ISIS Course

Introduction to the Making of Nuclear Weapons Concepts, including Trade-offs and Miniaturization

Challenge of Building a Nuclear Weapon

- A major challenge faced by proliferators is to build a nuclear explosive device or a weapon.
- Crude nuclear weapons can be delivered by plane, ship, or truck.
- It is more difficult to develop and construct a nuclear weapon as part of a military system able to be delivered to a target.
- For many states, the preferred method of delivery is a ballistic missile, which requires the miniaturization of the warhead.
- Typically, miniaturization efforts have started early in a nuclear weapons program.
- Although the construction of a nuclear explosive, or “weaponization,” typically poses less formidable challenges than acquiring the means to make plutonium or HEU, weaponization requires overcoming many technical hurdles.

Initial Designs

- States have typically started by developing relatively simple fission nuclear weapons, which involve obtaining an uncontrolled chain reaction in a solid core of nuclear explosive material. Later, more sophisticated designs are sought.
- There are two basic types of simple fission weapons, an implosion design and a gun-type design, where the former is usually considered more difficult to master.
- As programs develop, proliferators have sought boosted or thermonuclear weapons.

Schematic of an Implosion Design

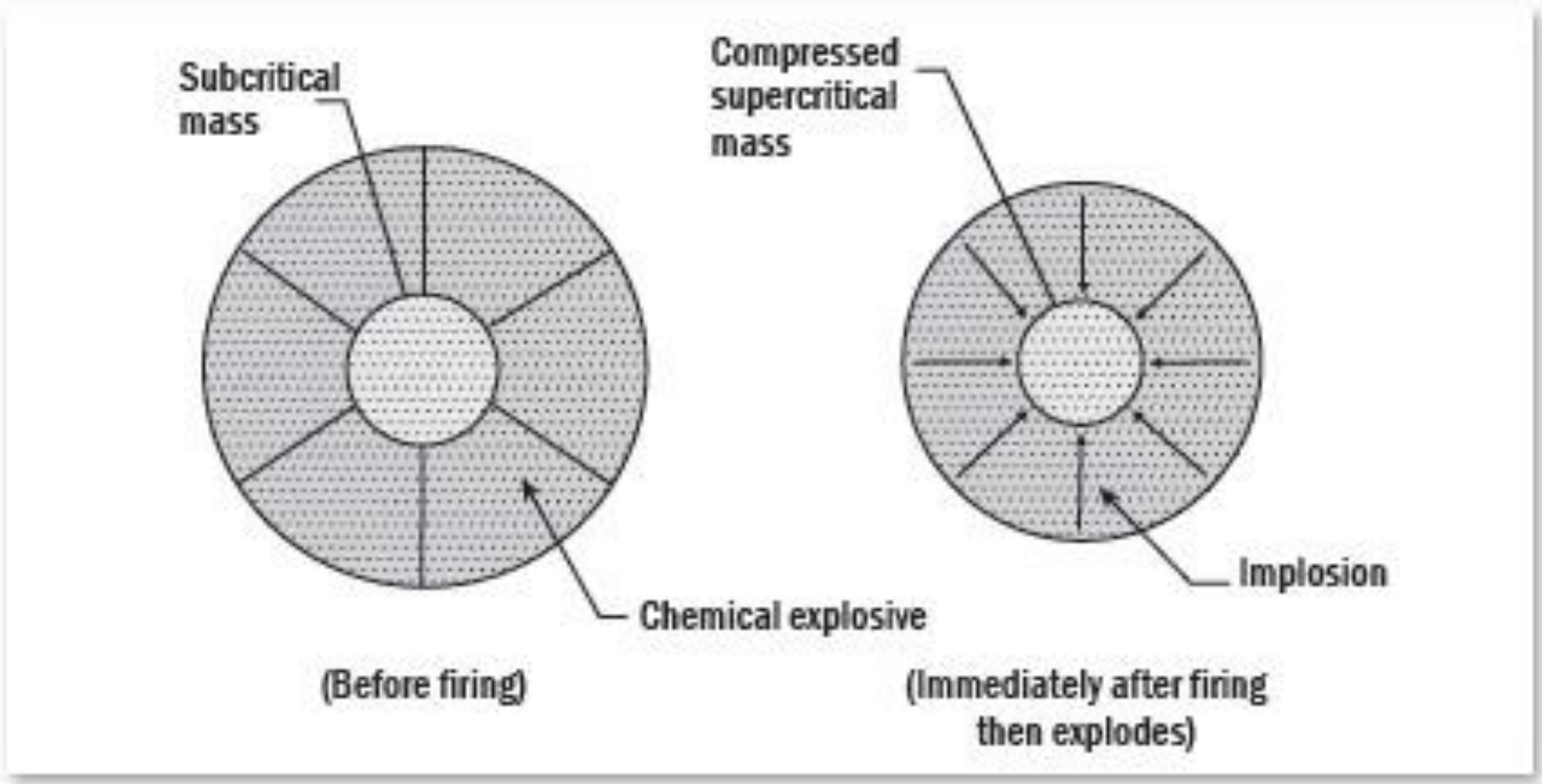
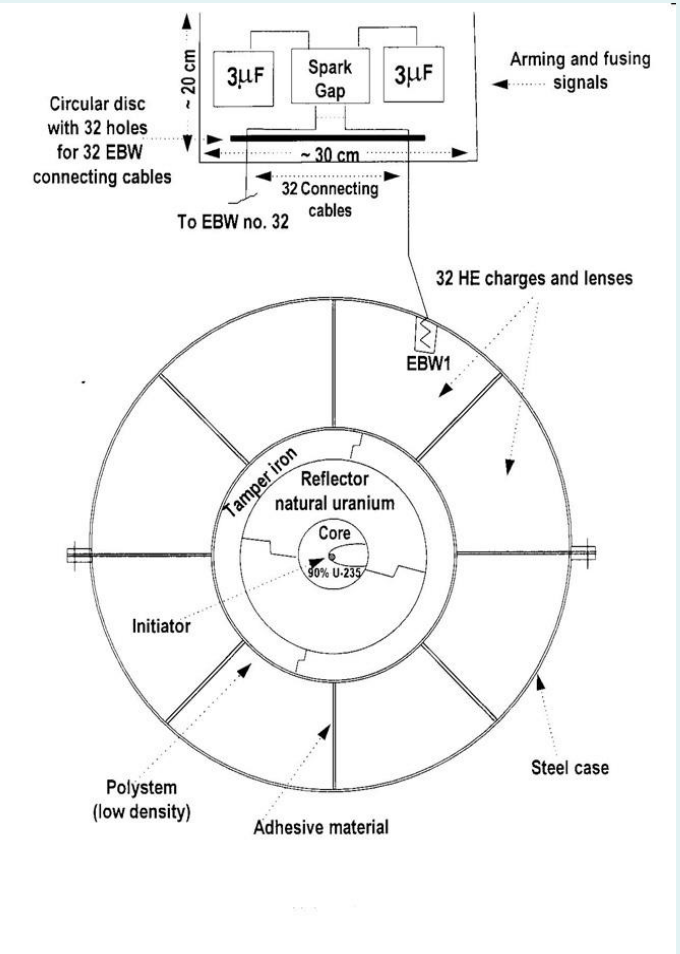


