NTS

nevada test site

Agriculture
- → 150 km away from Las Vegas
- → Some cow grazing

Winds
- → East/North
  - ↳ Utah, Nevada, Wyoming
- → man-made winds
  - → airplanes

Ground water
- → Lake Meade, Colorado
  - ↳ in path of winds
- → underground aquifers

Semipalatin's IK

Agriculture
- ↳ 9% land arable
- ↳ 5% GDP
- ↳ none near site
- ↳ uninhabitable

Wind Currents
- ↳ goes SW, into mountain
- ↳ Uz, Tajik, Kyrg

Ground Water
- ↳ mostly use surface water
- ↳ Irtish
- ↳ 85% rainfall in water
  - → fallout contained

Population
- ↳ 1 mill. Almaty

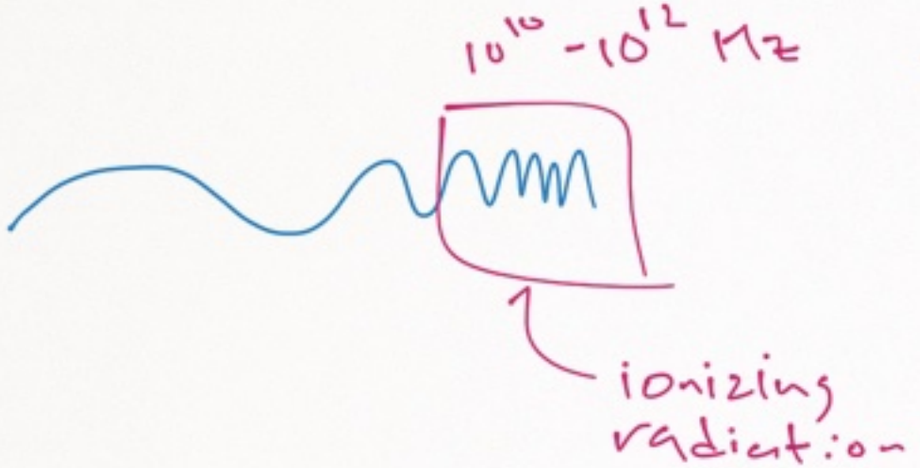
Nuclear Weapon on Battlefield

→ "Tactical Nuclear Weapon"

→ Tested proximity soldiers could be from explosion.

At most, 7% of US citizens were exposed to fallout.

Radiation & The Human Body #1



- alpha particles
- beta particles
- gamma-rays *
- x-rays *
- cosmic rays
- neutrons *

ionization

→ charging otherwise neutral atom

→ knocking out e^- to create cation

→ giving e^- to create anion

Ionized molecules are unstable and quickly undergo chemical change.

↳ ∴ cell damage ≠ tissue damage

because DNA sensitive to ionizing radiation

- breaking bonds in DNA (ex. by ionizing H_2O)

can kill cell, or mutate cell that doesn't but replicates itself

can also consume contaminated products

QUIZ ON SECTIONS 8, 9, 11, 12, 15, EXPONENTIAL GROWTH

SESSION 8 - FISSION BOMB DESIGN

FISSILE MATERIAL - URANIUM - 235

"highly enriched" → 90% U-235 (weapons grade)

"low-enriched" → 3-4% U-235 (reactor grade)

natural uranium → 0.7% U-235

(rest is U-238)

FISSILE MATERIAL - PLUTONIUM - 239

MIN. MASS REQUIRED TO SUSTAIN NUCLEAR CHAIN REACTION

↳ CRITICAL MASS

DEPENDS ON
- → DENSITY
- → SHAPE
- → TYPE OF MATERIAL

Also the effectiveness of surrounding material to reflect neutrons back into fission mass

↳ TAMPER

CRITICAL MASSES

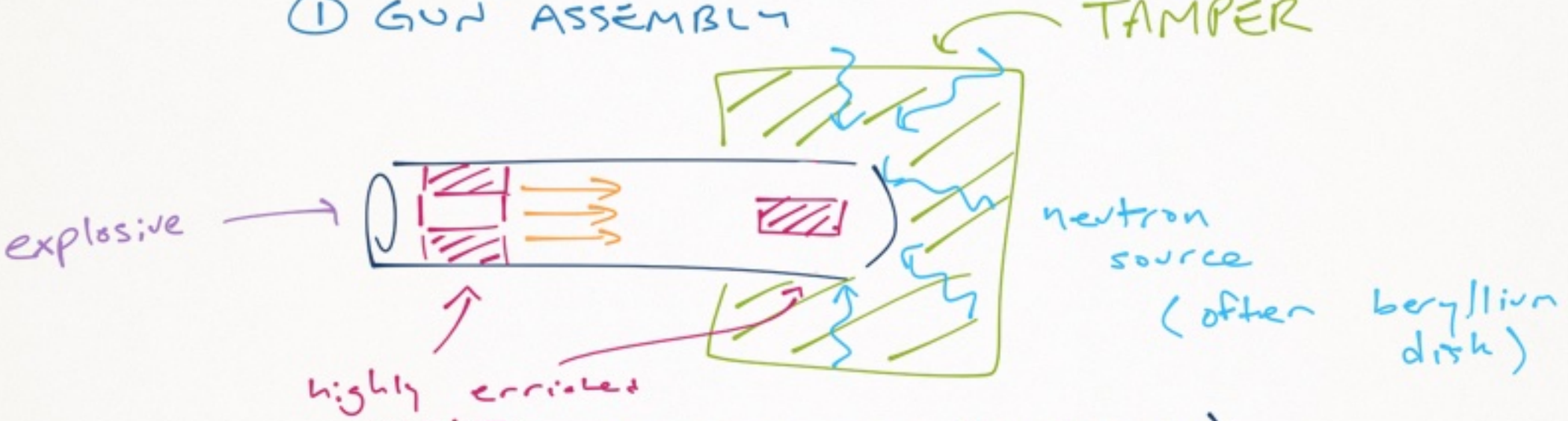
	U-235	P-239
BARE SPHERE	56kg	11kg
THICK TAMPER	15kg	5kg

} rare & expensive material determines if & how many bombs a country can develop

fission weapons work by creating a chain reaction critical mass in U-235 or P-239

