Scientific Networks and The Bomb

An Analysis of the Manhattan Project Scientific Network

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INTRODUCTION

> *"The greatest achievement of the combined efforts of science, industry, labor and the military in all history."*[1]

The Manhattan Project was the United States led effort to develop the atomic bomb during World War II. Started in 1939, the project would eventually employ more than 130,000 people across more than 30 sites at a cost of $2.2 billion dollars.[2] The success of the Manhattan Project, which won the race against parallel German and Russian efforts to create a nuclear bomb, and the subsequent bombing of Hiroshima and Nagasaki, would change the global geopolitical landscape and shape human history for generations to come.

The scientific community had a major leadership role from the very beginning of the nuclear effort. It was a letter written by physicists Leo Szilard and Albert Einstein that first alerted United States President Franklin Roosevelt of the possibility of "extremely powerful bombs of a new type."[3] Soon, myriad scientific efforts pursuing a number of important lines of research were initiated across Britain, Canada and the United States that would help create "a practical military weapon in the form of a bomb in which the energy is released by a… chain reaction in one or more materials known to show nuclear fission."[4] It is undeniable that the scientific community was at the forefront of the initiation and development of the Manhattan Project.

This paper examines the interaction between the Manhattan Project and the networks of participating scientists. It is clear that World War II and the Manhattan Project unified scientists

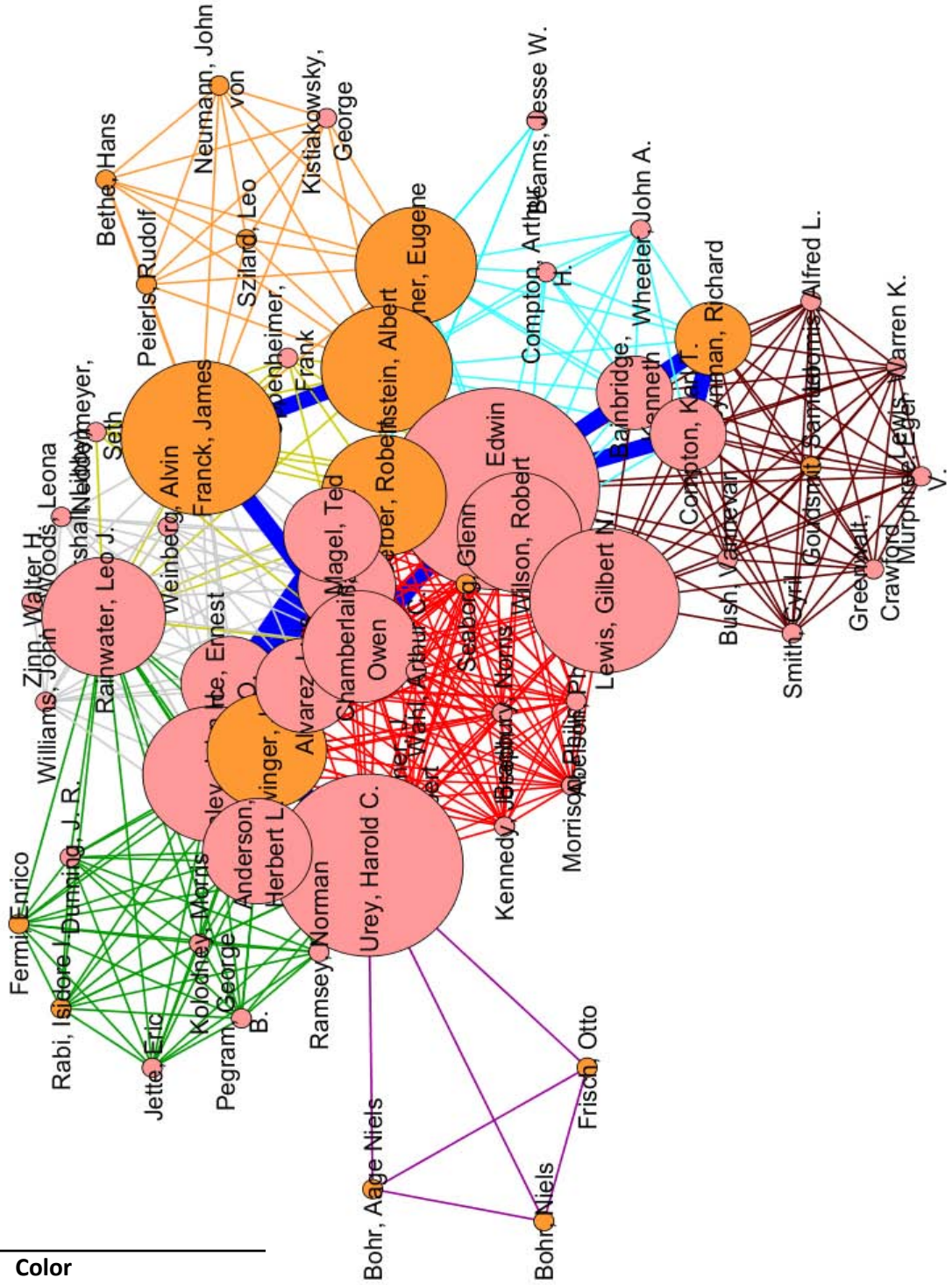
[1] Hughes (2002)
[2] Ibid.
[3] Smyth (1945)
[4] Baggot (2010)

