Dangers of Nuclear Proliferation

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” We Shall Eat Grass but Have Our Bomb”

Case Studies: Pakistan and DPRK

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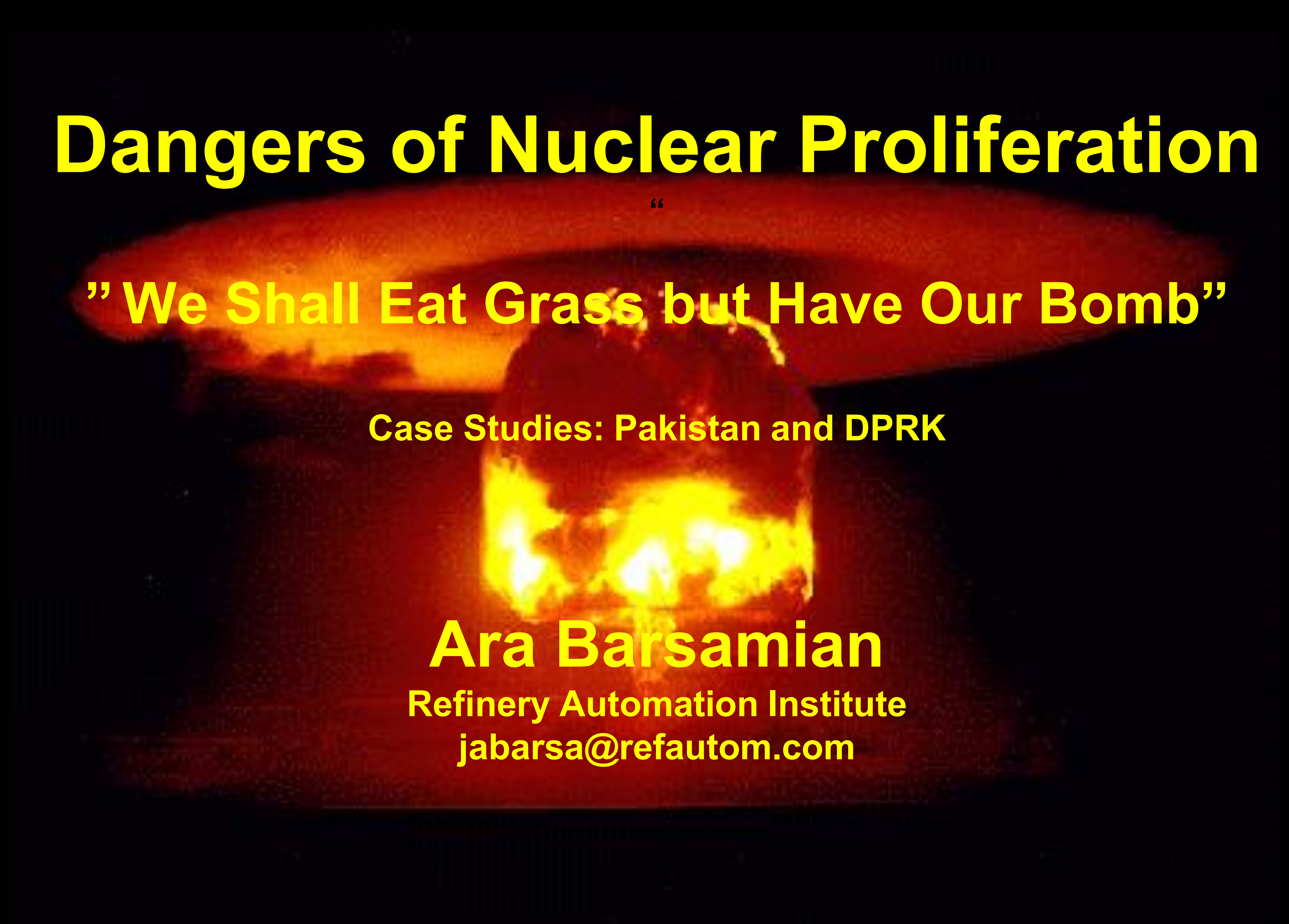


Contents

- Why Are We Afraid of Nuclear Weapons
- Motivation for Going Nuclear
- How Difficult is to Make Nuclear Weapons
- Case Studies: Pakistan and DPRK
  - Path to Nuclear Weapons
  - Current Status
- Lessons Learned???!!!
- So What Do We Do and Path Forward


Why Are We Afraid of
Nuclear Weapons?

