The Past, The Present, The Future
THE GEOGRAPHY AND HISTORY OF THE CHERNOBYL NUCLEAR POWER PLANT
1967
- February 1970 Construction of Pripyat begins
- January 1967 Gosplan recommends a new power plant at Kopachi, Ukraine

1972
- April 1972 Pripyat officially named
- August 1972 Construction begins on Chernobyl Unit 1

1977
- May 1979 Unit 1 goes online
- June 1982 Unit 3 goes online

1982
- April 1986 Unit 4 destroyed, Pripyat is evacuated
- September 1982 Partial core melt, Unit 1

1987
- March 1984 Unit 4 goes online
- November 1987 Unit 3 back online

1992
- November 1996 Unit 1 shut down permanently

1997
- March 1994 Unit 2 goes online
- November 1996 Unit 1 shut down permanently

2002
- September 2010 Construction begins on New Safe Confinement to replace Shelter Object

2012
- October 2011 Unit 2 shut down permanently; end of power-producing era at ChNPP

2017
Chain-reacting systems are familiar (e.g., fire). Feedback, stability, and control concepts in nuclear reactors may be compared to the behaviors of fires.
**Feedback:**
Feedback refers to a system influencing its own behavior.

**Positive Feedback:**
A perturbation to a parameter of the system causes a response that moves that parameter in the same direction as the stimulus. Can promote instability.

**Negative Feedback:**
A perturbation causes a response that moves the parameter in the opposite direction of the stimulus. Favors stability.

**Poisoning:**
Fires and nuclear reactors both generate byproducts that interfere with—or “poison”—the chain reaction.

**Fires and Nuclear Reactors**

**Fires**
Fuel is combustible material that reacts with air when exposed to heat, producing more heat, which can cause combustion in additional fuel.

**Nuclear Reactors**
Fuel is atomic nuclei that explode when they absorb slow-moving neutrons, producing more neutrons (generally fast-moving ones). The moderator slows down fast neutrons so they will cause fission in additional fuel.

**Controlling Reactions**
1. Increase or reduce the efficiency of neutron transfer between fuel.
2. Decrease efficiency by putting neutron-absorbing material (typically called control rods) between fuel elements.
3. Increase efficiency by withdrawing the control rods.

**Controlling Fires**
1. Increase or reduce the efficiency of heat transfer between fuel.
2. Decrease efficiency by putting water, or damp fuel, in the fire (water evaporation removes heat).
3. Increase efficiency by moving fuel pieces closer together, or by burning dryer fuel.
EVOLUTION OF THE ACCIDENT
# EVOLUTION OF THE ACCIDENT

<table>
<thead>
<tr>
<th>Time</th>
<th>Event / Action</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>~12:00 AM</td>
<td>Failure to maintain computerized automatic control of reactor power at intended power level.</td>
<td>Reactor almost shuts down. Xe-135 poison builds up, suppressing ability to resume intended power.</td>
</tr>
<tr>
<td>April 26, 1986</td>
<td></td>
<td></td>
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<tr>
<td>~1:00 AM</td>
<td>Operator attempts to maintain power. He must remove almost all the control rods.</td>
<td>Only neutron absorber left in core is boiling water. Positive power reactivity feedback scenario. Power begins rising.</td>
</tr>
<tr>
<td>1:23 AM</td>
<td>Test concludes, operator presses button to insert all control rods. (Unknown whether he does this because of power surge, or because he was attempting a normal shutdown.)</td>
<td>Control rod tips push water out of the core, adding reactivity because the tips are made of a poor absorber. Reactor power rises uncontrollably; core damage impedes further control rod entry. <em><strong>EXPLOSION</strong></em></td>
</tr>
</tbody>
</table>
The operator withdrew most control rods to counteract poisoning, leading to positive power reactivity feedback as water boiled in the core. When the operator attempted to replace the control rods, their tips accelerated the power surge and control was lost.
CONTRIBUTING FACTORS

**Operator Fault:** ChNPP staff performed contrary to regulation and technical instruction from the designer, contributing to the accident and its consequences. Six ChNPP staff convicted of misconduct in the Chernobyl Trial (1987), but the trend since has been exculpatory.

**Flawed Design:** RBMK had dangerous characteristics, did not meet official safety mandates; some views suggest catastrophe “built in”. Upgrades addressed reactor issues most significant to accident.

**Deficient “Safety Culture”:** Phrase coined by INSAG encompasses faults specific to Chernobyl and the wider system of nuclear power regulation and management in USSR; the Soviet industry, by its priorities, ideology, and organization, was accident-prone.

**Residual Risk:** The constellation of technical / human circumstances leading to accident was preemptively unknown and practically unknowable; nuclear power is “inherently dangerous” even when handled competently; from an alternative viewpoint, “Science requires victims.”
ASSESSING THE DAMAGE
CONSTRUCTION OF THE SARCOPHAGUS
Задание правительства выполним!
NEW CONFINEMENT STRUCTURE
Объект "Укрытие"

Пути надвижки

Укрытие

92.99 м
102 м
108.89 м

257.44 м
150 м
108.89 м
RADIOLOGICAL CONDITIONS AT CHERNOBYL
Entombed part of turbine hall: TG-8 and TG-7
REDUCING WORKER EXPOSURES
CONTAMINATION IN THE ENVIRONMENT
<table>
<thead>
<tr>
<th>Isotope</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am-241</td>
<td>3,782 pCi/g</td>
</tr>
<tr>
<td>Ba-133</td>
<td>42 pCi/g</td>
</tr>
<tr>
<td>Cs-137</td>
<td>78,274 pCi/g</td>
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<tr>
<td>Eu-154</td>
<td>48 pCi/g</td>
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<tr>
<td>Gd-153</td>
<td>21 pCi/g</td>
</tr>
<tr>
<td>Ra-226</td>
<td>384 pCi/g</td>
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CHERNOBYL INTO THE FUTURE
THE WORKERS OF CHERNOBYL
Thank you for supporting the workers at the Chernobyl Nuclear Power Plant

Acknowledgements
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