↳ METHODS

① GUN ASSEMBLY



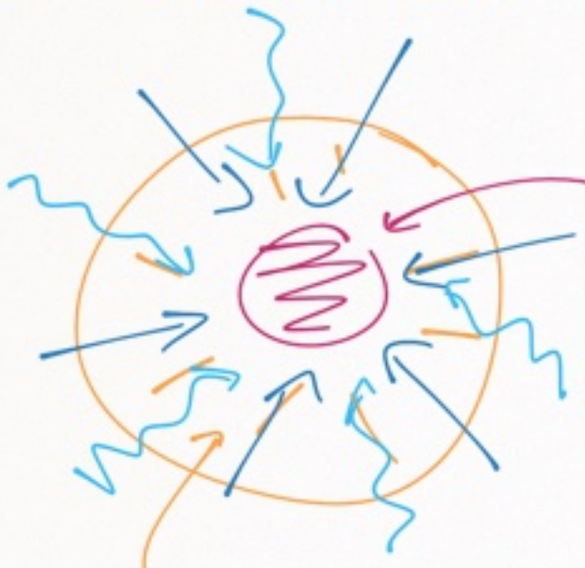
LITTLE BOY (HIROSHIMA) WAS GUN-TYPE → 1.4% efficient → 64kg U-235 80% enrichment

GUN-TYPE IS SIMPLE & RELIABLE, BUT NOT REALLY USED ANYMORE BECAUSE INEFFICIENT

(wasn't even tested, so reliable)

SOUTH AFRICA MADE 6 OF THESE.

(2) IMPLOSION DESIGN



enriched fissile material

explosive material } compresses fissile material into crit. mass → then → neutron source (beryllium disk) sends stream of neutrons

→ nagasaki

FAT MAN WAS IMPLOSION, → 17% efficient

USED 6.2kg → 21kT yield

more difficult to build but more efficient (less material, more yield)

Iraq attempted to build implosion bomb w/ U-235

N. Korea used P-239 to build implosion

(3) BOOSTED FISSION WEAPONS

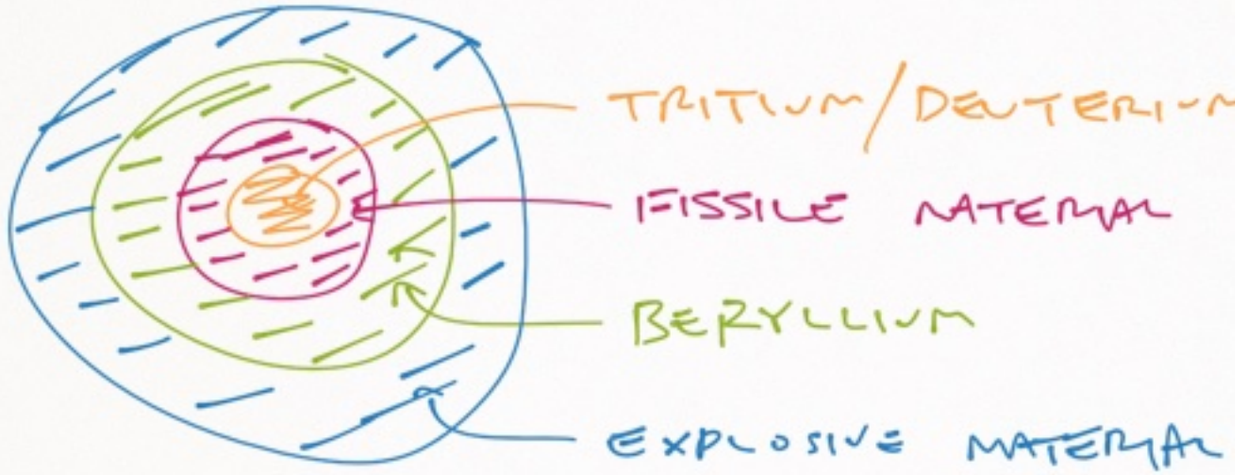
↳ almost all of bombs by major nuclear powers

(more efficient, smaller & lighter)

USES MATERIAL THAT UNDERGOES FUSION PLACED AT CORE

↳ TRITIUM OR DEUTERIUM

↳ fusion creates more neutrons ∴ more chain reaction



SESSION 9 - FUSION

fusion most prevalent weapons in service by main 5 nuclear powers
- → USA
- → Russia
- → UK
- → France
- → China

Israel is probably capable of making these

India might have a fusion type, but not certain

FUSION HAS MUCH HIGHER YIELD THAN FISSION

Fusion: nuclei of 2 atoms combine to form single heavier atom
- → release energy in process

unlike fission, fusion occurs in nature in stars

(ex. $H + H \rightarrow He$)

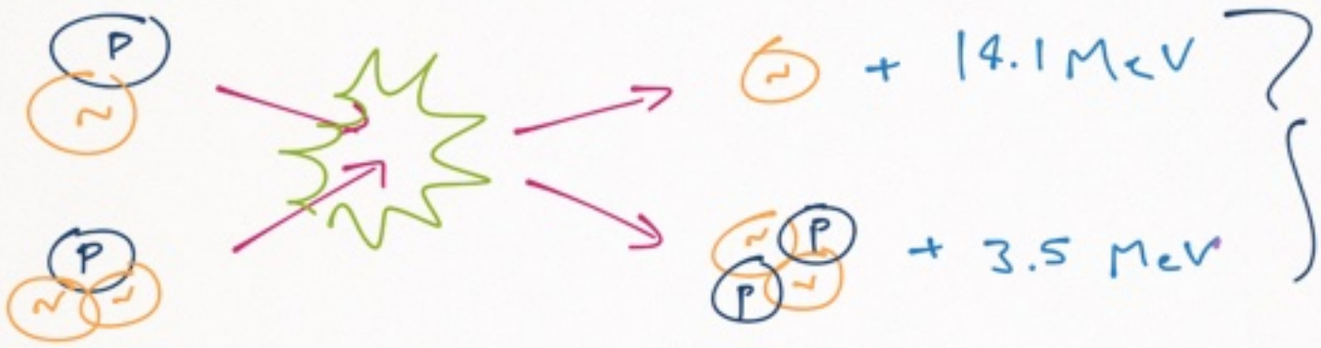
Easiest fusion is H isotopes Deuterium + Tritium
- → varying # of neutrons

mass # = protons + neutrons

$^{1}_{1}H$	protium	p	e^-	∅ neutrons
$^{2}_{1}H$	deuterium	p n	e^-	1 neutron
$^{3}_{1}H$	tritium	p n n	e^-	2 neutrons