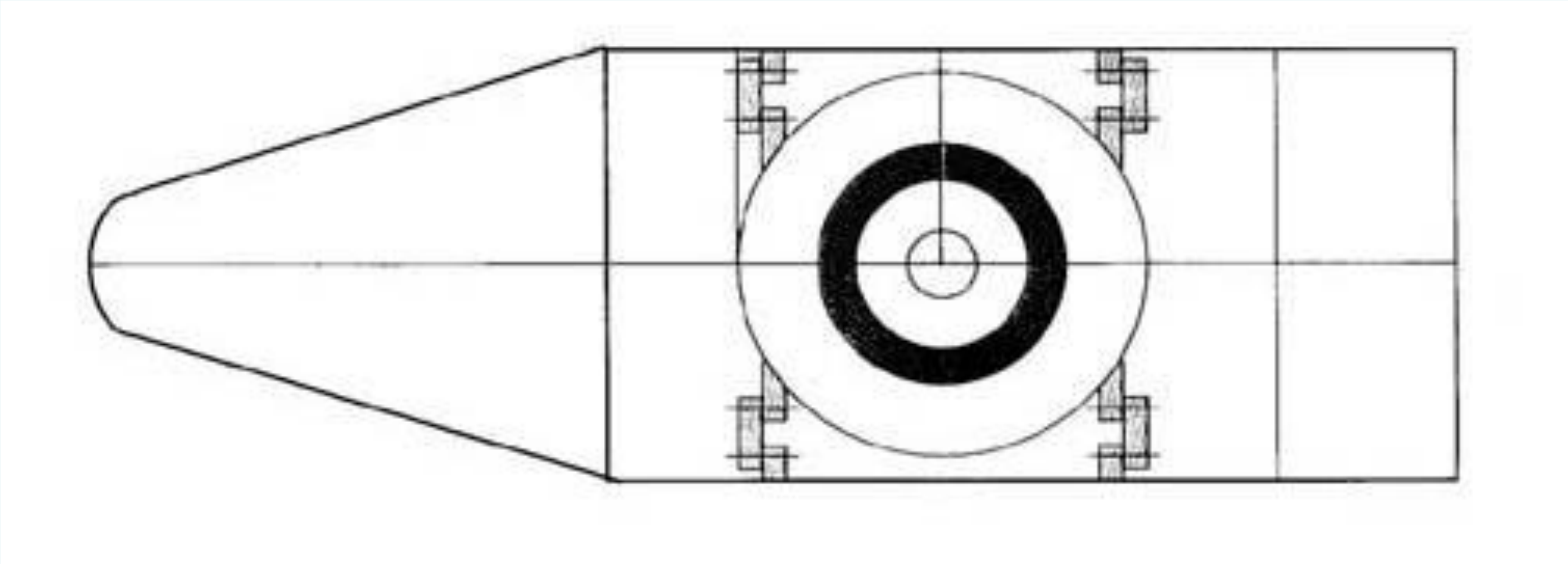
Figure C.8 TCG-NAS-2 Unclassified Illustration of a GA Weapon

Schematic of an Implosion Design (Iraqi)

