Dangers of Nuclear Proliferation

"We Shall Eat Grass but Have Our Bomb"

Case Studies: Pakistan and DPRK

Ara Barsamian
Refinery Automation Institute
jabarsa@refautom.com
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")
Chain Reaction Energy Released
Proportional to Number of Fissions

\[ n = n_0 e^{\alpha t}, \]

Neutron Population

Reaction Speed depends on Alpha, neutron multiplication factor

Condition for explosion: \( \alpha > 1 \) = Supercritical

- Where \( \alpha = \nu / \tau \) where \( \tau \) - neutron generation time
- \( \tau \) - generation time = determines speed of reaction = \( \sim 10^{-8} \)s

\[ e.g. \ \tau = 10 \text{ ns for U235 and 3ns for Pu239} \]
Fission Energy Release

Depends on **SPEED of Reaction**, Alpha=**Neutron Generation Time**, $\tau$

- U235=\(~10\text{ ns}\)
- Pu239=\(~3\text{ ns}\)
- ergo, Pu 3 times more effective than U:

Energy release by $g$ neutron generations=$7\times10^{-21} \text{ e}^g$

Or $E=7\times10^{-21} \text{ T/fission } \times e^{54 \text{ fissions}}=\sim12.5 \text{ kT} \ (\text{Hiroshima})$

- Inserting $E$, From $E=nkT$, $E=12.5kT=12.5 \times 4.18 \times 10^{16} \text{ erg}$; $T=\sim(1.37 \times 10^7) \text{ K}$

- From $P=2/3 E_{\text{mat}}$, $P=(0.82 \times 10^8)\rho/T/M)$, $P=\sim1.15 \times 10^{15} \text{ atm}$

- **MOST OF FISSION ENERGY Liberated in the last 7 generations or 70 ns pulse**
Basic Design of Fission Weapons

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

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

1. Enrichment
   - Reactor-grade uranium
   - Bomb-grade uranium

2. Reprocessing
   - Spent-fuel
   - Plutonium
   - Weapons production
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 $^{238}\text{UF}_6$ concentrates closer to the rotor wall, while lighter $^{235}\text{UF}_6$ 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.
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

Likely North Korea nuclear arsenal:
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
- Proliferant Countries (Pakistan, China, DPRK, Iran)
- 3rd Party Smugglers and Suppliers
Non-Proliferation Options

venues
Economics: disincentives ← blockades, sanctions ← export controls ← foreign aid
Politics: political isolation ← int'l organizations ← alliances
Military Force: war ← peacekeeping ← covert operations ← military sales ← military asst.

confrontation ← cooperation

COUNTERPROLIFERATION ← NONPROLIFERATION
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….Noooooooooo!