Extreme Nature of Nuclear Explosions

- **10 to 100 Million degrees K temperatures**
- **Megabar shock & blast waves**
- **Radiation**
  - Neutrons
  - Thermal X-rays
  - Gamma rays
  - EMP (ElectroMagnetic Pulse)

- **And all these in a SMALL hand-carried package, delivered in a 70 nanoseconds pulse**
- **Nothing Can Survive a DIRECT HIT**

Mass to Support Explosive Chain Reaction

- **Sub-critical mass**: Convergent chain dies out
- **Critical mass:** Stationary chain: no explosion
- **Super critical mass**: Divergent, exponentially increasing chain leads to explosion

Bare critical masses (Mc) for spherical shapes:

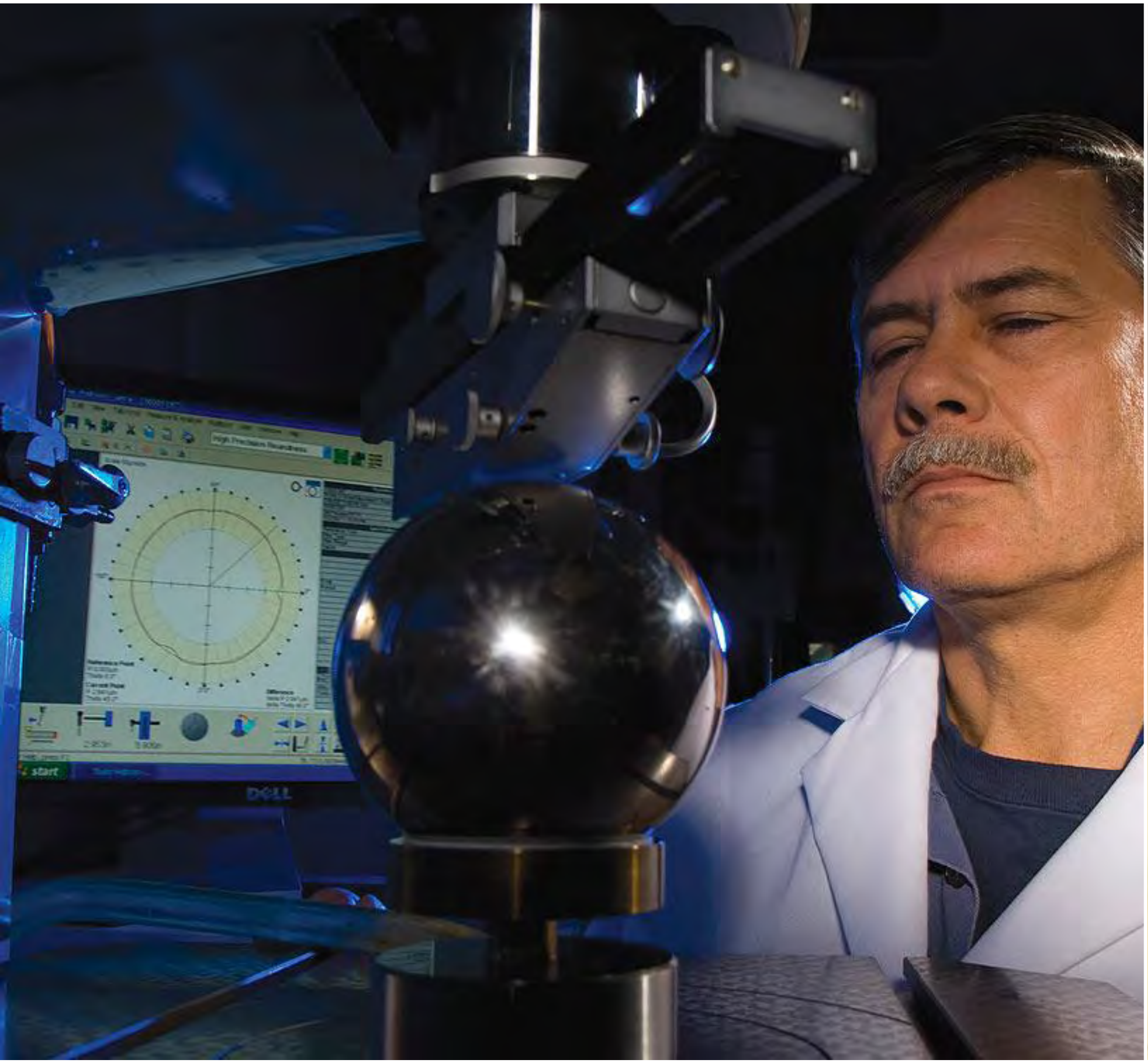
U-235 (93)=52.5 kg

Pu-239 (σ)=16.6 kg

Reduction in Mc

- Reflectors reduce Mc by factors of 3 or more
- Compression reduces Mc by square of density increase

