Chapter

13

Mark II: July 4 – August 17, 1944

Within the entire commercially published Manhattan Project historical literature there is only one specific mention of the Mark II by that designation. That instance is found in *The New World, 1939/1946,* which is Volume I of a two-volume U.S. Department of Energy-funded history of the U.S. Atomic Energy Commission published, 1962, by the Pennsylvania State University Press and subsequently republished by the University of California Press. *The New World, 1939/1946* was written by DOE contract historians Richard G. Hewlett and Oscar E. Anderson, Jr. In addition to the information that Hewlett and Anderson provided about the Mark II there are presently three identified Manhattan Project documents that also name the Mark II and supply additional information about the Mark II.

James B. Conant (left) with Vannevar Bush after witnessing the atomic bomb explosion at Trinity site, Alamogordo, New Mexico, 16 July 1945.

Those three documents, all from the summer of 1944, are dated 4 July, 27 July and 17 August. All three documents were written by Atomic Bomb Military Policy Committee alternate member, Harvard University President James B. Conant. The document dated 27 July reports events of 17 July 1944, the day of the Port Chicago explosion. No publicly known document dated before 4 July 1944 names the Mark II; no publicly known document dated after 17 August 1944 names the Mark II. Hewlett and Anderson do not identify the documentary sources they had consulted to prepare their description of the Mark II, but comparison of that text with the text of the three identified Manhattan

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Project documents that name and describe the Mark II discloses that those three documents were the source of the description of the Mark II that Hewlett and Anderson published in *The New World.*

The information descriptive of the Mark II disclosed in the text of *The New World* and the information descriptive of the Mark II disclosed in the text of the three presently identified germane Manhattan Project documents permits the following composite description of the Mark II and the state of its development during the period 4 July–17 August 1944:

Mark II was a low-efficiency implosion bomb suitable for use with either U^{235} or plutonium (Pu^{239}). The nuclear fission chain reaction achieved by the Mark II utilizing a U^{235} active would be the result of slow (thermal energy) neutron fission. On 4 July the predicted energy yield of the Mark II was 1,000 tons TNT equivalent. On 17 July a test of the Mark II was predicted to yield a "moderate" explosion equivalent, at minimum, to "only a few hundred tons of TNT." By 17 August the "upper limit of effectiveness" achieved by the Mark II was known, but that information is classified. On 17 August, the Mark II could be developed for combat use in 3 or 4 months time and the upper limit of effectiveness could be "raised somewhat."

We will now review in detail the four available descriptions of the Mark II. The report of the Mark II provided by Hewlett and Anderson appears on pages 251-252 of the first edition of *The New World.* In autumn 1990 Richard Hewlett acknowledged in telephone conversation that he had been the lead author of that segment of *The New World* that describes the Mark II; he could then remember only one of the documentary sources he had consulted, James Conant's "Historical Note. Written July 27, 1944."

"Findings of Trip to L. A. [Los Alamos] July 4, 1944"
James Conant's report to General Groves.

On **4 July 1944** James Conant informed Gen. Groves by memorandum that detonation of the Mark II utilizing a 9 kg U^{235} active, or detonation utilizing a 2 kg plutonium active, was expected to yield a nuclear

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James Conant, "Findings of Trip to L.A. [Los Alamos] July 4, 1944"

fission explosion equivalent to the detonation of 1,000 tons of TNT. An optimal air burst of the Mark II with an energy equivalent of 1,000 tons TNT was expected to cause Class B damage (damage beyond repair) to an area of 2-5 square miles. Ten square miles of Class B damage was the goal Los Alamos set for optimal development of the Mark II. Conant informed Gen. Groves on 4 July 1944 that the Joint Chiefs of Staff should be informed they could "count on the Mark II for the purposes of operational planning," but Conant informed Gen. Groves the "Mark II will require one proof firing before the design is ready for use against the enemy."

During most of 1944 James Conant visited Los Alamos once each month to review technical and scientific developments and problems; during those visits he met with Los Alamos Director J. Robert Oppenheimer and others members of Oppenheimer's scientific staff. Conant would then make written reports of those visits addressed to Gen. Groves, which summarized his "findings." Conant either preferred travel by train or Gen. Groves had prohibited him to travel by airplane. For his trips to Los Alamos Conant boarded the Chicago-to-Los Angeles "Southwest Chief" at Chicago, Illinois, and rode one day and one night to Lamy, New Mexico, a few miles southeast of Santa Fe. A car and driver from Los Alamos would meet the "Chief" at Lamy and deliver Conant to Los Alamos.

On 23 June 1944 Conant wrote "Dear Oppie" that he planned to arrive at Lamy Sunday, 2 July, on the "Chief." He wrote, "Please do no feel that you or George [Kistiakowski], or any hard working scientist who needs his Sunday off, should come to meet me . . . I am planning to leave on Thursday [6 July] at 10:15 A.M." In consequence of this visit Conant wrote the document, "Findings of Trip to L. A. [Los Alamos] July 4, 1944," which is presently discovered only in his manuscript draft.

The second page of this report to Gen. Groves begins with Conant's advisement: "Recommend the following report to the 'top,' assuming one is confident of [SENSITIVE INFORMATION DELETED]." We cannot in fact determine from the text of this document what person or persons Gen. Groves would understand Conant to mean by the "top," but

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President Franklin D. Roosevelt had designated five persons to have determination of general policy in the Project, namely, Vice President Henry A. Wallace, Secretary of War Henry L. Stimson, Chief of Staff General George C. Marshall, James B. Conant, and Vannevar Bush. Those five men composed the President's General Policy Group, also known as the "Top Policy Group." Conant's recommendation to Gen. Groves that he provide this report to the "top" most probably is correctly interpreted to mean the Top Policy Group. Assuming the Top Policy Group to be the correct interpretation of Conant's allusion to the "top," those four men, Conant himself, and Gen. Groves may be said to have been cognizant of the information that Conant reported in this document.

