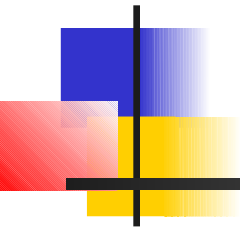
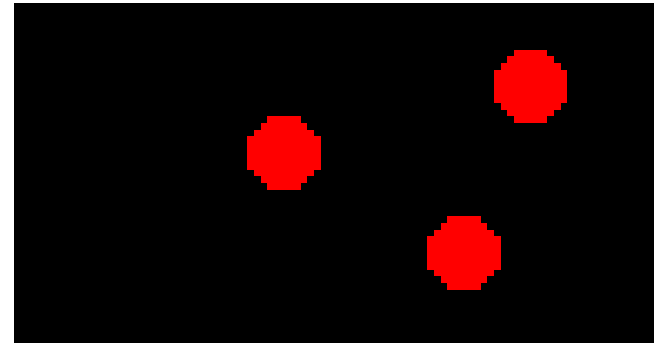


# Weapons of Mass

Destruction:

Nuclear  
Biological  
Chemical



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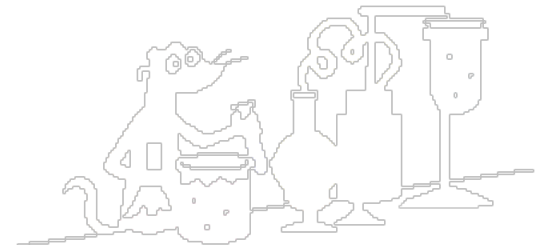
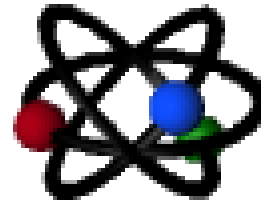
Prof. Lynn R. Cominsky  
SSU Department of Physics  
and Astronomy



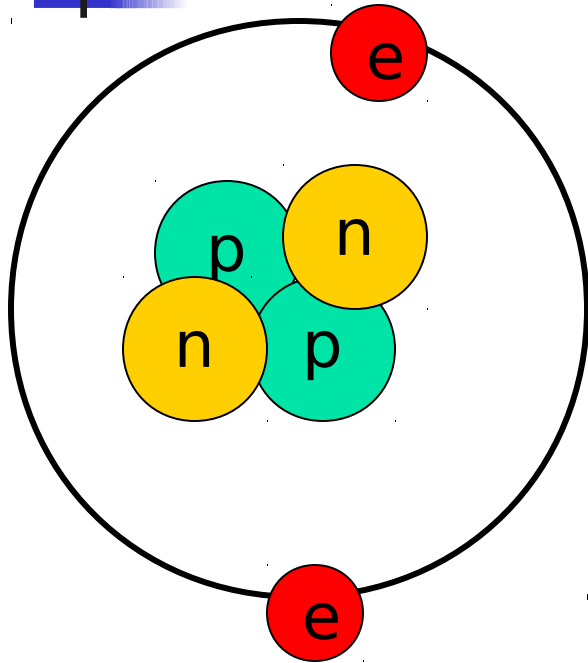
# Talk Outline

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- Nuclear Weapons
  - Background
  - Fission
  - Fusion
  - Effects
  - Proliferation
- Biological Weapons
- Chemical Weapons



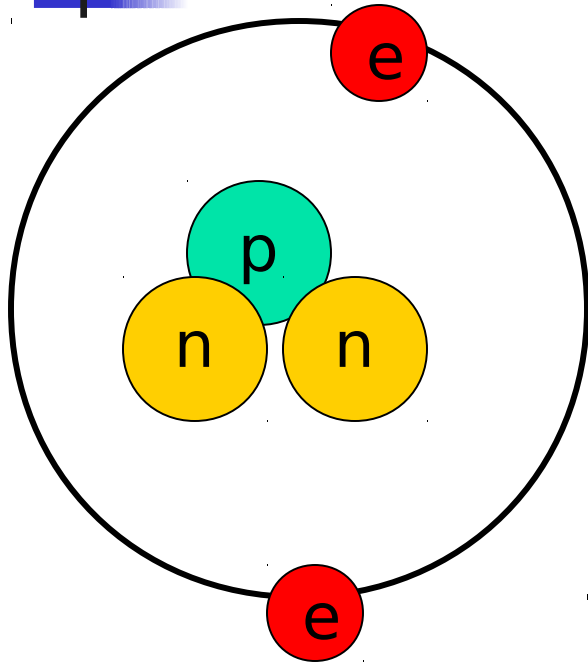
# The Helium Atom



${}^4\text{He}$

- Two electrons orbiting a nucleus with:  
2 protons =  $Z$  = atomic number  
2 neutrons =  $N$
- Total mass =  $A = Z+N$
- Singly ionized Helium is missing one electron =  ${}^4\text{He}^+$
- Doubly ionized Helium is missing both electrons =  $\alpha$  particle =  ${}^4\text{He}^{++}$

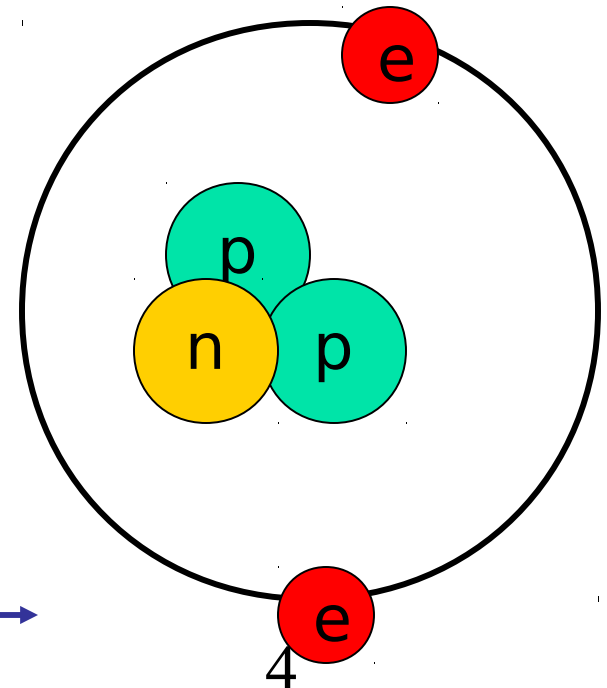
# Isotopes and Elements



- If Helium loses one of its protons, it becomes a different element



- If Helium loses one of its neutrons, it becomes an isotope





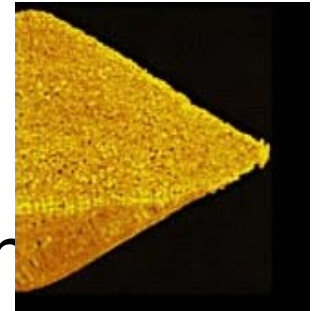
# Materials

---

- Tritium =  ${}^3\text{H}$  = very heavy Hydrogen ( $1\text{p} + 2\text{n}$ ), used in fusion weapons
- Deuterium =  ${}^2\text{H}$  = heavy Hydrogen ( $1\text{p} + 1\text{n}$ ), used in fusion weapons
- Uranium:  ${}^{238}\text{U}$  is >99% in nature  ${}^{235}\text{U}$  is ~0.7% in nature - major ingredient in fission weapons
- Plutonium:  ${}^{239}\text{Pu}$  is not found in nature

# Uranium processing

- Uranium is mined as ore from open pits or deep shaft mines, often with the help of extracting solutions
- At nearby mills, ore is crushed and **U** is extracted, leaving behind radioactive tailings
- Extracted **U** is then leached (with sulfuric acid) forming a concentrate known as “yellowcake” (aka Uranium oxide **U<sub>3</sub>O<sub>8</sub>**)
- Yellowcake is then turned into **UF<sub>6</sub>** gas, which can be cooled to a solid for easier transport