Tritium + deutrium $\longrightarrow$ $(^1n + 14.1\ MeV) + (^4He + 3.5\ MeV)$

^3H ^2H



17.6 MeV

↳ freeing neutrons releases bonding energy

THIS IS THE PROCESS IN NUCLEAR FUSION WEAPONS

energy density of fusion $\gg$ nuclear fission

MOTIVE FOR DEVELOPING FUSION (HYDROGEN) BOMB

↳ fear of soviets getting it first, restore US superiority

MOTIVE FOR DEVELOPING FISSION (ATOMIC) BOMB

↳ fear of Nazis getting it first

Fear of Communism spreading

First soviet test: RDS-1 "first lightening" - 29 August 1949

EDWARD TELLER
→ "father of fusion bomb"
→ leading scientific proponent of development
→ said scientist should do what could be done, and have no political authority

J. ROBERT OPPENHEIMER
→ opposed development of fusion bomb
→ "weapon of genocide"
→ fusion weapons are powerful enough to deter & retaliate

ENRICO FERMI
→ "only practical effect of fusion bomb is genocide"
→ "evil thing"
→ but should be developed to be catalyst of arms control

JAN 1950 → PRES. TRUMAN APPROVED DEVELOPMENT OF HYDROGEN BOMB

FIRST FUSION BOMB TEST: IVY MIKE, NOV. 1, 1952
→ Marshall Islands (Enewetak Atoll)
→ 10-12 MT
→ mushroom cloud 40km high, 160km wide

Subsequent proliferation of fusion bombs

USA → 1952
USSR → 1953
UK → 1957
China → 1967
France → 1968

} USA only had monopoly for 1 year

India → 1998 unconfirmed
Israel → unknown

FUSION WEAPONS NOW PRIMARY TYPE OF NUCLEAR BOMB FOR MAJOR NUCLEAR POWERS

SESSION 11 — NUCLEAR TESTING

Note: different test count methods (explosions vs. attempts, etc.)
So we'll be using CTBTO method/data

1945-1996 : ~2050 nuclear explosions around the world
1996-present : 7 explosions
ranging over ~60 different test sites

1945-1996 - 500/25% atmospheric tests
- avg. 1 test every 9 days for 50 years

FROM 1955-1989 - 55 tests a year
PEAK YEAR, 1962, - 178 tests
→ 96 by USA
→ 79 by USSR

TSAR BOMBA → lugest bomb ever detonated, OCT 1961
→ 50-58 MT
→ island in USSR arctic, Novaya Zemlaya

country	first test	last test	# tests	
US	1945	1992	1032	
USSR	1949	1990	715	
Uk	1952	1991	45	
France	1960	1996	210	
China	1964	1996	45	
India	1974	1998	3	← spurned Pakistani tests
Pakistan	1998	1998	2	
N. Korea	2006	2013	3	
Israel	1979 (!)	1979(?)	1?	} suspected
S. Africa	1979(?)	1979(?)	1?	} suspected

TESTING LOCATIONS

→ Atmospheric test → exploded from top of tower – Trinity
→ underground → dropped from plan – Tsar Bomba
→ Shoot into high atmosphere
→ underwater

→ 1963
after partial test ban treaty ∴ virtually all underground tests
(except for France & China who didn't enter treaty right away)

Vela Incident

↑ detected by American satellite "Vela Hotel"

→ two flashes of light on Prince Edward Island of coast of Antarctica

→ probably joint Israeli ≠ South African nuclear test

MORE ABOUT FUSION BOMB DESIGN

First design was Teller - Ulam design

"the super"

Edward Teller ≠ Stanislaw Ulam

→ "the calculations required the largest math effort ever undertaken"

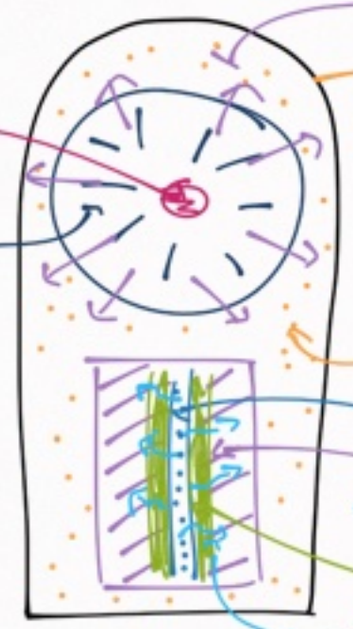
→ Ulam & another scientist did it mostly by hand.

Main feature is separation of bomb into stages

PRIMARY STAGE
→ fission explosion is trigger
→ energy released triggers fusion reaction

SECONDARY STAGE
→ fusion reaction

1. FISSION BOMB DETONATES
2. X-RAYS GO THROUGH BOMB CASING
3. POLYSTYRENE TURNS INTO PLASMA
4. LITHIUM DEUTERIDE IS SQUEEZED
5. PLUTONIUM ROD UNDERGOES FISSION
6. NEUTRONS GO INTO DEUTERIDE & FUSE INTO TRITIUM
7. THEN FISSION HAPPENS IN U-238 TAMPER



FISSION → FUSION → FISSION

ALL HAPPENS IN ABOUT 6 BILLIONTHS OF A SECOND.

it is a fission bomb

Could theoretically keep adding stages of the secondary
→ "no theoretical limit to Fusion bomb"
→ Tsar Bomba was probably 3-stage

SUMMARY:

1. FISSION EXPLOSION
2. XRAYS FROM FISSION
3. IRRADIATES CASING INTO PLASMA
4. LITHIUM-DEUTERIDE IS COMPRESSED
5. PLUTONIUM UNDERGOES FISSION, RELEASING NEUTRONS
6. FUSION OF NEUTRONS + DEUTERIUM INTO TRITIUM

IVY MIKE → 10.4MT
→ 4.8km diameter fireball

FISSION BOMBS RESTRICTED TO 10-100kT, FUSION BOMBS 10MT RANGE

SESSION 18 - DELIVERY SYSTEMS

Nuclear weapons combination of 1. nuclear warhead
2. delivery system

Politics of nuclear weapons very concerned w/ delivery systems
→ deployment
→ capability of delivery system dictates how a nuclear war would
1. start and 2. develop
→ more arms control negotiations have been about delivery systems than about the actual warheads
→ many delivery systems are "dual use", could carry conventional payloads OR nuclear payloads