Two other men were probably cognizant of the information this report provides about the Mark I and Mark II bombs—General Wilhelm D. Styer and Rear Admiral William R. Purnell. On 23 September 1942 the Top Policy Group, designated by President Roosevelt to have determination of general policy in the Project, had appointed the Military Policy Committee "to consider and plan military policy" relating to the Project. Members of the Military Policy Committee were Vannevar Bush, James Conant as Bush's committee alternate, Gen. Styer for the Army, and Adm. Purnell for the Navy. Because this document, "Findings of Trip to L. A. July 4, 1944," forecasts the availability of the Mark I and Mark II bombs for military use, we must reasonably infer that Gen. Styer and Adm. Purnell were among those men cognizant of the information this document discloses about the Mark I and Mark II bombs.

Furthermore, I have no doubt that President Franklin D. Roosevelt was, at least in summary, also informed of the information this report discloses about the Mark I and Mark II bombs. Of the Top Policy Group, Vice President Wallace, Secretary of War Stimson, Chief of Staff General Marshall, and Vannevar Bush did report directly to the President. Conant's report to the "top" forecasts the availability of the Mark I and Mark II bombs for military use, and those forecasts, he wrote, were "certain enough to be used as a basis for operational planning by the JCS [Joint Chiefs of Staff] . . . One can count on either 4 Mark I bombs (20-40 sq. [square] miles class B damage) or 20 Mark

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II bombs (2-5 sq. miles class B damage).” It is inconceivable that this information would not have been immediately conveyed to the President—that atomic bombs of superlative power could and certainly would be made, by what date and in what number those bombs would be available.

Although Conant’s 4 July 1944 forecasts were certain enough to be used as a basis for operational planning by the Joint Chiefs of Staff, he does stipulate in this report that the “Mark II will require one proof firing before the design is ready for use against the enemy.” That one required proof firing of the Mark II would, if successful, fulfill the requirement Conant would stipulate 13 days later, on 17 July, that a test of the Mark II was necessary to prove the Mark II a “fairly sure thing,” and which proof would permit a decision to put the Mark II on the shelf, and would permit Los Alamos to work on the Mark III with less nervousness.

The text of James Conant’s 4 July 1944 report, which he recommended that Gen. Groves provide to the “top,” is transcribed below. The reader should keep in mind the important fact that James Conant was not ever informed of the exact quantity of enriched uranium produced during the war. In this report Conant does report that U^{235} was then “in full scale manufacture,” but all references to the availability of U^{235} he identifies to be assumptions based on “present indications.” In one paragraph of this document, which does not occur in that portion of the document that is his report to the “top,” he asks, “What is the schedule for ‘25’ production in Sept., etc.?”

Conant did not have a need to know the exact U^{235} production results and Gen. Groves believed that secret information would be best kept during the war, and in the postwar years, by those few men who had a specific need to know that information to plan and implement use of the bombs for military purposes. From the several thousand wartime document pages of Conant’s authorship that I have carefully read, I have taken the conviction that Conant chose not to know the actual quantity of U^{235} that had been produced at any time during the war.

As shown in Chapter 12, Conant was aware that significant quantities of U^{235} had been produced during 1943, but he did not know to what

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degree that material had been enriched. I am confident that during the period 4 July–17 August Conant did not know that sufficient U^{235} had been separated to permit the required test of the Mark II. In my opinion, by 27 July 1944 Conant had deduced that the Port Chicago explosion had been the one proof firing of the Mark II that he had informed Gen. Groves on 4 July was necessary. In my opinion, on 27 July Conant made his "Historical note" to evidence in his own historical record, and for posterity, that the proof of the Mark II at Port Chicago had been planned, and that Oppenheimer was cognizant that test would occur later that same day, 17 July 1944. The text of Conant's 4 July 1944 report to Gen. Groves, which he recommended be transmitted to the "top," reads thus:

> "**Recommend the following report to the 'top' assuming one is confident of [SENSITIVE INFORMATION DELETED].**
>
> " 'We are confident that one bomb can be dropped on the enemy on Aug. 1 [1945] with every prospect of a success; the area of class B damage will be 20-40 square miles. Additional bombs could be dropped every six weeks thereafter. These bombs use the method of assembly (Mark I) which we are now confident will work for one of the two products under manufacture [i.e., U^{235}]. It suffers from the disadvantage that relatively large quantities are required. Work is now being pushed at [one word unreadable] speed on a second method of assembly (Mark II) which use[s] considerably smaller amounts of material. This in turn allows earlier delivery of a bomb and a greater number of bombs during the next twelve months. Initially this second method (Mark II) will represent a less efficient use of material but eventually after all the development work is complete it will probably prove a much more efficient bomb than Mark I. The present indications are that the first Mark II bomb (class "B" damage, 2-5 sq. [square] miles) will be ready in March and 3-6 such bombs can be produced before July 1. This forecast in regard to Mark II while extremely probable can not be made with the same confidence as the statement about Mark I since the research and development of the Mark II bomb is less far advanced and by the very nature of construction Mark II will require one proof firing before the design is ready for use against the enemy. These forecasts which we believe are certain enough to be used as a basis

> for operational planning by the JCS [Joint Chiefs of Staff] involve only material “25” [U^{235}] which is now in full scale manufacture. If the production of “49” [plutonium] which should commence in a few months is according to schedule the output of Mark II bombs before July 1 should be increased by two or three bombs. For the six months following July 1, 1945 one can count on either 4 Mark I bombs (20-40 sq. miles class B damage) or 20 Mark II bombs (2-5 sq. miles class B damage) as a minimum with a possible increase in production of 50% and a possible increase of effectiveness per bomb of 1.5-3 fold in area of class B damage.’ ”

James Conant, “Findings of Trip to L. A. [Los Alamos] July 4, 1944”; page 4 text enlargement

Page 4 of Conant’s “Findings of Trip to L. A. July 4, 1944” is mostly legible, with difficulty, but may not be legible in the reproduction of that page available earlier in this chapter. Therefore, a significant portion of the text of page 4 of this document is enlarged and a transcription of that text is provided. This particular text segment discloses that the Mark II was susceptible to use with either a 9 kg U^{235} or 2 kg plutonium active and would produce an explosion equivalent to 1,000 tons of TNT. The enlarged text of that page reads thus:

Assume 9 [kg] “25” by Jan 1 [1945], 1 test end of Jan, 1,000 T – “B” damage 2-5 sq miles (goal of 10 sq miles)

> Assume 9 “25” Feb 15, 1 gadget Mar 1

Assume 50 “25” by July 1, 1 test & 1 gadget Mar 15; 1 gadget April 15; 1gadget June 1; 1 gadget July 1 [5 gadgets at 9 kg U^{235} each = 45 kg]

> Assume 2 “49” [plutonium] by Jan 1, one test Jan
>
> Assume 10 “49” by July 1, one test, 4 gadgets by July 1
>
> 1 Gun gadget by Aug 1 in the bag, “B” damage 20-40 sq. miles
>
> If [text illegible] “25” by [one word illegible], then 1 G every 6-8 weeks

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“Historical Note. Written July 27, 1944.