# Enriching Uranium

---

- Naturally occurring Uranium must be enriched to  $>90\%$   $^{235}\text{U}$  in order to make fission weapons (or to  $\sim 5\%$  for nuclear power plants)
- Enrichment methods
  - Gas centrifuge (now under construction in Iran and found in Iraq after 1<sup>st</sup> Gulf War)
  - Gaseous diffusion (used in USA)
  - Electromagnetic isotope separation – (unexpectedly found in Iraq after 1<sup>st</sup> Gulf War)



# Depleted Uranium

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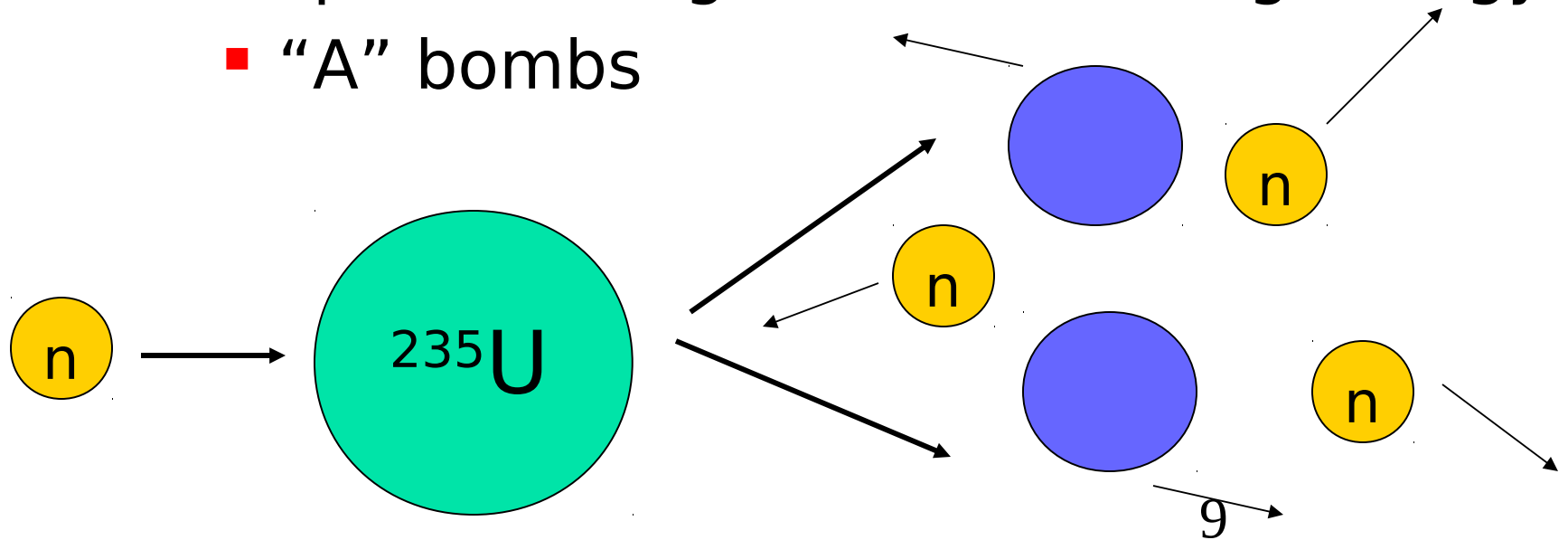
- After isotope separation, the remaining  $^{238}\text{U}$  is said to be “depleted” as it is missing  $^{235}\text{U}$  – however,  $^{238}\text{U}$  is still naturally radioactive
- Uranium is a very dense metal (1.7 x Pb), making it ideal for use in armor and shell casings
- Uranium is pyrophoric – friction causes it to burn
- The USA used depleted Uranium weapons in the Persian Gulf War (1991), in Bosnia (1995) and Kosovo (1999)
- Various health problems have been associated with the inhalation of<sup>8</sup>vaporized



# Fission Weapons

## ■ Fission

- releases energy in elements heavier than Iron
- Bombard U or Pu with neutrons, they split into fragments, releasing energy
- “A” bombs



# Critical mass → chain reactions

- When a large enough mass of either  $^{235}\text{U}$  or  $^{239}\text{Pu}$  is assembled, a self-sustaining chain reaction results after the first fission is produced.
- The minimum (“critical”) mass of fissile material that can sustain a nuclear chain reaction depends on the density, shape, and type of fissile material, as well as the effectiveness of any surrounding material (called a reflector or tamper) at reflecting neutrons back into the fissioning mass.
- Depleted  $\text{U}$  is often used in the tamper

# The first “A” bombs

- Trinity - Gadget (7/16/45)
  - Alamagordo test range in New Mexico
  - 20 kTon yield
- Little Boy (8/6/45)
  - Hiroshima
  - 15 kTon yield
- Fat Man (8/9/45)
  - Nagasaki
  - 20 kTon yield

Museum display in NM



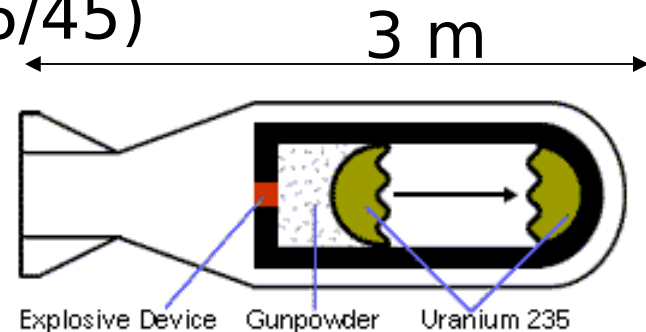
# How to make an “A” bomb

- Use  $>90\%$   $^{235}\text{U}$
- Squeeze and confine evenly
- Reflect neutrons back into  $^{235}\text{U}$
- Use initial explosive device to



A-bomb dome

Little Boy (Hiroshima  
8/6/45)



# “Fat Man” style of A-bomb

- High explosives are arranged to form an imploding shock wave which compresses the fissile material to supercriticality

(Before Detonation)

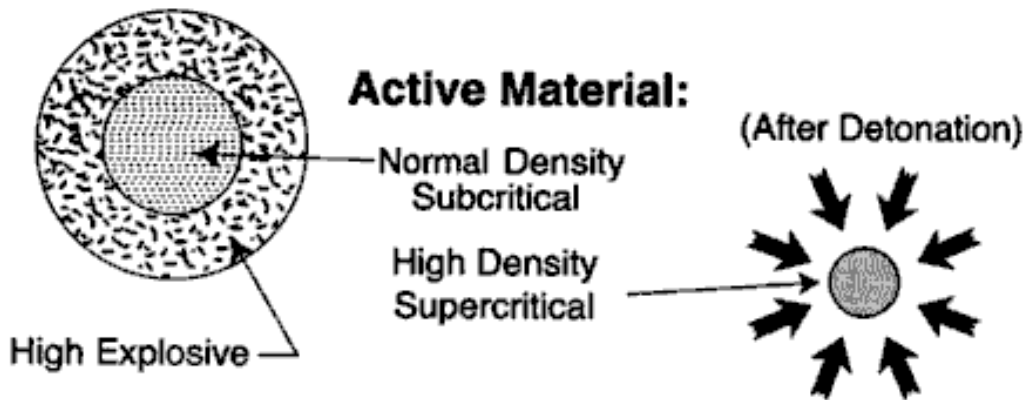
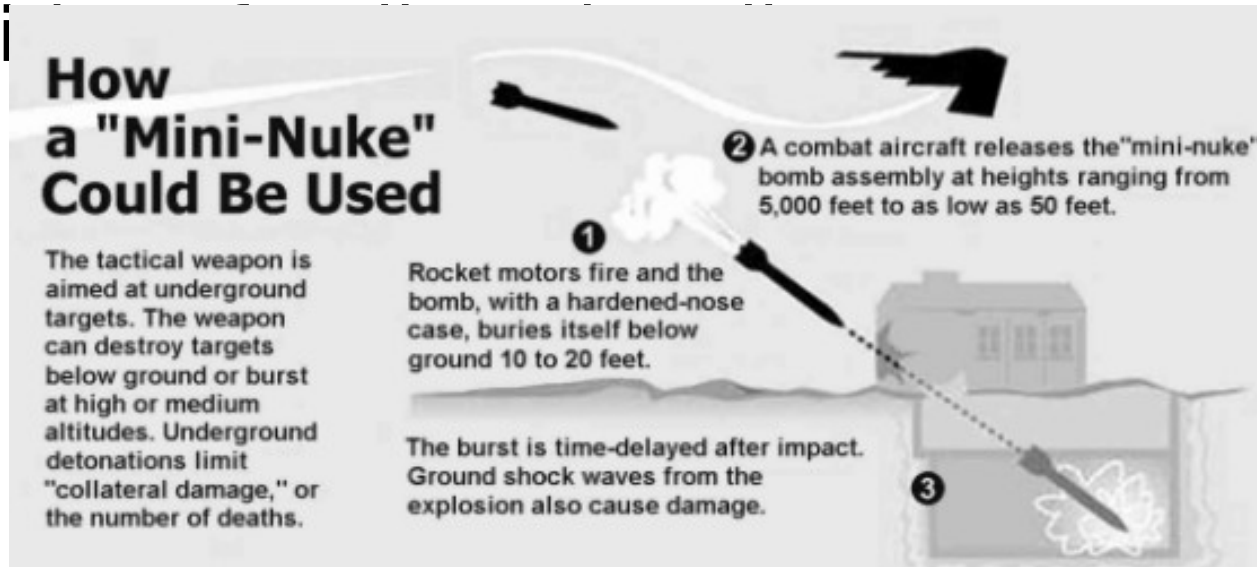


