# Nuclear Weapons in 360 Minutes (or Less!)

William Spaniel

https://williamspaniel.com/classes/nuclearpolitics2020/

# Outline

- The Nuclear Club (and Friends)
- Why Proliferate?
- Effects of Proliferation
- Managing the Atom

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- Managing the Atom

# United States (1945)

- Manhattan Project
- Hiroshima and Nagasaki bombings
- Would have been a lot worse if the Nazi scientists had won the race
  - …but fortunately the Nazis were Naziing


USA
33
Enrico
Fermi

# Soviet Union (1949)

- Manhattan Project spies
- US knew the Soviets were developing a bomb but chose not to launch preventive war
  - Immediately after WWII
  - No intelligence
- Cold War starts in earnest

# United Kingdom (1952)

- Tube Alloys
- Agreement with the United States

# France (1960)

- France and the United States do not have as intimate a relationship as the U.S. and the U.K.
- France sought strategic independence

# China (1964)

- Sino-Soviet split

# India (1974)

- India does not like Pakistan very much
- Tested the “Smiling Buddha,” a “peaceful nuclear explosion,” in 1974
- Remained mostly dormant until 1998. (Hold that thought…)

# Israel (1979)

- Israel does not have nuclear weapons

# South Africa (1979)

- The Vela Incident
  - A US satellite (Vela Hotel) detected a flash in the Atlantic Ocean between South Africa and Antarctica
- Built due to concerns of civil war spillover from Angola
- Dismantled at the end of Apartheid

# Soviet Successor States

- Ukraine, Kazakhstan, and Belarus had nuclear weapons on their soil during the Soviet Union's breakup
- Moscow still had command control
- Countries accepted cash to dismantle the weapons and forgo native nuclear development

# Pakistan (1998)

- Five weeks after India's nuclear tests in 1998, Pakistan tested six bombs
- Pakistan is now "too nuclear to fail"
- A.Q. Khan network

# The 1998 Ig Nobel Prize Winners

*The 1998 Ig Nobel Prizes were awarded at the 8th First Annual Ig Nobel Prize Ceremony, at Harvard's Sanders Theatre. The ceremony was webcast live.*

**SAFETY ENGINEERING**: Troy Hurtubise, of North Bay, Ontario, for developing, and personally testing a suit of armor that is impervious to grizzly bears. [REFERENCE: "Project Grizzly", produced by the "National Film Board of Canada. ALSO: *Bear Man: The Troy Hurtubise Saga*, by Troy Hurtubise, Raven House Publishing, Westbrook, ME, USA, 2011.]

**BIOLOGY**: Peter Fong of Gettysburg College, Gettysburg, Pennsylvania, for contributing to the happiness of clams by giving them Prozac.

[REFERENCE: "Induction and Potentiation of Parturition in Fingernail Clams (Sphaerium striatinum) by Selective Serotonin Re- Uptake Inhibitors (SSRIs)," Peter F. Fong, Peter T. Huminski, and Lynette M. D'urso, "Journal of Experimental Zoology, vol. 280, 1998, pp. 260-64.]

**PEACE**: Prime Minister Shri Atal Bihari Vajpayee of India and Prime Minister Nawaz Sharif of Pakistan, for their aggressively peaceful explosions of atomic bombs.

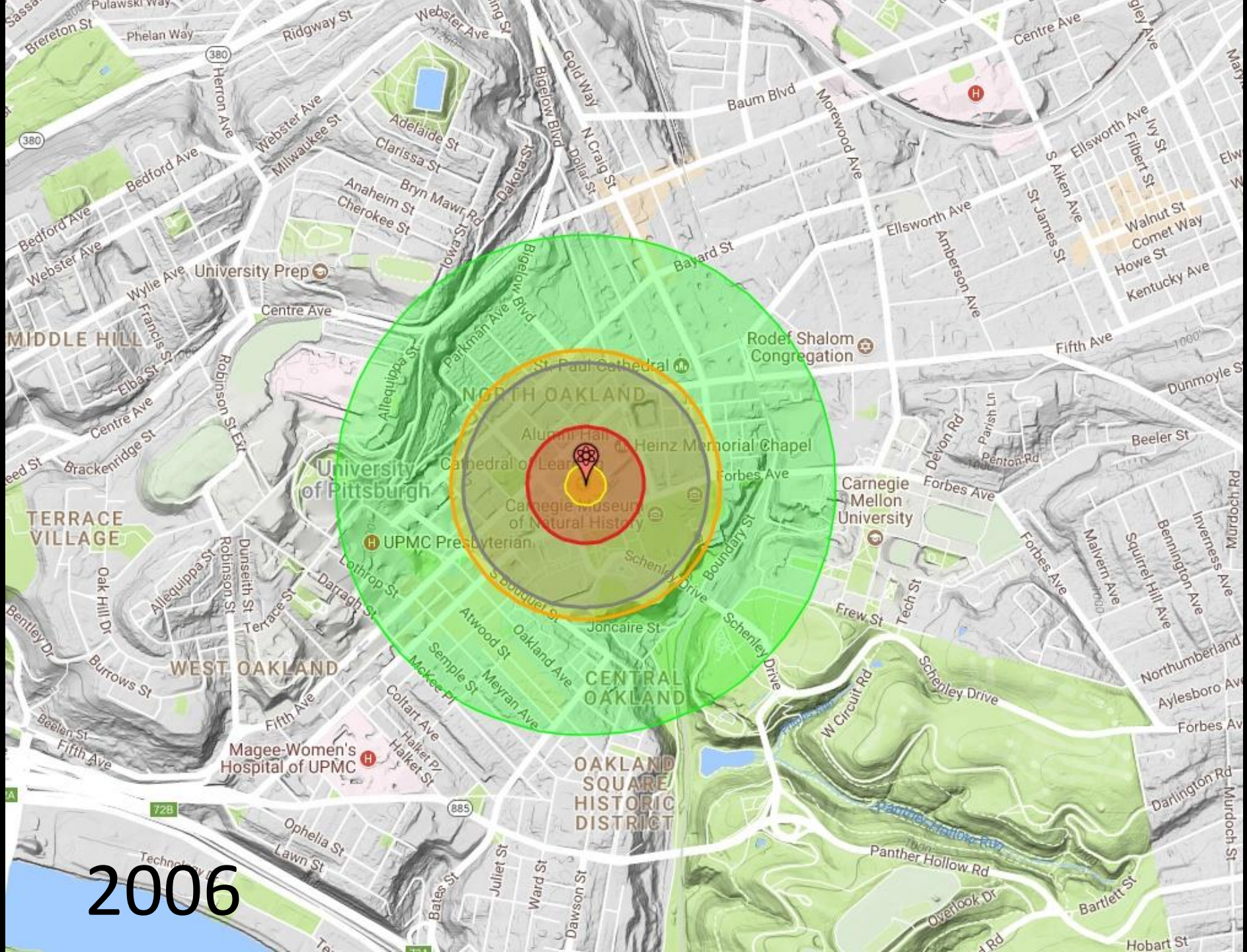
**CHEMISTRY**: Jacques Benveniste of France, for his homeopathic discovery that not only does water have memory, but that the information can be transmitted over telephone lines and the Internet. [NOTE: Benveniste also won the 1991 Ig Nobel Chemistry Prize.]

[REFERENCE:"Transatlantic Transfer of Digitized Antigen Signal by Telephone Link," J. Benveniste, P. Jurgens, W. Hsueh and J. Aissa, "Journal of Allergy and Clinical Immunology - Program and abstracts of papers to be presented during scientific sessions AAAAI/AAI.CIS Joint Meeting February 21-26, 1997"]

**SCIENCE EDUCATION**: Dolores Krieger, Professor Emerita, New York University, for demonstrating the merits of therapeutic touch, a method by which nurses manipulate the energy fields of ailing patients by carefully avoiding physical contact with those patients.

# North Korea (2006)

- Conducted crummy tests in 2006 (possibly a fizzle), 2009, and 2013
- Scarier tests twice in 2016 and once in 2017


2006
University Prep
MIDDLE HILL
Centre Ave
Webster Ave
Bedford Ave
Herron Ave
Ridgway St
Phelan Way
Brereton St
Adelaide St
Clarissa St
Bryn Mawr Rd
Anaheim St
Cherokee St
Dakota St
Iowa St
Bigelow Blvd
Gold Way
Dollar St
N Craig St
Baum Blvd
Morewood Ave
Centre Ave
Ellsworth Ave
S Aiken Ave
St James St
Amberson Ave
Filbert St
Ivy St
Walnut St
Comet Way
Howe St
Kentucky Ave
Bayard St
Fifth Ave
Rodef Shalom Congregation
St. Paul Cathedral
NORTH OAKLAND
Heinz Memorial Chapel
Forbes Ave
Carnegie Mellon University
University of Pittsburgh
Cathedral of Learning
Carnegie Museum of Natural History
UPMC Presbyterian
TERRACE VILLAGE
WEST OAKLAND
CENTRAL OAKLAND
Schenley Drive
Boundary St
Joncaire St
Atwood St
Oakland Ave
Meyran Ave
Semple St
McKee Pl
Coltart Ave
Halket St
Fifth Ave
Magee-Women's Hospital of UPMC
OAKLAND SQUARE HISTORIC DISTRICT
Ophelia St
Lawn St
Juliet St
Ward St
Dawson St
Bates St
Panther Hollow Rd
Overlook Dr
Bartlett St
Hobart St
Darlington Rd
Murdoch St
Northumberland
Aylesboro Ave
Forbes Ave
Frew St
Tech St
Malvern Ave
Squirrel Hill Ave
Bennington Ave
Inverness Ave
Beeler St
Penton Rd
Parish Ln
Devon Rd
Dunmoyle St
Elba St
Francis St
Wylie Ave
Robinson St Ext
Brackenridge St
Allequippa St
Parkman Ave
Bigelow Blvd
Oak Hill Dr
Bentley Dr
Burrows St
Beelen St
Dunseith St
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Darragh St
Lothrop St
S Bouquet St
Frew St
W Circuit Rd
Schenley Drive
Panther Hollow Rd
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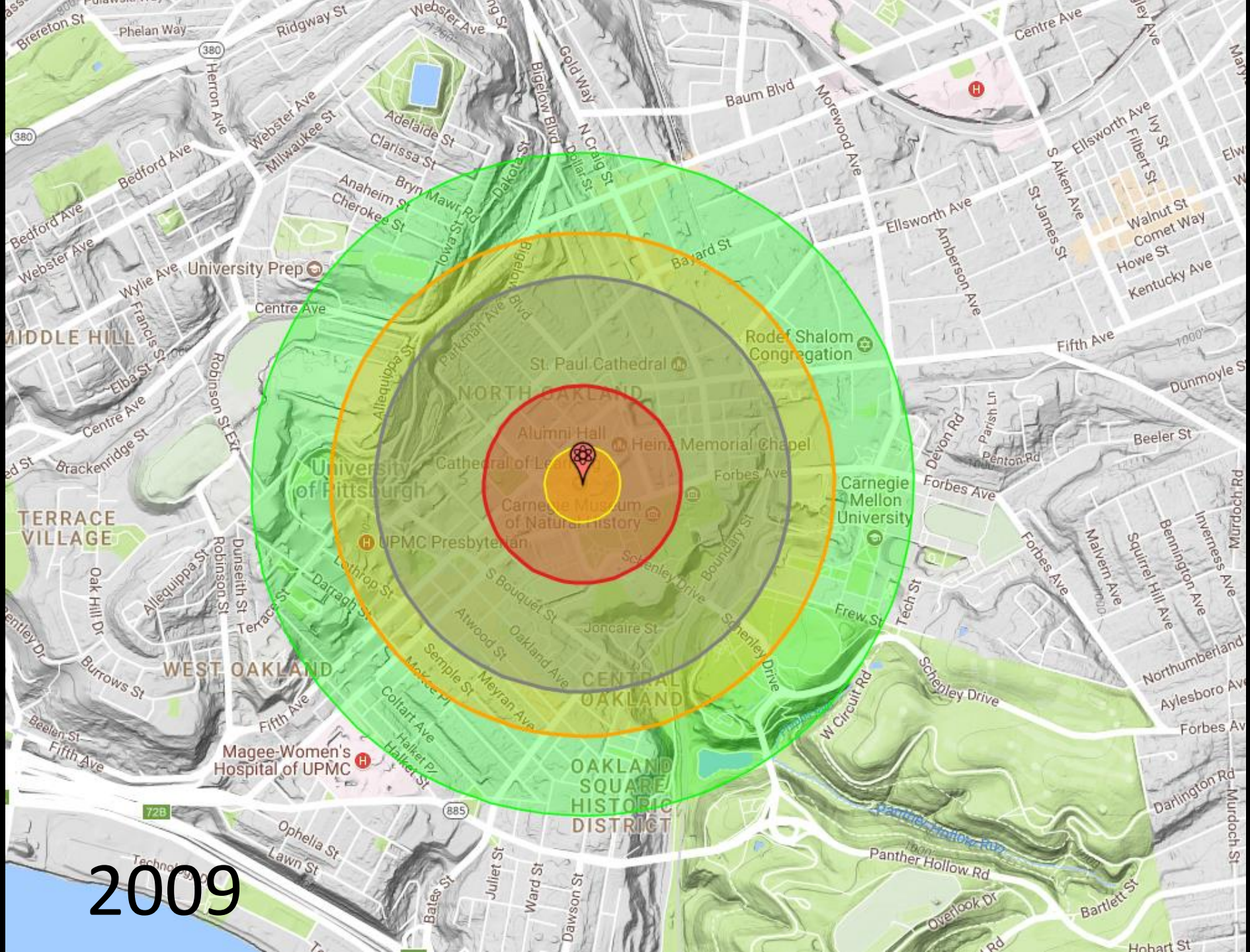
2009
Phelan Way
Ridgway St
Webster Ave
Brereton St
Herron Ave
Bedford Ave
Webster Ave
Milwaukee St
Adelaide St
Clarissa St
Bryn Mawr Rd
Anaheim St
Cherokee St
Iowa St
Dakota St
Bigelow Blvd
Gold Way
N Craig St
Bellaire St
Baum Blvd
Morewood Ave
Centre Ave
Ellsworth Ave
S Aiken Ave
Ivy St
Filbert St
St James St
Amberson Ave
Walnut St
Comet Way
Howe St
Kentucky Ave
Bayard St
Fifth Ave
Dunmoyle St
Wylie Ave
University Prep
Centre Ave
Francis St
MIDDLE HILL
Elba St
Robinson St Ext
Centre Ave
Brackenridge St
Parkman Ave
Allequippa St
St. Paul Cathedral
NORTH OAKLAND
Rodef Shalom Congregation
Alumni Hall
Heinz Memorial Chapel
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TERRACE VILLAGE
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Darragh St
S Bouquet St
Schenley Drive
Boundary St
Malvern Ave
Squirrel Hill Ave
Bennington Ave
Inverness Ave
Tech St
Frew St
Joncaire St
Atwood St
Oakland Ave
Semple St
Meyran Ave
WEST OAKLAND
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Burrows St
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Forbes Ave
Darlington Rd
Murdoch St
72B
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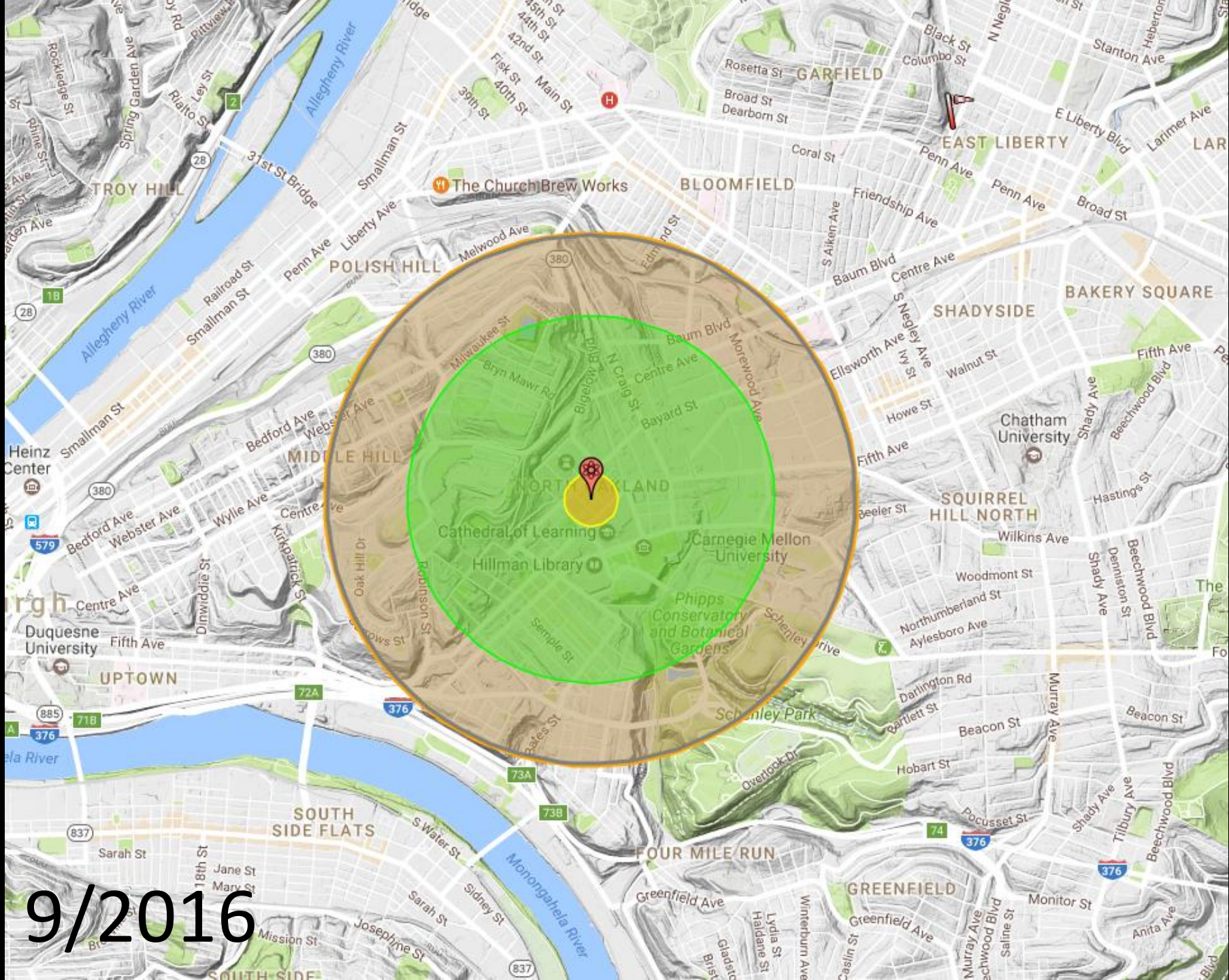
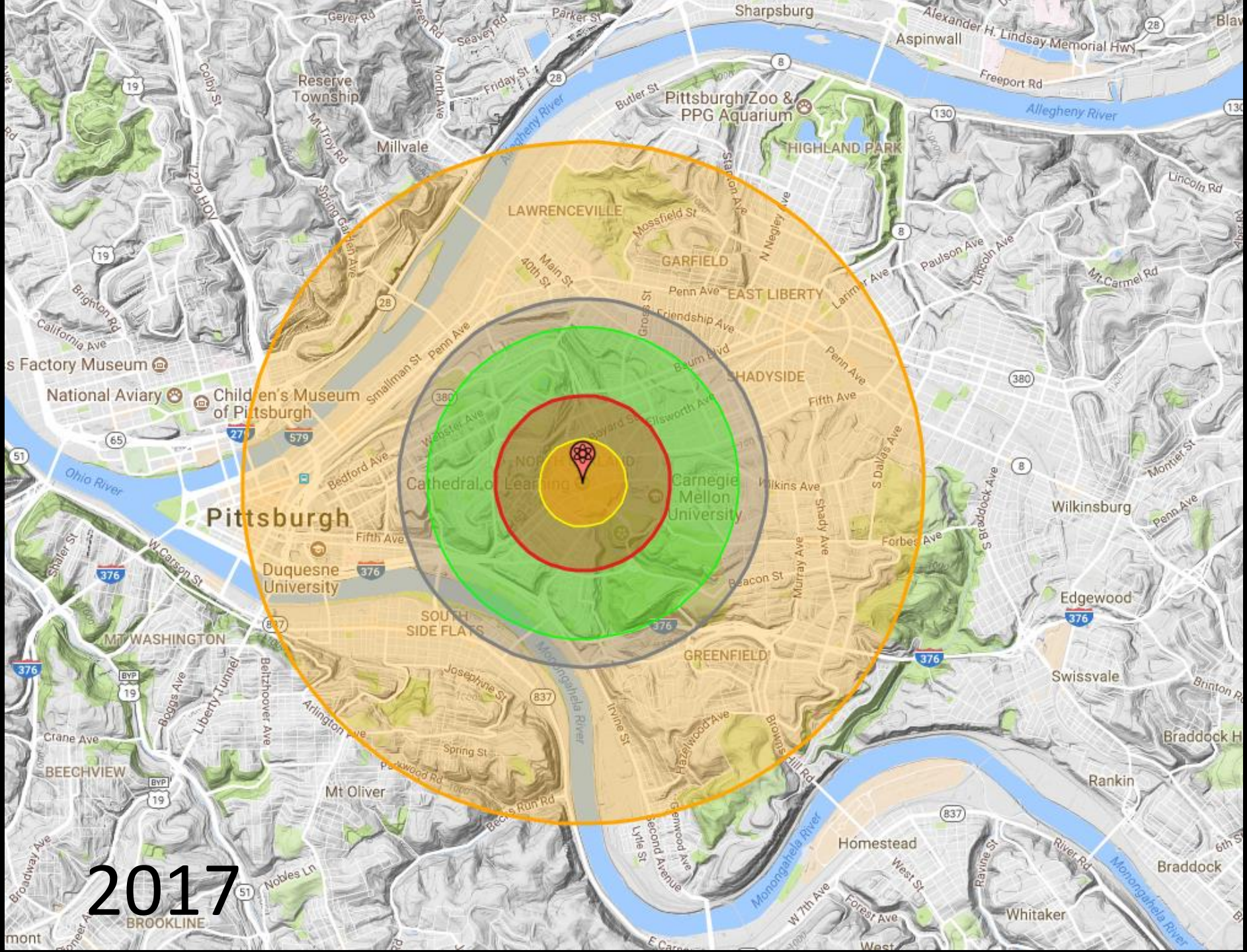
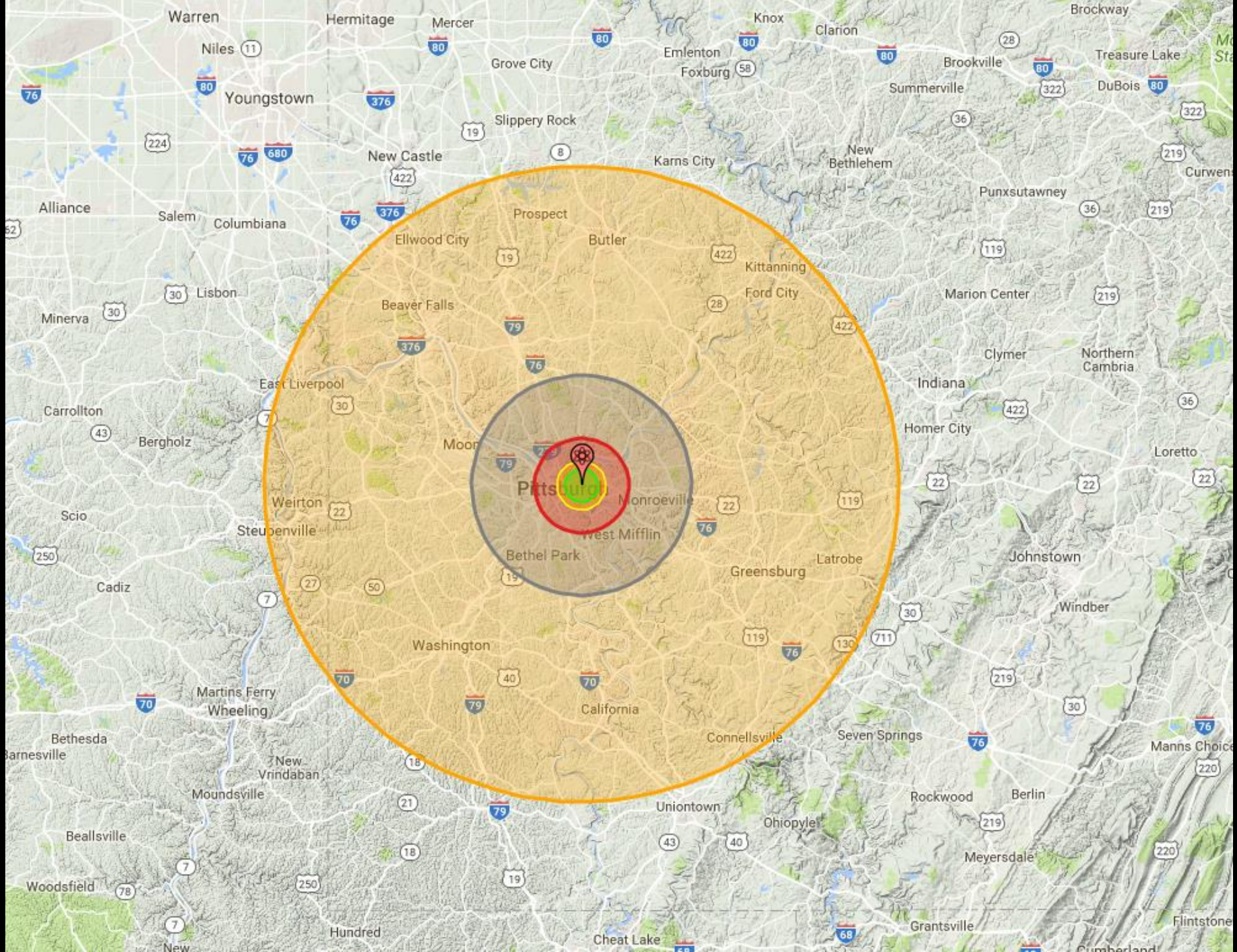
Ophelia St
Lawn St
Juliet St
Ward St
Dawson St
Bates St
OAKLAND SQUARE HISTORIC DISTRICT
Panther Hollow Rd
Overlook Dr
Bartlett St
Hobart St