U-235 vs. Pu-239 Bomb Cores ("Pits")



Credit: NNSA

Chain Reaction Energy Released Proportional to Number of Fissions

Neutron Population $$n = n_o e^{\alpha t},$$

Reaction Speed depends on Alpha, neutron multiplication factor

Condition for explosion: α>1=Supercritical

- Where α=ν/τ where t-neutron generation time
- τ =generation time=determines speed of reaction=~10^{-8}s

e.g. τ =10 ns for U235 and 3ns for Pu239

Fission Energy Release

Depends on SPEED of Reaction, Alpha=**Neutron Generation Time, τ**

- U235=~10ns
- Pu239=~3 ns
- ergo, Pu 3 times more effective than U:

Energy release by g neutron generations=$7x10^{-21}$ e^{g}

Or E=$7x10^{-21}$ T/fission X e^{54} fissions=~12.5 kT (Hiroshima)

- Inserting E, From E=nkT, E=12.5kT=12.5 x 4.18 10^{16}erg; **T=~(1.37x 10^{7}) ^{0}K**

and

- From P=2/3 E_{mat}, P=(0.82 x 10^{8})ρ/T/M), **P=~1.15 x 10^{15} atm**

- MOST OF FISSION ENERGY Liberated in the last 7 generations or 70 ns pulse

Basic Design of Fission Weapons

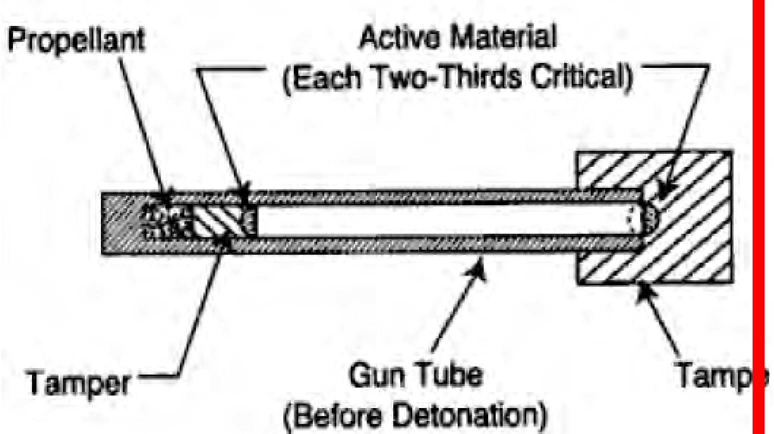


Figure 2-VII. Gun Assembly Principle

Simple, Foolproof No Testing ,
Easy to Hide, V Inefficient,
Can Only work with U

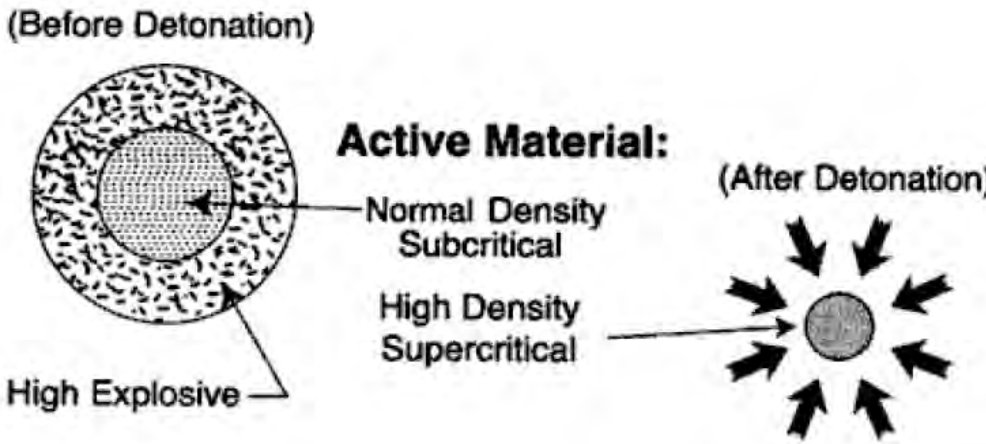


Figure 2-VIII. Implosion Assembly Principle

Complex, Requires Testing ,
Efficient
Can use BOTH U or PU

Proliferation Motivation

- **USSR:** Existential Fear of Losing Control to a Superior Armed America
- **UK and France:** Desire for “Seat at the Table” to stay relevant
- **China:** Fear of USSR/Khruschev Era
- **India:** Rising Hindu Nationalism
- **Israel:** Fear of overrun by Arab neighbors
- **Apartheid South Africa:** fear of Cuban invasion from Angola and African National Congress takeover
- **Pakistan:** Fear of India after Kashmir/Loss of Bangladesh
- **North Korea:** fear of deposing KIM family/forced reunification of N/S Koreas

How Difficult to Make NW?