Figure 2-VIII. Implosion Assembly Principle

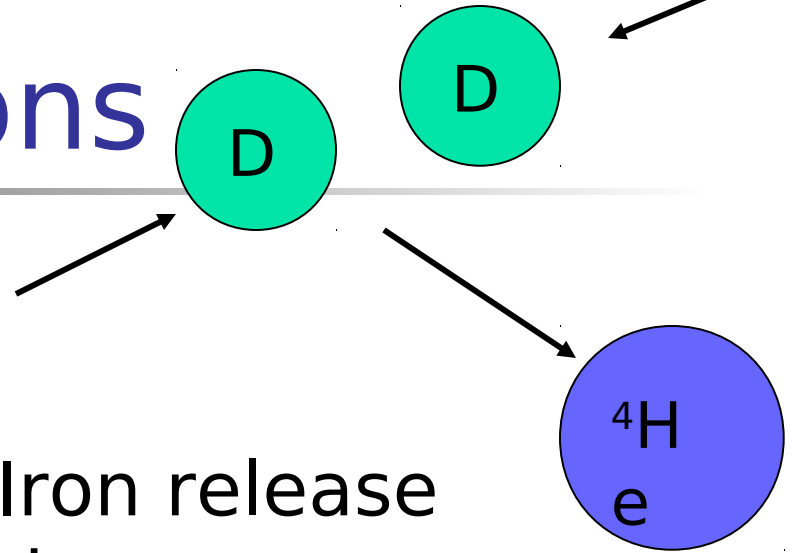
- Burst of neutrons from generator is timed for moment of maximum compression

# Low Yield Nuclear Weapons

- Designed to “threaten hard and deeply buried targets.”
- Despite claims to produce less fallout due to underground explosion, a 5 kTon weapon would produce considerable quantities



# Fusion Weapons



## ■ Fusion

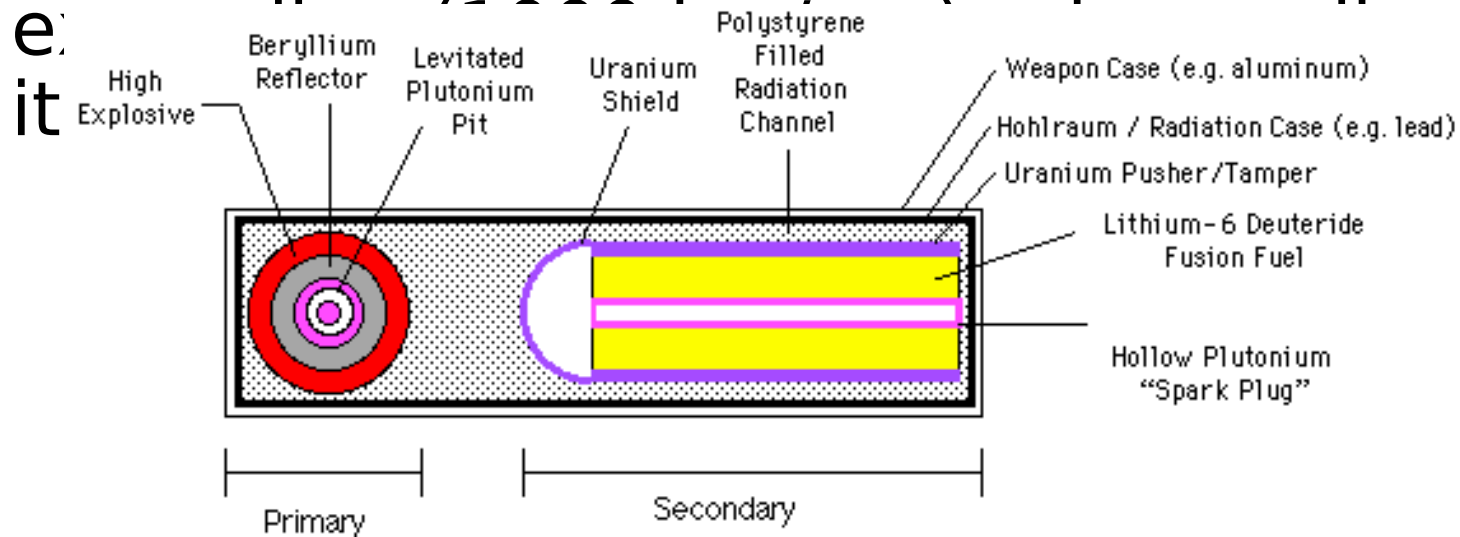
- Elements lighter than Iron release energy when combined
- Deuterium, Tritium, Lithium
- Reactions that occur inside Sun
- “H” bombs

## ■ Thermonuclear Reactions

- Heat from reaction increases reaction rate, so less fuel is needed → “efficient” bomb

# The "secret" of the H-bomb

- At the high temperatures of a fission bomb 80% or more of the energy exists as soft X-rays
- The X-rays heat a polystyrene channel, causing plasma which can compress and ignite the second (fusion) stage before the





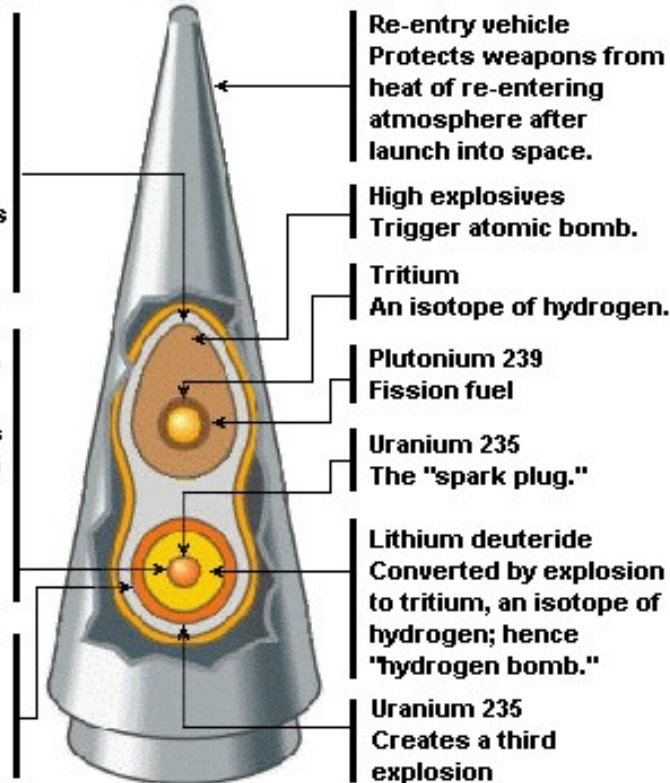
# Fusion weapons

## W-88 warhead

1. A fission bomb, the "primary," creates the heat and pressure that detonate the second device. The egg shape, a crucial advance in miniaturization, reduces diameter for better fit into the nose cone.