9/2016
Cathedral of Learning
Hillman Library
Carnegie Mellon University
Phipps Conservatory and Botanical Gardens
Schenley Park
Chatham University
The Church Brew Works
Heinz Center
Duquesne University
Allegheny River
Monongahela River
TROY HILL
POLISH HILL
BLOOMFIELD
GARFIELD
EAST LIBERTY
SHADYSIDE
BAKERY SQUARE
SQUIRREL HILL NORTH
UPTOWN
SOUTH SIDE FLATS
FOUR MILE RUN
GREENFIELD


2017
Pittsburgh
LAWRENCEVILLE
GARFIELD
EAST LIBERTY
SHADYSIDE
HIGHLAND PARK
Carnegie Mellon University
Duquesne University
SOUTH SIDE FLATS
MT WASHINGTON
BEECHVIEW
Mt Oliver
BROOKLINE
GREENFIELD
Millvale
Reserve Township
Sharpsburg
Aspinwall
Pittsburgh Zoo & PPG Aquarium
Wilkinsburg
Edgewood
Swissvale
Rankin
Homestead
Braddock
Whitaker
Allegheny River
Ohio River
Monongahela River


Warren
Hermitage
Mercer
Knox
Clarion
Brockway
Niles
Emlenton
Grove City
Foxburg
Brookville
Treasure Lake
Youngstown
Summerville
DuBois
Slippery Rock
New Castle
Karns City
New Bethlehem
Punxsutawney
Alliance
Salem
Columbiana
Prospect
Ellwood City
Butler
Kittanning
Ford City
Lisbon
Minerva
Beaver Falls
Marion Center
Clymer
Northern Cambria
East Liverpool
Indiana
Carrollton
Bergholz
Homer City
Loretto
Pittsburgh
Monroeville
Weirton
Scio
Steubenville
West Mifflin
Bethel Park
Latrobe
Johnstown
Greensburg
Cadiz
Windber
Washington
Martins Ferry
Wheeling
California
Connellsville
Seven Springs
Manns Choice
Bethesda
Barnesville
New Vrindaban
Moundsville
Uniontown
Rockwood
Berlin
Ohiopyle
Beallsville
Meyersdale
Woodsfield
Hundred
Cheat Lake
Grantsville
Flintstone

# Outline

- The Nuclear Club (and Friends)
- Why Proliferate?
- Effects of Proliferation
- Managing the Atom

# Argentina/Brazil

- Had simmering tensions in the 1980s
- Both proficient in nuclear technology but opted against proliferating
- Now have a joint nuclear commission and share technology

# Australia

- Site of UK's initial nuclear tests
- Largest uranium reserves in the world
- Had a brief exploration

# Belarus, Kazakhstan, and Ukraine

- Soviet nuclear weapons
- Ukraine had 3rd largest stockpile
- No command and control
- Allowed Moscow to recover them in exchange for economic concessions

# Egypt

- Slow exploration and pursuit in the 1970s
- Effort went away after the Camp David Accords

# Iran

- Long running interest in nuclear weapons
- 2015: Joint Comprehensive Plan of Action
- 2019: No more plan of action

# Iraq

- Also had long running interest in nuclear weapons
- Never made real progress
- Operation Scorch Sword
- Operation Opera
- Potential motivation for Iraq War

# Japan

- Most nuclear proficient country of the non-nuclear weapons states
- US reaffirmed alliance support when Japan moved toward proliferating
- Now is a staunch supporter of non-nuclear norms

# Libya

- One of the longest-running programs
- Ultimately went nowhere
- U.S. traded what little progress they made for some minor economic concessions

# Saudi Arabia

- Has started showing greater interest in nuclear technology since Iran’s push

# South Korea

- Another very nuclear proficient non-nuclear weapons state
- US reaffirmed alliance support when South Korea moved toward proliferating

# Sweden

- Neutrality preference
- Limited military budget and chose to build conventional weapons instead

# Syria

- Very small progress in nuclear science
- Operation Orchard

# Taiwan

- US reaffirmed its alliance benefits when Taiwan moved toward proliferating

# (West) Germany

- Another highly proficient non-nuclear weapons states
- Has a nuclear weapons “sharing” agreement with the United States

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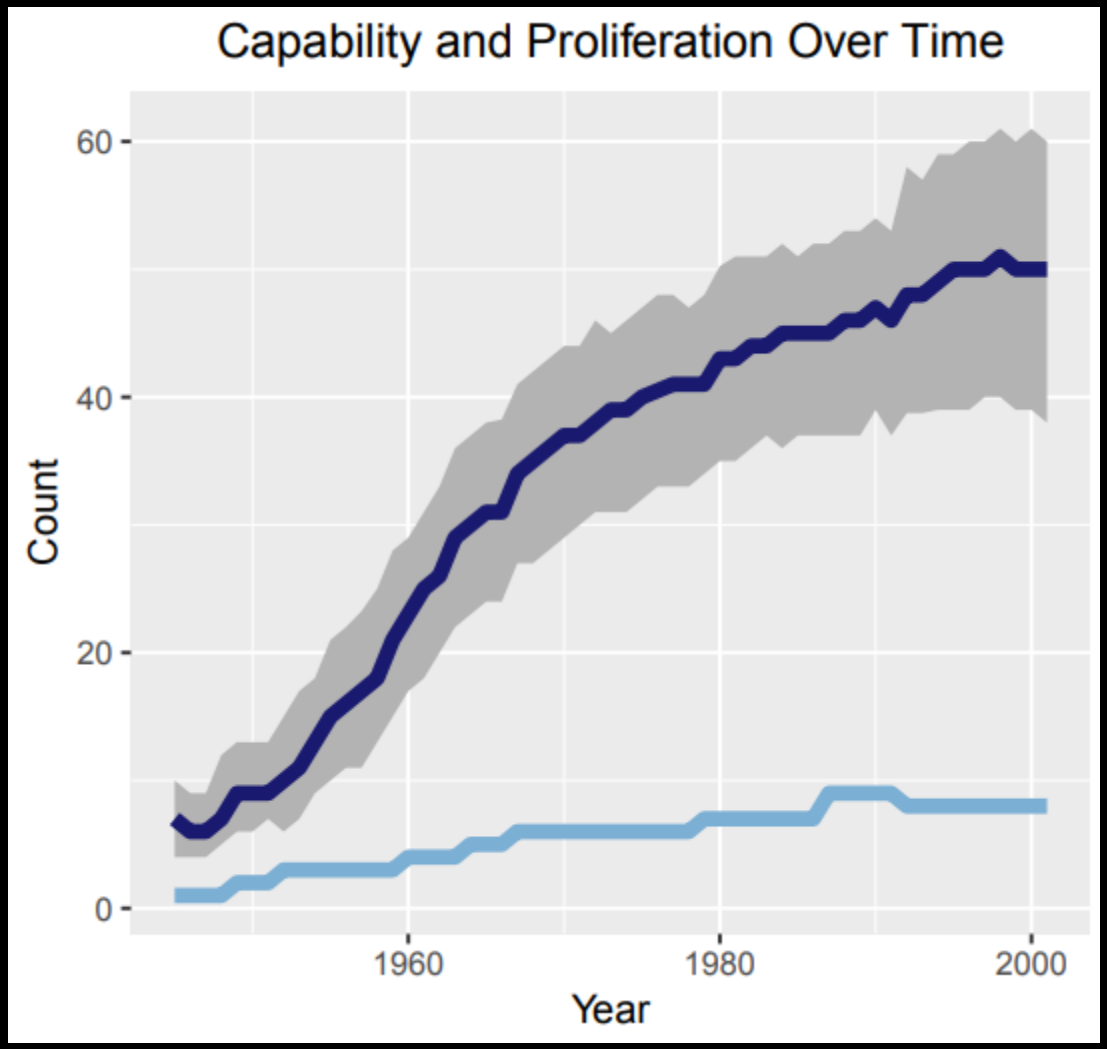
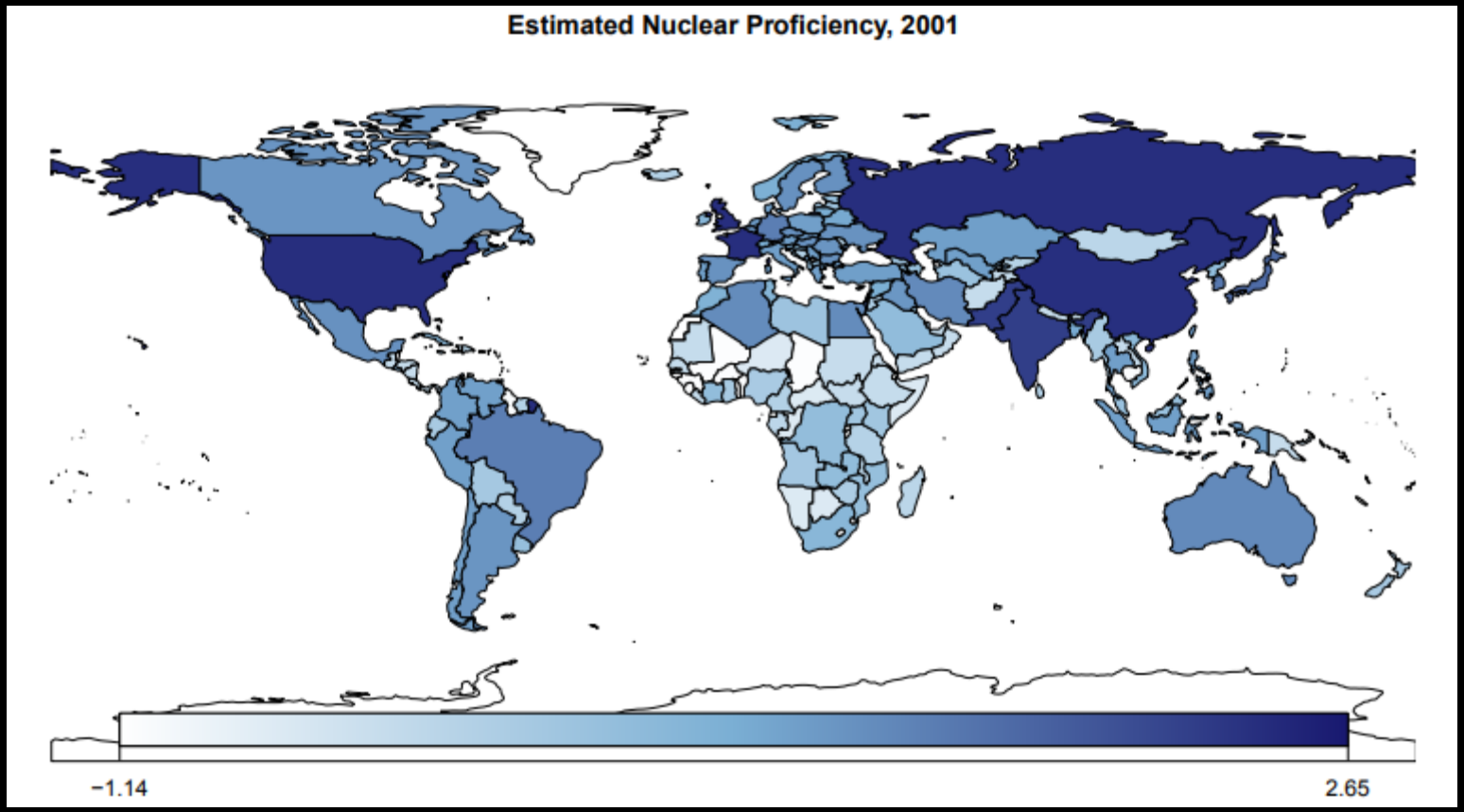
# Capacity (Supply Side)