Simply question of fissile material availability U235 and Pu239

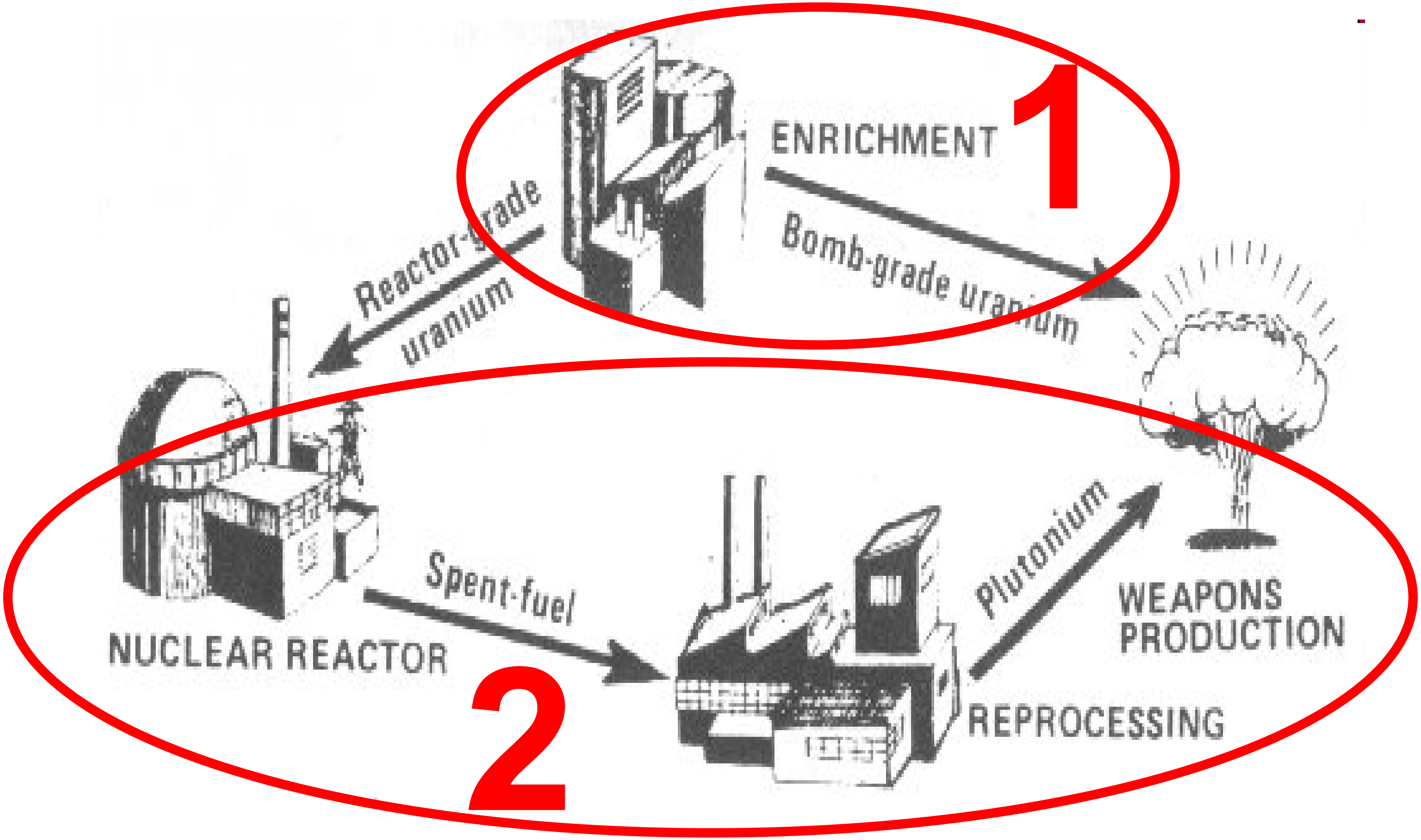
Uranium 235 preferred by proliferators

- Simply Explodes by dropping one piece on top of another
- No pre-detonation; no spontaneous fission neutrons
- Foolproof, no testing needed
- Enrichment by centrifuge has small footprint/hard to detect

Plutonium 3 times more efficient than Uranium 235

- Requires nuclear reactor, highly visible, fuel reprocessing
- Requires Complicated Implosion because of Pre-detonation
- Compact device (3X smaller than U235)

Paths to Getting Materials



Pakistan vs. DPRK Path to NW

Pakistan Relied on Foreign Countries

- STOLEN Centrifuge Enrichment Technology
- Direct Weapons help from China: Sample bomb design, HEU, “borrowing” nuclear test site and support
- Surreptitious access to Western Universities and Research
    - E.G. running bomb implosion calculations by grad students on Oxford University supercomputers

DPRK Is Mostly Indigenous

- Reactor Training for engineers and scientists in USSR