2. A spherical fusion bomb, the "secondary," is the most powerful. Huge amounts of X-rays from the first explosion compress and heat the fusion fuel in the secondary capsule, and it explodes.

3. A layer of enriched uranium around this device fissions on detonation, creating a third blast.

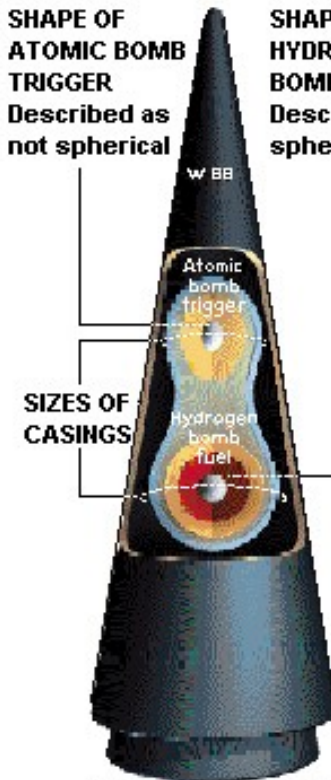


(c) 1999 San Jose Mercury News, by Reid Brown, Karl Kahler, and Dan Stober

Some secret specifications of the W-88, an American miniature hydrogen bomb, that were found in a Chinese document.

SHAPE OF ATOMIC BOMB TRIGGER  
Described as not spherical

SHAPE OF HYDROGEN BOMB FUEL  
Described as spherical



### BOMB PLACEMENT

Atomic bomb trigger is placed above the hydrogen bomb fuel

(c) 1999 New York Times,  
by Mika Grondahl

Published due to Wen Ho Lee case

<http://www.fas.org/sgp/eprint/morland.htm>

# Why is an atomic bomb so much worse than a TNT bomb?

- Amount of heat and light energy released is 1000 times greater
- Explosion is accompanied by invisible, penetrating and harmful radiation
- After explosion, radioactive fallout remains and continues to damage living things for days → weeks → years



Ground level  
view of  
Hiroshima cloud

# Physical Effects of Nuclear Weapons

- Thermal
  - Fireball → Firestorms
  - Mushroom Cloud
- Initial (prompt) Radiation
  - Alpha particles ( ${}^4\text{He}^{++}$ )
  - Beta particles ( $e^+$  and  $e^-$ )
  - Gamma-rays ( $\gamma$ )
  - Neutrons ( $n$ )

<http://nuketesting.enviroweb.org/>

*Trinity*  
y



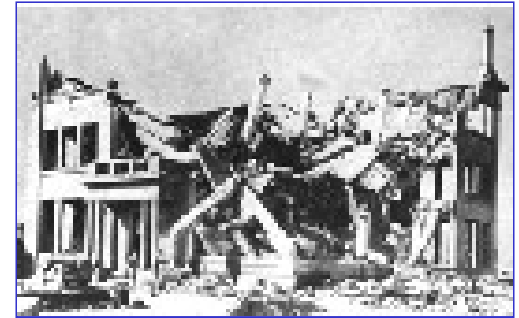
*Bridge in*



# Physical Effects of Nuclear Weapons

- Pressure Blast Wave
  - Buildings collapse
- Fallout
  - Radioactive fragments which stick to air particles or dirt that is sucked up mushroom stem
  - 80% falls back down in first day
  - 90% falls back down in first week
  - 10% lasts weeks → years

Hiroshima buildings



Nagasaki victim

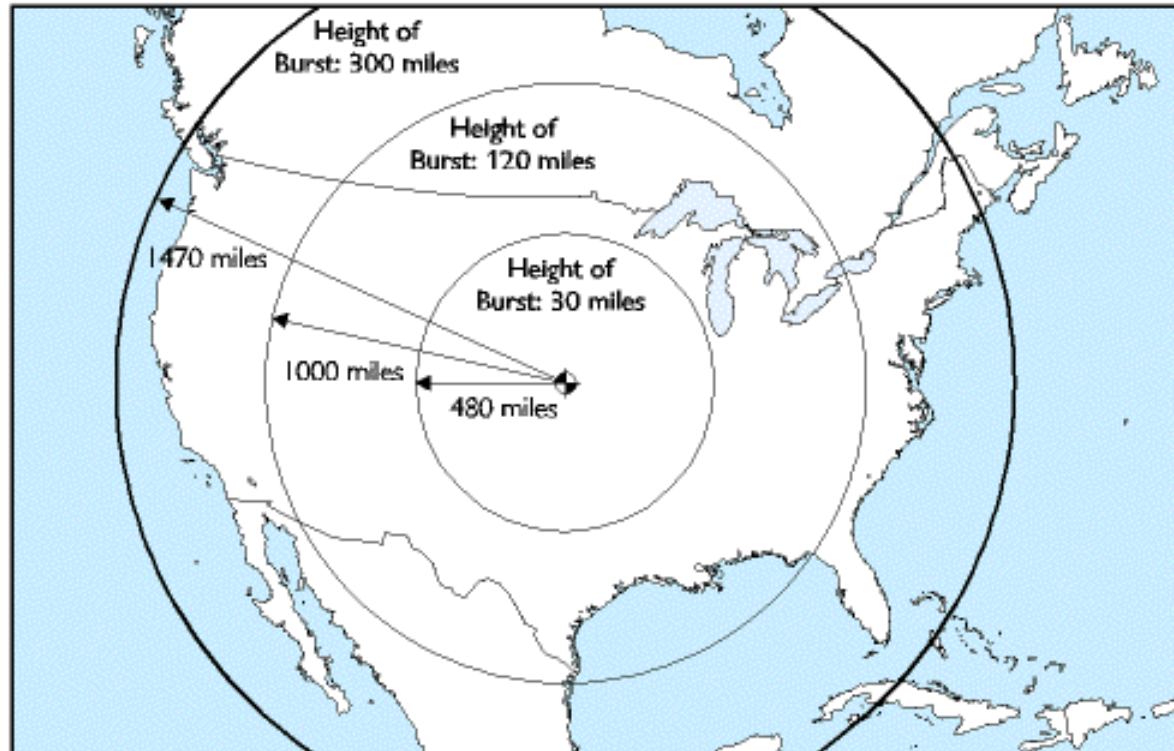


# Physical Effects of Nuclear Weapons

---

- Electromagnetic Pulse
  - Strongest for very high bursts
  - $\gamma$ -rays ionize air  $\rightarrow$  electrons
  - Electrons create large currents in air
  - Currents are picked up by power lines
  - Power surges shut down grid, destroy attached electrical devices
- 1.4 Mton airburst in 1962 knocked out lights in Hawaii over 1000 miles away

# Electromagnetic Pulse Effects



**Area Effected by an Electromagnetic Pulse, by Height of Burst**

Source: Gary Smith, "Electromagnetic Pulse Threats," testimony before the House National Security Committee, July 16, 1997.



