Eric Altenburg HST-415 October 7, 2020

Week 6: The Hydrogen Bomb — Video

Teller's Super

1. Nuclear Fusion
   - **Nuclear fusion** is when two nuclei are combined to make a single, new nucleus
   - Known before nuclear fission because it is how the Sun and other stars generate their energy
   - Only elements lighter than iron can undergo nuclear fusion and release energy
   - **Fission = heavy elements**
     fusion = light elements
   - Some fusion reactions are more likely (easier) than others: hydrogen is the easiest, deuterium (H-2) and tritium (H-3) is even easier
   - Per individual reaction: More energy in fission (198 MeV) than fusion (17.6 MeV)
     BUT fusion atoms (hydrogen) are smaller, so there are more per unit of mass:
     - 1 kg of fissioning = ~18 kt
     - 1 kg of fusioning = ~ 50 kt
   - You can put as much fusion fuel together as you want without risk of premature explosion (unlike fissile material) because you need millions of degrees
2. Fusion
   - Nuclear Fusion: Trying to force two light atoms close enough together to overcome the electrostatic repulsion, so that the nuclear force (strong force, green dots) can kick in
3. Why does fusion release energy anyway?
   1. Deuterium and Tritium are heated up really hot and so they are flying around really really fast
   2. They smack into each other forming He-5 (very very very unstable since so much energy), since they're moving so fast, they overcome the repulsion barrier
   3. Since He-5 is so unstable, it shoots apart:
      3.5 MeV ← He-4 * n → 14.1 MeV
   - **TL;DR:** You have really fast moving hydrogen atoms shooting at each other, they hit into each other forming He-5 which is really unstable, then it releases the extra neutron it had giving off 17.6 MeV
4. Edward Teller (1908-2003)
   - Anti-Nazi, Anti-Communist, Pro-US
   - Very involved in weapons development
   - Right winged
   - *Had noice eyebrows*
5. The idea of the H-bomb
   - Late 1941: Fermi and Teller — fission ignites fusion — the "super"
   - Initial estimates on Super's explosive yield: 10-100 million tons of TNT
   - Teller fixated — Oppenheimer allows to work on Super during WWII, but seen as a future problem
     - Teller's fission work is done by Fuchs instead, he's the spy
   - Very little progress on the Super during WWII
     - Basic info about fusion reactions not known
     - Much basic info about fission bombs still not known
   - Super is the main driver for **international control** by Bush and Conant — Super is kept secret from the public, not mentioned in Smyth Report
   - The idea of using fission to ignite fusion was mentioned **5 times** by other Manhattan Project scientists
   - Deuterium is cheap, Tritium is expensive
     - Tritium is made in the same reactors that make the Plutonium, so either one or the other is produced
6. Postwar Work
   - During postwar, not much progress made:
     - Working on producing more (and better) fission bombs

- Manhattan Projects remnants in disarray
- Computers not powerful enough to do Super calculations
- Still not a lot known about fission bomb energy/radiation output
  * Only ~3 have been set off

H-bomb debate

1. Post-"Joe-1" resurgence of interest
   - Teller leads the call for making a crash H-bomb program the US "response" to Soviet test
     - Crash = top priority
   - H-bomb would be a quantum leap in weapons technology — qualitative advantage
   - Other scientist is enlisted, Ernest Lawrence
   - Gets support of the AEC Commissioner Lewis Strauss
   - **J. Robert Oppenheimer** is an opponent to the H-bomb, David Lilienthal also opposes
   - Reasons:
     - Technical — can't do it Pu-prod
     - Strategic — dangerous to the US
       * Big bomb so hard to get into the heart of USSR, but major US cities are on the coast, so if Soviets can make their own, then US is easier target
     - Moral — weapon of genocide
2. GAC
   - Is okay with Hiroshima and Nagasaki, but don't like the idea of H-bomb
   - A-bomb is appropriate for like wiping out bases and stuff, but the H-bomb is on par with the Holocaust
   - Nuclear fallout with the H-bomb
     - Will give a Chernobyl-like effect
3. Effects of a 10 megaton nuclear weapon
   - ***You mapped the 10 MT bomb as a surface detonation, why is that? Does the H-bomb require a surface detonation as opposed to an airburst like the Japan bombs?***
4. H-bomb debate goes public
   - Until November 1949, debate is only between people with secret clearances in government
   - Was leaked on talk-show on live TV by Pro-H-bomb JCAE member
   - Debate is now public — most scientists lobby groups against the crash program
5. Truman and the H-bomb
   - Doesn't know A-bomb from H-bomb
     - Doesn't seem to care
   - Once public, feels his "hand is forced"
   - Demands the gov't scientists stop talking about the H-bomb <u>at all</u> ("gag order")
   - Asks National Security Council for their recommendation as to whether to order H-bomb built
     - Says to build it
6. Truman's decision, Feb. 1950
   - Truman says to make it
     - For "security" pending an atomic pact
   - "You've been working on it, continue"
7. Two days later
   - Klaus Fuchs confesses to being a Soviet Spy
   - Caught by Venona program: decoding old Soviet communications

The Teller-Ulam design

1. The "crash" program
   - Computer simulations finally, conclusively show in 1950 that "Runaway Super" won't work
     - Heat will not sustain
   - **back to square one**
   - Early 1951: Polish Stanislaw Ulam has breakthrough — "bomb in a box"

- Teller extends: "radiation implosion"
- By Spring of 1951, they have fleshed-out new approached ("Equilibrium Super") — becomes known as the **Teller-Ulam design**

2. Teller-Ulam Design
   - Basic idea: instead of putting the atomic bomb right next to the fusion fuel, keep them separate ("staging"), but put them in a heavy "box" (hohlraum/radiation case)
   - The radiation energy of the atomic bomb will fill the "box" and compress the fusion capsule = **radiation implosion**
   - By pre-compressing the fusion fuel with radiation *before* heating it, it creates the conditions for fusion reactions
   - Increase density of deuterium by 1000%, in the Fat-man, its density is increased by like 50%
3. How it will work
   - ***What percentage of the material in the Teller-Ulam design is actually fissioned compared to the Nagasaki? If I recall correctly, percentage wise, the amount fissioned is relatively low.***
4. Teller-Ulam paper (1951)
   - Changes the minds of many people, shows that it is possible
   - Since the project is technically inevitable, then they feel they have to build it
     - Oppenheimer included
   - Since it can be built, they feel like they have to be the first to have it
   - ***Does the moral argument go out the window now since if they can make it first, then since they think they're more moral than the enemy, they can use it for good?***
5. Implications of the H-bomb
   - Total destruction of nations now very feasible — maybe even civilizations?
   - High-yields compensate for poor accuracy of rockets — ICBMs now seen as feasible
   - New frontier of weapons design open — solid fuel, miniaturization to be studied next
   - Those who long supported H-bomb work seen as vindicated, those who opposed it are seen as being suspicious
   - But US does not announce test success for several years