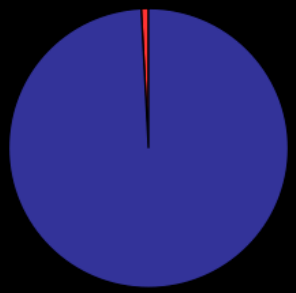
- Can’t build what you don’t understand
- Also need good industrial base (or lots of manpower) to construct weapons
- Explains initial nonproliferation, but does not have much explanatory power anymore


Capability and Proliferation Over Time
60
40
20
0
Count
1960
1980
2000
Year

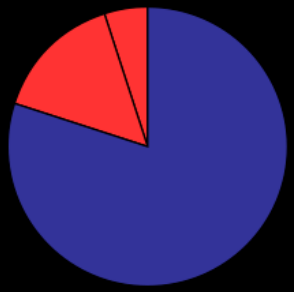

Estimated Nuclear Proficiency, 2001
−1.14
2.65

# Aside: How to Build a Nuclear Bomb

- Step 1: Acquire fissile material
  - This process always starts with uranium
  - Naturally occurring uranium is not fissile, though
    - Almost all of it is uranium-238
    - Only uranium-235 is fissile, but its concentration is only 0.72%



Natural



Low Enriched (Power)

High Enriched (Bombs)

# Aside: How to Build a Nuclear Bomb

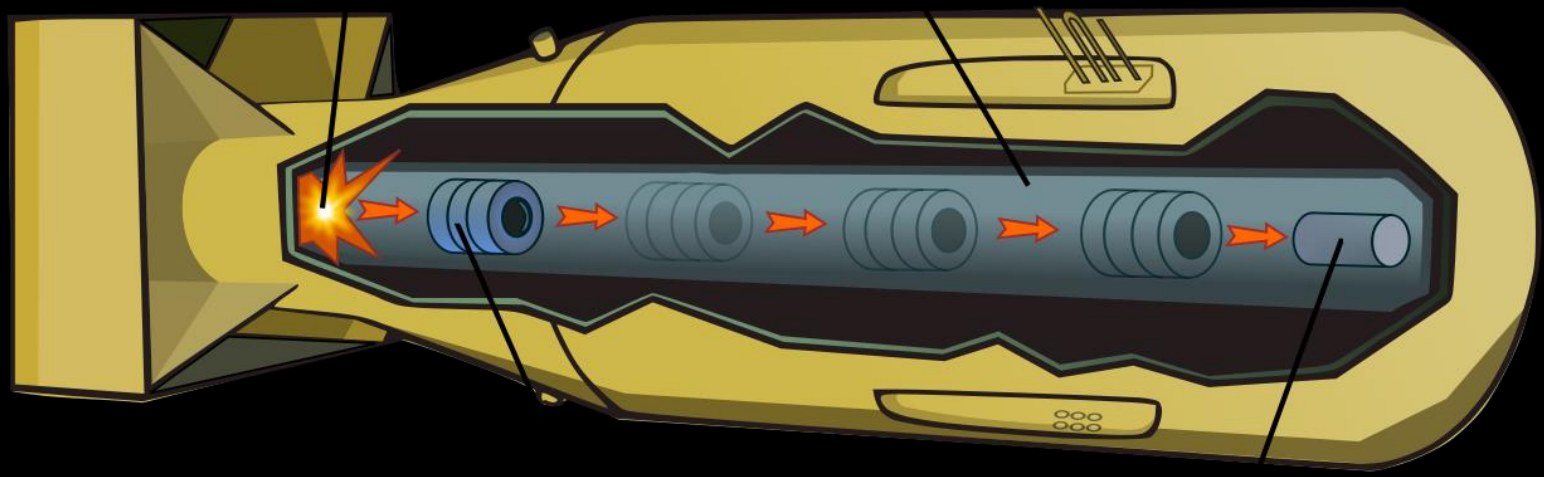
- Step 1: Acquire fissile material
  - This process always starts with uranium
    - Step 1a: Enrich the uranium, separating U235 from U238

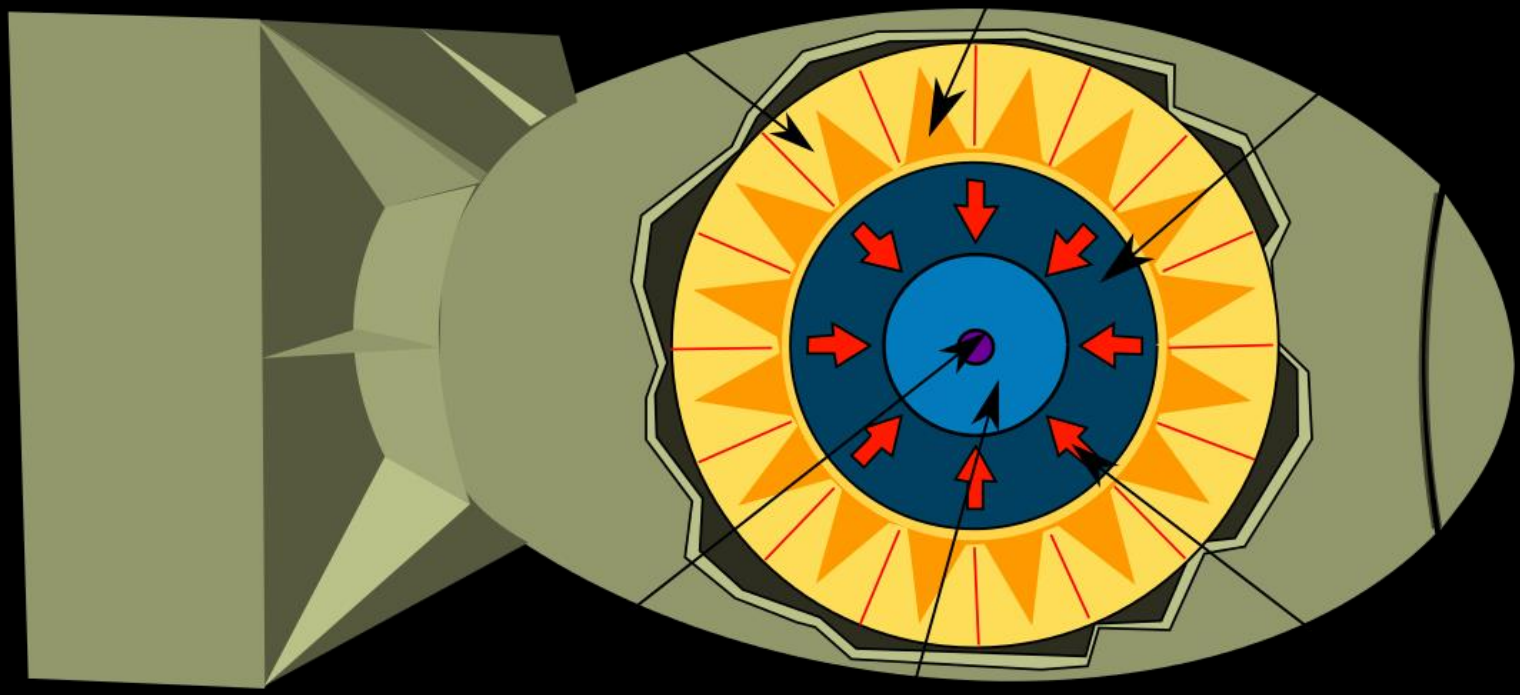
# Aside: How to Build a Nuclear Bomb

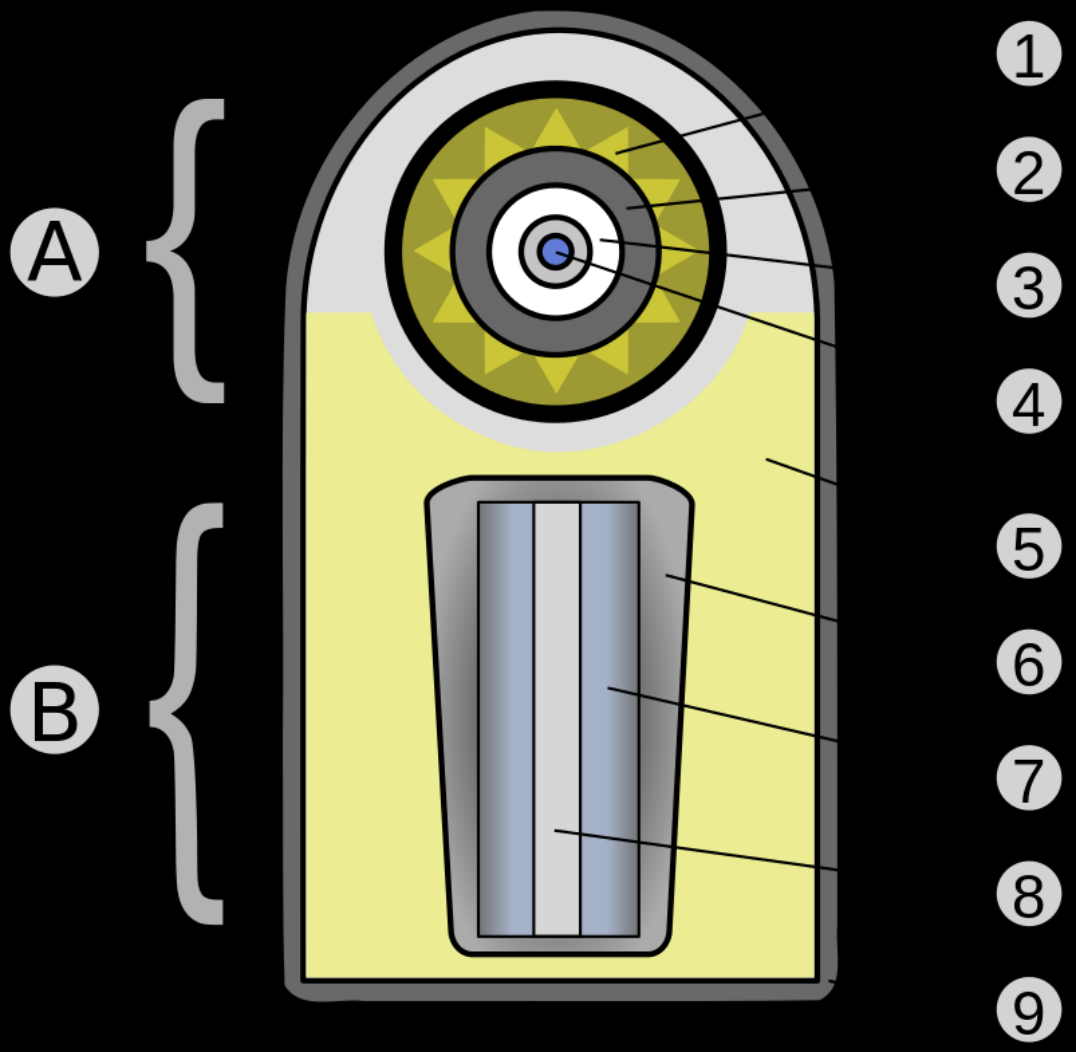
- Step 1: Acquire fissile material
  - This process always starts with uranium
    - Step 1a: Enrich the uranium, separating U235 from U238
    - Step 1b: Use unenriched uranium to run a research or power reactor. Create a reprocessing plant to extract plutonium, a byproduct of the reaction. It is fissile.

# Aside: How to Build a Nuclear Bomb

- Step 1: Acquire fissile material
- Step 2: Assemble device
  - U235 spits off neutrons
  - If those neutrons hit other U235, then more neutrons get spit off
  - Chain reaction goes boom






A
B
1
2
3
4
5
6
7
8
9

# Aside: How to Build a Nuclear Bomb

- Step 1: Acquire fissile material
- Step 2: Assemble device
- Step 3: Create delivery system


ENOLA
GAY
82

Terminator 3: Rise of the Machines

# Security (Demand Side)

- Main purpose of nuclear weapons is coercive
- Don’t need to build nuclear weapons if you don’t have any disputes

# Prestige

- Nuclear weapons possession is an exclusive club
- Makes other countries recognize your importance, allegedly
- Also makes everyone hate you, and there are other things that a state could do with the money

# Domestic Politics

- Centralized decision structure makes them useful for insecure autocrats
- But autocrats also take a long time to build weapons

# Costs

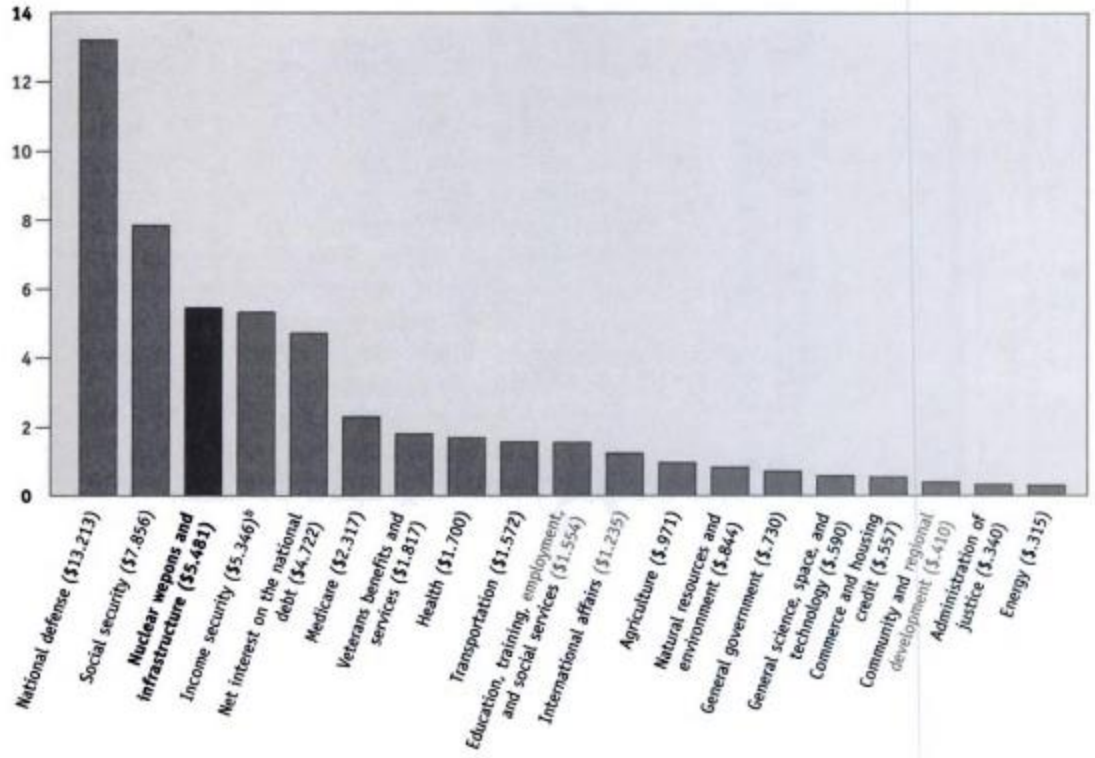
- Development is expensive, but it’s only one piece
  - Maintenance
  - Delivery
  - Disposal
- There are more costly than actually building a bomb!