# How big are the weapons?

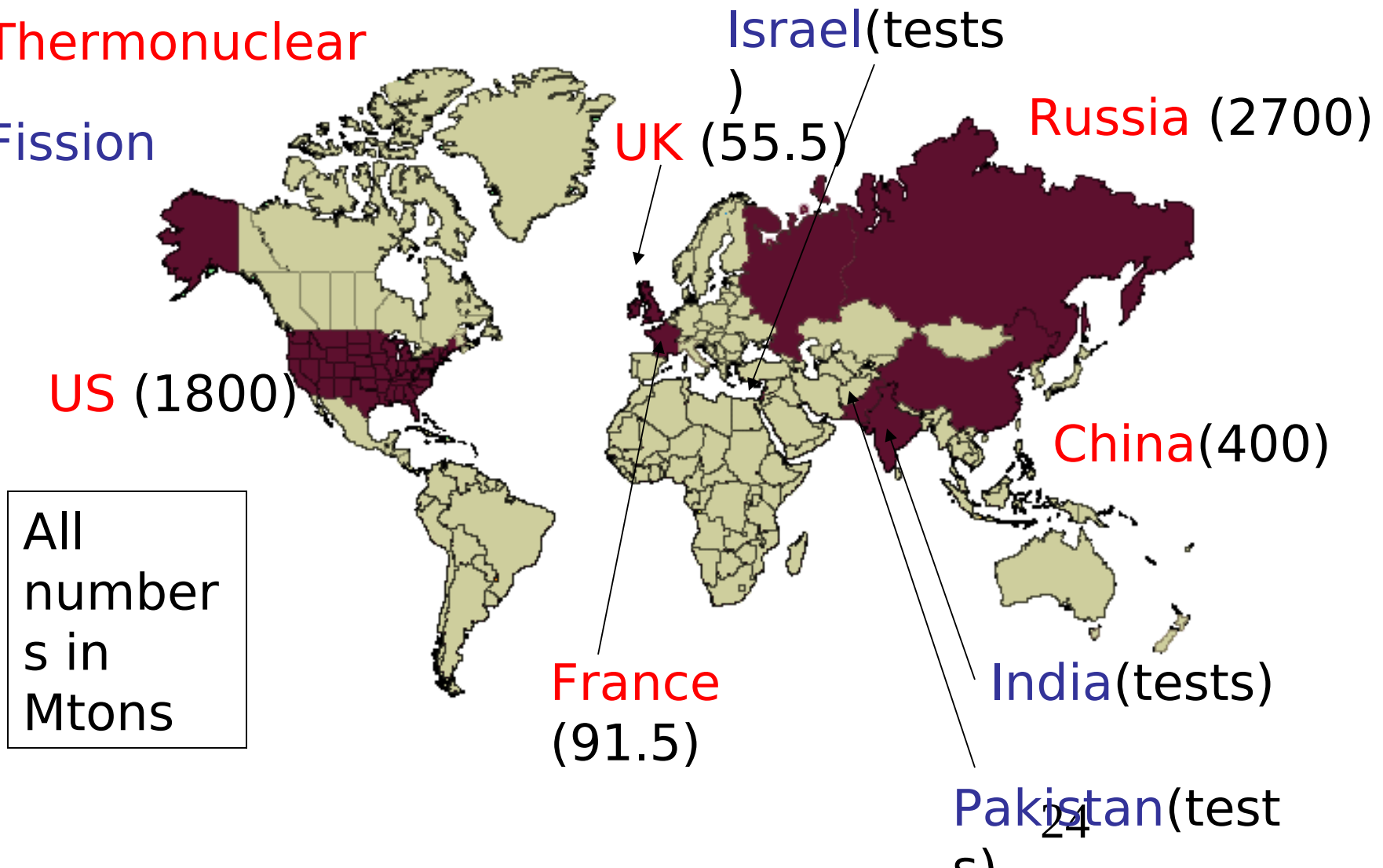
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- 1 kTon = 1000 tons = 2,000,000 pounds of TNT equivalent
- ~2 pounds of  $^{235}\text{U}$   $\rightarrow$  20 kTons
- Today's warhead is 100-200 kTons
- MX missiles have 10 warheads
- Largest underground burst: 4.5Mtons
- Largest airburst: 58 Mtons
- Over 1700 known tests since 1945

# Who has nuclear weapons?

Thermonuclear

Fission







# Nuclear Non-Proliferation Treaty

---

- Vertical – development of new weapons by the “Big 5”
- Horizontal – spread of weapons to other countries
- “Haves” agree not to spread weapons, materials or technology to “have-nots” – also, to stop vertical proliferation
- “Have-nots” agree not to try to acquire weapons from the “haves,” and will accept inspection and regulation of “peaceful” nuclear technology by IAEA- this stops horizontal proliferation



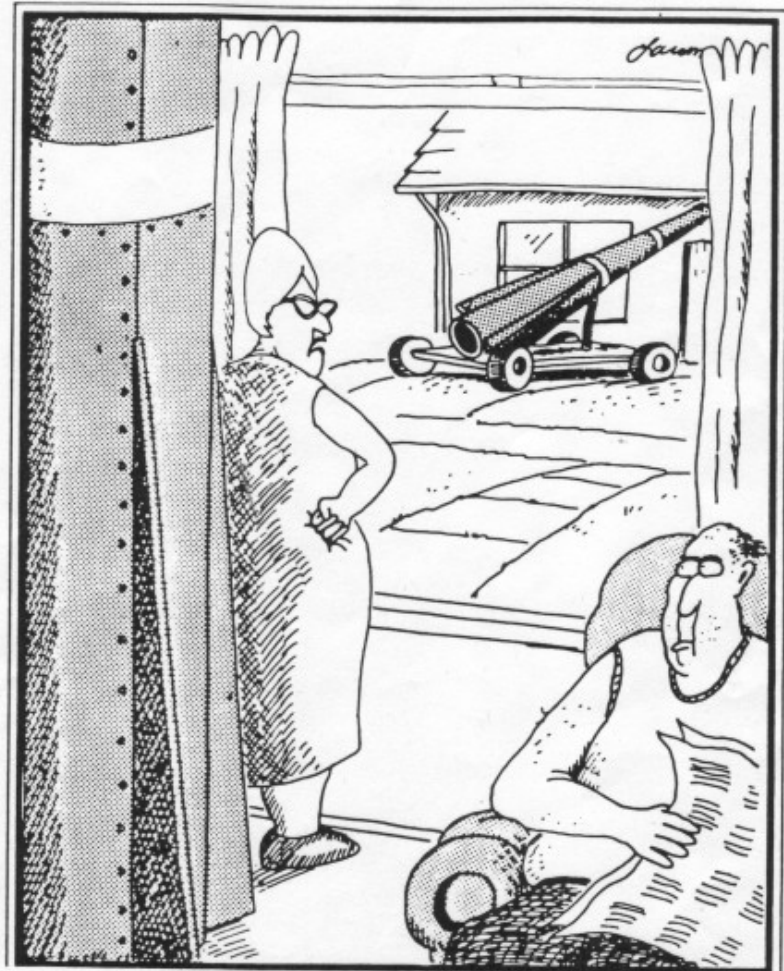
# Nuclear Non-Proliferation Treaty

---

- NPT indefinitely extended since May 1995, confirmed again in 2000
- Now signed by 187 countries
- In 1994, North Korea affirmed its signature, and agreed to allow IAEA inspections
- On 1/10/03, N. Korea withdrew from NPT, blaming US “axis of evil” designation, and US first strike intentions. N. Korea is now “in its final stages” to begin Pu production from 8000 spent fuel rods
- Cuba, Israel, India and Pakistan<sup>26</sup> still

# Who still wants nuclear weapons?

- North Korea (may have ~2 untested)
- Iraq
- Iran
- Libya
- Algeria
- Syria
- All subject to severe constraints



"Wouldn't you know it! Now the Hendersons have the bomb."