of different nationalities, specialties and personalities to work towards a singular goal. This is demonstrated in multiple ways. First, the scientists that contributed to the Manhattan Project collectively represented a very broad range of nationalities. Scientists from throughout Europe and the United States were brought into close collaboration by the Manhattan Project. Second, the racism and religious persecution that so characterized the Nazi and Fascist ideologies that unified the Axis forces drove many of the leading Jewish scientists to contribute to the Manhattan Project. Though not without frictions, the overall willingness of the Allies to welcome and collaborate with scientists of different nationalities and religions was a crucial element to the success. Furthermore, the Manhattan Project, with the oversight of the US Army, was able to bring many of the greatest minds together in remote, dusty Los Alamos where the first atomic bomb was built and tested. This level coordination would have been impossible through prior scientific and university affiliations, but World War II provided the extraordinary circumstances to make this a reality. Ultimately, the Manhattan Project represents the first scientific collaboration of its scope and ushered in a new era of "big science" where large-scale government funded international scientific collaborations became more and more commonplace.

VISUALIZATION OF MAIN NETWORK

We used the Manhattan Project Hall of Fame Directory, compiled by the Atomic Heritage Foundation and Manhattan Project Heritage Preservation Association, as our source for the most important scientists involved in the Manhattan Project.[5] Below is the visualization of the main network of scientists describing several characteristics. The nodes are the main scientists in the Manhattan project network, and the links indicate if any two scientists are connected by a shared university that the studied or taught in. The size of the node also indicates the betweenness centrality of the node. Orange nodes indicate scientists with Jewish heritage or relation. Finally, the color of each link indicates the university through which the connection occurred. For example, the red links indicate that both scientists studied or taught at Berkeley. The network of each university is clustered together and can be seen through the colors in Figure 1.

[5] www.mphpa.org and www.atomicheritage.org



Key

University	Color
Berkeley	Red
Berlin (or close by)	Orange
CalTech	Dark Yellow
Chicago	Grey
Columbia	Green
Copenhagen	Purple
MIT	Maroon
Princeton and	Light Blue
Multiple Links	Dark Blue

BACKGROUNDS OF CONTRIBUTING SCIENTISTS

"If Congress knew the true history of the atomic energy project I have no doubt it would create a special medal to be given to meddling foreigners for distinguished services."

- Leo Szilard

It is a well documented fact that émigré and Jewish scientists played decisive roles in the Manhattan Project. The Manhattan Project Hall of Fame Directory compiled by the Manhattan Project Heritage Preservation Association illustrates the enormous influence foreigners had. The foreign contributors read like a small who's who of the most prominent physicists of the time, including Niels Bohr, Hans Bethe, James Chadwick, Albert Einstein, Enrico Fermi, James Franck, Isidor Rabi, Emilio Segre, Leo Szilard, Edward Teller, and Eugene Wigner. Jewish scientists also played an enormous role. 11 out of the 12 scientists listed above had Jewish ties, and other Jewish Americans, such as Richard Feynman, Robert Oppenheimer, played prominent roles in the Manhattan Project.

While it is difficult to ascertain the exact percentage of the Manhattan Project's scientific contributors that were comprised of foreign or Jewish scientists (no one to date has compiled a comprehensive list of Manhattan Project scientists) the influence of these groups is undeniable. Of the 21 Nobel Prize winning scientists that contributed to the Manhattan Project, 10 were born outside of the country, and 12 were Jewish or had Jewish family members.[6] Also, as measured by betweenness, we can see that many of the most interconnected scientists are Jewish.

