Week 2 - Building the Bomb

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1. Atomic Energy for Military Purposes Book
   - Released 3 days after the bombing of Nagasaki
     - *NOTE:* War was not yet over
   - Written during the Manhattan project
   - Translated to Russian and people were able to know about atomic bombs outside of their govt.
   - Groves (Major General, USA) in foreword:
     - This book contains everything we can say about the bomb
     - If you say anything else not in this book, then you will be punished by Espionage Act
     - Reason for releasing: If you give them something, then they won't go looking on their own accord
   - Mainly about theoretical physics since Smyth was a theoretical physicist
     - Missing chemistry, engineering, and other types of work
     - It's the least sensitive stuff about the bomb, and everyone mainly understood the ideas prior to the war
2. Timeline
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phase	**goal**	**methods**	**primary output**
exploratory	to see if a nuclear weapon program is feasible	small-scale experiments and theoretical studies	reports
pilot	to evaluate the feasibility of manufacturing methods	building medium-scale facilities	reports, plans, tacit knowledge, test samples
production	making actual nuclear weapons	building large-scale facilities, designing bombs, preparing for use	fissile material, atomic bomb

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country	**exploratory**	**pilot**	**production**
United States	1939	1941	1942
Germany	1939	1942 (reactor only)	x
UK	1940	x	x
USSR	1940	x	x
Japan	1941	x	x

   - You need a production program to get an atomic bomb
   - "Why did the United States make an atomic bomb?"
     - No one else made one
3. State of knowledge in 1939
   - U-238 (99%) and U-235 (<1%)
   - Only U-235 fissions from fast and slow neutron energies
     - U-235 is thus fissile (can sustain fission chain reactions in sufficient quantities)
   - U-238 will absorb slow neutrons without fissioning
     - Kills chain reaction
   - Both isotopes are chemically identical - can only be separated physically, but differ by only 3 neutrons
   - If you could separate U-235, you can make a bomb. But can you? If you can't, what are the options?
   - But nuclear reactors are very possible
     - Some confusion between a reactor and a bomb (out of control reactor)
4. Einstein-Szilard Letter, 1939
   - Written by Szilard but signed by Einstein for importance

- Unsure about many characteristics of the bomb (ie. power, size, weight)
  - Undersold
  - Better to undersell than to oversell
- This is a policy letter
  - Appoint a guy to keep an eye on the situation
- FDR did not read this, he got a summary
  - Said: "make sure the Germans can't blow us up"
- Asks to make a committee

5. Uranium Committee
   - Roosevelt created it in 1939
   - Used to coordinate the fission research with universities
   - Figure out if a bomb is worth worrying about
   - Gets absorbed in to the National Defense Research Committee
   - Office of science and research and development was eventually made as well
     - Was used to develop physical things (ie. camo stuff being put on planes from MIT)
6. James Conant, President of Harvard
   - Thought the innovation would take a long time
   - With other things to do (ie. camo), he doesn't want the scientists to waste their time on the bomb
     - Doesn't think it'll work
7. Atomic Piles
   - Bomb
     - Produces **exponential** chain reaction
     - Uses **fast** neutron reactions
     - Require **enriched** fuel (80-90% fissile material)
   - Reactor
     - Produces **stable** chain reaction
     - Uses **slow** neutron reactions
     - Uses **unenriched** or **lightly-enriched** fuel and a **moderator** to slow neutrons
   - When U-238 absorbs a neutron, it will (in several days) turn into plutonium-239 (relatively stable) which is **fissile**
     - Could use it as bomb fuel
     - Figured it out at 1941 and paved new path for the bomb
8. Other Programs
   - Germans though the bomb wasn't necessary for this war, for the next war
     - **Why did the United States decide to make the bomb?**
   - Japan kept program small and thought the US couldn't make an atomic bomb in time for the war
   - France was invaded by Germany by 1940 :(
   - USSR didn't have too many sources, so they just accumulated info for post war
9. United Kingdom
   - Physicist were figuring out how much material would be needed for the atomic bomb
     - only 5 kg of U-235 was necessary
10. United Kingdom/USA
    - UK committee (MAUD) goes to USA and says the bombs feasible but you need to do it because of resources
    - US cleans house on the Uranium Committee and changes name to S-1 Committee
    - It is then estimated at $400 million cost (5x under)
    - It's actually much harder than expected, Germany, Japan, and USA were on the right path of saying it's too hard but the UK are dead-afraid and push the USA to think it's doable
      - The US has too much money already spent that they keep going
    - FDR approves ARMY taking control over construction job with goal of **making an atomic bomb = Manhattan Project**
11. The Manhattan Project
    - Manhattan Engineer District, 1945
      - Spans the entire country