1. AIRCRAFT/BOMBERS

→ original delivery system & just extension of strategic bombing
→ readily available
→ less significant now (slow, expensive, can be defended against)
(except stealth bombers)

B-29 superfortress (used for Fat Man & Little Boy)

B-59 Stratofortress
→ 1955 - present
→ 32 000 kg payload
→ easily configurable for different weapons

B2 Spirit → stealthy/evade radar
→ capabilities of this aircraft exclusive to USA

Mirage 2000 D/N (French)
→ nuclear capable
→ not conventional bomber, two-engined jet

MINITURIZING NUCLEAR WARHEADS
→ lead to thinking about tactical/battlefield nuclear weapons
→ W54 warhead (implosion, diameter 27cm, length 40cm, 23 kg)
↳ lightest nuclear weapon developed (1960-1971), 10-1kT

2. ARTILLERY
→ not tremendously significant
→ no arsenals in world that deploy nuclear artillery
→ in early cold war, idea was to use battlefield nukes
→ extension of conventional tactical mentality

M65 ATOMIC CANNON (ATOMIC ANNIE)
→ 1953, fired 15kt nuclear projectile
→ 32km range (only tested once)

M28/29 DAVEY CROCKET
→ tactical rocket projectile (mortar-like thing)
→ 2-4km range
→ mobile, deployed on jeeps & such

9M21 MISSILE (FROG-7)
→ 1964, Soviet Truck w/ a launcher on it
→ 70km range
→ no guidance system

SPECIAL ATOMIC DEMOLITION MUNITION
→ backpack nuke for W54, left behind enemy lines etc.

SESSION 21 – DELIVERY SYSTEMS III

BALLISTIC MISSILES
→ RANGE (LONG FREE FLIGHT/NO FUEL CONSUMPTION PHASE)
→ VERY FAST
↳ COULD REACH USA–USSR IN 30-35 min
→ LARGE PAYLOAD

ICBM (INTERCONTINENTAL BALLISTIC MISSILE)

STARTED W/ NAZI V2 MISSILES
↳ WERNER VON BRAUN "FATHER OF ROCKET SCIENCE"
→ BECAME NASA MARSHALL SPACE FLIGHT CHIEF DESIGNER

SPUTNICK (1957)
↳ FIRST SATELITTE IN ORBIT
↳ HAD MISSILE

LGM-30 MINUTEMAN III
→ 1962
→ 13000 km
→ 24000 $\frac{km}{hr}$ = mach 23

450 IN SERVICE STILL

THE MIRV
↳ MULTIPLE INDEPENDENTLY TARGETABLE REENTRY VEHICLE
→ 3 WARHEADS ON ONE MISSILE DETATCHING OVER LARGE AREA

AGNI III (INDIA)
→ 2013
→ 3000-5000km (NOT ICBM)
→ 15-150KT

DELIVERY SYSTEMS PART 4

SUBMARINE LAUNCHED BALLISTIC MISSILES
→ HARD TO DETECT/ATTACK
→ CAN ASSURE RETALIATORY CAPABILITY EVEN IF LAND BASED ARSENAL DESTROYED

OHIO CLASS SLBM
→ 12 IN SERVICE IN USA

CRUISE MISSILES
→ DUAL USE (used in multiple wars)
→ DO NOT FLY ON BALLISTIC TRAJECTORY
→ FLY LIKE AIRCRAFT & ARE JET POWERED
→ NO PILOT, LOW ALTITUDE, DIFFICULT TO DETECT, ACCURATE

TOMAHAWK CRUISE MISILE
SELF GUIDED
CAN HIT MOVING TARGET
VERSITILE

SESSION 23 - DETERRENCE

ORIGINS

→ STRATEGIC AIR COMMAND (1946)
→ MASSIVE RETALIATION (SAC)
  → DON'T NEED TO RESPOND CONVENTIONALLY
→ NUCLEAR BATTLEFIELD
  → SMALLER, DISPERSED MILITARY UNITS

CURTIS LEMAY
  → BEHIND JAPANESE STRATEGIC BOMBARDMENT
  → COMMANDER OF SAC

GEN. THOMAS POWER
  → "IF TWO AMERICANS & ONE RUSSIAN LEFT ALIVE, WE WIN."

In 1960s thinking shifted
  → arsenals grew
  → higher payloads on better delivery systems
  → war plans became irrelevant & defence looked superfluous

PEOPLE DECIDED NO ONE COULD WIN A NUCLEAR WAR & THEY WERE POLITICAL TOOLS NOT MILITARY ONES

DETERRANCE THEORY

→ GAME THEORY
→ RATIONALITY
→ HEAVILY CRITICIZED TOO

discouraging action by confronting opponent w/ consequences

BY DENIAL
→ deters by convincing opponent they can't achieve goal

BY PUNISHMENT
→ deters by threat of unacceptable damage in return

DIRECT DETERRENCE
→ own country
EXTENDED DETERRENCE
→ for allies, USA promised save for east. european countries

DETERRENCE EASY TO ACHIEVE?

YES BECAUSE EASY TO MAKE NUCLEAR WAR HAVE NO ADVANTAGES (MINIMUM DET.)

BRITISH DETERRENCE → CAPABLE OF MINIMUM DETERRENCE

NO BECAUSE YOU NEED LOTS OF WEAPONS TO GIVE CERTAINTY (MAX. DET.)

SUCCESFUL DETTERENCE NEEDS HUGE RETALIATORY CAPABILITY UNDER ALL CIRCUMSTANCES.