[6] Austria-Hungary: Isidor Rabi and Eugene Wigner. Denmark: Niels Bohr. England: Sir James Chadwick. Germany: Hans Bethe, Albert Einstein and James Franck. Italy: Enrico Fermi and Emilio Segre. Nobel Prize winners with Jewish connections were Hans Bethe, Niels Bohr, Sir James Chadwick, Albert Einstein, Enrico Fermi, Richard Feynman, James Franck, Isidore Rabi, Julian Schwinger, Emilio Segre and Eugene Wigner.

Table 1: Religious Status of the Most Interconnected Scientists

	Betweenness Centrality	Jewish
McMillan, Edwin	0.17048629	no
Urey, Harold C.	0.1415595	no
Franck, James	0.09848102	yes
Lewis, Gilbert N.	0.08411708	no
Manley, John H.	0.07110485	no
Einstein, Albert	0.05686022	yes
Serber, Robert	0.04763519	yes

Clearly, the presence of foreign and Jewish scientists was incredibly influential in determining the direction and success of the Manhattan Project.

It should be noted that integrating foreign scientists into a research initiative with direct national security and wartime implications was not a trivial matter. Important decisions on whether or not to include foreign scientists had to be made on a regular basis. For example, initially only US citizens could be members of the National Defense Research Council (NDRC) that Roosevelt set up to explore the possibility of atomic weapons.[7] It took a special intervention by Robert Oppenheimer for Jewish, Hungarian-born Edward Teller to be included in the Chicago Met Lab.[8] Manhattan Project Director Leslie Groves once petitioned for the Hungarian–born Leo Szilard to be interned as an enemy alien.[9] These are just a few examples of the frictions that were caused by trying to utilize scientists of so many different nationalities.

[7] Baggot (2010)
[8] Ibid.
[9] Ibid.

Indeed, a delicate balance had to be struck between collaboration and confidentiality. It was later revealed that a number of individuals working on the Manhattan Project were illegally funneling information about nuclear technologyback to Russia. Hans Bethe "is reported to have said that Klaus Fuchs was the only physicist he know that truly changed history."[10] These episodes and many others illustrate that integrating foreign scientists was far from a trivial task.

Table 2: Scientist Country of Birth

Country of Birth	USA	Germany	Austria-Hungary	Britain
Scientists	47	4	9	2

It is interesting to observe that these scientists were not necessarily tightly connected before World War II. An analysis of pre-World War II university affiliations revealed that these scientists were only loosely connected before 1939. In fact the average shortest path length of 2 implies an intermediary was necessary to bring everyone together. Figure 2 below shows two kinds of nodes: (1) the main universities that the scientists were affiliated to before the Manhattan Project began, and (2) the scientists themselves. The sub graph shows the interconnectedness of the scientists through this university network and how these universities served as hubs. . The green hexagons are universities and the other nodes are the scientists. The size of the node indicates the degree of a node. Berkeley and Chicago were the universities with the most connections to the scientists. Later analysis will compare the same graph adding Los Alamos as an institution to provide connections between scientists in the same way as a University

[10] Website: spyinggame.wordpress.com accessed 5 May 2011.