James Conant, “Historical note. Written July 27, 1944”

James Conant. Reports events of 17 July 1944.

On the afternoon of **17 July 1944** James Conant in conversation with Los Alamos Laboratories Director J. Robert Oppenheimer urged that a test of the Mark II be conducted “as soon as possible” because, Conant said, the Mark II and was “almost a sure way” to produce a “moderate” nuclear fission explosion but, Conant added, a test of the Mark II might yield “only a few hundred tons of TNT equivalent.” A successful test of the Mark II, Conant urged Oppenheimer, would permit Los Alamos “to put Mark II on the shelf” and development of more powerful bombs at Los Alamos could proceed “with less nervousness.” Oppenheimer agreed a test of the Mark II was “a distinct possibility” but he told Conant “it was too early.” The Port Chicago Naval Magazine explosion occurred several hours later, the evening of 17 July 1944.

Richard Hewlett’s one paragraph that discloses information about the Mark II is derived from information exchanged in a 17 July 1944 conversation, at Chicago, Illinois, between Atomic Bomb Military Policy Committee alternate member, Harvard University President James B. Conant and Los Alamos Laboratories Director J. Robert Oppenheimer. The substance of that conversation is reported in James Conant’s “Historical Note. Written July 27, 1944”. Hewlett’s abstract and paraphrase of that “Historical note” reads thus:

“Those July [1944] days at Los Alamos were on the discouraging side. With the gun method out for plutonium, implosion remained the only hope for using the Hanford [plutonium] production. When Conant talked privately with Oppenheimer at the Chicago conferences, he found him pessimistic about the chances of developing it quickly. Conant suggested that the laboratory make plans for a low-efficiency implosion bomb suitable for both uranium 235 and plutonium. It seemed to him an almost certain way of utilizing some atomic energy, even if only the equivalent of a few hundred tons of TNT. Should the Los Alamos staff develop this bomb to the point where it seemed a fairly sure thing, they could set it aside as Mark II (the uranium gun bomb being Mark I) and go to work with less nervousness on Mark III, an

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implosion weapon that would require less metal and be more powerful. Oppenheimer agreed that this was a distinct possibility but thought it too early to tell."

Richard Hewlett's text provides this July 1944 information about the Mark II:

> Mark II was a low-efficiency implosion bomb susceptible to use with either U^{235} or plutonium. James Conant considered the Mark II an almost certain way to produce a nuclear fission explosion that would yield a minimum energy equivalent to a few hundred tons of TNT. Mark II was in development at Los Alamos, but not yet so sufficiently advanced that the bomb could be considered a fairly sure thing. If Los Alamos would so sufficiently develop the Mark II that it would seem a fairly sure thing, Mark II could be set aside and Los Alamos could work on a more powerful bomb, the Mark III, with more confidence. J. Robert Oppenheimer agreed that development of the Mark II was a distinct possibility, but he "thought it too early to tell." Although the Mark II would require more uranium or plutonium metal than the Mark III, Mark II would be a less powerful bomb.

Hewlett's abstract and paraphrase of Conant's "Historical note" does not, however, report the most important information about the Mark II that Conant's "Historical note" does disclose:

In conversation with Oppenheimer at the University of Chicago, several hours before the Port Chicago explosion, James Conant urged Oppenheimer that a test of the Mark II be conducted "as soon as possible." The Mark II, Conant said, "seemed to be almost a sure way of getting some atomic energy released." Conant's "Historical note" specifically characterizes the utilization of atomic energy that could be achieved by Mark II as a "moderate explosion." Conant further told Oppenheimer on 17 July that a successful test of the Mark II, "even if the resulting explosion were only a few hundred tons of TNT equivalent," would permit a Los Alamos decision that the Mark II could be "put on the shelf." And a successful test of the Mark II, Conant told Oppenheimer, would permit Los Alamos to "work on a Mark III with less nervousness," which is to say the theory of large scale nuclear fission weapons would have been proven by that test of the Mark II. Conant also reported in his "Historical note" that Oppenheimer responded "it was too early" to expect a test of the Mark II, but a test of the Mark II "was a distinct possibility." At 10:30 P.M. Pacific War Time Zone—00:30 A.M. Central War Time Zone, 18 July in Chicago, Illinois—the Port Chicago Naval Magazine exploded. Mark II had been tested.

Eckhart Hall, University of Chicago

Some information about that 17 July 1944 meeting in Eckhart Hall on the University of Chicago campus during which Conant and Oppenheimer discussed the Mark II is disclosed by a SECRET 11 July letter to Conant from University of Chicago Metallurgical Laboratory Project Director Arthur H. Compton. The letter, signed by Associate Project Director Norman Hilberry and received by James Conant 14 July, reads thus:

> "The next meeting of the Project Advisory Board will be held Monday evening July 17, 1944 at Eckhart. We are arranging for dinner at 6:00 o'clock preceding the meeting. The agenda will consist of two items:
>
> 1. Post-war plans for the Project as a guide for present changes in Project policy and organization.
>
> 2. The importance of light water moderated units in the over-all Project program and the effect on transfers of associated personnel required if the program is to be pushed."

I here provide a transcription of James Conant's manuscript, "Historical note. Written July 27, 1944"; the two manuscript pages of this document are also here reproduced.

"Historical note. Written July 27, 1944.

"On Monday July 17, 1944 [end of the line unreadable] conferences were held in Chicago involving the following people: A. H. Compton, J. R. Oppenheimer, C. [Charles] A. Thomas, J. B. Conant. And a special meeting in the evening attended by the above and Dr. Fermi & Gen. Groves & Col. [Colonel Kenneth D.] Nichols. The disquieting prospect first discovered [1 word unreadable] JBC by JRO on the visit to L. A. [Los Alamos] on July 4, (and confirmed by experiments reported on teletype of July 11, 1944 attached) was considered. It was concluded that the evidence was so clear

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that ‘49’ [plutonium] prepared at Hanford could not be used in the gun method of assembly that all work on the purification of ‘49’ & on the ‘49’ gun should be dropped (see attached letters).