TABLE 1. Breakdown of Total Actual and Estimated U.S. Expenditures for Nuclear Weapons, 1940–96

Billions of 1996 dollars

| *Activity* | *Cost* |
|---|---|
| Building the bomb (chapter 1) | 409.4 |
| Deploying the bomb (chapter 2) | 3,241.0 |
| Targeting and controlling the bomb (chapter 3) | 831.1 |
| Defending against the bomb (chapter 4) | 937.2 |
| Dismantling the bomb (chapter 5) | 11.1 |
| Nuclear waste management and environmental remediation (chapter 6) | 45.2 |
| Victims of the bomb (chapter 7) | 2.1 |
| Costs and consequences of nuclear secrecy (chapter 8) | 3.1 |
| Congressional oversight of the bomb (chapter 9) | 0.9 |
| Total | 5,481.1 |

FIGURE 2. U.S. Government Historical Obligations by Function, 1940–96[a]



# Opportunity Costs

- Best and brightest of a country's scientists spend their time on non-productive activities

# Preventive Action

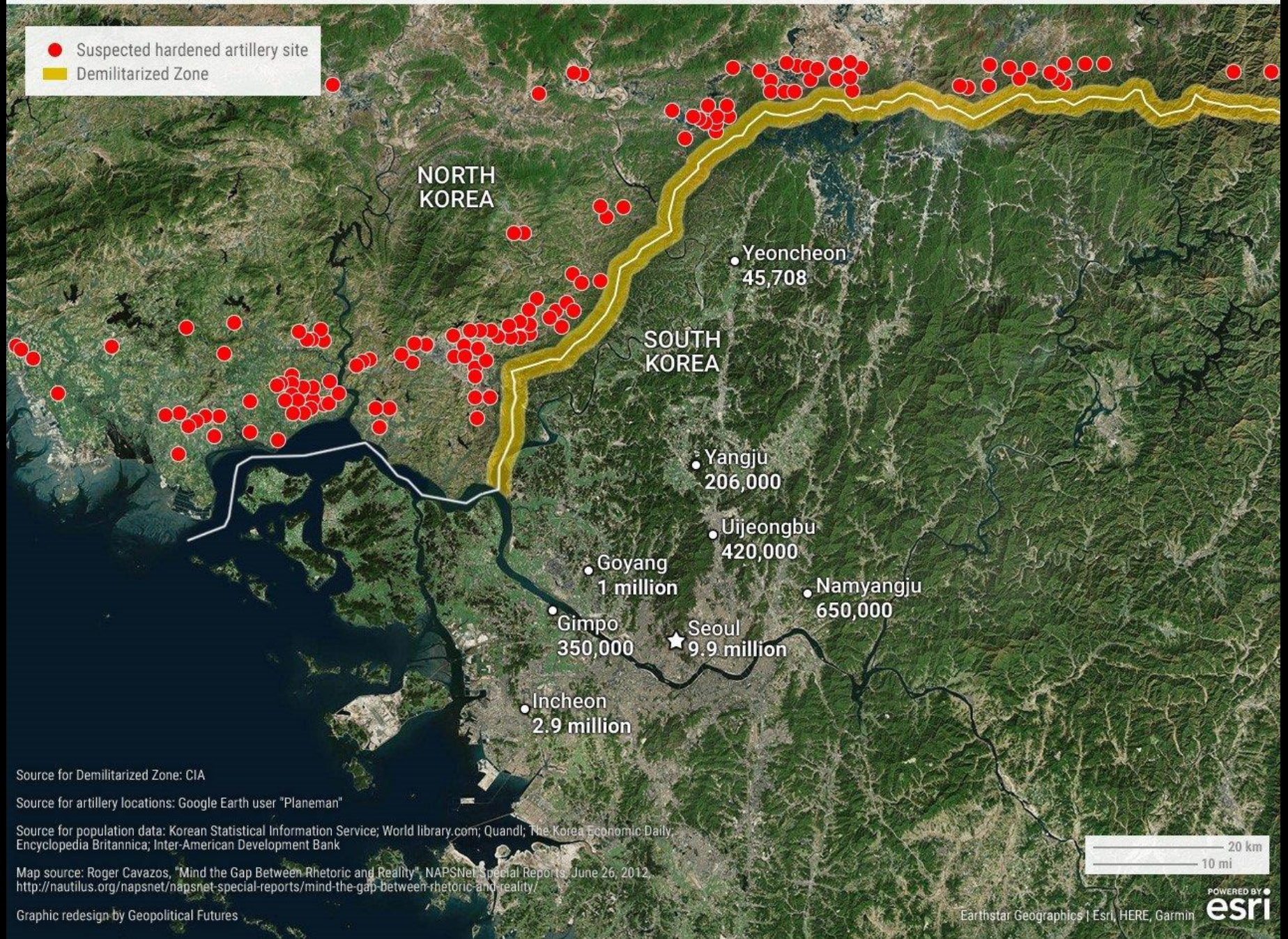
- Can’t build nuclear weapons if you don’t have the facilities to do it
- And if you can’t protect your facilities, then you might as well not build them in the first place


TURKEY
IRAN
Mediterranean Sea
SYRIA
LEBANON
Osirak
FUEL TANKS
RELEASED
IRAQ
ISRAEL
JORDAN
EGYPT
SAUDI ARABIA
Erwin P. Released under GFDL through www.en.wikipedia.org


U.S. GOVERNMENT


Fordow

# LIKELY LOCATION OF HARDENED ARTILLERY SITES AND PROXIMITY TO SOUTH KOREAN POPULATION CENTERS




Source for Demilitarized Zone: CIA

Source for artillery locations: Google Earth user "Planeman"

Source for population data: Korean Statistical Information Service; World library.com; Quandl; The Korea Economic Daily; Encyclopedia Britannica; Inter-American Development Bank

Map source: Roger Cavazos, "Mind the Gap Between Rhetoric and Reality", NAPSNet Special Reports, June 26, 2012, http://nautilus.org/napsnet/napsnet-special-reports/mind-the-gap-between-rhetoric-and-reality/

Graphic redesign by Geopolitical Futures

# 1990s War Planning

- Advisor to Clinton: We can do it. Six months. One trillion dollars. One million dead.
- Clinton: “No one told me that before.”


This was the most ridiculous image of Stuxnet I could find on Google.


یاد شهیدان باید همیشه در فضای جامعه زنده باشد


MERIDIEN
ETOILE

# Bargaining

- Proliferation causes externalities to others
  - One state's security gain is another's security loss
  - Additional risk of accidental nuclear war


KEVIN
COSTNER
SERGEY
SHNYRYOV
NATALIYA
VDOVINA
STANISLAV
PETROV
EVERY MOMENT COUNTS
WOODSTOCK FILM FESTIVAL
2014
OFFICIAL SELECTION
CPH:DOX
2014
OFFICIAL SELECTION
hotDOCS
DENVER FILM FESTIVAL
2014
A PETER ANTHONY AND STATEMENT FILM
THE MAN WHO SAVED THE WORLD
STATEMENT
STATEMENT


HL7442
大韓航空
KOREAN AIR
B-1886


Ukraine International
Міжнародні Авіалінії України
UR-PSR
UR-PSR

# Bargaining

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# Bargaining

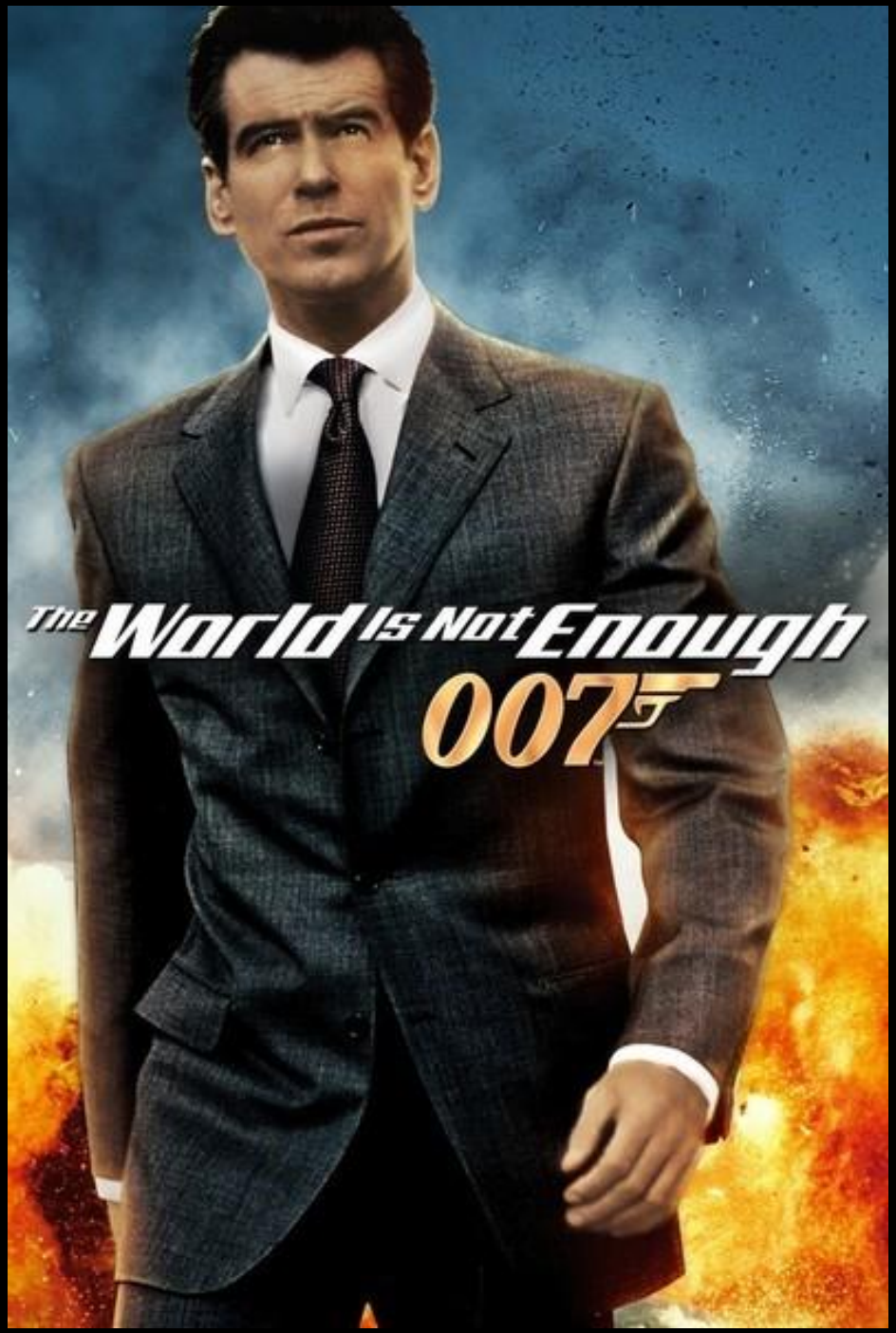
- Proliferation causes externalities to others
  - One state's security gain is another's security loss
  - Additional risk of accidental nuclear war
  - Environmental damage from testing


KODAK


第五福龍丸

# Bargaining

- Proliferation causes externalities to others
  - One state's security gain is another's security loss
  - Additional risk of accidental nuclear war
  - Environmental damage from testing
  - Additional risk of black market nuclear technology


The World Is Not Enough
007

# Bargaining

- Why not offer concessions instead?
  - Both win: no costs and no externalities
- Fairly common historically
  - Japan, Taiwan, South Korea, Soviet Successor States, Libya, Iran
- To explain proliferation, we need to first explain why parties couldn't reach a deal instead

# Outline

- The Nuclear Club (and Friends)
- Why Proliferate?
- Effects of Proliferation
- Managing the Atom

# Optimists and Skeptics

- Lots of people think that nuclear weapons are very important
- Lots of other people think they aren’t

# Compellence vs. Deterrence

- To compel someone is to convince them to give up something
- To deter someone is to convince someone not to alter the status quo

# Compellence vs. Deterrence

- Optimists think that nuclear weapons can compel states to give up concessions
  - Other weapons do that
  - Nuclear weapons are just bigger weapons

# Compellence vs. Deterrence

- Pessimists think that nuclear weapons do not work for compellence
  - Is “give me your outlying region or I will nuke you” a credible threat?

# Compellence vs. Deterrence

- More people think that nuclear weapons are useful for deterrence
  - Is “if you invade Washington DC, I will nuke you” a credible threat?

# Compellence vs. Deterrence

- Some really skeptical people think that nuclear weapons deter only in extreme cases
  - Is “if you invade Hawaii, I will nuke you” a credible threat?
  - Is “if you invade Seoul, I will nuke you” a credible threat?

# Compellence vs. Deterrence

- But perhaps this distinction is silly
- Imagine that nuclear weapons are good at deterrence
  - Then they act as an insurance policy in a war
  - That insurance policy raises a state's war payoff
  - If a state has a greater war payoff, then it must receive better negotiated settlements to not fight…
  - …which means it can compel more out of others

# Example

- War without nuclear weapons:
  - .1 chance A will win and will get value of 1
  - .3 chance of stalemate and A will get value of .5
  - .6 chance B will win and A will get 0
- A's expected gains are:
  - (.1)(1) + (.3)(.5) + (.6)(0) = .25

# Example

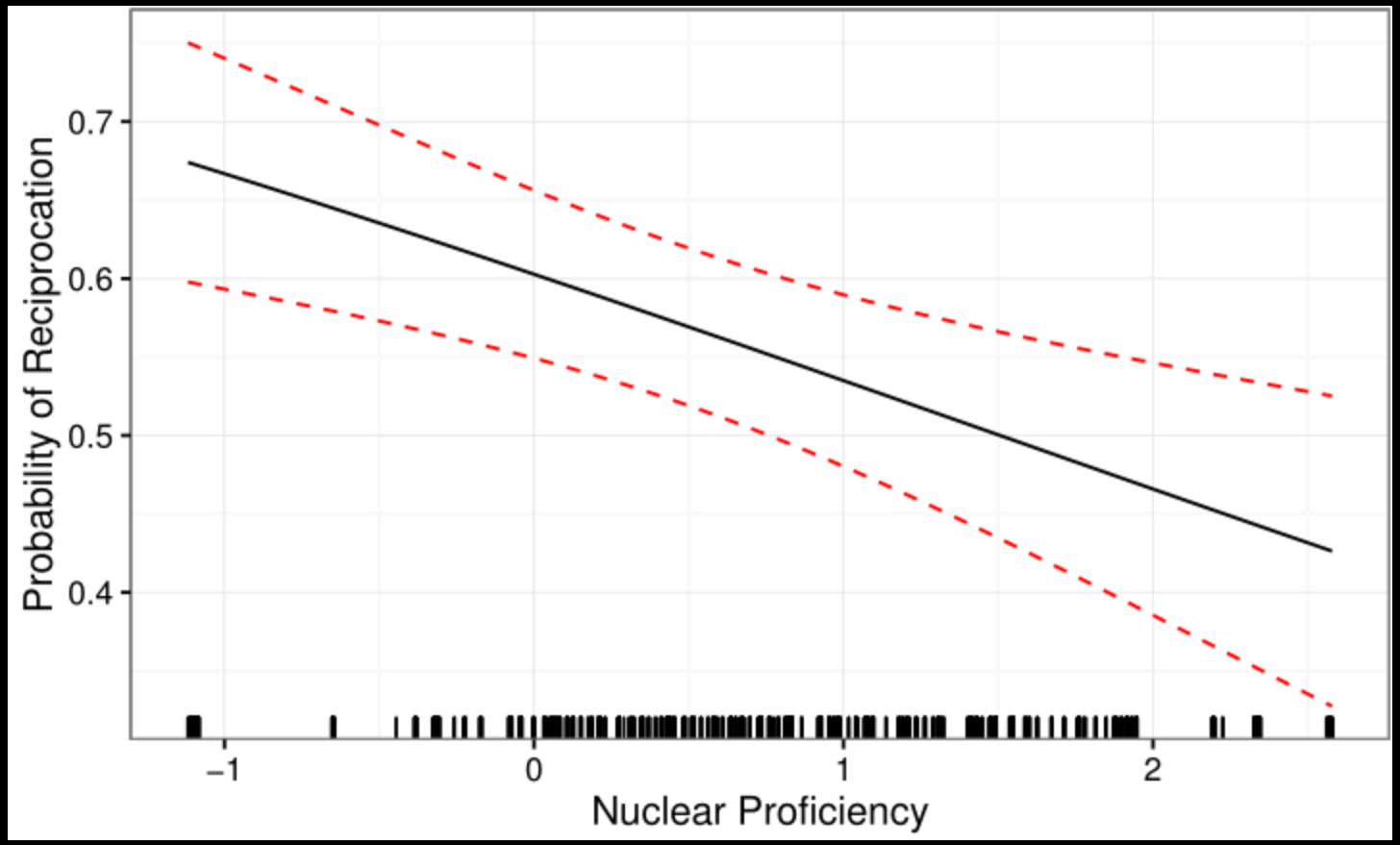
- War with compellent nuclear weapons:
  - .4 chance A will win and will get value of 1
  - .3 chance of stalemate and A will get value of .5
  - .3 chance B will win and A will get 0
- A's expected gains are:
  - (.4)(1) + (.3)(.5) + (.3)(0) = .55