- Stationing agents at IAEA to learn the latest in reactors
- Weapons design indigenous
- Pakistan assistance with centrifuges for HEU

Pakistan-Historical Background

- **War w India Over East Pakistan (1971):**
  - Pakistan attacked India pre-emptively over the East Pakistan declaration of secession
  - Defeated and surrendered to India within 2 weeks
  - Pakistan split in 2; split territory became Bangladesh

- **India "Goes Nuclear" in 18 May 1974**
  - India detonates "Smiling Buddha" 8kT
  - Pakistani prime minister Zulfikar Ali Bhutto swearing to reciprocate "We shall eat grass but have our bomb": **GDP=$135/capita**
  - Pakistan races for the bomb using stolen technology

- **Pakistan Shows NW Results in 1998**
- 11 May 1998 India test 5 bombs; 28 May 1998 Pakistan detonates 5 bombs; detonates 1 more in 2 days

Pakistan's Path to NW

Motivated by losing 1971 war w India (lost Bangladesh)

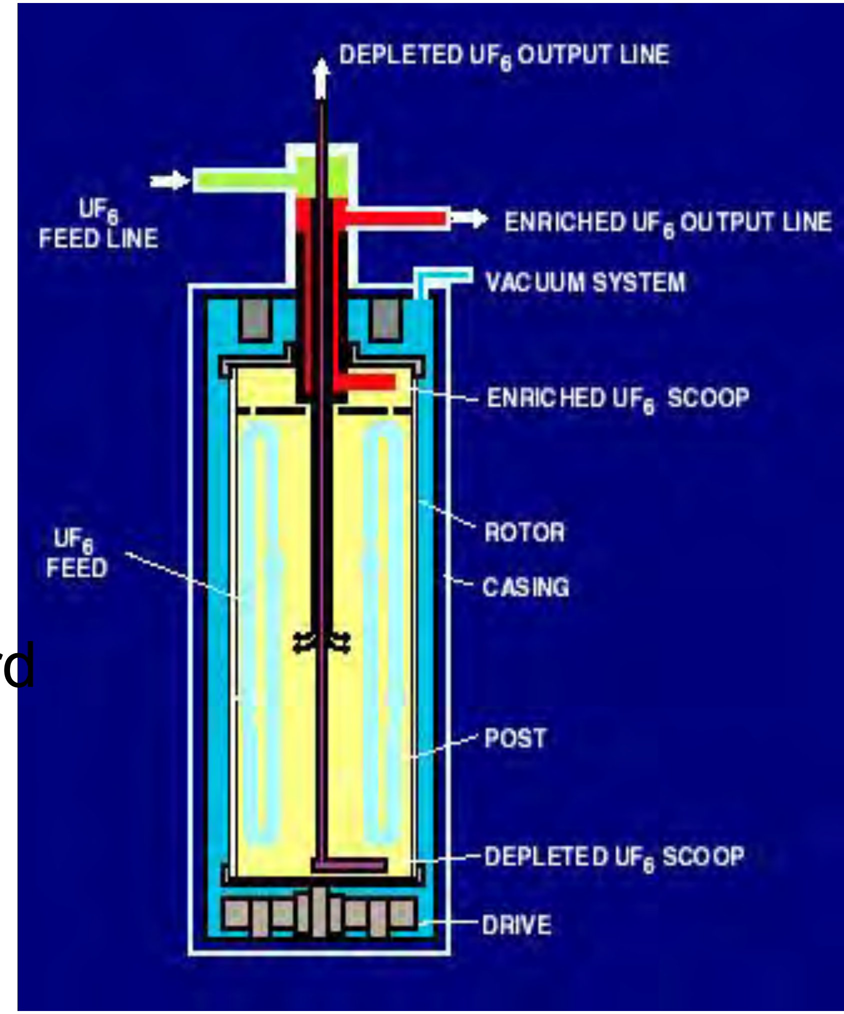
- Final Impetus from India's "peaceful" 1974 explosion