SECURITY DILEMMA ≠ ARMS RACES

$$n(t) = n_0 e^{\frac{-t \ln(2)}{t_{1/2}}} = n_0 2^{\frac{-t}{t_{1/2}}}$$

HANDFORD, WASHINGTON

↳ where they processed plutonium

↳ for implosion design

↳ on Colorbia river → used to cool reactors, then dumped contaminated water back → impacted salmon spawning area

↳ radioactive isotopes released into air

↳ farmland, increase in thyroid cancer among farmers

DOSAGE

$E \equiv J$

$m \equiv kg$

$\text{Dosage} \equiv \frac{J}{kg}$

how to relate radiation to a specific value of energy associated w/ it, and which energy is what.

not all energy is absorbed

not all energy effects everything in the same way

UNIT, GRAY (Gy)

↑ physical energy absorption unit

Absorbed Dose

Different radiation effects have different biological effects

UNIT, SIEVERT (Sv) → Equivalent ≠ Effective Dose

UNIT CONVERSION NONSENSE

$$\mu Ci \cdot X = MBq$$

$$X = \frac{MBq}{\mu Ci} = \frac{10^6}{10^{-6}} \frac{Bq}{Ci} = 10^{6-(-6)} \; 3.7 \cdot 10^{10} = 3.7 \cdot 10^{22} \frac{Bq}{Ci}$$

HALF-LIFE

$$n = \frac{t}{T_{1/2}} \qquad T_{1/2} = \frac{0.693}{k}$$

$$A(t) = A_0\left(\frac{1}{2}\right)^{\#\text{ of half lives}} = A_0\, 2^{-t/T_{1/2}}$$

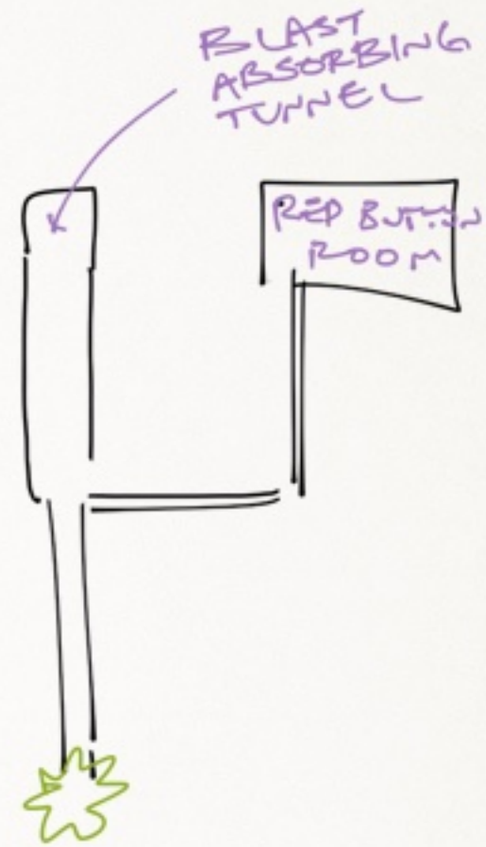
↑ QUANTITY OF RADIOISOTOPE AT $t = 0$

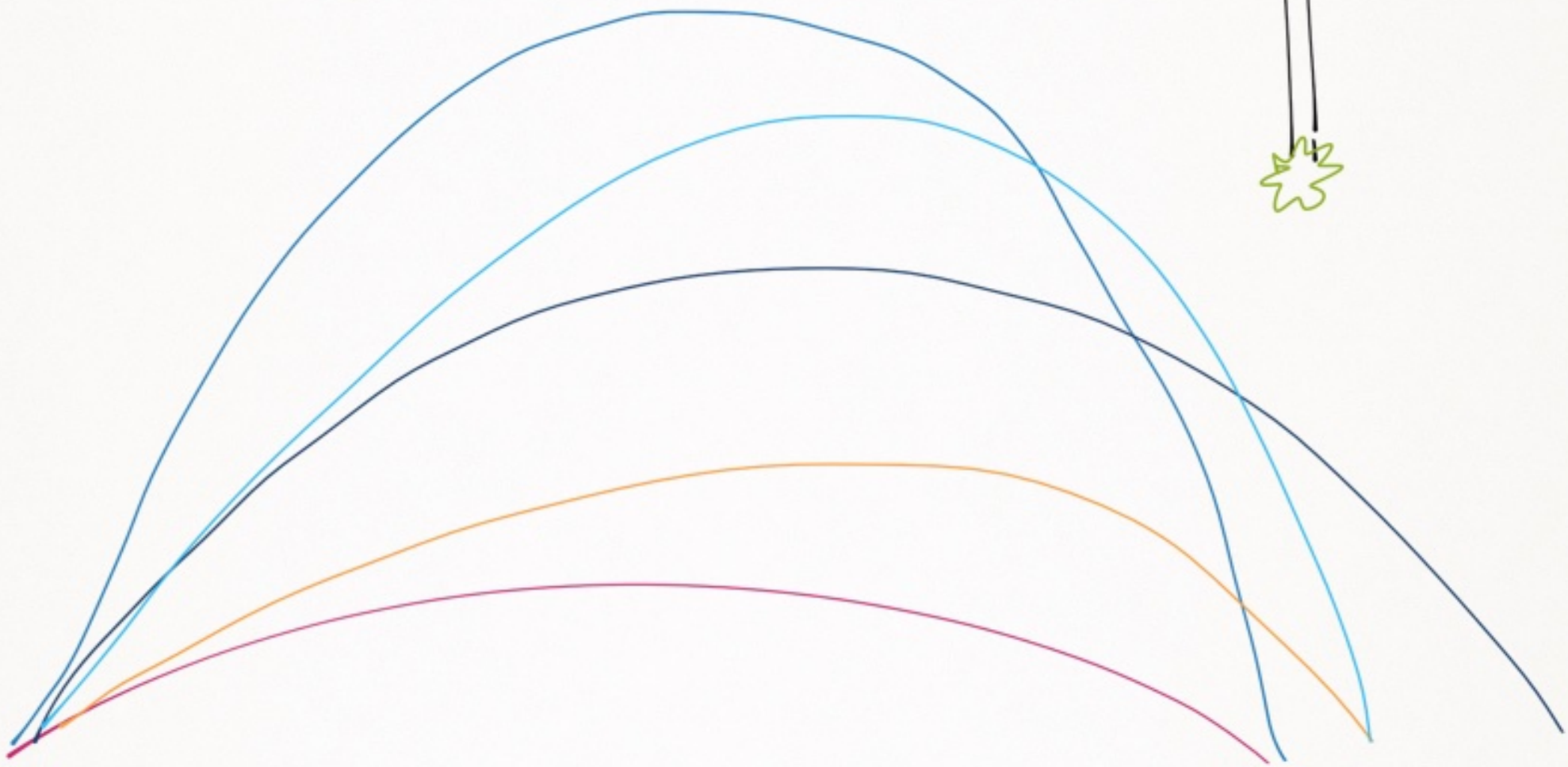
DELIVERY SYSTEMS

→ BOMBERS ⟶ 2nd MOST COMMON
→ ARTILLERY
→ SUBMARINES ⟶ ~~ONE OF~~ MOST COMMON (RELIABLE, MOBILE, HIDDEN)
→ BALLISTIC MISSILES
→ LAND BASED / SILOS
→ CRUISE MISSILES ⟶ ALSO RELEVANT
→ BACKPACK BOMBS

$$e^{\frac{v_f}{v_{ejection}}} = \frac{\text{initial total rocket mass}}{\text{final rocket mass}}$$

natural base





CHERYNOBLE

POTASSIUM IODIDE IS WHAT KIDS WERE ALL GIVEN VIAL TO DRINK
- → POLAND WAS ONLY COUNTRY TO HAVE PUBLIC HEALTH RESPONSE
- → WEST FOUND OUT THROUGH SCANDANAVIAN COUNTRIES
- → MAIN EFFECT IS THAT PEOPLE ARE AFRAID