“On Tuesday the decision to discontinue the chemical work [on plutonium] was announced by A. H. C. and C. A. T. to the group leaders at Chicago in somewhat cryptic terms. (The true story undoubtedly had leaked all around the shop, however!)

“Dr. Oppenheimer was not very optimistic about a speedy resolution of the implosion method which is now left as the only hopeful way of using 49. JBC in conversation with JRO urged that as soon as possible, plans be layed for [SENSITIVE INFORMATION DELETED] with moderate explosion as this seemed to be almost a sure way of getting some atomic energy released even if the resulting explosion were only a few hundred tons of TNT equivalent. If this could be considered a fairly sure bet it could be put on the shelf as ‘Mark II’ (the gun for ‘25’ [U^{235}] being Mark I) and people could work on a Mark III using [SENSITIVE INFORMATION DELETED] and correspondingly sure U. ε. with less nervousness. JRO said it was too early but this was a distinct possibility.

“Attached papers deal with this and related problems and status of work in July 1944.”

In August 1998, in consequence of an active intercession by the former Secretary of Defense, Stanford University Professor William J. Perry, the National Archives at College Park, Maryland, took action on a Freedom of Information Act (FOIA) request I had made two years earlier to obtain the complete text of Conant’s “Historical note.” The National Archives retained the classification of the two instances of redacted text which appear in the “Historical note” citing DOE classification codes NWDD 961083-1, DOE b(3) and DOE d(3).

The National Archives also reported that those papers which are cited in the concluding paragraph of Conant’s “Historical note,” and which are said there to be attached, could not be located. Specifically, the National Archives reported that Document 2 of the FOIA request, namely, “Attached papers deal with this . . .” was not located “in the withdrawn items or the open files.”

We now consider the descriptions of the Mark I, Mark II and Mark III bombs, and the differences between them, that Conant discussed in

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conversation with Oppenheimer 17 July 1944 and ten days later recorded in this “Historical note.” Those differences provide information about the design, technology and state of development of the Mark II by 17 July 1944.

Mark I.

Conant’s “Historical Note" identifies the Mark I as “the gun for ‘25’ [U^{235}]”— the gun-assembly Little Boy bomb. In earlier chapters we established that the Mark I utilized a highly enriched uranium active—uranium enriched to 90 or 93 per cent U^{235}. Conant’s “Historical note” confirms that the Mark I was not susceptible to use with plutonium; he wrote, “ ‘49’ [plutonium] prepared at Hanford could not be used in the gun method of assembly.”

Mark II.

Richard Hewlett reported in *The New World* that the Mark II was “an implosion bomb,” but he does not provide any documentary reference that we might review to confirm his attestation that the Mark II was an implosion bomb. Conant’s “Historical note” does not disclose that the Mark II was an implosion bomb, nor does Conant’s “Findings of Trip to L. A. 4 July 1944” disclose that the Mark II was an implosion bomb. As will be shown below, the Mark II was in fact an implosion bomb.

Hewlett also reported that the Mark II was a “low-efficiency” bomb, but again he does not provide any documentary reference that we might review to confirm that the Mark II was a low-efficiency bomb, nor does he identify the standard of comparison which determined his assessment that the Mark II was a low-efficiency bomb.

The efficiency of a nuclear fission bomb is expressed as that percentage of a bomb’s available fissile atomic nuclei that will fission before the bomb’s active material is so sufficiently heated, and consequently expanded, by the release of fission energy that the nuclear fission chain reaction ceases. A fission bomb would achieve 100 per cent efficiency if every available fissile nucleus did fission before the fission chain reaction ceased. We are able to use the Mark I bomb detonated at Hiro-

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shima as a standard to which the efficiency of the Mark II can be compared.

We have seen that the complete fission of 1 kg U^{235} would produce an energy of explosion equivalent to the explosion of 22,000 tons of TNT. Detonation of the Mark I at Hiroshima, which employed a 50 kg U^{235} active, produced an energy of explosion equivalent to 12,500 tons of TNT. The complete detonation of 50 kg U^{235} would have produced an energy of explosion equivalent to 1,100,000 tons of TNT; therefore the efficiency of the Mark I bomb is calculated to have been 1.14 per cent. Current designs of gasoline automobile engines operate in the range of 25-28 per cent fuel efficiency, or less.

In his “Findings of Trip to L. A. July 4, 1944” Conant forecast that the Mark II, with a 9 kg U^{235}, would yield an energy of explosion equivalent to 1,000 tons of TNT. The complete fission of 9 kg U^{235} would produce an energy of explosion equivalent to 198,000 tons of TNT. The efficiency of the Mark II, with a 9 kg U^{235} active, is therefore calculated to have been 0.51 per cent. The Mark II, with an efficiency of 0.51 per cent, was a low-efficiency bomb in a comparison with the 1.14 per cent efficiency of the Mark I.

Hewlett also reported in *The New World* that the Mark II was suitable for both U^{235} and plutonium, but he does not provide any documentary reference that we might review to confirm his attestation that the Mark II was suitable for both U^{235} and plutonium, and Conant’s “Historical note” does not name the fissile material that could be utilized by the Mark II. Conant’s “Findings of Trip to L. A. July 4, 1944” does, however, report that the Mark II, with either a 9 kg U^{235} active or a 2 kg plutonium active, would yield an energy of explosion equivalent to 1,000 tons TNT.

Close analysis of the text of Conant’s “Historical note” does in fact disclose that the Mark II was designed to utilize U^{235} and, more specifically, that the Mark II was designed to use slightly enriched uranium, rather than the highly enriched uranium for which the Mark I was designed. The information that the Mark II was designed to use a slightly U^{235}-enriched uranium active is gleaned from the text of the Conant’s “Historical note” which reports that, given a successful proof of the Mark II, “people could work on a Mark III using [SENSITIVE INFORMATION DELETED] and correspondingly sure U.ε. with less nervousness.”

