LEGAL CONTROL OF THERMONUCLEAR ENERGY:
THE ATOMIC ENERGY ACT AND THE
HYDROGEN PROGRAM

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The thermonuclear age can be dated from no later than the “Mike”
test explosion which occurred at the Atomic Energy Commission’s
Pacific proving grounds in the fall of 1952.¹ Former President Truman
announced as long ago as January 1953 that “from now on, man moves
into a new era of destructive power, capable of creating explosions of
a new order of magnitude, dwarfing the mushroom clouds of Hiroshima
and Nagasaki.”² Since the Mike test, the Commission has proceeded
to “refinement of design and other development” and has held a new
series of thermonuclear tests last winter and spring.³ The energy
release for hydrogen weapons is measured by multa “megaton” units.⁴
A megaton represents the equivalent in energy release of a million tons
of TNT and may be compared with the measurement of A-weapons
by the kiloton, or thousand tons of TNT equivalent.

The full significance of thermonuclear energy, however, is not
necessarily limited to the destructive power which underlies these
events. Shortly before his death Senator McMahon commented that
“there is now hope . . . that possibly there may develop—years hence—
important peacetime applications of hydrogen principles. This all
amounts—or may amount—to a basic change in the focus of the
control problem.”⁵ In the fall of 1952 Senator Hickenlooper said that

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¹ See the complete text of the motion picture, public release version, “Operation Ivy,”
³ Statement by Lewis L. Strauss, Chairman, Atomic Energy Commission, mimeo. press
Strauss, Chairman, AEC, and Charles E. Wilson, Secretary, DOD, announcing completion
of the 1954 series of “thermonuclear tests.”
⁴ Cf. Dept. of State pamphlet, Atomic Power for Peace, Address by President Dwight
⁵ Partial text of address, mimeo. release from the office of Senator Brien McMahon of
Connecticut, June 14, 1952, at p. 4.
“the hydrogen picture contains some hope, in time, for peaceful and constructive applications.” And recently, the Senator has seen “definite reason to hope that applications of new principles we are learning in the so-called fusion field can have great possibilities in the future for industrial and humanitarian uses.” These observations were foreshadowed by Dr. Hans Bethe as early as 1945, when he stated that reactions between light nuclei are of “possible interest for the future development of atomic power, although the difficulties are undoubtedly very great.”

If the extraordinary importance of thermonuclear energy be taken as a first point of departure, the second is that United States development may lag significantly behind where it might be. This statement is suggested by the apparent Russian progress in thermonuclear weapons and a comparison of the apparent rate of their development with our own.

In August 1953 the U.S.S.R. announced that they achieved a thermonuclear reaction by test and the United States has confirmed.

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7 Dr. George Gamow, an Atomic Energy Commission consultant, was reported to have commented that, while he didn’t know what Senator Hickenlooper had in mind, “It’s at least theoretically possible to get ‘a slowed-down’ atomic reaction with hydrogen bomb materials” and he referred to certain “theoretically possible techniques.” Carey, “H-bomb Taming for Peaceful Use Detailed,” The Evening Star, Washington, D.C., Dec. 5, 1952, p. A-36:2-4.
9 Hearings before the Special Committee on Atomic Energy Pursuant to S. Res. 179, 79th Cong., 1st sess., p. 224 (1945) (hereinafter cited as S. Res. 179 Hearings.)
10 On August 20, 1953 the Communist Party newspaper, Pravda, stated:
   “Recently in the Soviet Union, the explosion of a type of hydrogen bomb was carried out with an experimental aim.
   “As a result of the possession of the mighty power of thermonuclear fission in the hydrogen bomb, the explosion was of great strength.
   “The test showed that the power of the hydrogen bomb is many times greater than the power of the atomic bomb.” Partial text, as quoted in The Evening Star, Washington, D.C., Aug. 20, 1953, p. A-4:2-3.
11 It is to be noted that four days before the Soviet tests Premier Malenkov stated to the Supreme Soviet that his government deemed it “necessary to report to the Supreme Soviet that the United States has no monopoly in the production of the hydrogen bomb. . . .” Translation from the N.Y. Times, Aug. 9, 1953, p. 29:1. To have made such an assertion before the Soviets actually achieved their first explosion involving thermonuclear reactions is in its way extraordinary, and it would appear to bespeak the confidence of the Soviet officials in the device they were about to test. Immediately following the Malenkov remarks on August 8, 1953, Chairman Strauss of the Commission stated that “We have never assumed that it was beyond the capability of the Russians to produce such a weapon and that is why, more than three years ago, it was decided to press forward with this development for ourselves.” U.S.A.E.C. Release No. 494, Aug. 8, 1953.
12 The text of U.S.A.E.C. Release No. 495, Aug. 20, 1953, is as follows:
   “The Soviet Union conducted an atomic test on the morning of August 12. Certain information to this effect came into our hands that night. Subsequent information on the subject indicates that this test involved both fission and thermonuclear reactions.
   “It will be recalled that more than three years ago the United States decided to
the report. The Soviet test was of a “weapon or the forerunner of a weapon” and occurred within four years of their first A-bomb test, announced in September 1949.