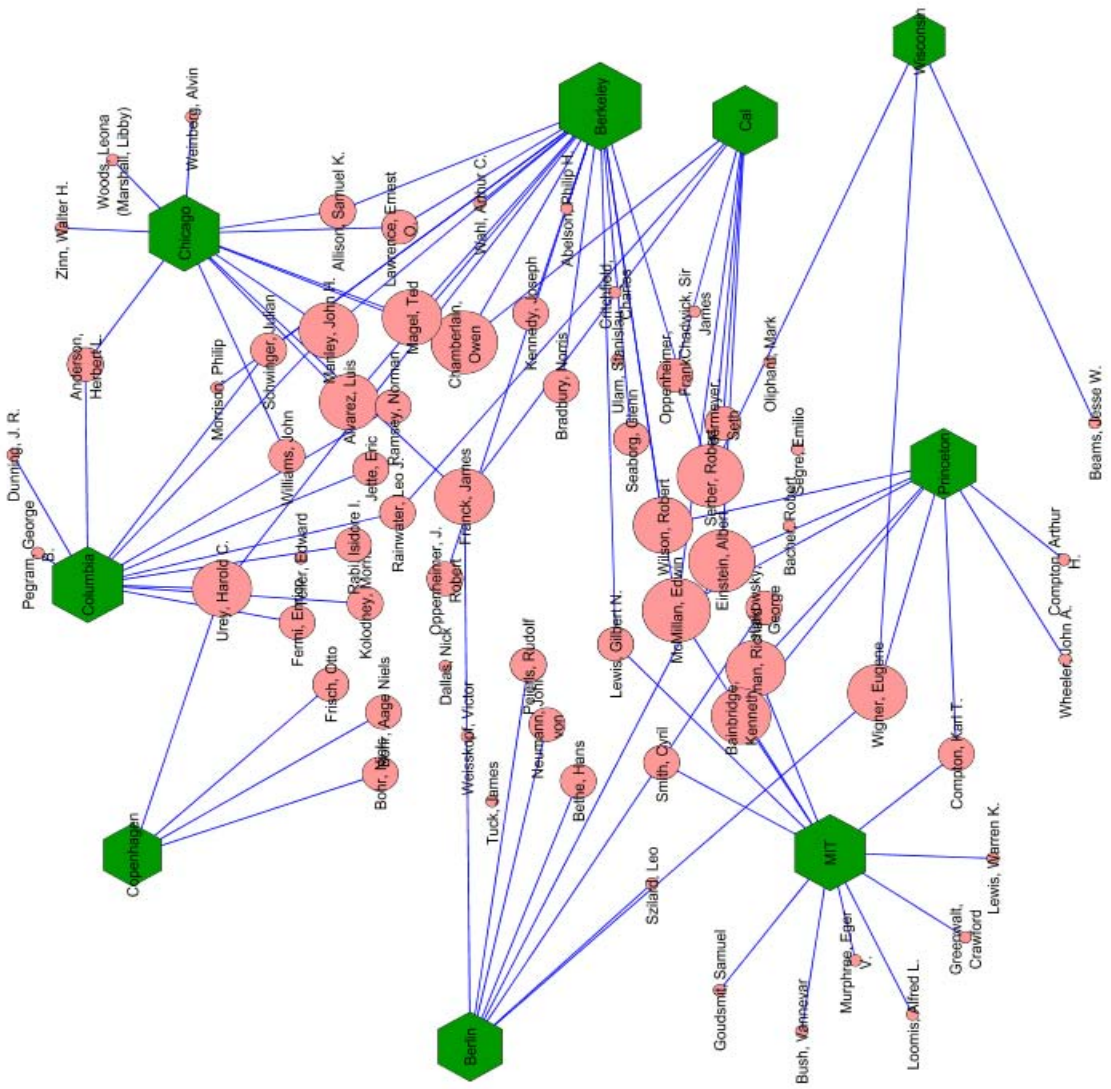


Figure 2: Network Showing University Connections before Los Alamos

Figure 2 reveals that the existing network of scientific institutions and collaborations was relatively weak before World War II and likely insufficient to organize an undertaking of the scale of the Manhattan Project. But other strong forcers were aligned to unify the scientists around the goal of creating an atomic bomb. Chief among these were fear of Nazi world domination, distaste for Nazi and Fascist racism and ideologies, and the organizing power of the US Army. Many Jewish-connected scientists,[11] such as Hans Bethe, Edward Teller and Enrico Fermi, had no choice but to flee Nazi and Fascist persecution. Many scientists had misgivings about the morality of creating a "super bomb" but often overcame these feelings by imagining a world of Nazi domination. Writes Jim Baggott:

> *"Teller was… uneasy with the prospect of working on weapons of such potentially massive destructive power, but… understood enough about German military and technical superiority to develop real fear of a Nazi victory. 'At that time,' he later said, 'I believed that Hitler would conquer the world unless a miracle happened.'"*[12]

Polish –born physicist Joseph Rotblat had similar thoughts, stating, "I have no doubt that the Nazis would not hesitate to use any device, however inhumane, if it gave their doctrine world domination." He explained, "It was a terrible time for me, perhaps the worst dilemma a scientist could experience. Working on a weapon of mass destruction was against all my ideas – all my ideas of what science should do – but those ideas were in danger of being eradicated if Hitler acquired the bomb."[13] Thus, a common fear of Nazi world domination drove many scientists to contribute the Manhattan Project effort.