Note: Current terminology in the commercial nuclear power reactor industry defines slightly enriched uranium fuel to be 2-5 per cent U^{235}, highly enriched fuel to be 20-30 per cent U^{235}, and fully enriched fuel to be greater than 90 per cent U^{235}. In preceding chapters, here, and hereafter I use the terms “slightly enriched uranium” and “highly enriched uranium” as those terms were current in Manhattan Project usage: respectively, 20-30 per cent U^{235} and 90-93 per cent U^{235}.

This text of Conant’s “Historical note” discloses a fundamental difference between the Mark II and Mark III, which difference enables us to determine that the Mark II was susceptible to use with a slightly enriched uranium active. In a comparison with the Mark II, Conant wrote that the Mark III would use the “correspondingly sure U.ε.” Readers acquainted with the fundamentals of nuclear physics will immediately recognize that the Greek alphabetical character epsilon, ε, is the symbol that designates the “fast fission factor” in highly enriched uranium, and that Conant here distinguishes between the Mark III the efficiency of which would depend on operation of the fast fission factor, necessarily, in a highly enriched uranium active, and the Mark II the efficiency of which would not depend on operation of the fast fission factor and, therefore, necessarily, a slightly enriched uranium active. All other readers will require an explanation of the fast fission factor (ε).

Fast fission

The neutron is an atomic particle that carries neither a positive nor a negative charge—the neutron is neutral. The neutron was first identified in 1932 by the British physicist James Chadwick who received the 1935 Nobel Prize in physics for that discovery. Neutrons produced by the nuclear fission reaction are the essential source of neutrons available to sustain a nuclear fission chain reaction in either a uranium-fueled nuclear power reactor or a uranium fission bomb. The

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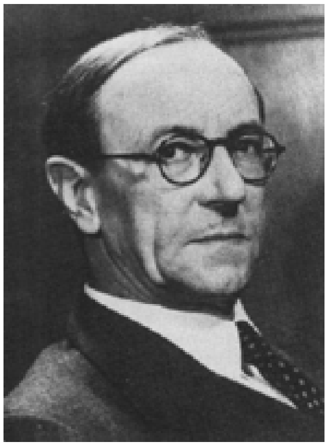
fission of one U^{235} nucleus produces an average of 2.5 free neutrons. Because the average number of free neutrons produced by the fission of one U^{235} nucleus is greater than the one neutron expended to induce that fission, a nuclear fission chain reaction is feasible.



James Chadwick
1891 - 1974

The greatest number of neutrons produced by the nuclear fission reaction begin their journey in their own minute space as fast, high energy neutrons with an average kinetic energy in the range of 1 million electron volts (1 MeV). In early February 1939 the Danish physicist Niels Bohr recognized that the principal isotopes of natural uranium, U^{235} and U^{238}, must have different fission properties. He predicted, in publication, that the least abundant uranium isotope, U^{235}, would be easily enough destabilized to be fissioned by slow neutrons, namely, a neutron that has a kinetic energy no greater than 1eV—one million times less than the original energy of the greatest number of neutrons produced by the fission process.

The initial high energy of a fission-produced neutron can, however, be reduced or moderated to the energy most likely to induce fission in the U^{235} nucleus, which is to say, reduced to slow or thermal neutron energy. The predominant isotope of natural uranium is the non-fissionable U^{238} isotope. Two possible effects result from the collision or impingement of a high energy fast neutron with a U^{238} nucleus. The majority of high energy neutrons (higher than 1 MeV) that collide with a U^{238} nucleus are captured by that nucleus, and those captured neutrons are lost to the process of a nuclear fission chain reaction. Alternatively, a high energy neutron that collides with U^{238} nucleus may not be captured but will be partially slowed by inelastic scattering from that nucleus. That scattered neutron is somewhat energy moderated, but to effect fission of a U^{235} nucleus that partially energy-moderated neutron must be reduced to slow energy by elastic scattering from collisions with lighter nuclei that may be naturally present or may be introduced artificially. When a neutron collides elastically with another nucleus at rest in the medium, it transfers some of its energy to that nucleus. The maximum transfer of energy occurs when the target nucleus is comparable in mass to the impinging neutron.

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Among all atomic nuclei, the mass of the hydrogen nucleus is most comparable to the mass of the neutron. Water (H_2O), which consists of two hydrogen atoms and one oxygen atom, is a good neutron energy moderator, but the particular hydrogen isotope (protium) of which the water molecule is composed has a fairly high propensity to capture and hold an impinging neutron, thereby removing those captured neutrons from the fission process. Three isotopes of hydrogen are known. The most abundant is protium (H, with a single proton) followed by deuterium (D, with one proton and one neutron) and the least abundant tritium (T, with one proton and two neutrons).

Of the three hydrogen isotopes, deuterium (also known as the deuteride isotope of hydrogen) manifests the least propensity to capture and hold an impinging neutron, and therefore offers the greatest probability, among the hydrogen isotopes, that an impinging neutron will be elastically scattered, rather than captured, and an energy reduction accomplished. After a series of, on average, 18 elastic collisions an initially high energy, fast neutron is moderated to slow or thermal energy. So, if the deuteride hydrogen isotope, deuterium, could be separated from natural hydrogen, that isotope would be the best possible neutron energy moderator.

For a uranium fission bomb with a slightly U^{235}-enriched active, a significant percentage of the U^{238} nuclei present in natural uranium would have been removed from the active material by isotope separation, which would significantly reduce the number of U^{238} nuclei in the active and, therefore, reduce the number of fast neutrons lost to the fission chain reaction by U^{238} capture. Thereby, a greater number of fast neutrons produced by U^{235} fission would be available to be elastically scattered by collision with a deuterium nucleus and, in consequence, moderated to the slow neutron energy most effective to sustain the bomb's U^{235} nuclear fission chain reaction.

In 1921 Harold Clayton Urey (1893-1981) entered the University of California and in 1923 was awarded the degree of Ph.D. in Chemistry, by which time he was well acquainted with J. Robert Oppenheimer at the Berkeley campus of the University of California. Urey spent the following year in Copenhagen at Niels Bohr's Institute for Theoretical

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Harold Clayton Urey
1893-1981

Physics and then returned to Johns Hopkins University as an Associate in Chemistry. In 1929 he was appointed Associate Professor in Chemistry at Columbia University. In 1931 he devised a method for the concentration of any possible heavy hydrogen isotopes by the fractional distillation of liquid hydrogen, which led to his discovery of deuterium and the Nobel Prize in Chemistry in 1934 for that discovery. With E. W. Washburn, Urey then quickly evolved the electrolytic method for the separation of hydrogen isotopes. During the period 1940-1945 Urey was Columbia University's director of war research.