Comparable United States dates appear to be July 1945 when the first A-bomb was detonated in New Mexico and the fall 1952 test in excess of seven years later. In terms of the interval between the A-bomb and a major thermonuclear reaction, the Russians appear to have required only four years where we have consumed seven. In terms of the rate of thermonuclear development, we seemingly have consumed 75 percent more time than the Russians.

Both the Chairman of the Atomic Energy Commission, Lewis L. Strauss, and the Chairman of the Congressional Joint Committee on Atomic Energy, Sterling Cole, have addressed themselves to Russian progress and to United States development of hydrogen bombs. On September 30, 1953, Chairman Strauss said:

“I am sure that you will not expect me to say much about the newest weapons. We began their active development in 1950 which proved to be a fortunate decision as the Soviets with their smaller industrial establishment were able to test a thermonuclear device within nine months of our own. If one concedes our industrial and technical superiority, I can only deduce—and here I speak solely as an individual—that the Soviets had begun their development some considerable time before we did—benefiting through the espionage and treason of which we have been the victims. I profoundly wish that research might have proved the whole principle impossible, but, since it was feasible, I am grateful that the counsel did not prevail which would have deferred or accelerated work on all forms of atomic weapons. Both the 1951 and the 1952 Eniwetok test series included tests involving similar reactions.”

See also the statement of President Eisenhower before the General Assembly of the United Nations, note 4 supra, at p. 5: “. . . the Soviet Union has exploded a series of atomic devices, including at least one involving thermo-nuclear reactions.”

Prior to the August 12, 1953 test, the announcement of Soviet atomic test activity had first been made by the United States, with the Soviet Union issuing any confirmation later. The order of announcement was reversed for the first time with the August 12, 1953 test.

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12 The fall, 1952 date is the one used for purposes of comparison by Chairman Strauss. See note 10 supra and note 14 infra.
13 The Joint Committee on Atomic Energy was established by §15 of the Atomic Energy Act of 1946, 60 Stat. L. 755 (1946), 42 U.S.C. (1946) §§1801-1819 (hereinafter referred to as the “Atomic Energy Act” or the “McMahon Act” and cited by section number only). The Joint Committee on Atomic Energy is composed of nine Senators and nine Congressmen and has powers and responsibilities which are in many ways unique.
For a compilation of the Atomic Energy Act and background material, including legislative history, see The Atomic Energy Act of 1946 with Amendments Through the Eighty-Third Congress, First Session (Joint Committee on Atomic Energy Print 1953).
unilaterally renounced our development of this weapon. Its sole possession by an unfriendly country would have posed for us and for the free world a very difficult situation, to say the least."\(^{14}\)

Chairman Cole stated shortly thereafter:

"... Moscow has mastered the intricacies of atomic and hydrogen energy so quickly because Soviet scientists and technicians are good—very good. And further, the Soviets have progressed with unexpected speed because they have assigned supreme and overriding priority to their project from the very outset.