Chose U235 enrichment as faster, cheaper and easier to hide than Plutonium path

- Based on stolen URENCO U235 centrifuge technology and complete supply chain and business contacts by Dr. A.Q. Khan, employed by URENCO in 1975
- China supplied CHIC4 bomb design (12kT) and engineering and test site assistance
- Designed fission implosion weapons, later adding boosting using D+T to increase yields, tested in 1998
- Later added Plutonium designs using Canadian CANDU reactor and indigenous reactor Plutonium production

Stolen URENCO Ultra-Centrifuge

- Uses physical principle of centripetal force to separate U-235 from U-238
- Very high speed rotor generates centripetal force
- Heavier $^{238}UF_6$ concentrates closer to the rotor wall, while lighter $^{235}UF_6$ concentrates toward rotor axis
- Separation increases with rotor speed and length.
- Need ~5000 centrifuges for 1 bomb



A.Q. Khan Smuggling Network

Sold P1 and P2 centrifuges, Uranium UO2 feed, and CHIC4 bomb design to:

- DPRK (North Korea) and possibly CHIC4 design for Modified SCUDS B and C (Nodong)

- Iran - Centrifuges and UO2 feed, possibly bomb blueprints

- Libya-Centrifuges and UO2 feed, CHICK4 bomb blueprints

Pakistan's P1 & P2 Centrifuges in Libya and Iran

Tests of May 1988

May/28: 5 devices (one with power of 30-45 kt)
May/30: 1 device (lighter, smaller size,15-18 kt)

China tested a Pakistani nuclear device in 1990 at Lop Nor proving ground.

DPRK-Historical Background

- Korean War (1950-1953):
  - War started by N Korea; China involved to prevent DPRK collapse
  - US repeatedly threatened to use nuclear weapons
- From 1958, US stored various types of nuclear weapons in South Korea.
  - At its peak in 1967 there were 950 nuclear weapons of 8 different types. In 1980, that number dropped to 150
- DPRK maintained an aggressive stance re: S. Korea and US to ensure Kim dynasty continuity
  - False promises of peaceful coexistence and de-nuclearization failed. During periodic thaws, GWBush removed all nuclear weapons from South Korea.

DPRK-North Korea Path to NW

In 1963,DPRK asked USSR and China for Weapons

- **Both refused**, triggering decision to “GO NUCLEAR”

DPRK signed Civilian Agreement w. USSR

- USSR provided in 1965 a small research reactor of 5MWe; expanded to 8MWe
- Used as test bed to extract and reprocess Plutonium
- Developed indigenous Uranium ore deposits and processing

Indigenous Design of Yongbyon 5MWE reactor in 1979

- Design like UK Magnox gas-graphite design maximized Plutonium production

DPRK NW Facilities

Yongbyon Reactor

U-nat-Gas-graphite-Magnox

20 MWt (5 MWe)

5.5 to 8 kg of Pu/year

Pu Reprocessing

U235 Centrifuge Plant

<u>Likely North Korea nuclear arsenal</u>:
30 to 60 bombs (there
are estimates well above this).