During early February 1939 Niels Bohr had predicted, in publication, that the least abundant uranium isotope, U^{235}, would be easily enough destabilized to be fissioned by slow neutrons. On 5 February 1939, J. Robert Oppenheimer wrote to the physicist George Uhlenbeck, then a visiting professor at Columbia University, "I think it really not too improbable that a 10 cm [centimeter] cube of uranium deuteride (one should have something to slow the neutrons without capturing them) might very well blow itself to hell."

J. Robert Oppenheimer to George Uhlenbeck, 5 February 1939

In this 5 February 1939 letter to Uhlenbeck, Oppenheimer first proposed what Los Alamos would develop to be the low-efficiency Mark II uranium hydride bomb, in which the deuteride hydrogen isotope was used to moderate the energy of fast fission neutrons to slow (thermal) energy neutrons in a slightly U^{235}-enriched active.

There are, therefore, so far three men identified who can be said to have been principal to the development of the Mark II: James Chadwick, who discovered the neutron by which artificially induced nuclear fission was achieved in the Mark II; Harold Urey, who discovered the deuteride hydrogen isotope by which the neutron energy moderation requisite to the nuclear fission chain reaction in the Mark II was achieved; and J. Robert Oppenheimer who first proposed that a slow neutron fission of uranium deuteride "might very well blow itself to hell."

By March 1940 British experiments showed that both fast and slow neutrons would induce fission in U^{235}, but to accomplish fast neutron fission of uranium the U^{235} isotope would need to be separated from the U^{238} isotope to the degree of 90 to 93 per cent. The result of that

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concentration of U^{235} would increase the proximity of U^{235} nuclei and that proximity would permit U^{235} fission by fast fission neutrons. Fission of highly enriched uranium by fast neutrons was, by 1940, designated the fast fission factor and identified by the Greek alphabetical character epsilon, **ε**. In March 1940 refugee German scientists Otto Frisch and Fritz Peierls, living in England, proposed to the British government that an atomic bomb would be feasible if the least abundant and most readily fissionable of the uranium isotopes, U^{235}, were separated from its occurrence in natural uranium, which would eliminate the depletion of neutrons in the system by non-fission neutron capture by nuclei of the U^{238} isotope. An accumulation of essentially pure U^{235}, Frisch and Peierls argued, would be susceptible to fission entirely by fast neutrons. That proposal was the basis of the Mark I gun assembly bomb and the Mark III.

"Report to Gen. Groves on Visit to Los Alamos on August 17, 1944"
James Conant's report to General Groves.

Report to Gen. Groves on Visit to Los Alamos on August 17, 1944

On **17 August 1944** in this memorandum to Gen. Groves, James Conant reported the decision had been made at Los Alamos "that Mark II should be put on the shelf for the present. If all other implosion methods fail, Mark II can be taken off the shelf and developed for combat use in 3 or 4 months time." He additionally reported in this memorandum, "If all other implosion methods fail, it may be necessary to work on the Mark II to see if at least the upper limit of effectiveness [SENSITIVE INFORMATION DELETED] cannot be raised somewhat." In conclusion of this memorandum, in his "Note on explosive damage," Conant informed the General, "It was agreed that Class B damage was damage beyond repair. For the phrase to be of significance the type of structure must also be named. It was agreed that for dwelling houses the area of 90% Class B damage was about as follows for 1,000 tons of TNT: 90% Class B damage = 0.5 mile radius = 0.75 square mile."

The reader will recall that on the afternoon 17 July 1944 (reported 27 July 1944) Conant stipulated in conversation with Oppenheimer that a decision to put the Mark II on the shelf would require that a successful test of the Mark II had been accomplished. Because on 17 August 1944

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Conant reported the decision "that the Mark II should be put on the shelf for the present," the reader may infer that the stipulated successful test of the Mark II had been accomplished in the period between the afternoon of 17 July and 17 August 1944.

The reader will recognize that Conant's 17 August 1944 "Note on Explosive Damage" refers to explosive damage that "was damage beyond repair" and that "the area of Class B damage was . . . 0.5 mile radius." The reader will reasonably want to know what particular explosive damage Conant reports "was damage beyond repair" and what particular explosive damage Conant reports did occur within a 0.5 mile radius, where and when. The explosive damage to which Conant refers is not named in the declassified portions of this document, and informally the National Archives, College Park, Maryland, has told me that the explosive damage to which Conant refers is not named in the classified portions of this document.

Earlier chapters of this book have established that the radius of Class B damage that did result from the Port Chicago Naval Magazine explosion was 2,500 feet, which is a 0.5 mile radius (1 mile = 5,280 feet; 0.5 mile = 2,640 feet). Specifically, Los Alamos physicist Ensign George T. Reynolds, USNR, wrote in his 27 July 1944 "Report on Port Chicago, July 20-24, 1944": "From all observations, smoothing out directional effects, the average B radius is considered to be 2500 feet."

Ensign Reynolds' "Report on Port Chicago, July 20-24, 1944" is Enclosure (C) of Capt. William Parsons' 4 August 1944 memorandum to Atomic Bomb Military Policy Committee member Adm. William R. Purnell, "Port Chicago Disaster: Second Preliminary Report."

The decision made at Los Alamos, reported by James Conant on 17 August 1944, to put the Mark II on the shelf was made specifically in consequence of the Port Chicago explosion. The upper limit of the Mark II's effectiveness was known specifically in consequence of the Port Chicago explosion. James Conant's 17 August 1944 report to Gen. Groves that the Mark II could be developed for combat use in 3 or 4 months time was made specifically in consequence of the Port Chicago explosion.

Previous chapters have shown that the fireball and column of flame that did result from the Port Chicago explosion were typical of a nuclear fission explosion and could not have been generated by the explosion of the 1,750 tons TNT and torpex charge weight of munitions emplaced upon the Port Chicago Naval Magazine pier and loaded as cargo aboard the Liberty ship *E. A. Bryan,* which was moored to the Port Chicago Naval Magazine ship loading pier.

Mark II: The autocatalytic uranium hydride lateral implosion experimental device.