"POSITIVE VOID COEFFICIENT"

BAD DESIGN + OPERATOR ERROR

UNCERTAINTY + PERCEPTION

NUCLEAR POSTURE

- NOT SUBJECT TO DEMOCRATIC PRESSURES
- CHINA DOESN'T HAVE POLITICAL ENEMIES

two proposition

SECURITY DILEMMA

two possibilities neither of which is practically acceptable

→ TO BUILD OR NOT TO BUILD.

"INCREASE NATIONAL SECURITY"

∴ THEY BUILD SO INCREASE IN INSECURITY

"INCREASE INSECURITY"

WE COMPARE SECURITY DILEMA TO RESONANCE (GALLOPING GURTY) FOR NO COHERRENT REASON.

DETERRENCE IN CLASS

CURRENT PLAN TO REBUILD US NUCLEAR WARHEADS — $355 BILLION

YUCCA MOUNTAIN (NEVADA)

USA VS. USSR

SDI (star wars)

↳ strategic defense initiative

↳ knock missiles out of sky

↳ helps saying that this specific event directly results in the collapse of soviet union

IRAN VS. ISRAEL

- "awakening of nationalism of muslim nations"
- BOTH AMBIGUOUSLY BUILDING

JAPAN VS. NORTH KOREA

-Japan wants to build

$$\frac{\text{mushroom cloud tsar bomba}}{\text{volume tsar bomba}} = \frac{\text{height cup bomb}}{\text{volume cup}}$$

volume tsar bomba $\leftarrow \pi r^2 L$

$$\frac{64\text{km}}{\pi(1.05\text{m})^2(8\text{m})}(470\text{mL}) = \text{height cup} = 1\text{m}?\ \text{wtf?}$$

$$\text{height cup} = 1\text{m}$$

MASS?

$$\frac{64\text{km}}{60{,}000\text{lb}} \cdot 1\text{lb} = 1\text{m}$$

LINEAR HEIGHT $\frac{64\text{km}}{8\text{m}} \cdot 120\text{mm} = 1\text{km}$

AREA $\frac{64\text{km}}{2\text{m}\cdot 8\text{m}} \cdot 120\text{mm} \cdot 60\text{mm} = 30\text{m}$

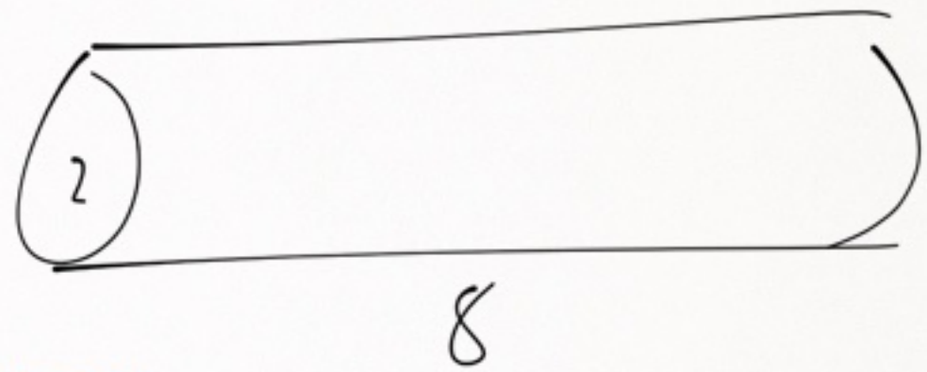
IVY MIKE

$$\frac{37\text{km}}{(1\text{m})^2 \cdot \pi \cdot 6.2\text{m}} \times (470\text{mL}) = 0.8\text{m}$$

MASS NOT VOLUME

22cm...

AREA $\frac{37\text{km}}{2\text{m}\cdot 6.7\text{m}} \cdot 60\text{mm} \cdot 120\text{mm} = 21\text{m}$



BEST REAL MATH

CASTLE BRAVO?

$$\frac{40\text{km}}{\pi(0.68\text{m})^2(4.5\text{m})} \cdot 473\text{mL} = 7.9\text{m}???\ \text{wtf}$$

$\frac{40\text{km}}{1.3\text{m}\cdot 4.5\text{m}} \cdot 120\text{mm} \cdot 60\text{mm} = 50\text{m}$

WEIGHT $\frac{40\text{km}}{23{,}500\text{ lb}} \cdot 1\text{lb} = 1.7\text{m}$

YES $\frac{40\text{km}}{4.5\text{m}} = \frac{x}{120\text{mm}} \rightarrow x = 1\text{km}$