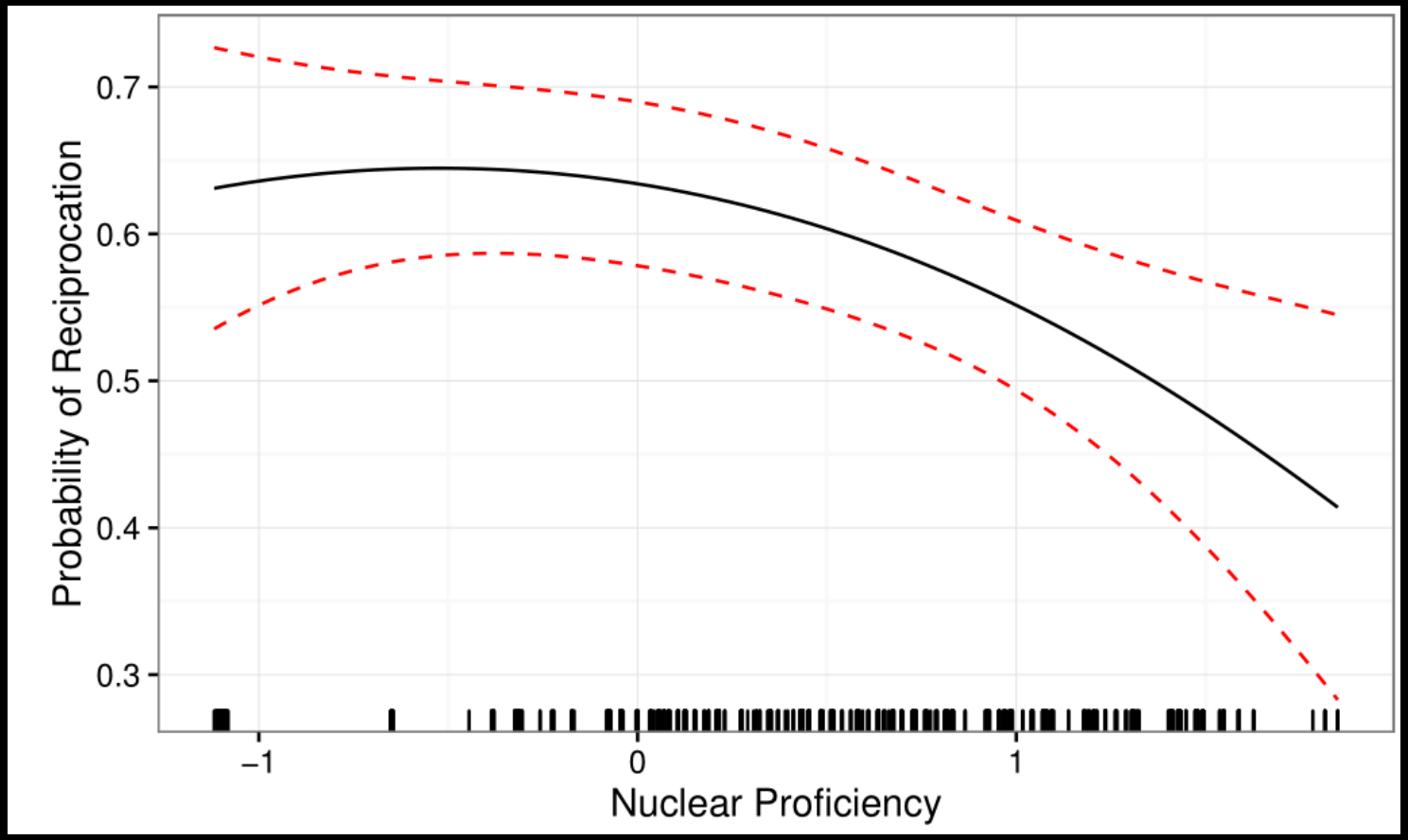
# Example

- War with deterrent nuclear weapons:
  - .1 chance A will win and will get value of 1
  - .3 chance of stalemate and A will get value of .5
  - .6 chance B will win but A's nukes deter B from going more than half way, so A earns .5
- A's expected gains are:
  - (.1)(1) + (.3)(.5) + (.6)(.5) = .55

# Latent Nuclear Capacity

- Suppose nuclear weapons are useful and states don't want others to develop them
- Then those countries should act with caution when in disputes with countries that could proliferate


Probability of Reciprocation
0.7
0.6
0.5
0.4
−1
0
1
2
Nuclear Proficiency


Probability of Reciprocation
0.7
0.6
0.5
0.4
0.3
−1
0
1
Nuclear Proficiency

# Mutually Assured Destruction

- Suppose two nuclear weapons states are self-preserving and possess secured, second-strike capable nuclear weapons
- Is there incentive to fight a war?

# Secured Second Strikes

- The United States had three methods of nuclear retaliation
  - Strategic bombers
  - Intercontinental ballistic missiles
  - Submarine-launched ballistic missiles

# Secured Second Strikes

- Reason why Soviet Union and United States had way more nuclear weapons than necessary to destroy the entire world
- 68,000 down to 4,100

# Instability Paradox

- But if we both have secured second strikes, what stops me from engaging in a conventional war against you?
- You can’t nuke me because I can nuke you right back

# Obsolescence

- Some think that major war has been obsolete for a long time
  - Mutually assured destruction did not do much to add to the peace

# Outline

- The Nuclear Club (and Friends)
- Why Proliferate?
- Effects of Proliferation
- Managing the Atom

# Nuclear Non-Proliferation Treaty

- Developed in 1968 as a 25 year treaty
- Extended indefinitely as it was about to expire
- Obliges recognized nuclear weapons states to work toward eliminating nuclear weapons

# Nuclear Non-Proliferation Treaty

- Three pillars:
  1. Disarmament
  2. Nonproliferation
  3. Scientific use

# By Some Accounts…

- The best treaty ever
- The worst treaty ever
- A treaty with a marginal but useful effect
- Maybe a reflection of the regime rather than a thing by itself?

# Nuclear Non-Proliferation Treaty

- Who isn’t living up to their obligations?

# Nuclear Non-Proliferation Treaty

- Who isn't living up to their obligations?
  - United States, Russia, United Kingdom, France and China?
    - No, the NPT gives them a legal *right* to the weapons.
    - They just have to engage in a good-faith effort to get rid of them (eventually)

# Nuclear Non-Proliferation Treaty

- Who isn't living up to their obligations?
  - India, Pakistan, Israel?

# Nuclear Non-Proliferation Treaty

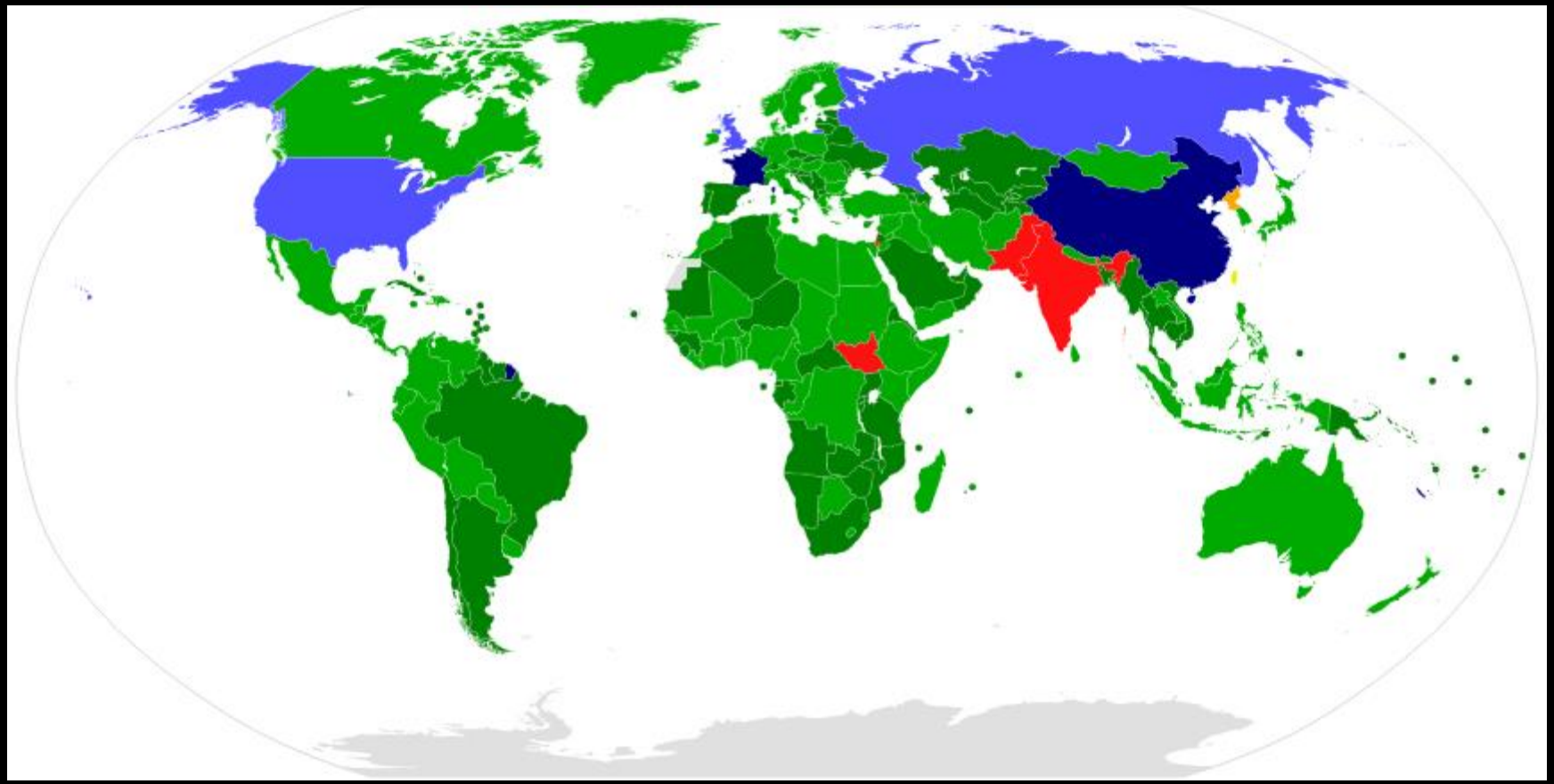
- Who isn't living up to their obligations?
  - India, Pakistan, Israel?
    - No, they never signed the treaty

# Nuclear Non-Proliferation Treaty

- Who isn't living up to their obligations?
  - North Korea. After all, they signed the treaty…

# Nuclear Non-Proliferation Treaty

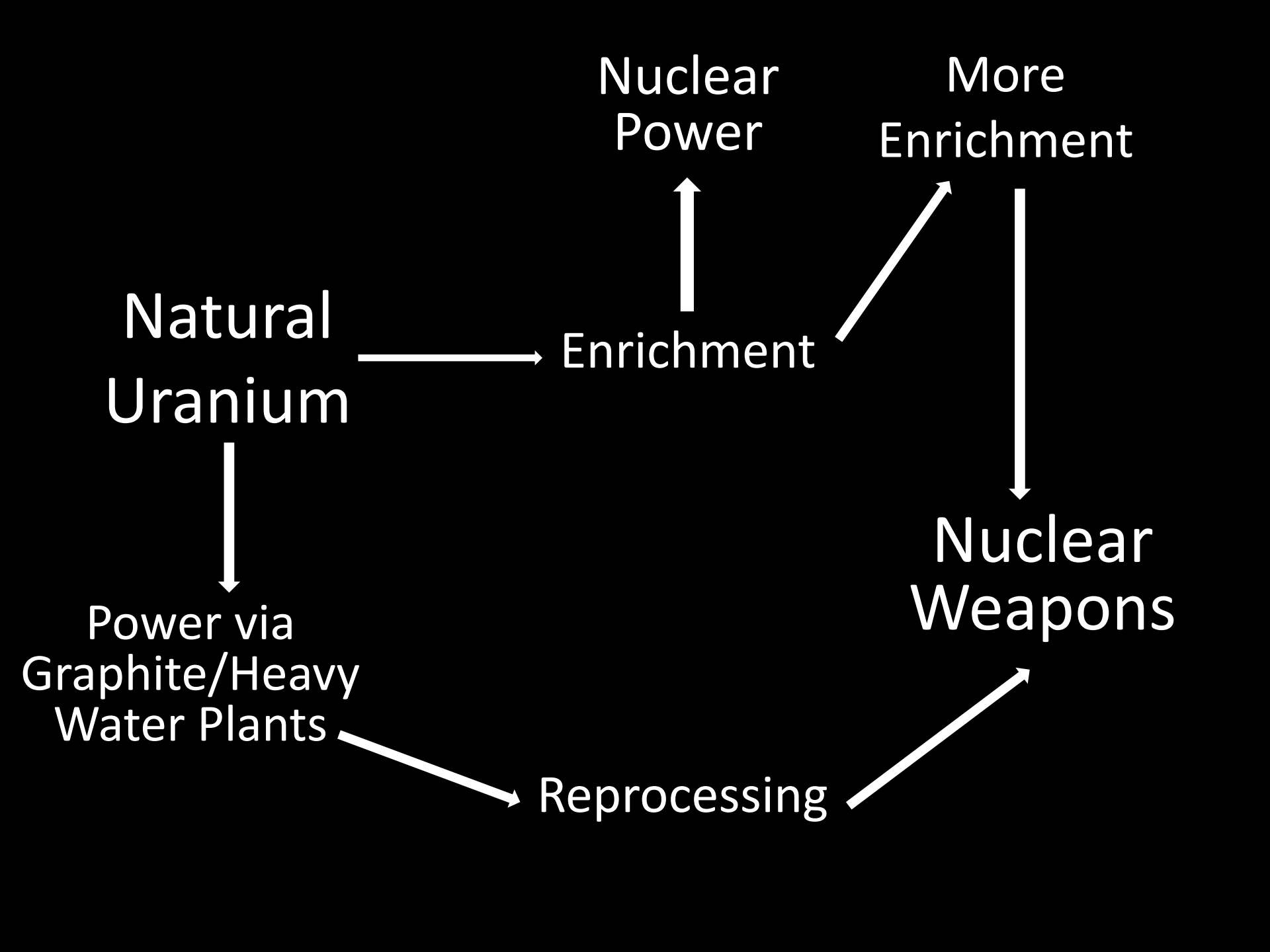
- Who isn't living up to their obligations?
  - North Korea. After all, they signed the treaty…
    - Article X allows a country to withdraw with three months' notice
    - North Korea gave notice in January 2003



# Atoms for Peace Program

# Atoms for Peace Program

- US-based initiative to begin nuclear science sharing
- Has led to extensive bilateral relations, power assistance, fuel delivery, and research reactor construction
- Central idea: increase opportunity costs of assigning nuclear scientists to weapons programs


Nuclear Power
More Enrichment
Natural Uranium
Enrichment
Nuclear Weapons
Power via Graphite/Heavy Water Plants
Reprocessing

# You Want Nuclear Power?

- Natural Uranium —> Enrichment —> Power is the way to go
- Centrifuges are the best way to run the operation profitably
- Safer too because they run on light water reactors

# How Does Nuclear Power Work?

- Step 1: Use a nuclear reaction to get something very, very hot
- Step 2: Pour water on that very, very hot surface
- Step 3: Water turns into very high pressure steam, which turns turbines
- Step 4: Profit

# How Does Nuclear Power Work?

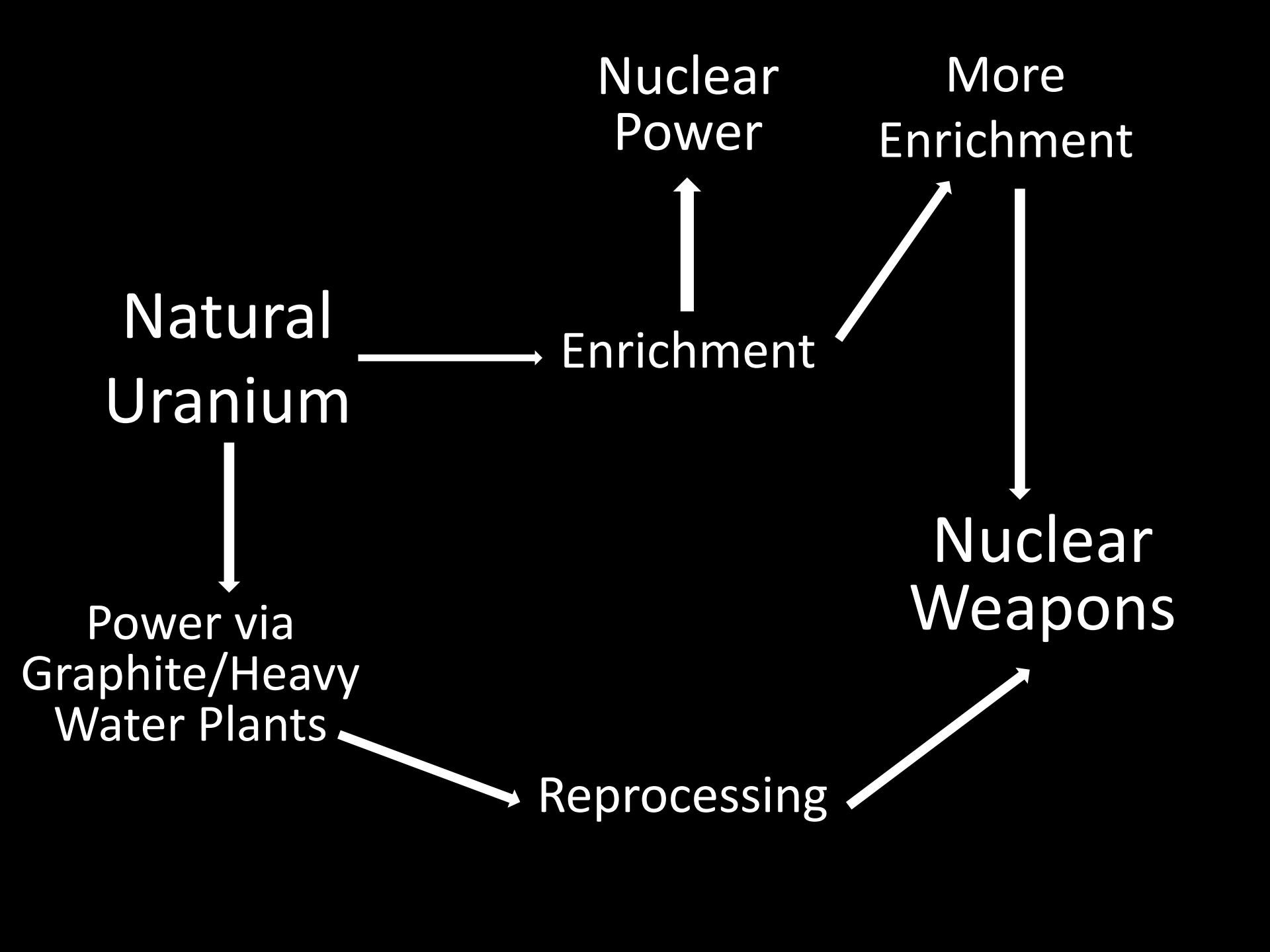
- Step 1: Use a nuclear reaction to get something very, very hot
  - This is the tricky part
  - U235 spits off neutrons
  - Neutrons naturally move too fast to hit other U235
  - So you need a *moderator* to slow them down
    - Moderators make the process work—they don't limit the reaction

