen not because they are “the best”
- What “the best” means changes over time
- Assigning blame:
  - Inherently unsafe design?
  - Inept or insufficiently trained operators?
  - Dysfunctional industrial system?

ANY technological development involves personal ambition, politics, and risk-taking.

ANY reactor design is “inherently risky”.

Conclusions (2)

- Rather than calling for more standardization we might ask what elements of socio-technical system can be standardized, and what elements cannot, should not.
- Radical innovation, “technical fix,” is unlikely to solve all problems, not only because there might be unintended consequences, but because we first need to agree what the problem is.
- We are likely to learn most from exploring the messy origins of reactor design choices, and how decisions that in retrospect are sometimes presented as “purely technical” were in fact shaped by historically specific social, economic, and policy contexts.

Producing Power: The Pre-Chernobyl History of the Soviet Nuclear Industry (MIT Press 2015)

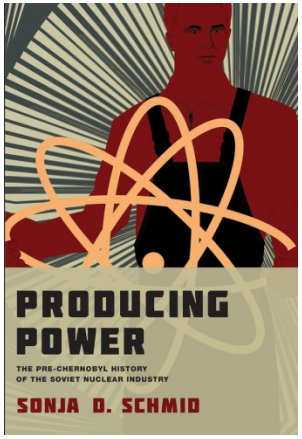
Introduction

1. Envisioning a Nuclear-Powered State
2. Between Atomic Bombs and Power Plants: Sharing Organizational Responsibilities
3. Training Nuclear Experts: A Workforce for the Nuclear Industry
4. "May the Atom Be a Worker, Not a Soldier!": A New History of Soviet Reactor Design Choices
5. Chernobyl: From Accident to Sarcophagus

Conclusion

Epilogue: Writing about Chernobyl after Fukushima

http://mitpress.mit.edu/books/producing-power



Thank you!

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