NAGASAKI? FAT MAN

$\frac{17\,km}{\pi(0.75m)(3m)}$ 470mL = 1.5 m

$\frac{17km}{10300\,lb} \cdot 1\,lb = 1.6\,m$

$\frac{17km}{14\,lb} \cdot 1\,lb = 1.2\,km$

LITTLE BOY

$\frac{40,000\,ft}{\pi(35cm)^2 \cdot 3m} \cdot 470mL = 5m$

$\frac{40000\,ft}{9700\,lb} \cdot 1\,lb = 1.2m$

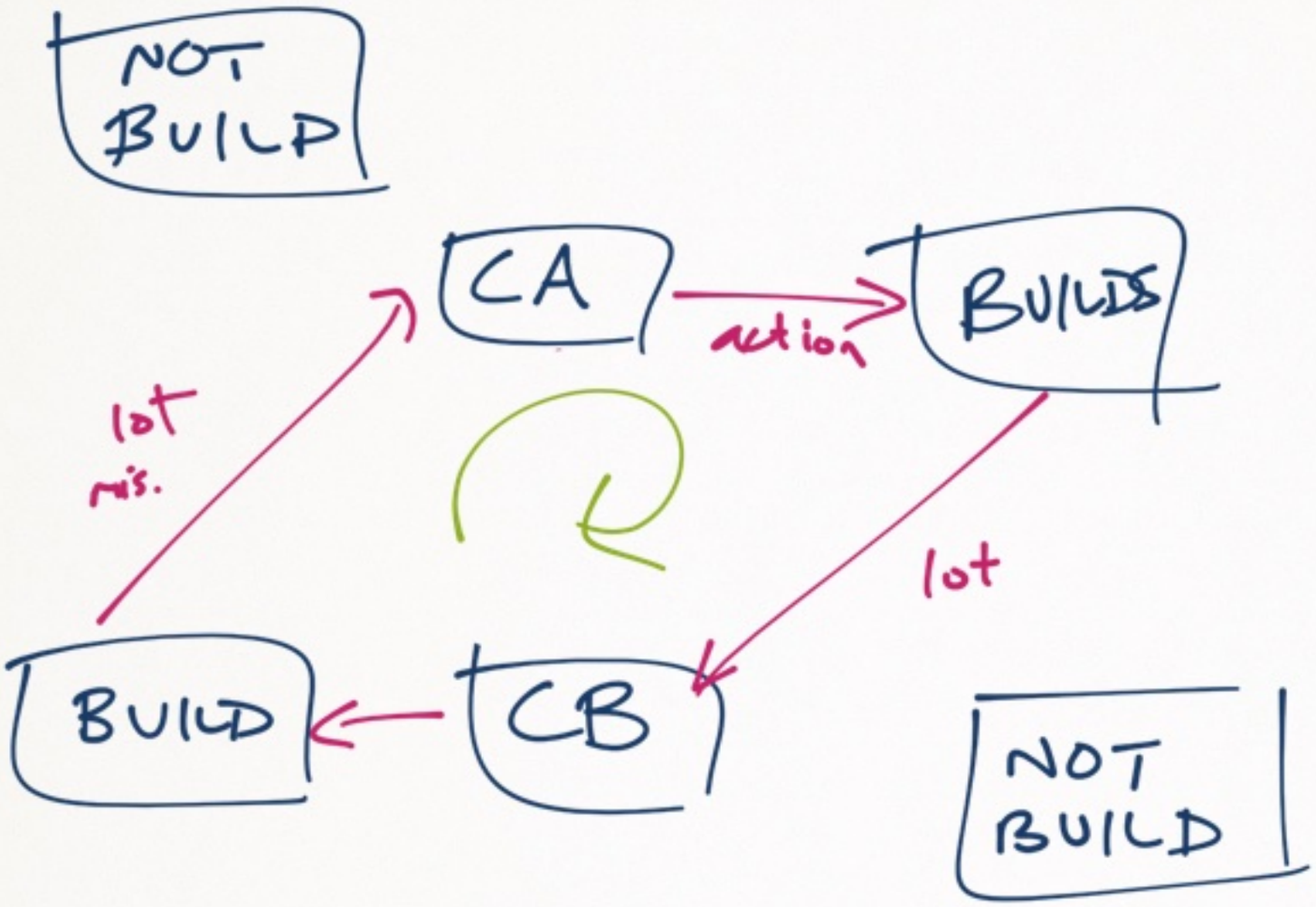
oh FUCK THIS

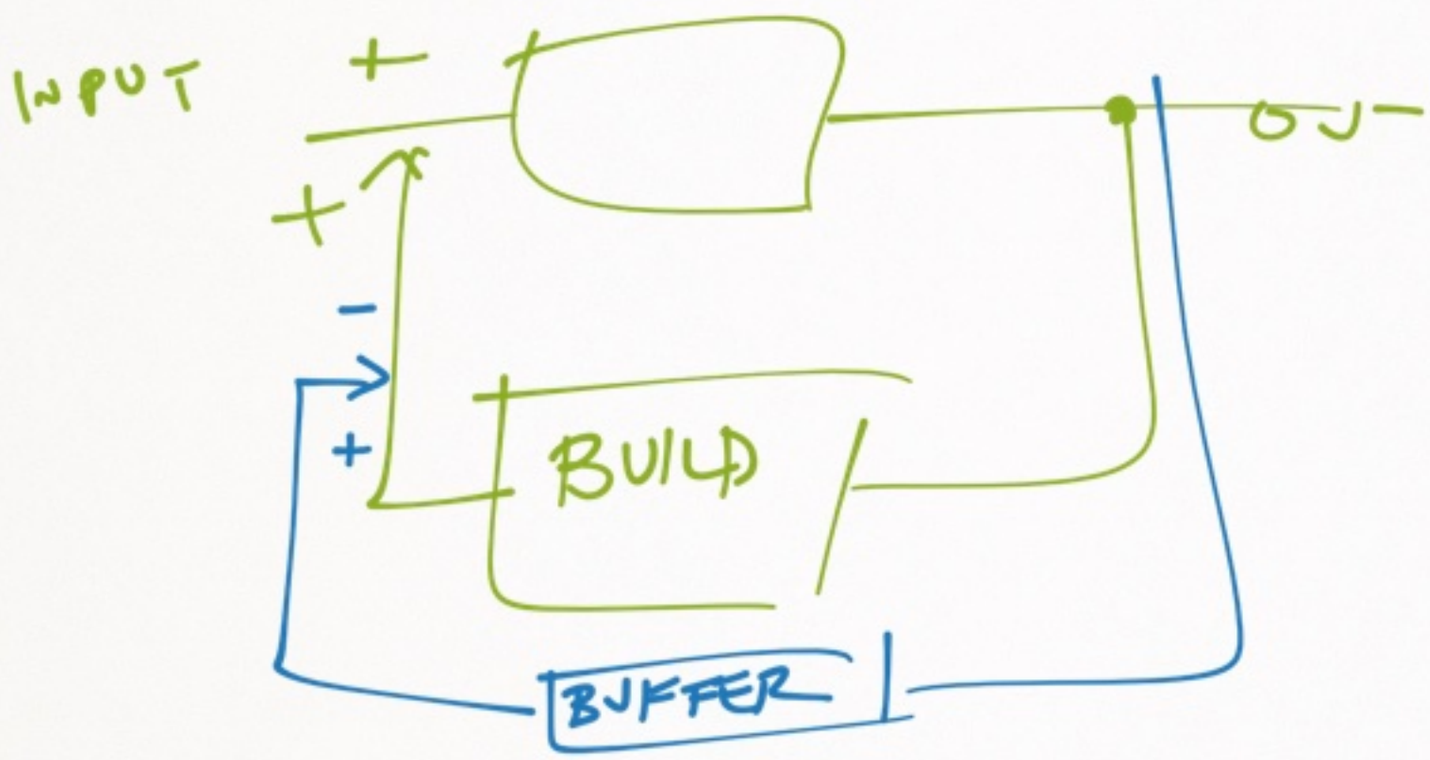
FILLING WEIGHT

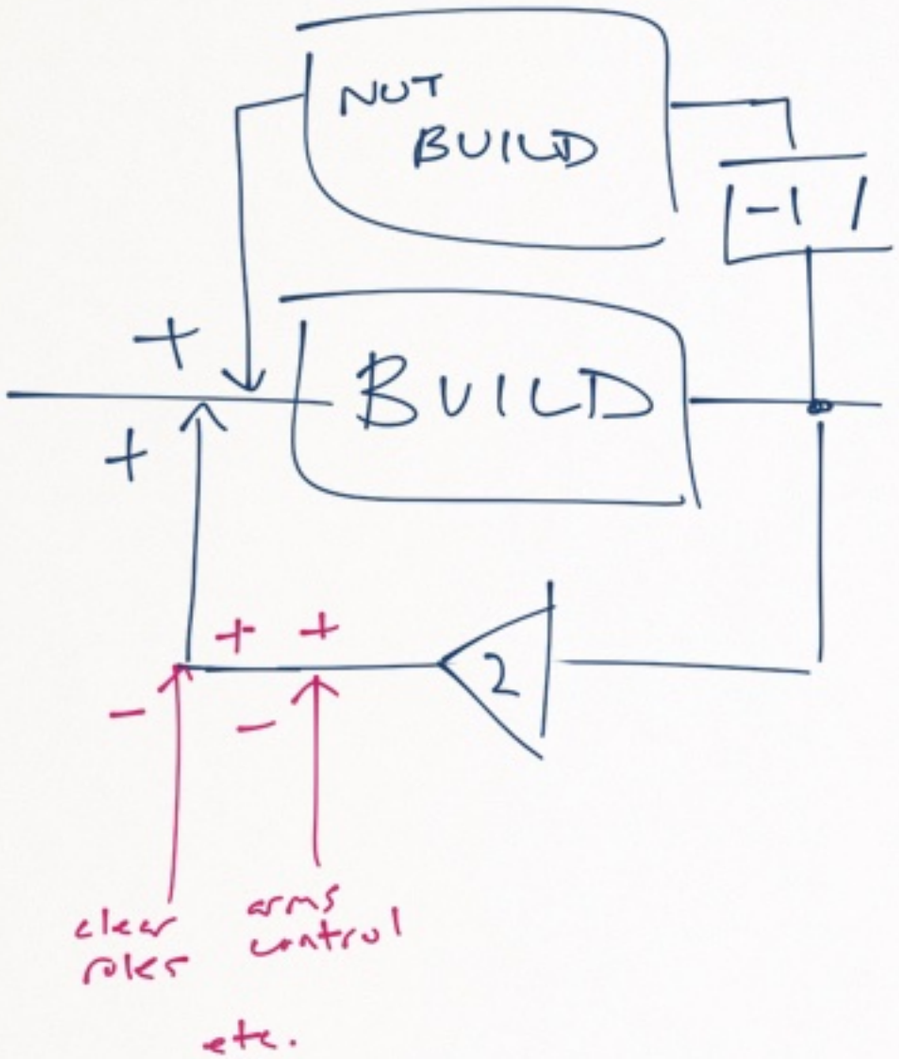
$\frac{40000\,ft}{140\,lb} \cdot 1\,lb = 286\,ft$

$= 87m$

BEST FAKE MATH


NOT BUILD
CA
action
BUILDS
lot mis.
lot
BUILD
CB
NOT BUILD


INPUT
+
+
-
+
BUILD
OUT
BUFFER


NOT BUILD
-1 1
BUILD
+
+
+ +
2
-
-
clear rules
arms control
etc.

ARMS TRADE TREATY

DISARMERMENT -> ABOLITION