# How Does Nuclear Power Work?

- Step 1: Use a nuclear reaction to get something very, very hot
  - Naturally occurring water is a bad moderator
  - So you need to enrich uranium if you are going to use it
    - Conditional on that, the process is safer
    - Natural water serves as both the source of the steam and what controls the reaction

# How Does Nuclear Power Work?

- Step 1: Use a nuclear reaction to get something very, very hot
  - Heavy water is a very good moderator of uranium
    - But it is expensive to produce
    - Also dangerous
    - But good solution if you want to build a bomb but can't master enrichment—e.g., North Korea


Nuclear Power
More Enrichment
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Enrichment
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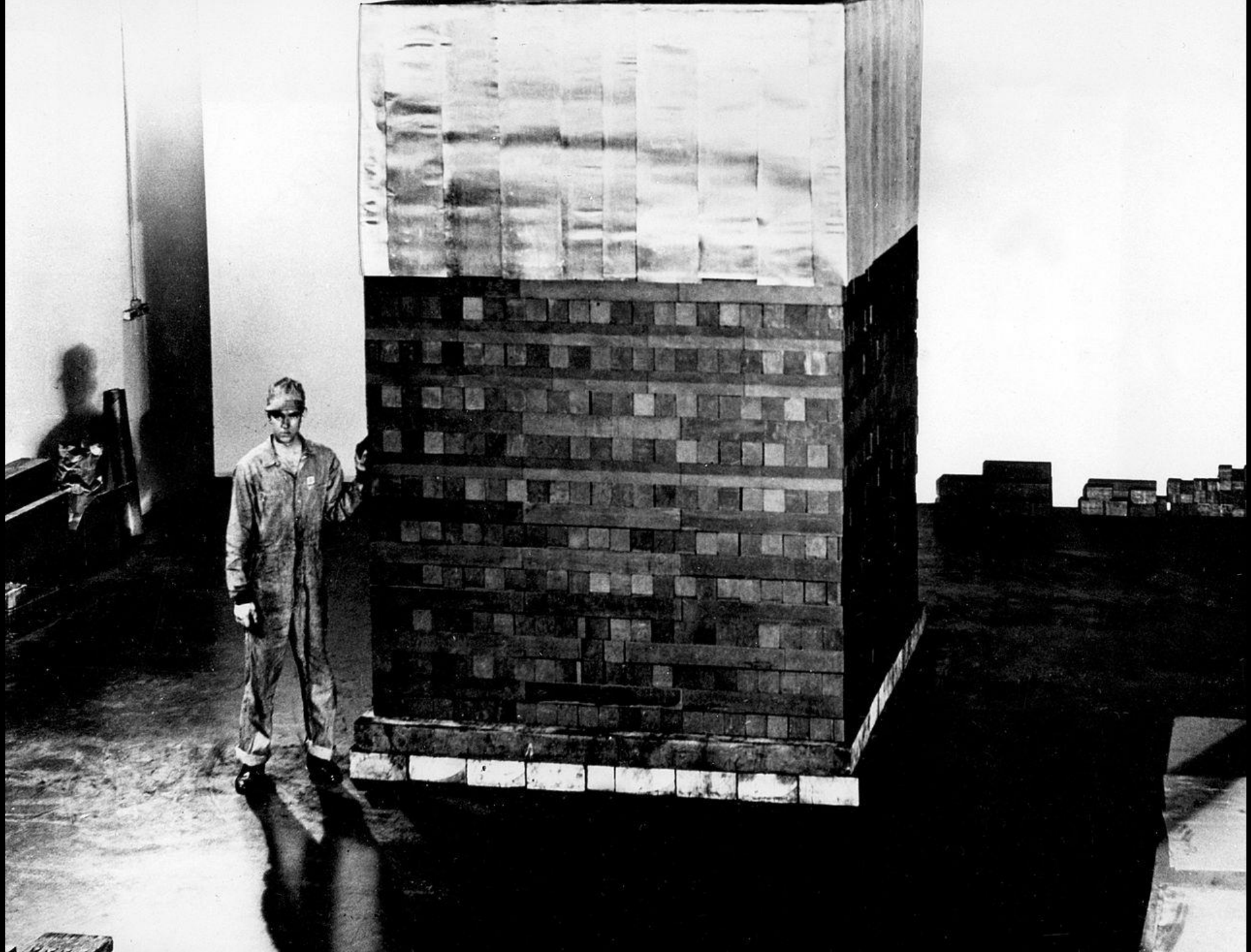
Reprocessing

# How Does Nuclear Power Work?

- Step 1: Use a nuclear reaction to get something very, very hot
  - Graphite is also a very good moderator of uranium
    - It is cheap and easy

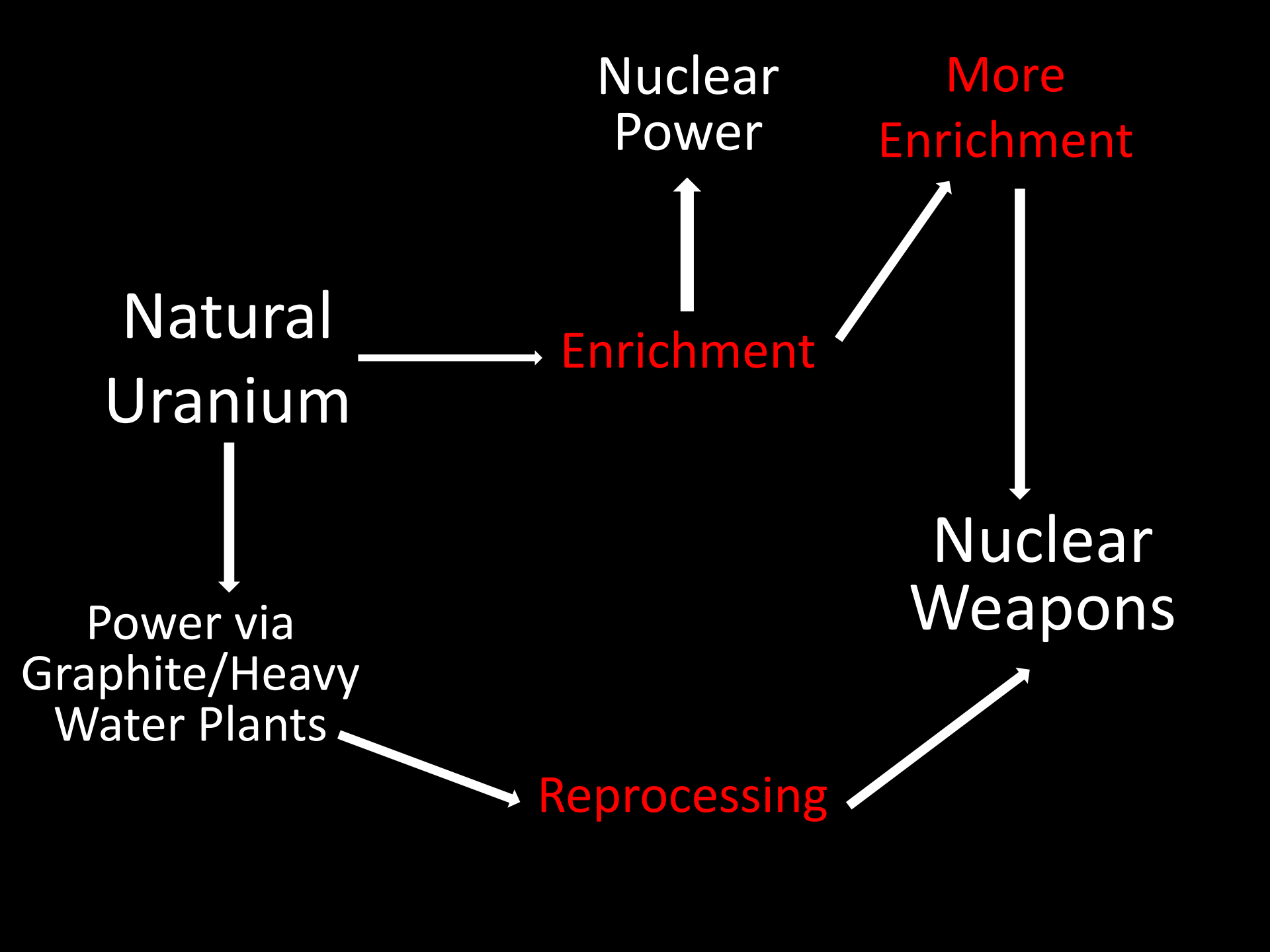


# How Does Nuclear Power Work?

- Step 1: Use a nuclear reaction to get something very, very hot
  - Graphite is also a very good moderator of uranium
    - It is cheap and easy
    - But it is also flammable

# Dual Use Problem

- If you want to run light water reactors, you need to enrich uranium
- But if you want to build a bomb, you just need to run that enrichment process for longer
- International community's response: control ENR technology


Nuclear Power
More Enrichment
Natural Uranium
Enrichment
Nuclear Weapons
Power via Graphite/Heavy Water Plants
Reprocessing

NSG Nuclear Suppliers Group

# The Supplier's Deal

- Imagine you want to run nuclear power reactors
- You can ask for low enriched uranium from a supplier
- They will give it to you provided that
  - You don't run your own enrichment plants
  - You don't build reprocessing plants
  - You return the spent fuel

# Agreed Framework

- 1994 deal between Clinton and North Korea
- Swapped NK heavy water reactors for construction of light water power plants, fuel for those power plants, and heavy oil
- Congress upheld full implementation

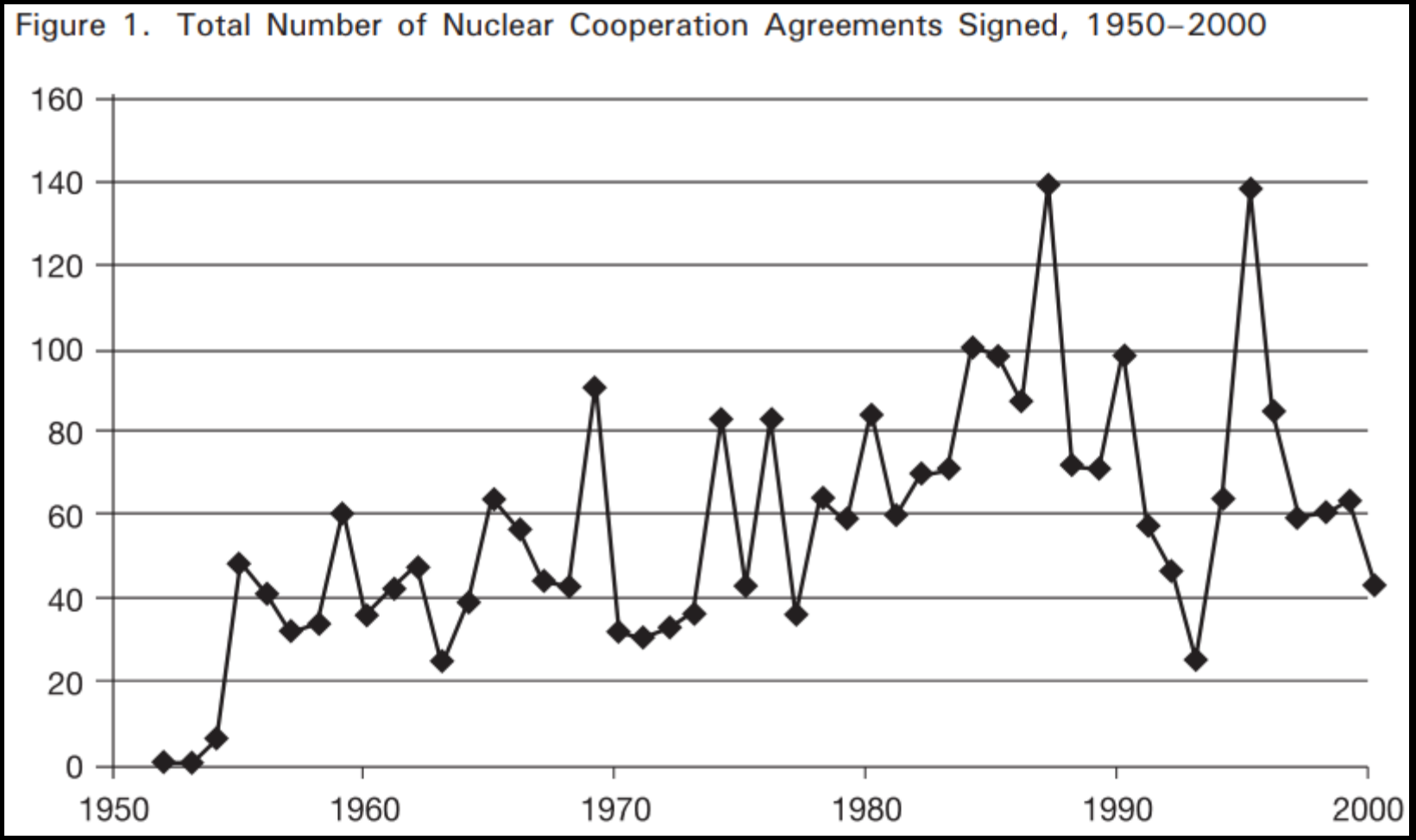
# Problems

- Recipient could take the enriched uranium and not give it back
- This is bad, but not the end of the world
  - Low enriched uranium still needs to be further refined before it is fissile
  - So stealing the gives a head start, but not much of one

# Problems

- Nuclear power plants have enormous start up costs
  - Interest payments can be as large as 30% of the overall cost
- But *very* cheap to operate once completed
- Gives supplier great bargaining power over state with power plant but no fuel source

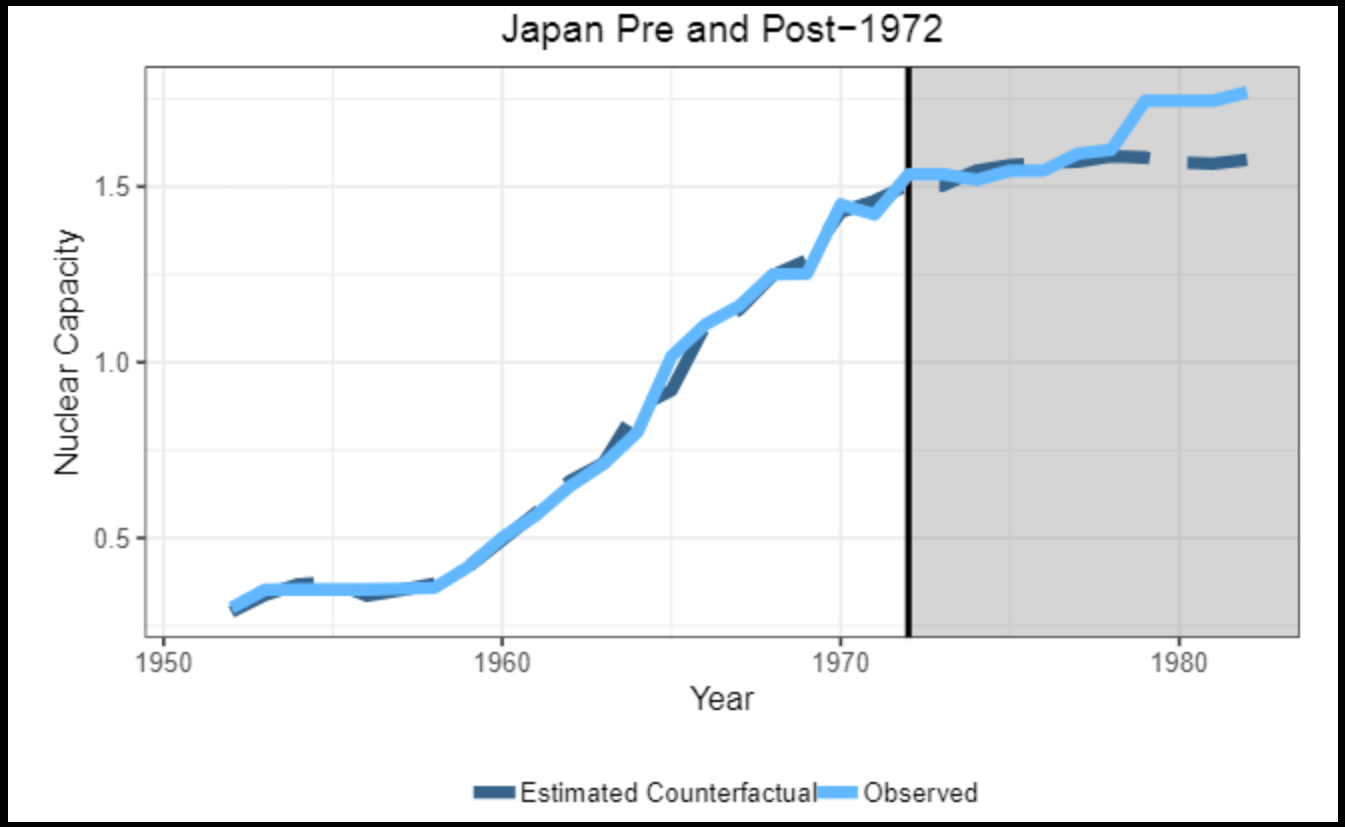
Figure 1. Total Number of Nuclear Cooperation Agreements Signed, 1950–2000