[11] An individual is considered Jewish-connected if he/she is or has a direct relative who is of Jewish descent.
[12] Baggot (2010)
[13] Ibid.

ALIGNMENT AND COORDINATION

However, individual motivation in and of itself would have been insufficient to create success. What was needed was a coordinating body to align the myriad scientific efforts. This section illustrates how the US Army through Leslie Groves and Robert Oppenheimer provided just such coordination. Overall, Manhattan Project research activities occurred across 30 different sites and groups in US and abroad. Some of the most important early groups include the following:

- **MAUD Committee:** Represented the British atomic bomb project from Feb 1940 to July 1941 before UK joined forces with US in the Manhattan Project. The MAUD Committee created an influential report that concluded that a uranium bomb was feasible and provided rough specifications for such a bomb.
- **Westinghouse Electric and Manufacturing Company in Pittsburgh:** Tasked with making centrifuges required for full-scale production of U-235. Project was eventually shut down.
- **Columbia University:** Work on gaseous diffusion under oversight of chemist Harold Urey.
- **Met Lab in Chicago:** Research on experimental reactor overseen by Enrico Fermi
- **Rad Lab at UC Berkeley:** Developed the cyclotron which was used to develop the technique of electromagnetic enrichment of uranium which was applied in the Y-12 facility in Oak Ridge.

However, upon the initiation of the official Manhattan Project in 1942, the various research arms were highly unfocused and uncoordinated. At Pittsburgh, there were significant engineering

problems that would eventually lead to the site being shut down. In Columbia, Groves was skeptical that any practical value would come from the diffusion research. Progress was being made at the Met Lab in Chicago, but lacked the engineering perspective to apply the research for a bomb. Finally, the Rad Lab in Berkeley had made significant gains with the cyclotron but the machine was still too cumbersome to run at reasonable capacity. All this led Groves and Oppenheimer to conceive of a dedicated site where "all the scientists working on the principles of bomb physics and design [could] be brought together at a single, dedicated laboratory where they could work to solve the many problems they faced."[14] Eventually, Los Alamos was picked to be this site. Less than three years later after the founding of the Los Alamos Laboratory, the first nuclear weapon exploded in the nearby Jornada del Muerto desert in the Trinity test on July 16, 1945.

Analysis of the scientist network in Figures 3-5 shows the consolidating effect the Los Alamos site had. In Figure 3, the green hexagons represent universities, the pink nodes represent scientists, and the size of the node indicates the degree of a node. We found that while the shortest path distance in the network without Los Alamos was 3.7, the shortest path distance in the network with Los Alamos was reduced to 3.07.[15] Furthermore, Los Alamos was clearly the most connected hub in the network, helping to unify and coordinate all the scientists as Groves and Oppenheimer had envisioned.

[14] Baggot (2010)
[15] Note that these are longer path distances than observed in Figure 1 due to the use of Universities and Los Alamos as an intermediary link between the scientists.