DPRK-North Korea

First bomb used Plutonium from the Yongbyon reactor

- Used 2kg in sophisticated implosion, like US and UK
- Did not get it quite right (yield of only 1kT)

Subsequent Tests

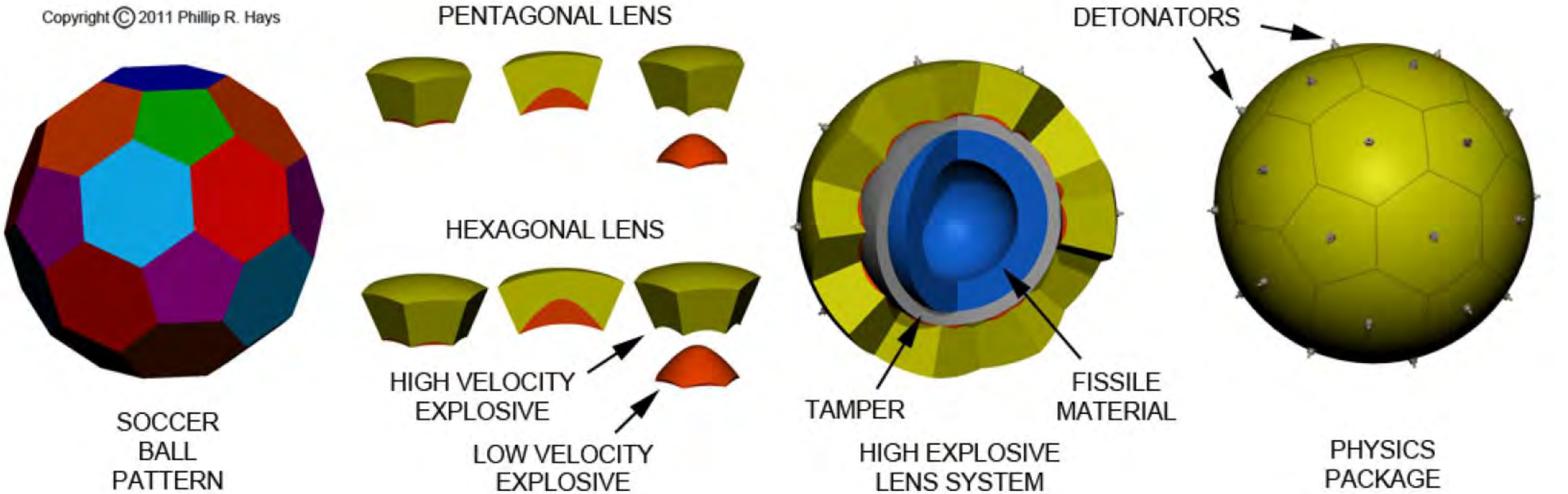
- Iterative tests increased yield to 9 to 10 kT
- Further test included yield boosting using D+T which doubles or triples yield to 30-60kT

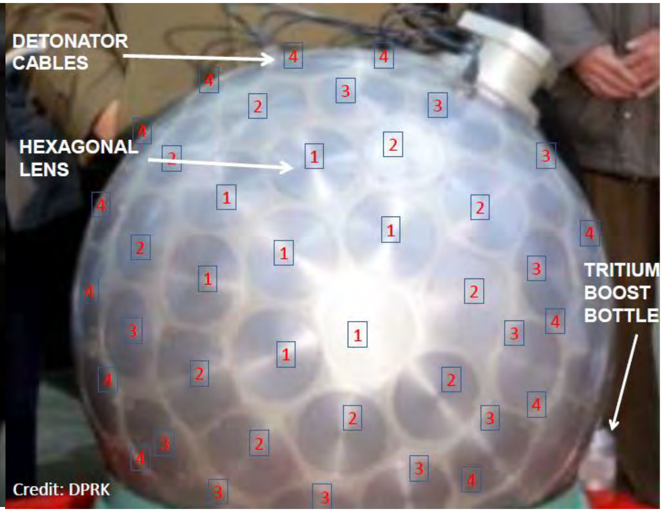
DPRK Designs More Advanced Than Pakistan

- Sophisticated Implosion Conserves Plutonium
- 2-stage H-Bomb
- Advanced Fuzing and Firing System