Vice Admiral Frederick L. Ashworth, USN, Ret.

In spring 1993 Los Alamos National Laboratory Archivist Roger Meade advised me that Adm. Frederick L. Ashworth was resident in Santa Fe, New Mexico, and Meade recommended I make arrangements to meet the admiral to discuss my preparation of a biography of Rear Admiral William S. Parsons. I was then in the middle of seven years at Stanford University and there employed in one of the molecular biology research laboratories in the Department of Biological Sciences. The Stanford University libraries hold one of the most comprehensive collections of Manhattan Project historical literature and materials of any university library. That collection was assembled to provide research materials of particular interest to two Stanford history professors and their students. In earlier years, the history of the Manhattan Project had been a defined curriculum emphasis for students in the Stanford History Department.

In summer 1993 I met Adm. Ashworth to discuss my proposal to research and write a biography of Adm. Parsons. Captain Parsons, before his assignment to Los Alamos, had been assigned to the office of National Defense Research Committee Chairman Vannevar Bush, to coordinate NDRC and Navy development of the proximity fuze, also known as the VT (variable time) fuze. (See: Ralph B. Baldwin, *The Deadly Fuze: Secret Weapon of World War II.* San Rafael, California: Presidio Press, 1980) During that time Commander Ashworth had been Capt. Parsons' "fly boy," which is to say that usually wherever Capt.

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Parsons was flown by Navy aircraft, Commander Ashworth was the pilot.

Captain Parsons arrived on duty at Los Alamos in May 1943 but when he began his assignment there he was persuaded by Gen. Groves not to travel by air and, with that restriction, Commander Ashworth's duty as Capt. Parsons' pilot was not required. However, three months after the Port Chicago explosion, in October 1944, Commander Ashworth was assigned duty at Los Alamos where he reported to Capt. Parsons and was his deputy. Their work together there, built upon their several years of prior acquaintance, enabled a remarkable association in the Project and a friendship that continued until Adm. Parsons' death in 1953. On 6 August 1945 Capt. Parsons was the bomb commander on the Hiroshima combat mission, and three days later Commander Ashworth was the bomb commander on the Nagasaki combat mission. In summer 1993 Adm. Ashworth's knowledge of Adm. Parsons, the man and naval officer, was the most comprehensive of any person living.

Tinian Island, prior to 6 August 1945. Left to right: Norman Ramsey; Capt. William S. Parsons, USN; Edward Doll; Col. Ernest Kirkpatrick, USA; Commander Frederick L. Ashworth, USN

Admiral Ashworth agreed that a biography of Adm. Parsons was very much needed. The Manhattan Project historical literature published by 1993 did only in several instances briefly mention the role of the United States Navy in the Project. That deficiency of the historical record existed because Adm. Parsons, Adm. Ashworth, nor the Navy service had written any detailed account of the Navy contributions to the Project. The Army had caused to be written and published a thorough account of the Army participation in the Project; Gen. Groves' autobiographical account of his role in the project had been published.

Another contributing cause of that deficiency lies in the fact that the memoirs of those civilian scientists who were associated with the Project assert mainly the authors' contributions to the project and

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ignore or minimize those aspects of the project of which they were ignorant or in which they could claim no principal credit. Furthermore, those academic historians whose publications have largely influenced the public perception of the Project history have been more sympathetic in common collegial association with the civilian scientists associated with the Project than with those few members of the Navy who were associated with the Project, whose appellations were Capt. and Comdr. rather than the collegial Prof. and Dr.; that collegial bias has caused the Navy role in the Project to have been minimized by academic historians, where it has not been ignored.

The needful task of writing the first biography of Adm. Parsons eventually was done by Albert Christman who, as a civilian Navy employee, had made a good start in the necessary research during the late 1960s and early 1970s at the China Lake Naval Weapons Station in California but soon thereafter abandoned the work. Following 1993 Christman was either persuaded or directed to complete that biography, *Target Hiroshima,* published by the U.S. Naval Institute Press in 1998.

In 1981, I had been admitted to the Archives at Los Alamos National Laboratory to review the 7 linear feet of documents, declassified at my request, held by the Archives that pertain to the Port Chicago explosion; prominent among those documentary resources are the extensive reports and analyses of the Port Chicago explosion transmitted by Capt. Parsons to Adm. Purnell from 24 July through 16 November 1944.

When Adm. Ashworth and I concluded our discussion of my proposal to write a biography of Adm. Parsons, I turned our conversation to the Port Chicago explosion, which necessarily would be an element of that biography because the principal reports and analyses of that explosion had been prepared by Capt. Parsons, and the major component analyses of those reports had been prepared by Los Alamos scientists Maurice M. Shapiro and Ensign George Reynolds under Capt. Parsons' direction.

I asked Adm. Ashworth if he had been aware of the Port Chicago explosion, at that time; he replied he had not arrived at Los Alamos until three months later. I explained that I had made a study of all the materials descriptive of the explosion that I had been able to locate during 13 years, including those reports that Capt. Parsons had transmitted to Adm. Purnell, and the “History of 10,000 ton gadget” which asserted that the ball of fire generated by the Port Chicago explosion had been typical of a nuclear fission explosion. I explained that I had also located three pertinent Manhattan Project documents, all authored by James Conant and dated from 4 July through 17 August 1944.

On 4 July 1944, I said, Conant had informed Gen. Groves that a bomb, which Conant named the Mark II, was available to the Joint Chiefs of Staff for the purposes of operational planning. In that report, I said, Conant forecast that the Mark II, with either a 9 kg U^{235} or 2 kg plutonium active, would yield an energy of explosion equivalent to 1,000 tons of TNT. In that report Conant had also informed Gen. Groves that the Mark II would require one proof firing before it could be available for use against the enemy.

On 17 July, I said, Conant had urged Oppenheimer to conduct a test of the Mark II as soon as possible, even if the energy yield were only equivalent to several hundred tons of TNT. A successful test of the Mark II, Conant then told Oppenheimer, would permit a decision by Los Alamos to put the Mark II on the shelf, and work on the more powerful bombs could proceed with less nervousness.