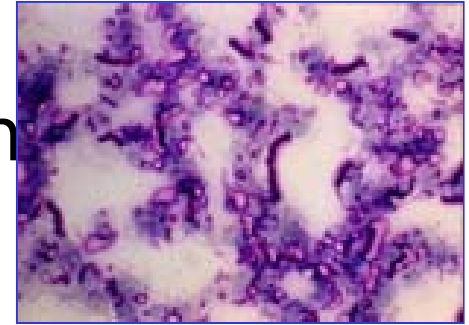
# No longer on the “watch” list

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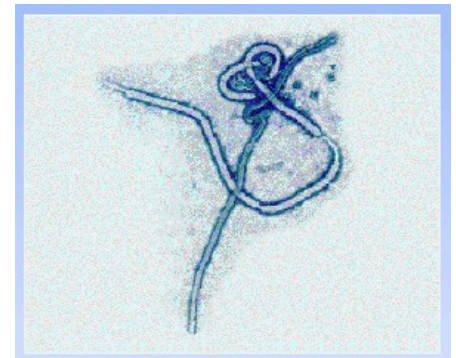
- S. Africa
  - Eliminated 6 weapons in 1991
  - Formal renunciation of use
- Have backed away or renounced use:
  - Argentina
  - Belarus
  - Brazil
  - Ukraine
  - Romania
  - Kazakhstan
  - Taiwan

# Types of Biological Weapons

- Bacteria
  - Cause disease by reproducing
  - Single cell organism
  - Typhus, anthrax
- Viruses
  - Multiply only inside host cells
  - Sub-microscopic organisms
  - Ebola, Chikungunya



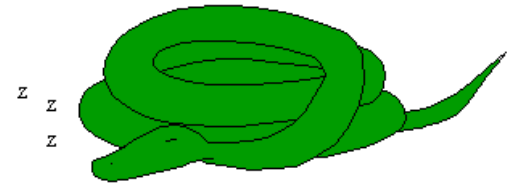
Anthrax



Ebola

# Types of Biological Weapons

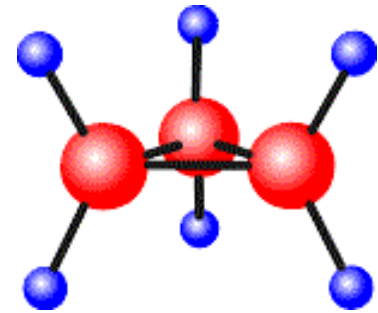
- Rickettsia
  - Larger than viruses
  - Smaller than bacteria
  - From fleas, lice and ticks
  - Q-fever



- Toxins
  - Poisons from living things
  - Snake venom
  - Botulinum most lethal known -  $<10^{-6}$  g!
  - But some beneficial uses

# Types of Chemical Weapons

- Nerve agents
  - Inhibit enzyme that transmits messages from nerve cells to muscles
  - Lethal dose <1-10 mg
- Mustard agents
  - Blistering of skin, lungs
  - Lethal dose >500 mg
- Hydrogen Cyanide (HCN) gas
  - Prevents blood from carrying oxygen
  - Lethal dose > 120 mg



# Types of Chemical Weapons

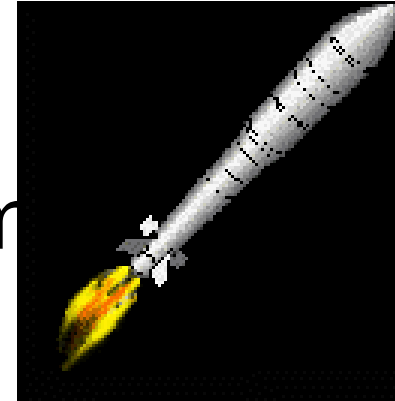
- Tear gases
  - Cause pain in eyes
  - Do not affect horses or dogs
  - Short term effects
- Arsines
  - Mixed with mustard gas
- Psychotomimetic agents
  - Cause temporary psychosis
  - LSD, atropine





# Why Use Chemical or Biological Weapons?

- Cheap
- Easy Technology
- Simple delivery system
  - Artillery shells
  - Rocket launchers
  - Aerosol sprays
- Research into biological weapons continues for treating diseases, developing vaccines, anti-toxins, etc.





# Chemical/Biological Weapons Problems

---

- Chemical weapons largely ineffective
- Biological weapons can't be stored
- Protection against both is relatively easy on the battlefield
- Both are really “weapons of terror” against citizens or “weapons of intimidation” against soldiers rather than “weapons of mass destruction”

<http://www.ceip.org/files/publications/Harigelreport.asp?p=>



# Biological/Chemical Terrorism

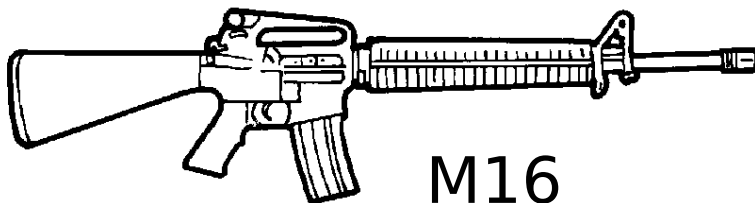
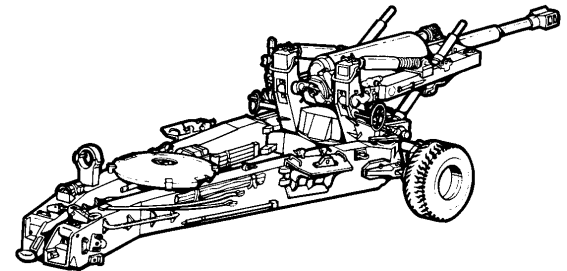
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- Since 1900, only ~75 terrorist attacks out of more than 40,000 used Chemical or Biological weapons
- Only 125 people died & ~4000 got sick
- ~20 people died in Japan in the well-publicized nerve gas attacks. This sect also tried to make biological weapons but failed, after spending \$1 billion

# Major killers in Wars

- Assault Rifles (64%)
- Handguns (10%)
- Landmines (10%)
- Hand grenades, Artillery, Mortars (16%)
- Since 1900: 34 million soldiers and 80 million civilians killed in wars

Howitzer



M16

killed 200,000

36

LOL!.

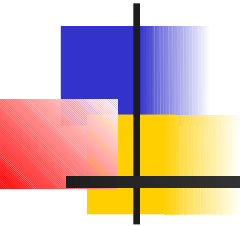


# Additional Resources

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- Carnegie Endowment for International Peace <http://www.ceip.org/>
- Biological and Toxin Weapons Convention  
<http://projects.sipri.se/cbw/docs/bw-btwc-mainpage.html>
- US position on BTWC (2001)  
<http://www.fas.org/bwc/news/USPublicPositionsOnProtocol.htm>
- CDC Vector Borne Diseases <http://www.cdc.gov/ncidod/dvbid/index.htm>
- Chemical Weapons Convention  
<http://www.opcw.nl/guide.htm>
- Federation of American Scientists  
<http://www.fas.org>