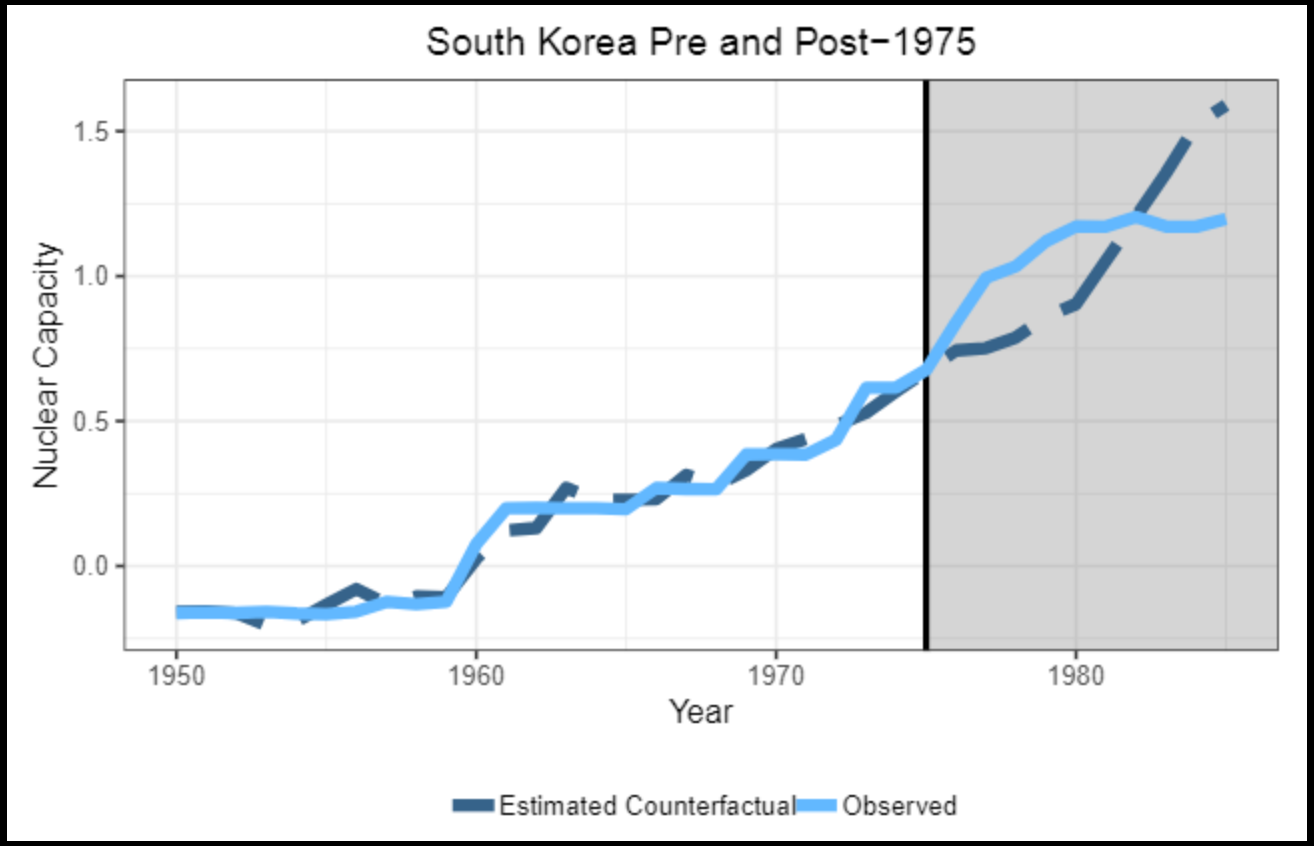


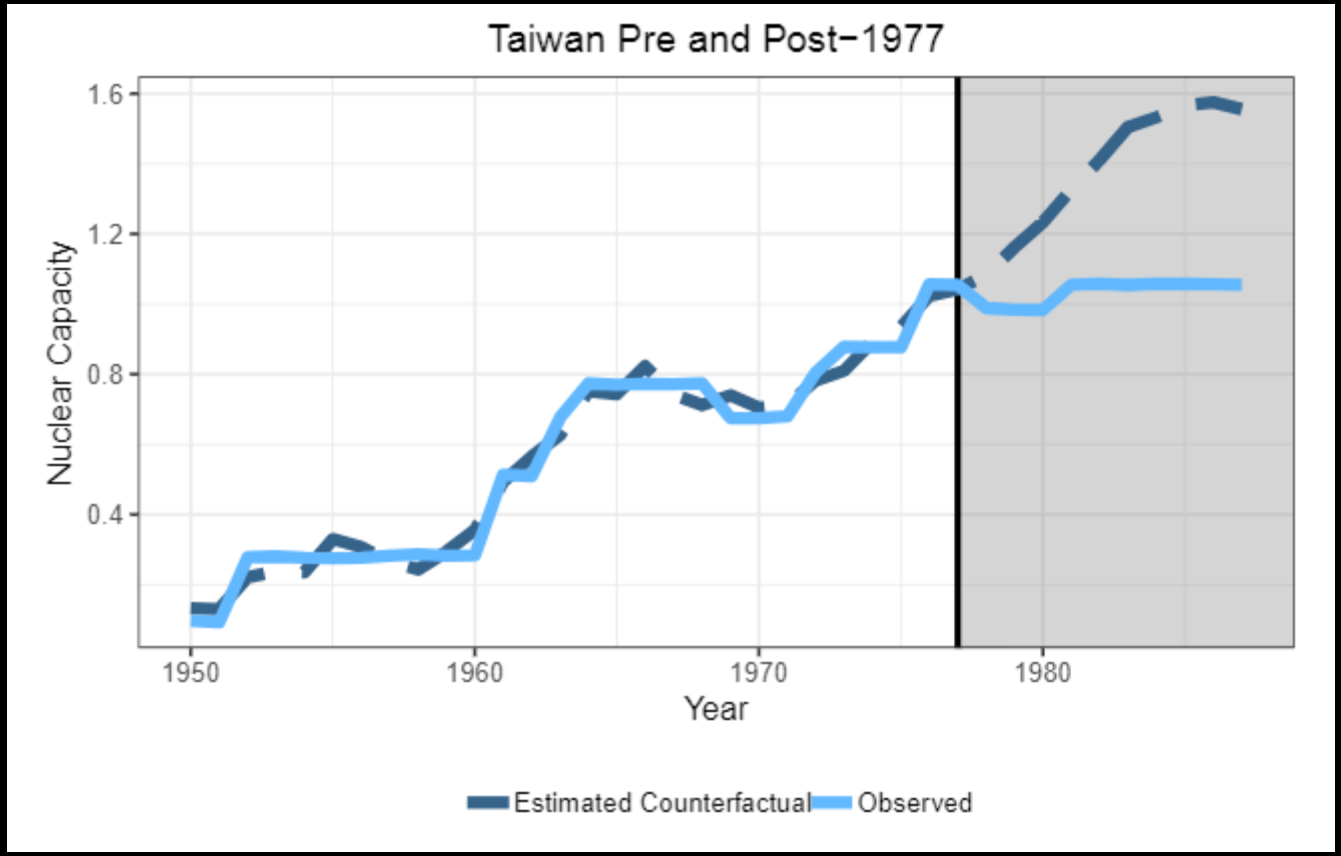

KORI

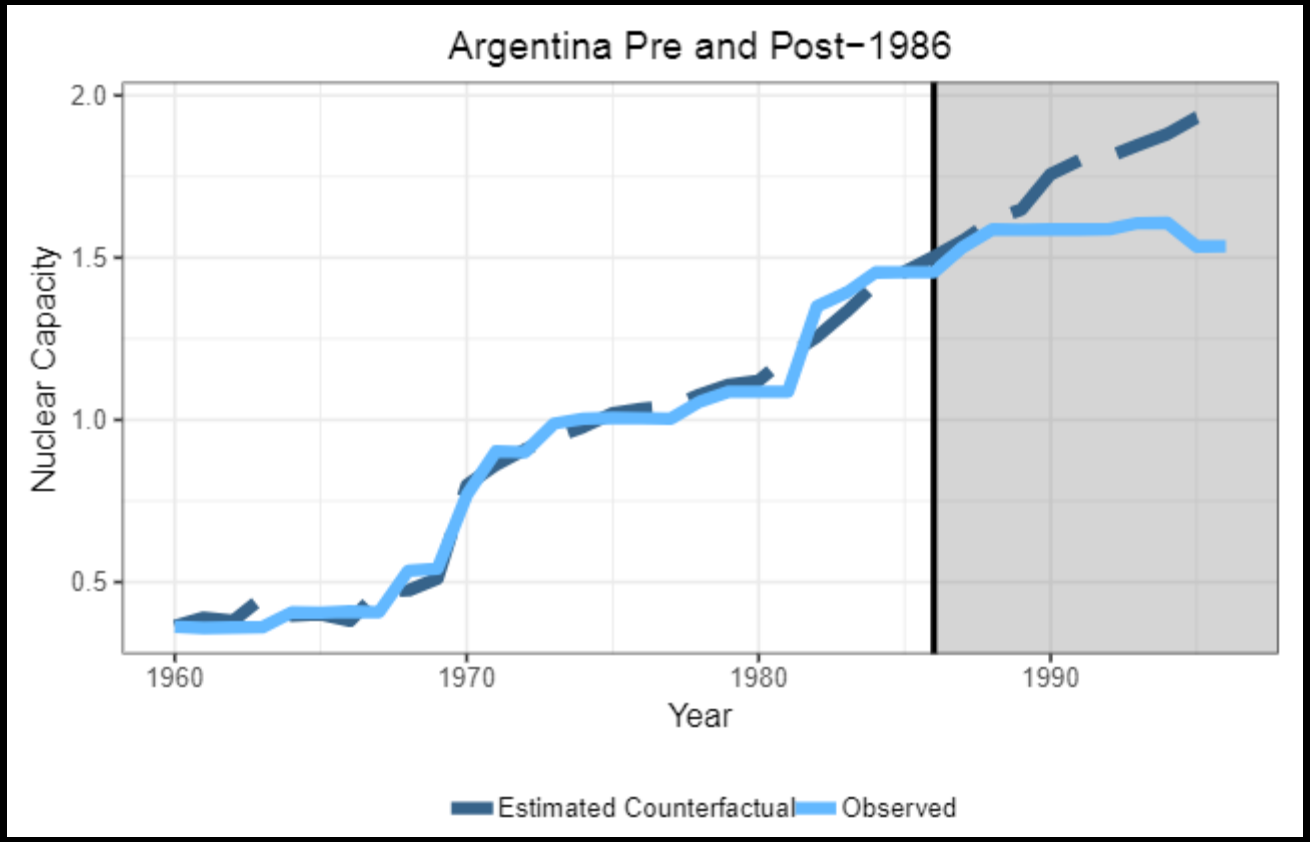
# Agreements and Capacity

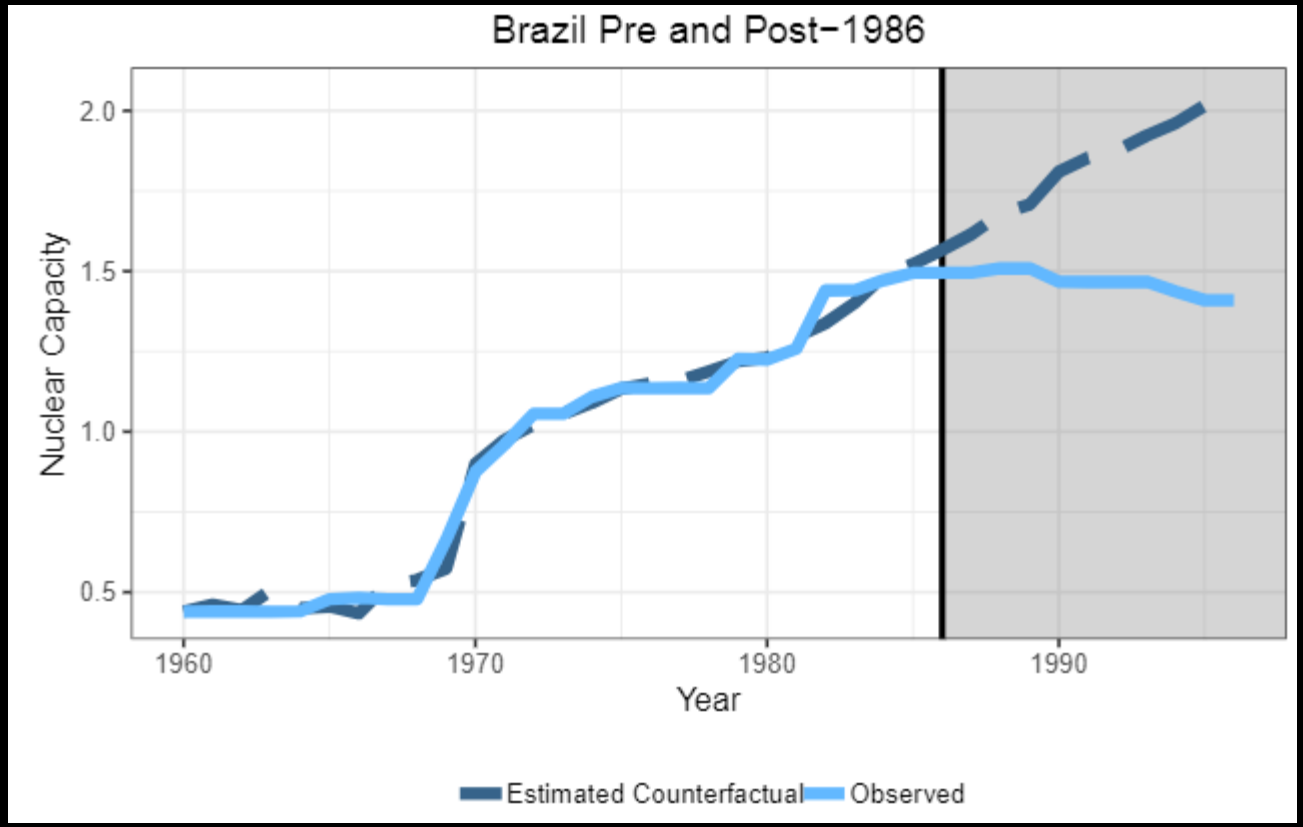
- Reaching agreements does not seem to slow down one's ability to produce nuclear weapons by much


Japan Pre and Post−1972
Nuclear Capacity
1.5
1.0
0.5
1950
1960
1970
1980
Year
Estimated Counterfactual
Observed


South Korea Pre and Post−1975
Nuclear Capacity
1.5
1.0
0.5
0.0
1950
1960
1970
1980
Year
Estimated Counterfactual
Observed