DPRK “Miniaturized 10kT Bomb

Anatomy of DPRK 10 kT Bomb

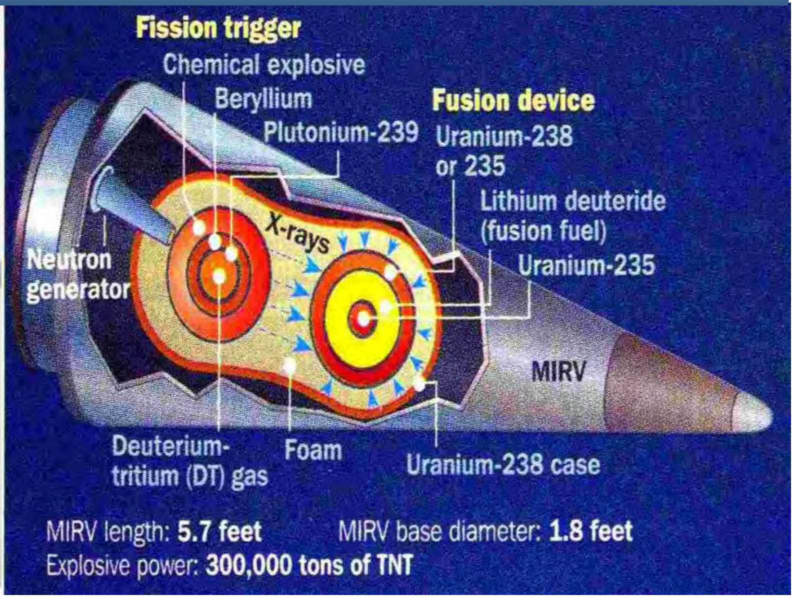




DPRK 2 Stage H-Bomb Design

Principle of 2-Stage “Peanut”

DPRK 140-250kT Peanut



W-87 300kT MIRV “Peanut”

Why Is DPRK Anxious to show its NW Technology to U.S.?

- DPRK was and is unusually open in showing its weaponry and reactor and centrifuge facilities to US officials, which are considered "State Secrets" in other countries

Question Is Why?

- Wants **CREDIBILITY**; to leave no doubt that it possesses the real NW technology.
  - It craves recognition from the US as a "nuclear power", to gain leverage in easing sanctions and be treated as an "equal".

Lessons Learned?

No Obstacle for a country determined to have NW even if very poor:

- Pakistan GDP per capita =$135 in 1974 (now $1500)
- DPRK GDP= $459 in 1974 (now $1800)

Technical Know-How Widespread

“Controlled” Technology available in Marketplace

- Proliferrant Countries (Pakistan, China, DPRK, Iran)
- 3rd Party Smugglers and Suppliers

Non-Proliferation Options

Is preventing nuclear proliferation even possible?

Yes

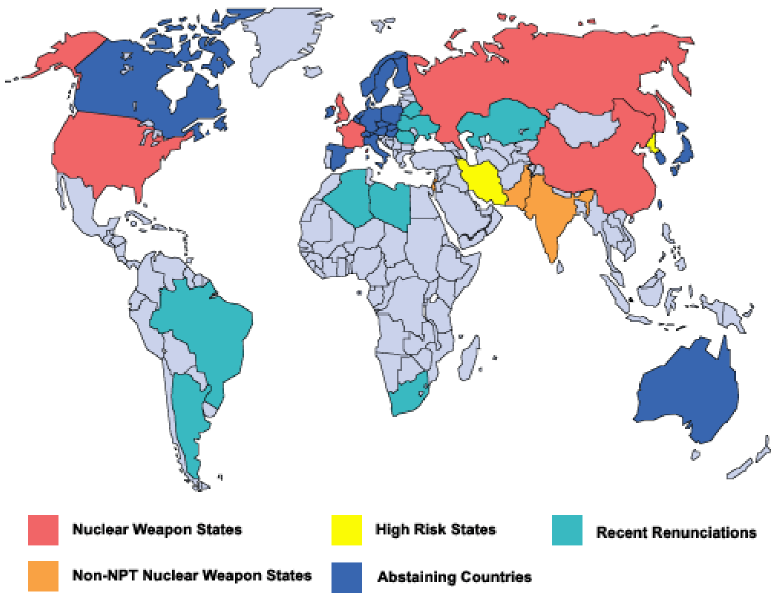
Japan, Germany (under US “nuclear umbrella”)
Algeria, Argentina, Brazil, Iraq, Libya, South Africa, Taiwan…

No

Pakistan, India, Israel(?)

Maybe w Incentives?

Iran, North Korea



Oh….Nooooooooo!