"Our own hydrogen effort—speaking in terms of a major, concerted attack on the problem rather than a series of research projects—dates back only to 1950. From the facts we now know, I presume that a full-scale Soviet hydrogen program was started earlier, perhaps several years earlier. I suspect, moreover, that very early in the history of their projects, the Soviets decided that they would by-pass certain of the evolutionary steps in fission weapon design and direct their effort *mainly* at achieving the hydrogen weapon at the earliest possible date....

"... I doubt that it is either possible or necessary to determine, with great precision, whether the Soviets are now up with us in hydrogen energy, or whether they lag behind by one or two or three years. This is a dynamic and rapidly changing field, and any conclusion we reach today may be outmoded six months from now. But this I say most solemnly: If our own hydrogen effort falters, as it must not and need not, the Soviets have it in their capacity to outstrip us—and outstrip us decisively—within a relatively short period of time."\(^{15}\)

Three of the possibilities suggested by these statements with respect to the direction of our thermonuclear program are that we might have started earlier; that we might have proceeded with greater priority; and that we might have proceeded more directly to thermonuclear development. Under any of these hypotheses, however, the United States apparently is substantially behind where it might be in the development of thermonuclear weapons. Whether one adopts a hypothesis of too late, too little, or too indirect to explain our program, our performance cannot be excused on the ground that Soviet espionage gave Russia significant information. Soviet espionage could well have aided Russia by supplying information upon which their decisions could be based, as well as helping technically to carry them out. But


whether they may have had almost as much to go on as we ourselves, or less, the circumstance apparently remains that they proceeded while the United States, the scientifically stronger country, misjudged a paramount issue in the technological race for discovery.

The Atomic Energy Act had been in effect some three years before the historic announcement of President Truman on January 31, 1950, that he had directed the Commission to continue work on all forms of atomic weapons, “including the so-called hydrogen or super bomb.” However, hydrogen investigation antedates the act by at least four years. The possibility of developing a hydrogen bomb was “actively explored” by U. S. scientists as early as 1942. Studies concerning the feasibility of a hydrogen weapon “were conducted as part of the wartime atomic project, although they were subordinate to studies on the A-bomb since it was believed that the A-bomb could be developed more quickly and could, therefore, be used to hasten the end of the war.” And the Tolman Report on Post-War Policy dated December, 1944, observed in the section of the Report dealing with military recommendations that: “... thermonuclear bombs of ten-thousandfold greater power [than A-bombs] may even be feasible. These latter would permit an enemy in a single day . . . to carry out an action which might be decisive for the outcome of a war.”

It is striking, in view both of the extraordinary importance of hydrogen energy and the lag in United States development, that the Atomic Energy Act makes no reference of any kind to hydrogen bombs, thermonuclear energy, or their development. The Atomic Energy Act was framed in 1946 to develop and control A-bombs and the energy obtainable from nuclear fission. Nor have amendments altered the single-minded preoccupation of the act with the heavy end of the periodic table. Indeed, during the first seven years of the act’s effectiveness, only one legislative item specifically dealing with thermonuclear

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16 The full text of the Presidential statement of January 31, 1950 is as follows:

“It is part of my responsibilities as Commander in Chief of the Armed Forces to see to it that our country is able to defend itself against any possible aggressor. Accordingly, I have directed the Atomic Energy Commission to continue its work on all forms of atomic weapons, including the so-called hydrogen or super bomb.

“Like all other work in the field of atomic weapons, it is being and will be carried forward on a basis consistent with the overall objectives of our program for peace and security.

“This we shall continue to do until a satisfactory plan for international control of atomic energy is achieved. We shall also continue to examine all those factors that affect our program for peace and this country’s security.”