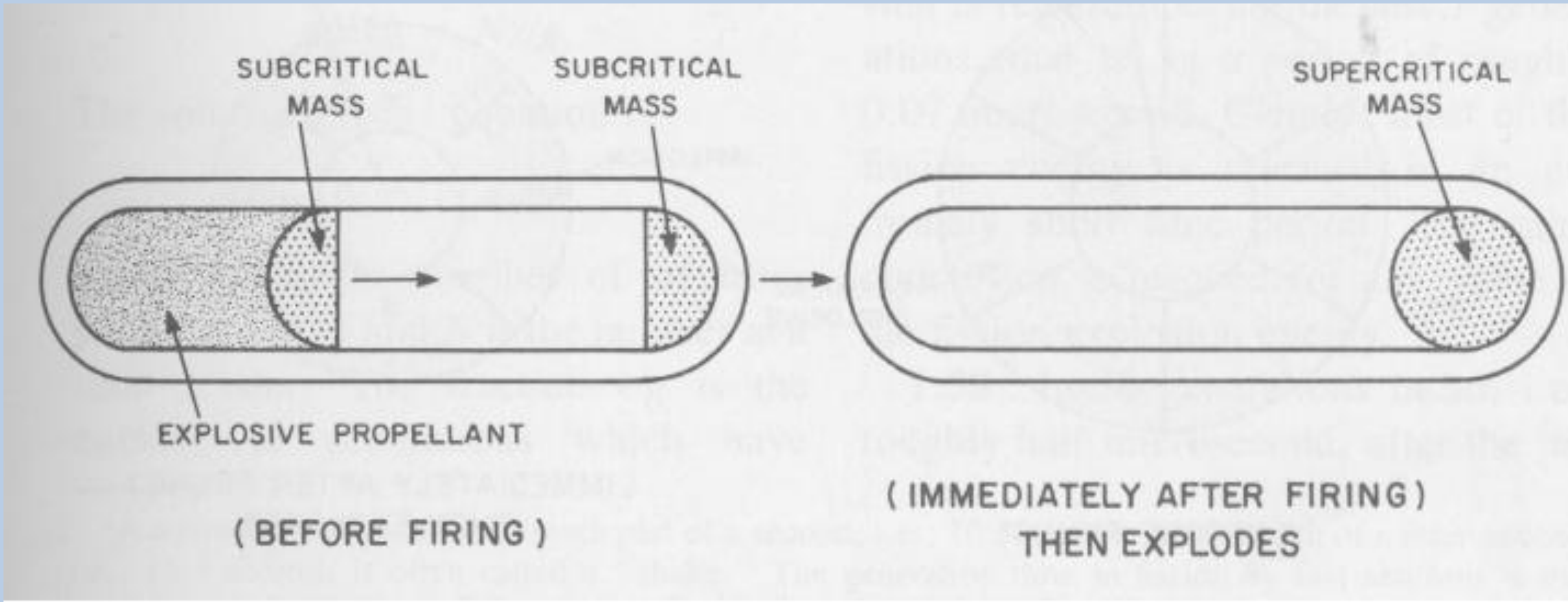


U.S. Implosion-Type

Schematic of a Warhead Mounting in a Ballistic Missile



Gun-Type Design Basics



Schematic diagram of a gun assembly design

Nuclear Explosive Materials

- Implosion designs can use plutonium, highly enriched uranium (HEU), or neptunium 237
- Gun-type designs can use HEU or neptunium 237 but not plutonium.
- An implosion design requires less nuclear explosive material:
  - contrast a South African gun-type with 55 kg of 80-90 percent enriched uranium to a Chinese implosion design for a missile warhead that has 25 kilograms of 90 percent enriched uranium.
  - The Iraqi implosion design was to use 15 kg of weapon-grade uranium, according to Iraqi official declarations.

Testing Requirements

- Gun-type and implosion type designs require considerable testing of components, firing subsystems, the initiation of the chain reaction, and overall performance.
- Although a full-scale nuclear test is desired, it is not necessary. Extensive testing and a robust certification program can substitute for a full-scale nuclear test for both gun- and implosion-type designs.
- Designing a substitute testing and certification program for both designs poses significant challenges, but such a program for gun-type devices can in general provide more assurance than one for implosion designs.
- In terms of implosion designs, Pakistan successfully pursued this pathway in the early 1980s using a Chinese supplied nuclear weapon design, and Iraq was pursuing this option in the late 1980s using its own design. Iran may have been following the Iraqi pathway in the early 2000s.
- Progress in the design can be achieved without full-scale testing. From the early 1980s until 1998. when it finally did test underground, Pakistan developed many design changes that led to more advanced designs.

Disadvantages of Not Testing

- However, without a full-scale nuclear test, a state may face uncertainties in predicting the explosive yield. Is it 5 kilotons or 20 kilotons, for example?
- In the case of an implosion design, additional uncertainties may result in its reliability. For states dependent on implosion designs, technical constituencies may press for a full-scale test to validate the design and improve it.
- Without full-scale testing, a state will face limitations in the type of nuclear weapons it can build, such as thermonuclear.

Gun-Type: Testing

- An advantage of a gun-type design is that one experiment in a pulsed reactor can substitute for a full-scale nuclear test.
- This experiment is called “tickling the tail of the dragon,” suggesting the danger inherent in the test. In essence, a simplified “dragon” machine, or pulsed fission reactor, involves a slug of highly enriched uranium sliding down a wire or track through a cylindrical annulus of highly enriched uranium, simulating in slow motion what occurs in firing a gun-type design. The United States conducted such experiments in early 1945 at Los Alamos during the Manhattan Project, prior to dropping a gun-type bomb on Hiroshima.