# Backup Slides





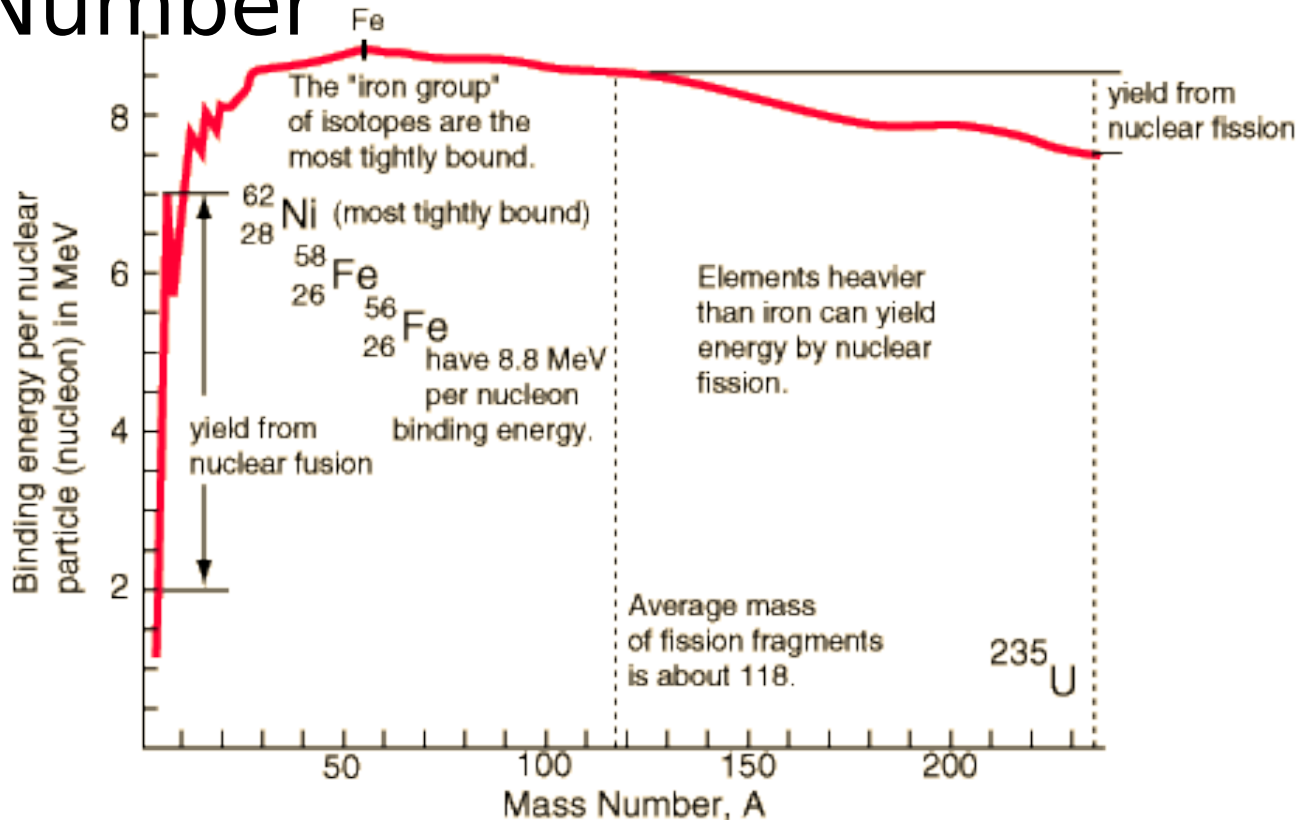
# Radioactivity

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- Primordial –
  - formed before Earth's creation
  - long half lives –  $^{238}\text{U}$  is  $4.5 \times 10^9$  y
- Cosmogenic – formed as a result of cosmic ray interactions
  - Examples:  $^{14}\text{C}$  (5730 y) and  $^3\text{H}$  (12.3 y)
- Man-made – typically in power plants or accelerators
  - Examples:  $^{239}\text{Pu}$  ( $2.4 \times 10^4$  y) and  $^{131}\text{I}$  (8 d) and also  $^3\text{H}$  (12.3 y)

# Fission or Fusion?

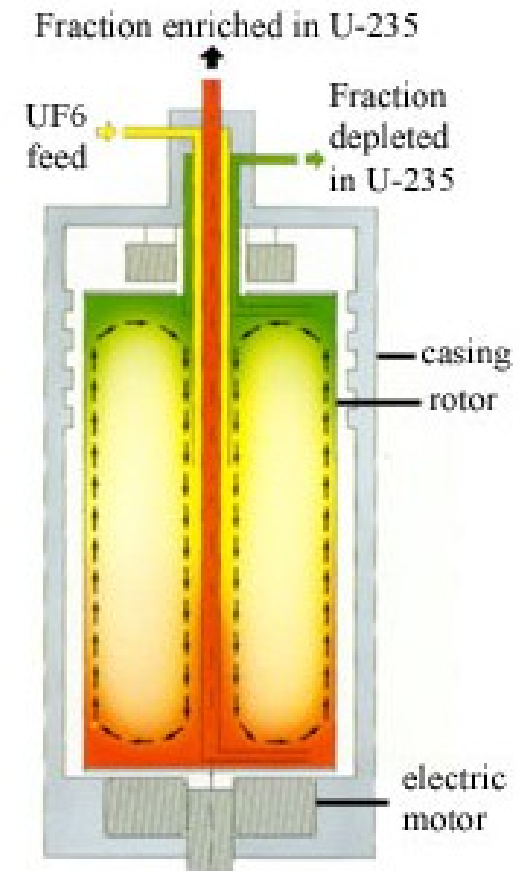
- Nuclear binding energy vs. Mass Number





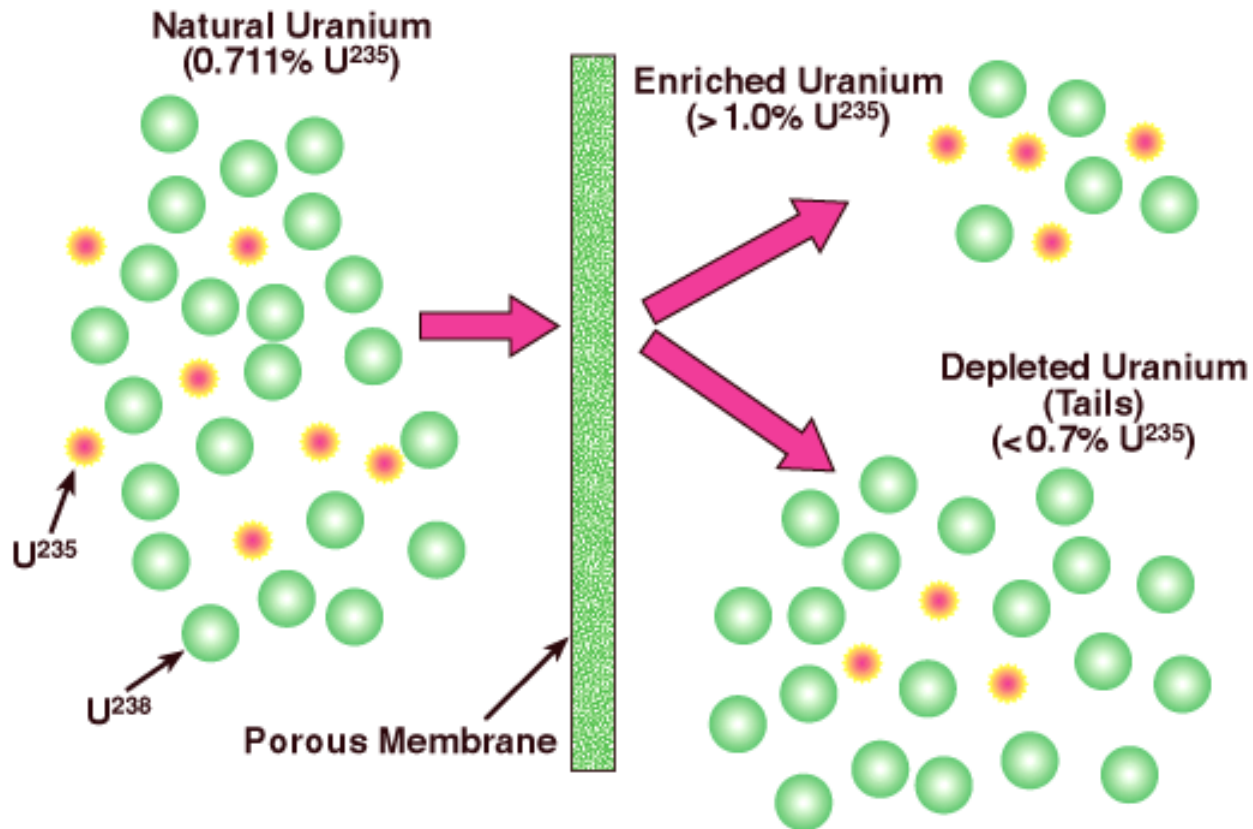
# Gas centrifuge

- Uses successive stages to isolate isotopes by weight – lighter mixture is sent on to the next stage, heavier mixture is sent back to the previous stage
- Requires thousands of successive stages to create weapons grade  $^{235}\text{U}$



# Gaseous diffusion

- Thousands of diffusion filters needed





# Electromagnetic isotope separation

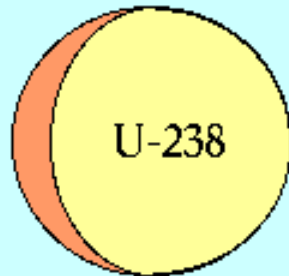
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- Iraq's extensive EMIS program was unknown until its discovery after the Gulf War by UN inspectors
- Several unreported and disguised facilities were found, capable of creating quantities of weapons grade U
- Huge power requirements for EMIS have precluded use in USA – and were thought to preclude use by others

# Reprocessing Plutonium

- $^{239}\text{Pu}$  is a waste product in nuclear power reactors, that is intermixed with other spent reactor fuels
- In order to become weapons grade, it must be separated out

an atom of  
uranium-238





# Reprocessing Plutonium

---

- Spent reactor fuel is chopped up, by remote control, behind heavy lead shielding.
- Chopped-up pieces are then dissolved in boiling nitric acid, releasing radioactive gases in the process.
- **Pu** is chemically separated from the acid solution, leaving large quantities of high-level radioactive liquid waste and sludge behind.
- After it has cooled down for several years, the liquid waste is solidified for ultimate disposal, while the separated **Pu** is fed into a fast breeder reactor.