18 Sec. 5(c) of the Report of the Tolman Committee on Postwar Policy, Dec. 28, 1944, as reprinted in ATOMIC POWER AND PRIVATE ENTERPRISE, 82d Cong., 2d sess., p. 168 (Joint Committee on Atomic Energy Print 1952).
matters has arisen, and this proposal not only was not submitted as an amendment to the McMahon Act but failed of passage.\textsuperscript{19}

On June 30, 1954 the Joint Committee on Atomic Energy reported out a series of amendments to the McMahon Act in the form of a bill revising and restating the atomic energy law. Although the objectives at which the bill is aimed are not particularly related to thermonuclear energy, the new legislation seeks within the framework of the present law to modernize some aspects of the 1946 act,\textsuperscript{20} one of which concerns control of thermonuclear energy. The new bill, however, makes no more explicit reference to the thermonuclear process, hydrogen bombs, or peacetime hydrogen possibilities than the McMahon Act; instead, the extension of control is sought through redefinition of key terms in the 1946 act which affect the Commission's authority over thermonuclear matters. Since consideration of changes required by the advent of thermonuclear energy proceed from the fundamentals in the McMahon Act, Part I below explores the extent to which that act provides control over H-bomb information and Part II whether suitable authority has been present to provide control of materials of special interest to the

\textsuperscript{19} The first and only bit of legislation specifically mentioning thermonuclear matters occurred in the closing hours of the Eighty-Second Congress. In July 1952 a sharp House-Senate dispute was in prospect over the extent to which the atomic energy program would be expanded. The dispute was phrased largely in terms of riders to the appropriations act which placed restrictions on use of funds for construction of facilities. While the program was finally approved, the thermonuclear rider introduced by Senator Bricker and passed unanimously by the Senate was lost in conference. The rider provided that "... appropriations for the fiscal year ending June 30, 1953, may be used, any other law to the contrary notwithstanding, to start new construction projects directly and primarily related to thermonuclear matters." 98 Cong. Rec. 9152 (1952).

For a collection of the relatively few and unimportant amendments to the act, see The Atomic Energy Act of 1946 with Amendments Through the Eighty-Third Congress, First Session (Joint Committee on Atomic Energy Print 1953).

\textsuperscript{20} During April 1954 companion bills, H.R. 8862 and S. 3323 were introduced by Chairman Cole and Vice-Chairman Hickenlooper. See 100 Cong. Rec. 4933, 4953 (House, April 15, 1954 and Senate, April 19, 1954). Following a May 21, 1954 draft, the amendments were reported out as H.R. 9757 and S. 3690, 100 Cong. Rec. 8805, 8949 (June 30, 1954). See H. Rep. No. 2181 and S. Rep. No. 1699, 83d Cong., 2d sess.

The references herein to the "new bill" or the "1954 bill" are to H.R. 9757 and S. 3690 as reported, which differ from the draft with respect to sections here pertinent in some matters of detail. The 1954 bill renumbers and restates the McMahon Act; however, citations herein are to the 1946 act except when revisions or new provisions are involved.

The press release announcing the favorable report of the new bill describes the new bill as one providing for the following objectives, all of which appear to be directed predominately to fission energy: "(1) Industrial participation in the atomic energy program, particularly as to the development of atomic power, by licensees of the Atomic Energy Commission; (2) A means of co-operation with our allies in the atomic energy field, under adequate security safeguards; (3) A means by which the President can implement an international atomic pool plan, under adequate security safeguards." Mimeo release from the office of the Joint Committee on Atomic Energy dated June 30, 1954. The relatively few changes directed at the subject of this article are discussed in Part III below.
hydrogen program. In Part III changes made desirable in order to clarify and extend such authority are discussed. In addition, Part III indicates areas of legislation accorded slight attention in either the 1946 act or the recent bill and which are directed affirmatively to maximum development and the scope and scale of thermonuclear objectives. Finally, Part IV discusses a question basic to atomic energy legislation: the relative emphasis and priority to be accorded thermonuclear energy in view of the virtually complete lack of legislative attention accorded its development and advent.