- Name: the OG headquarters was in Manhattan
  - Location: because all the manufacturing places and some education institutions were along this Northeast Corridor
- "I told you it couldn't be done without turning the whole country into a factory. You have done just that." -Niels Bohr, 1944
- Work conditions were poor so turnover rate was often 60%+
- Had nearly 125,000 workers in June 1944 with gradual decrease with total workers begin 600,000+
  - Most workers were laborers for making factories
- More women working on this than the Apollo project
  - Couldn't afford to count people out on the project because of prejudice
- Idea was to work now and worry about environmental/safety aspects later
- Had sites all across the globe

12. Manhattan Project Heads
    - General Leslie R. Groves - Military Head of the Manhattan Project
      - Vital to the success of the Manhattan Project
    - J. Robert Oppenheimer - Scientific director of project
      - Theoretical physicist from Berkeley
      - Unlikely choice: hasn't really led a big project
      - Chosen by Groves because he felt Oppenheimer had something to prove and that he was well liked in the science community to get people behind Groves' choices
13. Metallurgical Laboratory
    - University of Chicago
      - First reactor (CP-1) goes critical in December 1942
14. Radiation Laboratory, Berkeley
    - UC Berkeley: Develops particle accelerators, basic theory, isotope separation methods (uranium enrichment)
15. Site Y: Los Alamos
    - Meant for research and bomb design
    - Other sites had security issues because of the open access at universities and the attention they drew
    - All work that definitely had to do with the bomb was kept here for security reasons
    - Most reliable scientists were kept here
16. Site X: Oak Ridge
    - Meant for uranium enrichment
    - 3 major plants
17. Site W: Hanford
    - Built industrial-sized plutonium reactors to make neutrons to make plutonium (though not a lot of it)
      - Total of 3
    - Scaled up version of the Chicago reactor
18. Ways to Separate U-238 from U-238
    - None of these were really the best, instead they were chained together so one method would feed into another

    a) Thermal Diffusion Method (S-50)
       - Fluid uranium circulates, U-235 tends to concentrate toward top since lighter
       - **EX: given natural uranium, enriched it to 0.86% U-235 and pass into K-25**

    b) Gaseous Diffusion Through Barriers (K-25)
       - Passing gaseous uranium through a mesh barrier
       - The lighter U-235 tended to pass through
       - **EX: given uranium from S-50, you get 23% U-235**

    c) Centrifugal (*ABANDONED IN WW2*)
       - Spin gasified uranium rapidly and U-235 tend toward the center

    d) Electro-Magnetic (Y-12)
       - Get uranium ions and shoot them through magnet as a stream, then the stream gets split

with the U-235 being more deflected than U-238
    - **EX: given uranium from K-25, you get 84% U-235**
19. Uranium Ore
    - Uranium ore was a major supply issue for project
    - 73% of ore came from Belgian Congo (75% U/g)
    - 9% from Canada (30% U/g)
    - 14% from Colorado Plateau (0.25% U/g)
    - Groves works to secure all known world uranium and thorium supplies by contracts
20. Cost of the Bomb
    - $2 billion (1945) = $50-180 billion (2019)
    - 63% of the cost was for Oak Ridge (uranium enrichment)
        - 27% K-25
        - 35% Y-12
    - 21% on Hanford
    - 4% on Los Alamos
    - Fissile material production costs greatly exceed research costs
        - Making the fuel is the hardest cost