On 17 August 1944, I said, Conant informed Gen. Groves that the Mark II could be developed for combat use in 3 or 4 months times, but Conant reported that Los Alamos had decided that the Mark II should be put on the shelf unless all other implosion methods failed. On 17 August, I said, Conant had reported the upper limit of effectiveness for the Mark II to Gen. Groves, which he felt could be somewhat raised. I said all the information provided by Conant’s 17 August report to Gen. Groves had been determined in specific consequence of the Port Chicago explosion.

Taken together, I said, those three documents and the “History of 10,000 ton gadget” had persuaded me that a proof of the weapon that James Conant identified as the Mark II had been the cause of the Port Chicago explosion. However, I said, I had been unable to learn more about the Mark II than it was a low-efficiency implosion design suitable for use with either a 9 kg U^{235} or 2 kg plutonium active and that

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the predicted energy yield of the Mark II ranged between a few hundred tons of TNT and 1,000 tons.

I then asked Adm. Ashworth if he were able to provide more specific information about the design and technology of the Mark II than I had discovered. In response, Adm. Ashworth identified the Mark II to have been "the autocatalytic uranium hydride lateral implosion experimental device."

Lacking Adm. Ashworth's specific identification of the Mark II, I would not have been able to develop a comprehensive history of the development of that weapon, because nowhere in the presently declassified Manhattan Project documentary materials is that identification made, nor can that identification be deduced or inferred.

Frederick Lincoln Ashworth graduated from the United States Naval Academy and completed the Naval Postgraduate School course in ordnance engineering shortly before the Japanese attack on Pearl Harbor in 1941. After service in the Pacific Theater of Operations, then as Capt. Parsons' pilot, and following his assignment at Los Alamos, in company of then Commodore Parsons, Ashworth was assigned to Washington to lead the Navy into the nuclear age. Ashworth participated in the July 1946 Bikini atomic tests as Adm. Parsons' deputy. For the period August 1955–September 1957, Capt. Ashworth was Commander of the Naval Ordnance Test Station (NOTS), China Lake, California. After leaving China Lake, and elevated to the rank of rear admiral, Ashworth became Commander of the Sixth Fleet. Elevated to the rank of vice admiral, Ashworth was named Deputy Commander in Chief of the Atlantic Fleet.

Lamentably, a full account of Adm. Ashworth's life and United States Navy career has not been written. Two important filmed interviews with the admiral were conducted by the late historian Stanley Goldberg for the Smithsonian Institution and are available in the Smithsonian Videohistory Collection, "The Manhattan Project" (RU 9531. Collection Division 5: "Alberta": Session Seventeen, June 5, 1990, and Session Eighteen, June 6, 1990). Jerry Miller's *Nuclear Weapons and Aircraft Carriers: How the Bomb Saved Naval Aviation.* (Washington, D.C.: Smithsonian Institution Press, 2001) is a very important history

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that provides some discussion of Adm. Ashworth's naval career. See also, Albert Christman's two-volume history of the China Lake, California, Naval Weapons Station (Naval Ordnance Test Station, NOTS): *Sailors, Scientists, and Rockets* (Washington, D.C.: U.S. Government Printing Office, 1971) and *The Grand Experiment at Inyokern* (Washington, D.C.: U.S. Government Printing Office, 1978).

Photographs and illustrations credits.

"James B. Conant with Vannevar Bush after witnessing the atomic bomb explosion at Trinity site, Alamogordo, New Mexico, 16 July 1945." I am confident this photo was taken by the light of the Trinity fireball. The illumination of this photo is certainly not that of a camera-mounted flash bulb exposure, because the illumination comes from above Conant's right shoulder rather from the photographer's straight-on position, as is evident by the orientation of Conant's shadow cast on the background. The orientation of Conant's shadow reveals that the source of illumination is some 30 degrees above the horizontal. Conant and Bush were at least 10,000 yards from the explosion. Both men face away from the source of illumination. Conant and Bush are pictured in a moment of solemn acknowledgment that the purpose of their endeavor, to produce a militarily-decisive atomic bomb, has been accomplished. Source: Massachusetts Institute of Technology Museum, photograph VB120, "Vannevar Bush with James B. Conant after witnessing the first atomic bomb explosion at Alamogordo, NM, July 16, 1945." Used with permission.

"James Conant, "Findings of Trip to L. A. July 4, 1944." Source: National Archives Microfilm Publications, "Bush-Conant File Relating to the Development of the Atomic Bomb, 1940-1945; Records of the Office of Scientific Research and Development Record Group 227," reel No. 1, frames Nos. 828-833.

"James Conant, 'Findings of Trip to L. A. July 4, 1944.' " Page 4 text enlargement. Source: National Archives Microfilm Publications, "Bush-Conant File Relating to the Development of the Atomic Bomb, 1940-1945; Records of the Office of Scientific Research and Development Record Group 227," reel No. 1, frame No. 830.

James Conant, "Historical note. Written July 27, 1944." Source: National Archives Microfilm Publications, "Bush-Conant File Relating to the Development of the Atomic Bomb, 1940-1945; Records of the Office of Scientific Research and Development Record Group 227," reel No. (unrecoverable), frames Nos. 112, 113.

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"Eckhart Hall, University of Chicago." Source: University of Chicago.

"James Chadwick, 1891-1974." Source: University of California.

"Harold Clayton Urey, 1893-1981." Source: University of California.

"J. Robert Oppenheimer to George Uhlenbeck, 5 February 1939." Source: Smith, Alice Kimball and Charles Weiner, *Robert Oppenheimer: Letters and Recollections.* Cambridge, MA: Harvard University Press, 1980. Reference by the courtesy of Jonothan Logan.

James Conant, "Report to Gen. Groves on Visit to Los Alamos on August 17, 1944." Source: National Archives Microfilm Publications, "Bush-Conant File Relating to the Development of the Atomic Bomb, 1940-1945; Records of the Office of Scientific Research and Development Record Group 227," reel No. 8, frames Nos. 114-117.

"Tinian Island, prior to 6 August 1945." Left to right: Norman Ramsey, Project Alberta deputy director; Capt. William S. Parsons, USN, head of Project Alberta; Edward Doll, head of atomic bomb fuzing team; Col. Ernest Kirkpatrick, USA, coordinator of Project Alberta overseas construction; Commander Frederick L. Ashworth, USN, Alberta operations officer and Parsons' military alternate. Source: Courtesy of Morris Jepson, Capt. Parsons' electronics assistant on the 6 August Hiroshima combat mission.