ARMS CONTROL -> REDUCTION

SANCTION

BIASED MATH

CASTLE BRAVO

40km high

15 MT

7000 miles^2 contaminated

23500 lb

4.56m long

1.37m diameter

$\frac{40km}{23500lb} \cdot 1lb = 1.7m$

$\frac{15\,MT}{23500lb} \cdot 1lb = 638.3\,TONS$

$\frac{40km}{4.56m} \cdot 120nm = 1km$

αβγδφθ

λξωρξπ

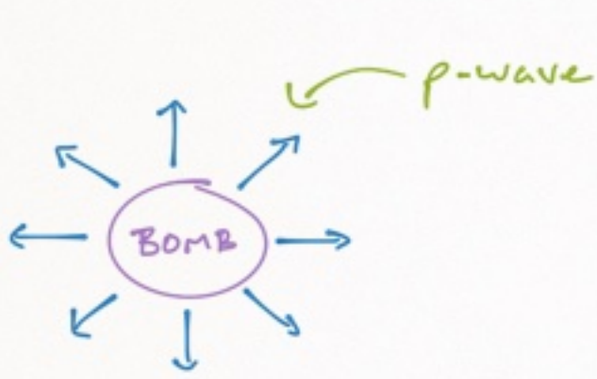
ΨΔΩΛΣΠΓΘΦ

P-wave
→ fastest
→ compression

S-wave
→ 2nd fastest (60% as fast as p)
→ shear

surface waves
→ 90% of s-speed
→ causes most damage

HOW ENERGY LEAVES BOMB



4 SHORT ANSWER
POLITICAL

3 CALCULATIONS
CONVERTING UNITS
+ half life

LARGEST COMPUTERS
DEVELOPED IN 1960s
WAS THE RESULT OF
BOMB MODELNG.

CHINA NPT

signed ~~1992~~

china-pakistan deal

↳1989 → 300MWe pow. plant