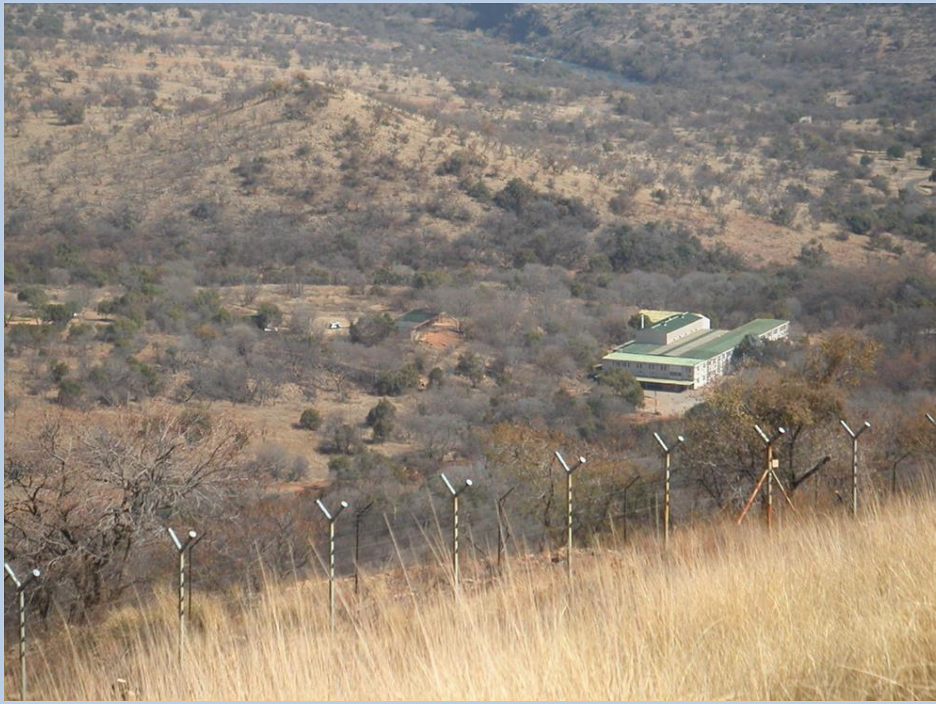
South Africa’s Building 5000

- South Africa conducted a dragon test in Building 5000 at the Pelindaba site in 1979, as soon as it had produced enough HEU.
- It conducted only one test and never used the pulse reactor again.

Danger of Dragon Experiments

- If a HEU slug becomes stuck in a dragon machine, the highly enriched uranium would have become supercritical, causing a small nuclear explosion (on order of tens or hundreds of kilograms of TNT).
- Thus, any dragon-type reactor must be built with safety as a primary concern, and it must be operated carefully.
- South Africa apparently attempted to mitigate this danger in several ways. It built Building 5000 at the bottom of a depression surrounded by hills in an isolated portion of its main nuclear site. It placed the control room in Building 5100, which was almost three quarters of a kilometer away and shielded from its dragon test by a hill.

Tickling the Dragon's Tail in Building 5000 (on left); Control room in Building 5100 (on right; 0.75 km away)



Google Earth Image of Buildings 5000 and 5100

Full-Scale Implosion Tests

- Proliferant states will plan to conduct full-scale nuclear tests and prepare the necessary infrastructure, even if actually doing so remains uncertain.
- An example is Pakistan, which had prepared a nuclear test site but only tested after India did so in 1998. But because of being prepared to test, it could do so in weeks.

Figure 5 -- Pakistan's first nuclear test site.
Annotated by ISIS and Frank Pabian.
(video courtesy of Pakistan Television)