# Depleted Uranium

- Depleted Uranium can be put into fuel cells in a nuclear reactor and used to produce weapons grade  $^{239}\text{Pu}$
- This is why Israel bombed the French-built OSIRAK nuclear reactor in Iraq in 1981

Targets made of depleted U which will be bombarded by neutrons to make Pu





# $^{238}\text{U}$ and the first Gulf War

---

- More than 640,000 pounds of contaminated equipment was left on the battlefields
- US-coalition forces used  $^{238}\text{U}$  in
  - Large caliber shells fired from tanks
  - Small caliber shells fired from aircraft
  - Sniper bullets
  - Tank armor in 1/3 (2000+) of tanks



# Problems from $^{238}\text{U}$ dust

---

- After burning,  $^{238}\text{U}$  creates fine radioactive and toxic vapor and dust
- More than 50% of these particles are just the right size to be inhaled, where they lodge in the lungs and remain for years
- It is easily carried by the wind, and stays in the air for hours after impact
- It also easily dissolves in water
- Ground contamination allows resuspension into the air and eventual water contamination
- No ground cleanup has occurred in Iraq





# Problems from $^{238}\text{U}$ fragments

---

- Unburned,  $^{238}\text{U}$  remains radioactive – is classified as a “low-level” waste, subject to proper disposal and controls
- Fragments corrode with time, creating more dust and contaminated soil
- High levels of radioactivity have been measured from fragments found after the first Gulf War in Iraq, Kuwait and Saudi Arabia



# Health problems

---

- Many US service people were exposed to depleted Uranium during the first Gulf War
- Local populations in Iraq, Kuwait and Saudi Arabia were also exposed
- Particles can be found in the brain, kidney, bone, reproductive organs, muscle and spleen
- Causing kidney damage, cancers of the lung and bone, non-malignant respiratory disease, skin disorders, neurocognitive disorders, chromosomal damage, and birth defects

# Weapons design considerations

- Fission bombs produce 90% of their output as kinetic energy of fission fragments → fast heat production
- Fusion bombs produce 80% of their output as fast neutrons with  $\langle KE \rangle = 14 \text{ MeV}$
- Fast neutrons can produce a fission event of  $KE=180 \text{ MeV}$ , boosting the bomb's "efficiency"
- Most modern weapons therefore consist of at least two stages
  - Primary – fission bomb, often boosted by fusion core produced neutrons
  - Secondary – fusion bomb, with fission "sparkplug" to produce heat that triggers fusion, and extra layers of external fissionable material to boost yield



# Other bomb designs

---

- Neutron bombs
  - Also known as “enhanced radiation” weapons
  - Designed to lower blast wave, thus sparing buildings, but killing people
  - However buildings do become radioactive
- “Clean” bombs
  - Designed with more fusion, and less fission, → more neutrons and less fallout
  - Needed three stages for sufficient



# Nuclear Weapons Free Zones

---

- Latin America and the Caribbean (the 1967 Treaty of Tlatelolco)
- South Pacific (the 1985 Treaty of Rarotonga)
- New treaties underway for
  - Southeast Asia (started December 15, 1995)
  - Africa (started April 11, 1996).



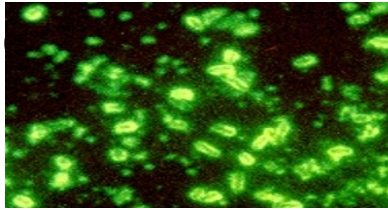
# Comprehensive Test Ban Treaty

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- Prohibits all nuclear testing
- Opened for signatures in 1996
- Prevents “Big 5” from developing or testing weapons of new design
- Approved by Russian Duma in 4/00
- Rejected by US Senate in 10/99
- Signed by 155 states, ratified by 55
- Needs ratification by 16

# Biological Weapons History

- 1300s: Plague spread by infected



Plague bacteria

- 1760s: Native Americans infected by small pox from British blankets
- WWII:
  - Japanese use POWs for anthrax, cholera “research”
  - US develops anthrax bomb, obtains Japanese research results



# Biological Weapons History

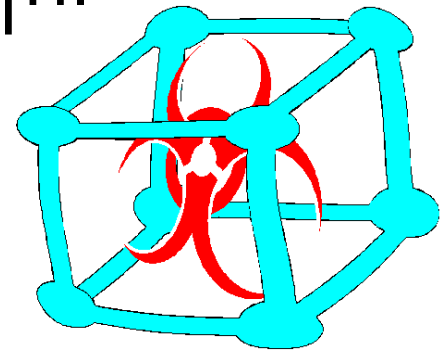
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- 1950: US exposes public to “harmless” bacteria (SF) and germs (NYC, DC)
- 1969: Nixon renounced US use, stockpiles and destroys supplies
- 1972: Biological and Toxin Weapons Convention signed and ratified
- 1975: BTWC in force
- 1970s → present
  - US and biotech research continues...



# Biological and Toxin Weapons Convention

- Signatories pledge to
  - Not develop, produce, stockpile, or acquire biological agents or toxins "of types and in quantities that have no justification for prophylactic, protective, and other peaceful purposes,"
  - Not develop weapons and means of delivery.
  - Destroy stockpiles within 9 months of the conventions entry into force.





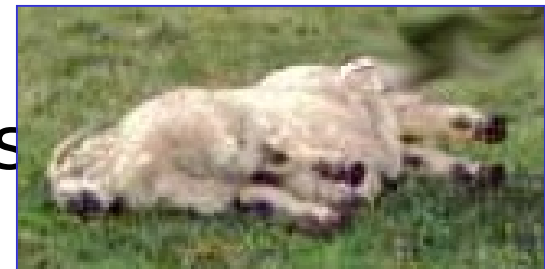
## BTWC Update: Fall 2003

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- Discussions stalemated to add verification provisions to BTWC
- In July 2001, USA officially rejected these provisions, negotiated under Clinton Administration
- Ongoing research projects by USA and others are arguably in violation of the new, strengthened treaty – we do not want these research facilities inspected

# Chemical Weapons History

- WWI: Mustard, Phosgene and Chlorine gases used on battlefields
- 1925 Geneva accord prohibits use in battle but development continues
- WWII: Nerve gases made, not used
  - Tabun, Sarin, Soman, VX
- 1968 Open air tests kill sheep in Utah
  - US bans air tests, stops unitary weapons
  - Not a weapons sheep



# Chemical Weapons History

- 1980s:
  - Iraq uses mustard gas vs. Iran, and possibly HCN vs. Kurds, kills > 5000
  - US proposes complete CW ban, but begins funding binary weapons
  - USSR halts production, starts destroying stockpiles
- 1993: Chemical Weapons Convention opens for signatures
- 2000: 172 signatories, 139 ratifiers



# Chemical Weapons Convention

- First disarmament treaty to include a time frame for the elimination of an entire class of weapons of mass destruction
- First multilateral arms control treaty to incorporate an intrusive verification regime
- In force since 4/29/97
- US must eliminate by 200