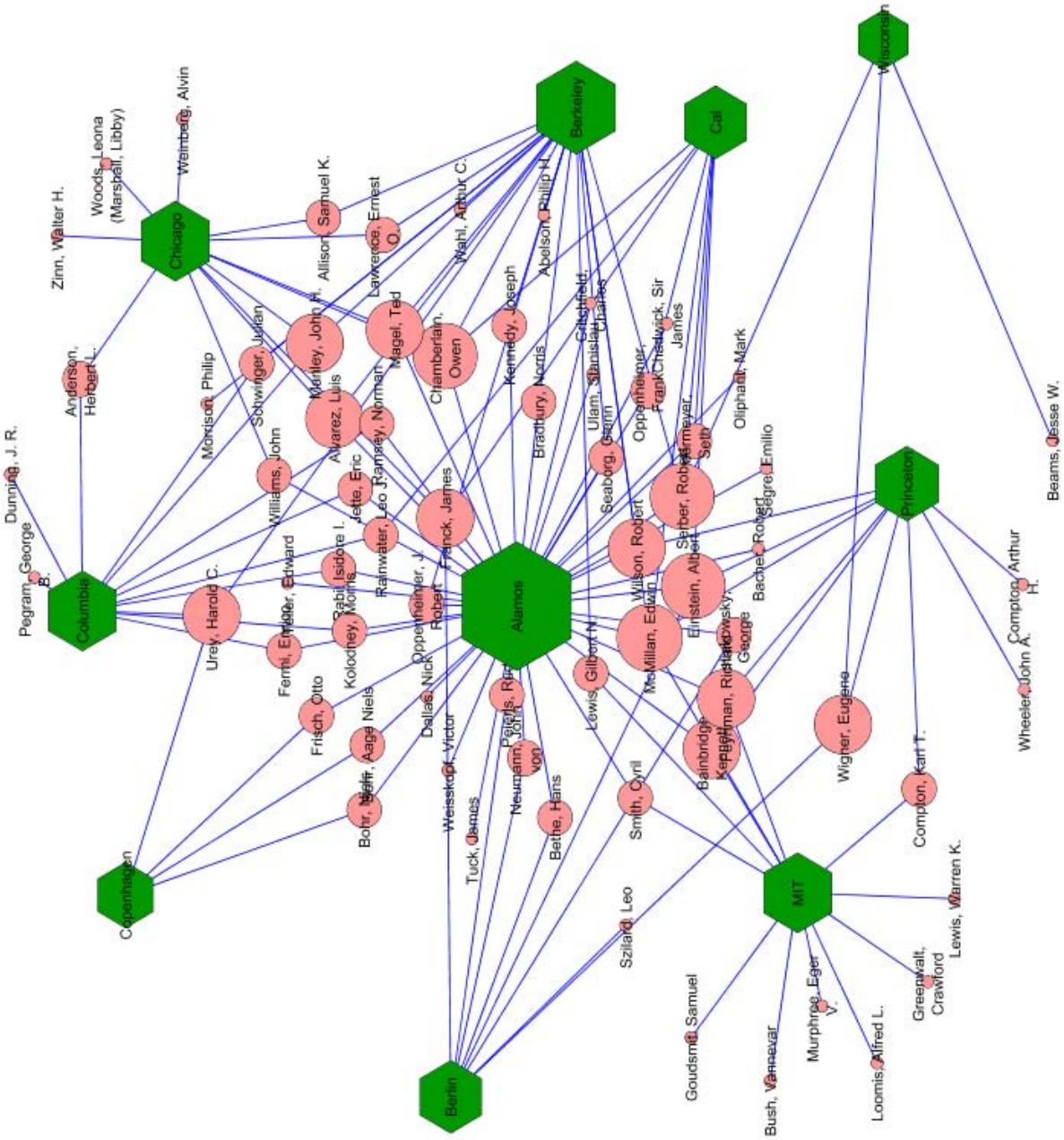


Figure 3: University Connection Network including Los Alamos

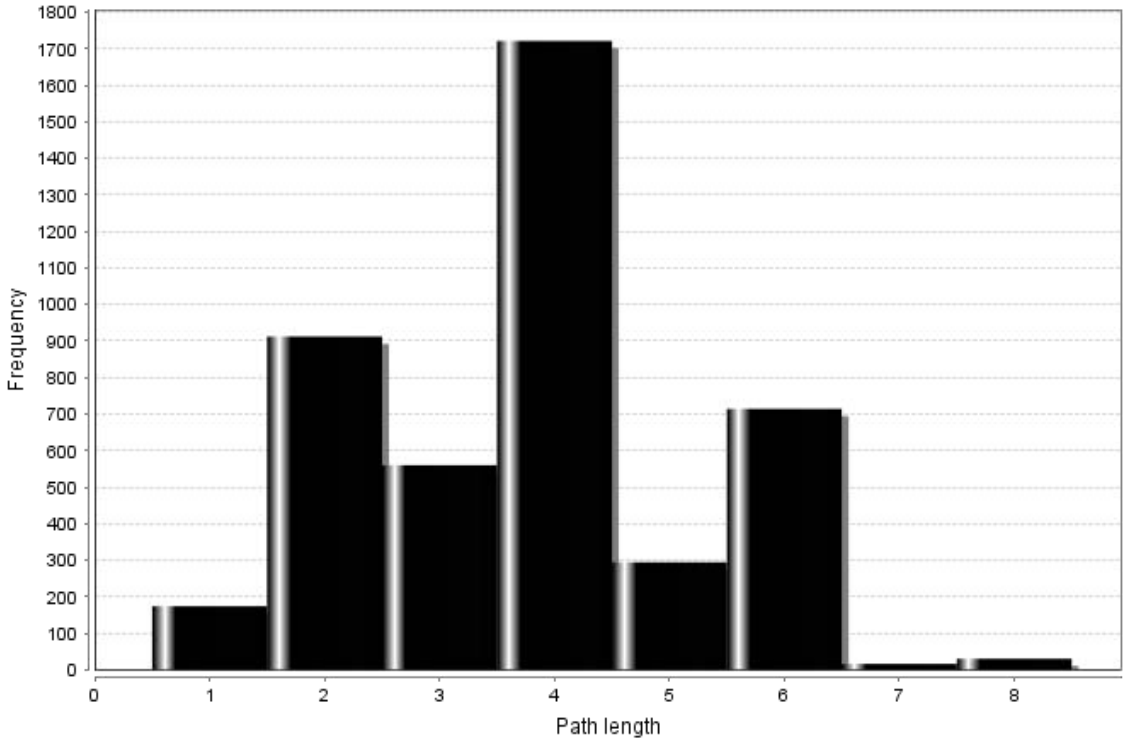


Figure 4: Path Length Distribution without Los Alamos (Average of 3.7)

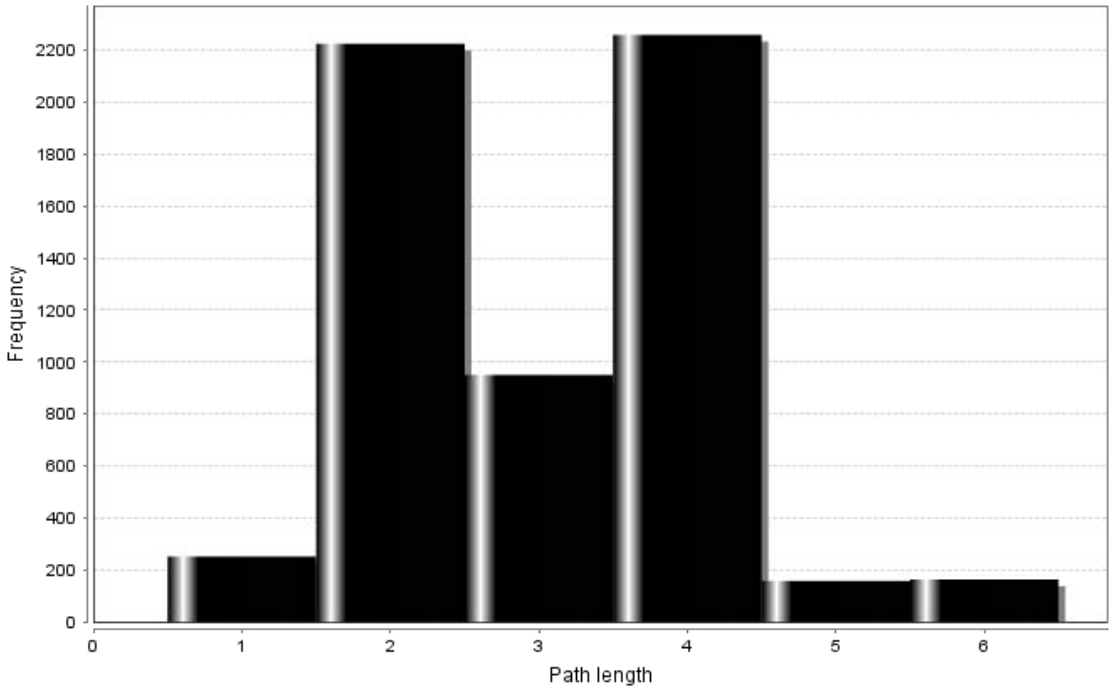


Figure 5: Path Length Distribution with Los Alamos (Average of 3.07)

THE DAWN OF BIG SCIENCE

Overall, it is clear that the Manhattan Project was a monumental achievement of science, will and coordination. The Manhattan Project, with the unifying forces of Nazism and Fascism, Allied collaboration, and the oversight of the US Army, achieved something that the academic collaboration and university networks in isolation would likely never have accomplished. In this way, the Manhattan Project may be the first ever occurrence of scientific organization which is oftentimes referred to as "big science." Nowadays, it is common to encounter enormous scientific projects and endeavors, such as particle accelerators like CERN or space projects like the Hubble Telescope, which are supported by huge amounts of public funding and attract scientists from varied backgrounds from all over the world. Such collaborations had never occurred at comparable scale before the Manhattan Project. In sum, World War II and the Manhattan Project changed the world in many ways – one of these ways was the manner in which scientific collaboration is imagined and conceived.

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