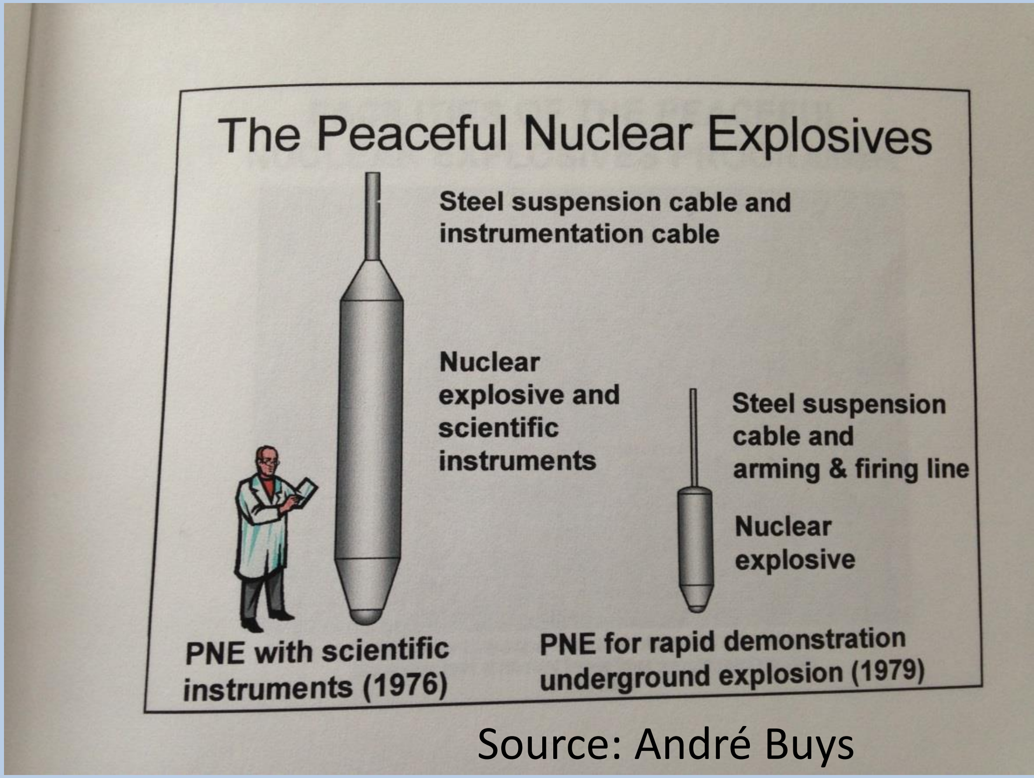
Figure 1 -- Before, during, and after the tests on May 28, 1998
at Pakistan's first nuclear test site; looking from west to east.
(video courtesy of Pakistan Television)

Miniaturization

- Most states focus on developing a nuclear weapon design able to be delivered by a priority delivery system.   For most states that leads to efforts to miniaturize the warhead to fit on the delivery system, which today is usually a ballistic missile. However, in the past the designs were often developed for aircraft delivery.

South Africa Miniaturization Efforts Started Early

- After the detection of the South African nuclear test site in 1977, the government ordered the development of a smaller nuclear explosive, about half the size of the 1977 design and more rapidly deployable.



Source: André Buys

Miniaturization (cont.)

- By the mid-1960s, China had miniaturized a warhead design for missile delivery. This design was given to Pakistan in the early 1980s; A.Q. Khan gave this design to Libya two decades later. It was 70-90 centimeters in diameter and able to fit on a Ghauri missile with a traditional re-entry vehicle but not with a triconic reentry vehicle.
- Based on intelligence reporting, North Korea has focused on miniaturization of its plutonium implosion design since at least the early 1990s.
- By about 1990, Iraq's implosion warhead design was about 120 centimeters in diameter, and it was working to develop one with a diameter of about 80-90 centimeters so the warhead could fit on its ballistic missile.
- According to IAEA's information, in 2003, Iran was developing (but had not finished) a warhead with a diameter of 55 centimeters, small enough to fit on a Shahab 3.

Example of a Non-Missile Delivery System

- In the 1980s, South Africa decided to develop a credible nuclear deterrent.
- Key to that decision was the development of a nuclear warhead for delivery on its British-supplied Buccaneer bombers.
- The goal was to be able to strike a range of targets, even though its nuclear strategy specifically excluded operational application of nuclear weapons, e.g. no use against an enemy.
- It was a bluff strategy to force U.S. assistance in a crisis
- But without a credible delivery system, South Africa worried that the US government would call its bluff.

South Africa's 1980s Nuclear Delivery System: Raptor 1, or H2, Glide Bomb with inertial and optical guidance

Warhead for the H2

- The warhead built to be deployed on the Raptor was a gun-type device that was 60 centimeters in diameter and one meter in length. It was shaped like a cylindrical canister.
- It was a highly sophisticated military weapon designed to give South Africa a credible nuclear deterrent.

Buccaneer with the non-nuclear Raptor 1 (H2) on the inner pylons,

(the H2-Comms Pod on the starboard outer pylon and an ECM pod on the port outer pylon. In nuclear strike mode, outer pylons would have a control pod for the nuclear weapons and an electronic warfare pod.)

Raptor II firing procedure, more advanced than Raptor 1 but similar