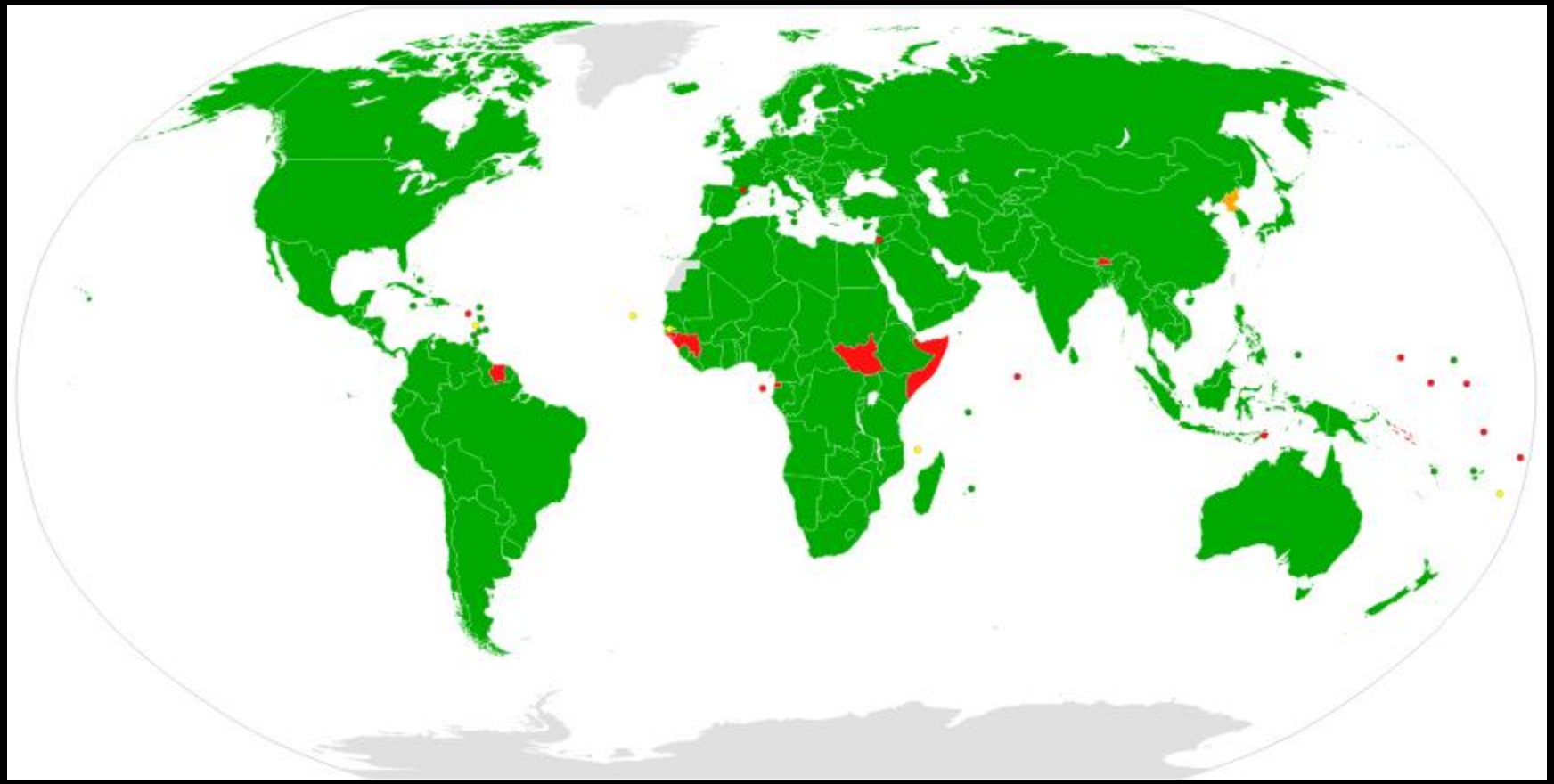

Taiwan Pre and Post−1977
Nuclear Capacity
1.6
1.2
0.8
0.4
1950
1960
1970
1980
Year
Estimated Counterfactual
Observed


Argentina Pre and Post−1986
Nuclear Capacity
2.0
1.5
1.0
0.5
1960
1970
1980
1990
Year
Estimated Counterfactual
Observed


Brazil Pre and Post−1986
Nuclear Capacity
2.0
1.5
1.0
0.5
1960
1970
1980
1990
Year
Estimated Counterfactual
Observed

# International Atomic Energy Agency

- Two primary functions
  - Weapons inspections
  - Distribution of nuclear technology



# Inspections

- Major part of NPT obligations is to declare nuclear sites and open up for inspection
  - Monitor
  - Tag
  - Investigate

# Inspections

- NPT's requirements are fairly weak
- Additional Protocol (1997) designed to strengthen inspections
  - IAEA can visit sites with only two hours' notice
  - Brazil has not joined (objects to it being necessary for ENR possession)
  - Egypt has not joined (waiting on Israel)
  - Iran has not joined (but complying under JCPOA)

# Inspections

- What if someone says “no” to inspectors visiting a site?
  - Tells the inspectors what they need to know by omission

# Inspections as a Nuisance

- Inspections make some sites off-limits for proliferation
- Does not make proliferation impossible
- But does make it more expensive

# JCPOA Requirements

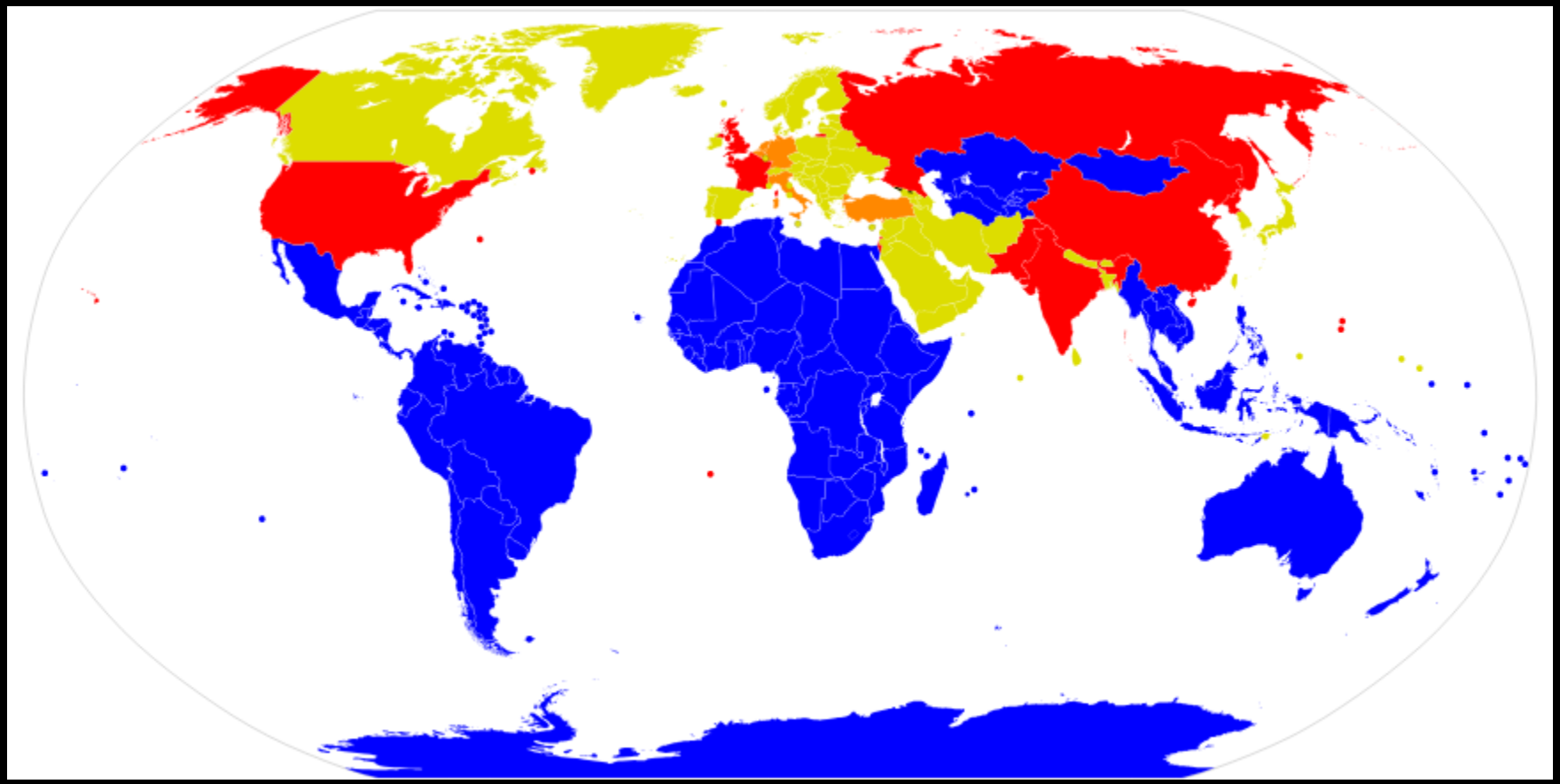
- Arak reactor to be filled with concrete
- Fordow enrichment plant to be turned into a science center
- Vast majority of uranium stockpiles to be downblended to 3.67% U-235
- Highest-quality centrifuges to be given to IAEA to be held under lock and key

# Tradeoff

- Negotiated agreements must be commensurate with a state's ability to proliferate
- The more onerous the inspections and divestment, the more costly it is to build
- So it is understandable that a state would not want to do too much

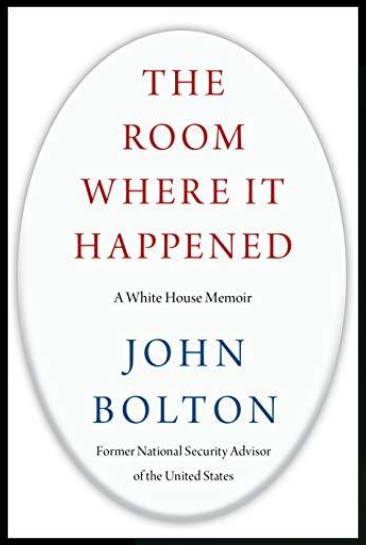
# Nuclear Weapons Free Zones

- Further legal fortification against development of nuclear weapons
- Also prevents stationing or passing through of other states' nuclear weapons



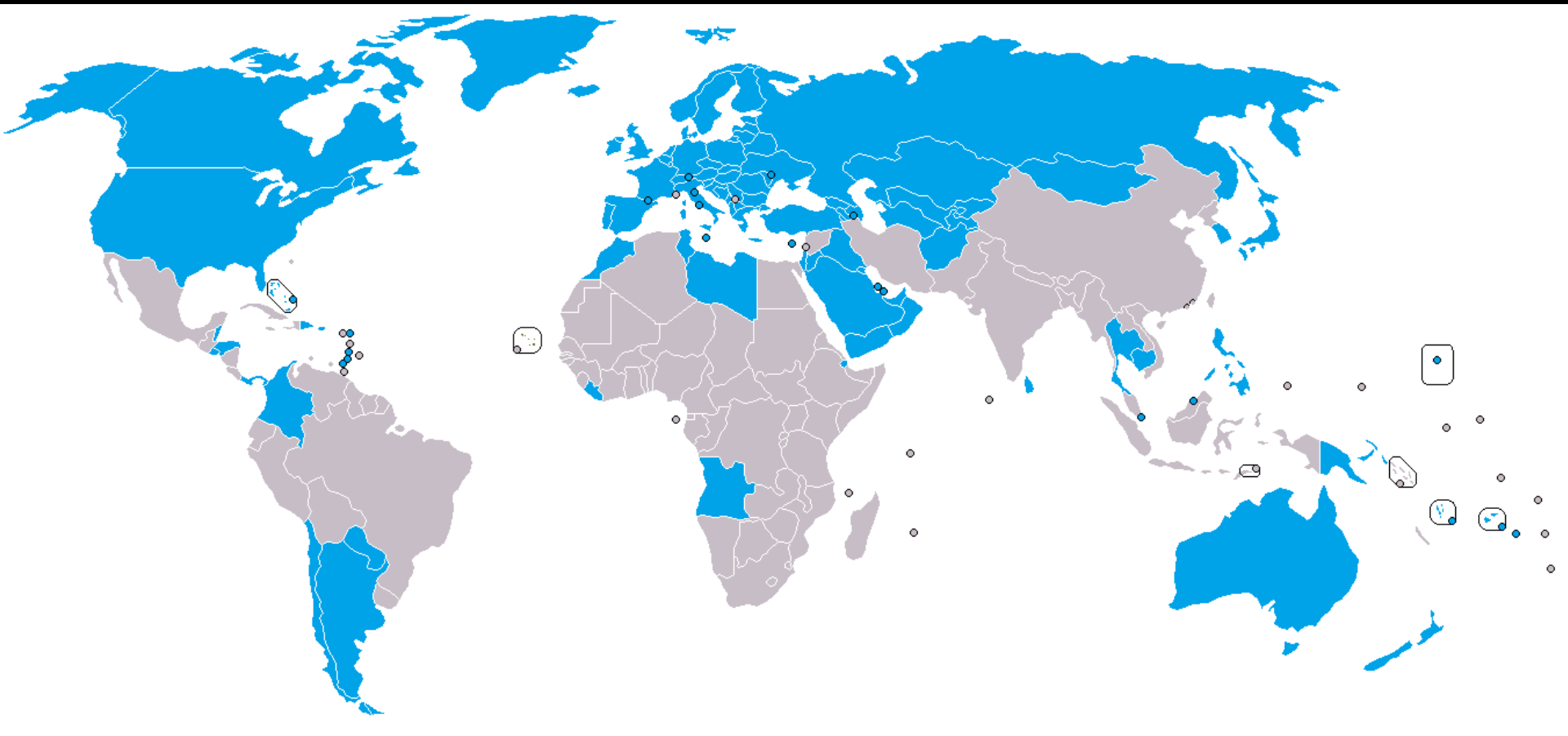
# Proliferation Security Initiative

- George W. Bush era initiative
- Created by John Bolton


THE
ROOM
WHERE IT
HAPPENED
A White House Memoir
JOHN
BOLTON
Former National Security Advisor
of the United States

# Proliferation Security Initiative

- George W. Bush era initiative
- Created by John Bolton
- Designed to create a worldwide anti-trafficking net
- Ships and intelligence



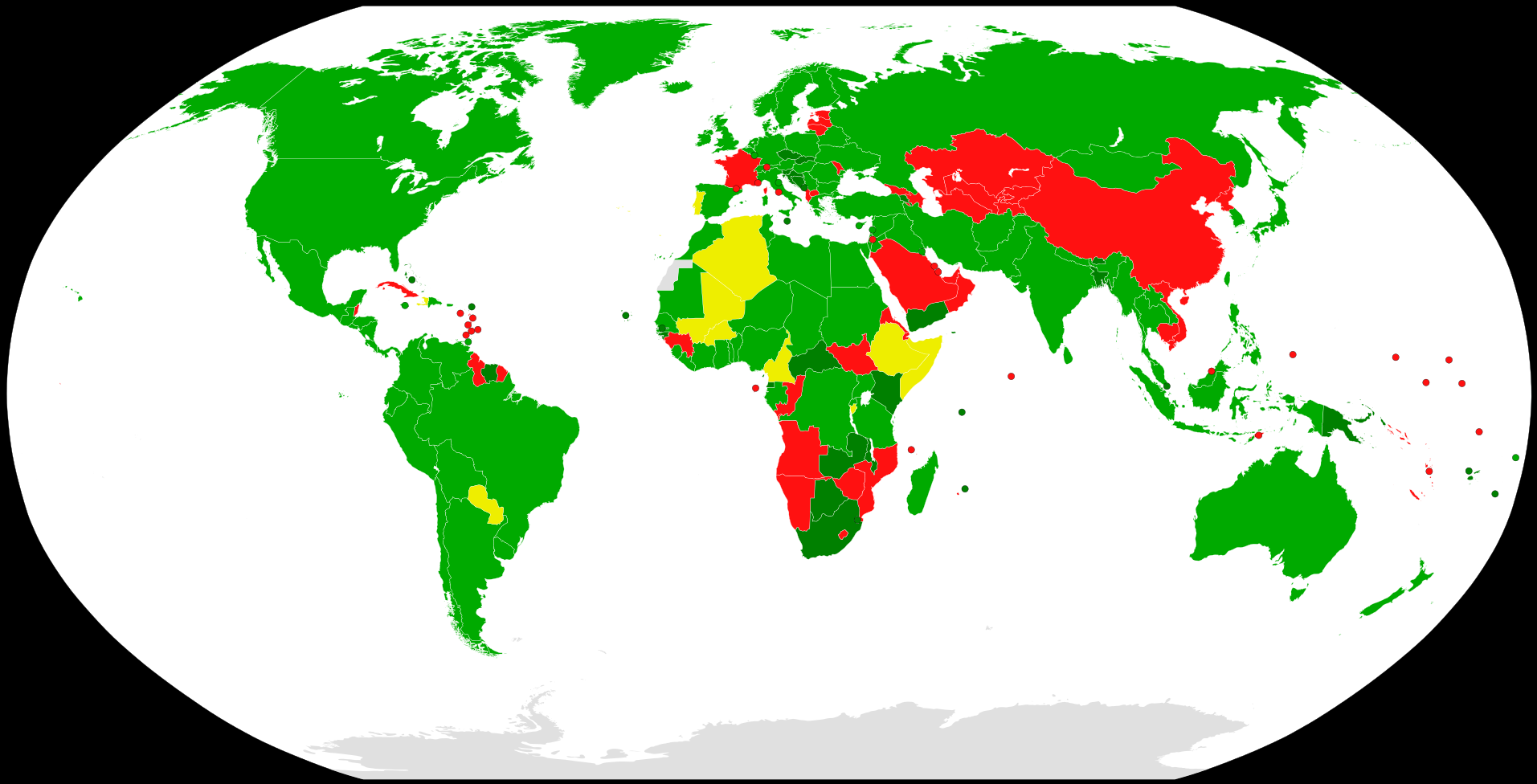
# Partial Test Ban Treaty

- Early tests of nuclear weapons started getting out of hand


TOTAL NUCLEAR TESTS BY LOCATION
ALASKA 3
COLORADO 3
NEVADA 935
MISSISSIPPI 2
JOHNSTON ISLAND 12
CHRISTMAS ISLAND 30
MAIDEN ISLAND 3
MURUROA ATOLL 178
FANGATAUGUA ATOLL 12
PACIFIC OCEAN 4
ALGERIA 17
SO. ATLANTIC OCEAN 3
KAZAKHSTAN 496
RUSSIA 214
UKRAINE 2
UZBEKISTAN 2
TURKMENISTAN 1
NORTH KOREA 1
PAKISTAN 5
CHINA 41
INDIA 5
ENEWETAK 43
BIKINI ATOLL 23
AUSTRALIA 12
TOTAL 2,057

# Partial Test Ban Treaty (1963)

- Early tests of nuclear weapons started getting out of hand
- Ban prohibited above-ground testing



# Comprehensive Test Ban Treaty (1993)

- Bans all testing of nuclear weapons
- Has not entered into force, and won't until all countries that were in on the design of the PTBT ratify it
  - Missing (among others): United States, China, India, Pakistan, North Korea