Criticisms which can be focused on our thermonuclear program arise primarily from human factors and not from past or present legislative silence. Nevertheless, our atomic energy legislation can suitably attempt to maximize the opportunities for achieving thermonuclear objectives and to minimize the chances of misjudgment in administration of the law. It is the special responsibility of lawyers that the law adequately recognize and implement so important a field as thermonuclear energy, or that it fail in these respects. The following discussion approaches atomic energy legislation from the new but necessary perspective of the thermonuclear program.

I

Control of Information

The initial problem is to assess the extent to which the McMahon Act can be construed to provide for control of thermonuclear energy. Perhaps the most immediate aspect of this issue is whether the Atomic Energy Commission has been accorded authority to control thermonuclear weapon information. That is, has the Commission been given the power since January 1, 1947, the effective date of the act, to control the dissemination of H-bomb data and to protect H-bomb secrets? Fortunately it has, but the authority can be developed only through an interpretation of a term of art in the McMahon Act which has probably been the only phrase in the act applicable to the thermonuclear program as such.

The touchstone of information control in the Atomic Energy Act is “restricted data,” a concept which establishes the area of security information for atomic energy and in terms of which the sanctions of the act are largely stated. “Restricted data” has been defined to mean “all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the
Commission from time to time determines may be published without adversely affecting the common defense and security."\(^\text{21}\)

Consideration for present purposes can be limited to the "atomic weapons" phrase. For reasons discussed in Part II, the other parts of the definition have not been applicable to the thermonuclear program, and doubt exists whether they could be invoked as the act has been phrased. The authority to protect hydrogen secrets therefore depends on the construction of the "atomic weapons" phrase—that is, whether an H-bomb is an "atomic weapon."

**Legislative History.** Not only is an atomic weapon undefined in the McMahon Act, but the phrase is infrequent in the law.\(^\text{22}\) The absence of a definition becomes less surprising when it is considered that the concept of an atomic bomb was probably quite specific indeed in 1946: the stockpile was nearly bare\(^\text{23}\) and only the so-called Hiroshima-type and Nagasaki-type A-bombs have been referred to in this period. No definition may have been needed as a practical matter because an atomic bomb was too specific and tangible to need elaboration.\(^\text{24}\)

Hearings before the Special Committee on Atomic Energy which drafted the McMahon Act also disclose some half-dozen references to the possibility of a bomb quite different from the Hiroshima or Nagasaki type. Although these references are vague and nebulous,\(^\text{25}\) they are to light element reactions and a potential energy release far in excess

\(^{21}\) Sec. 10(b)(1).
\(^{22}\) See note 40 infra.
\(^{23}\) See Stimson, "The Decision to Use the Atomic Bomb," 194 HARPER'S 97 at 105 (1947): "The two atomic bombs which we had dropped were the only ones we had ready, and our rate of production at the time was very small."

\(^{24}\) Compare the language used by Chairman Sterling Cole of the Joint Committee on Atomic Energy in reviewing the concepts of 1946:

"Eight short years ago, we spoke of the atomic bomb—in the sense of the Hiroshima and Nagasaki weapons. We thought of atom bombs exclusively as 'city-killers.' We imagined that a few score of these weapons, or a few hundred at the very most, would suffice to meet any conceivable military use. Today, we speak of an entire family of atomic weapons adapted to all types of tactical situations. Today, our thinking proceeds in terms of stockpiles numbering thousands and tens of thousands of nuclear weapons."

"Eight short years ago, the hydrogen bomb—that most hideous of all destroyers—was regarded by most of us only as an interesting topic for astounding science fiction stories in Sunday magazine supplements." Mimeo. release, from the office of Rep. Sterling Cole, Remarks before the Annual Banquet of the Colorado Mining Association, Jan. 29, 1954, at p. 3.

\(^{25}\) In addition to references cited below, see the testimony of Dr. Harlow Shapley with reference to helium synthesis in Hearings before the Special Committee on Atomic Energy on S. 1717, 79th Cong., 2d sess., pp. 162-163 (1946) (hereinafter cited as S. 1717 Hearings). See also the remarkable testimony of Dr. Irving Langmuir in the S. Res. 179 Hearings at p. 109 et seq. (much more powerful new bombs envisioned in fourth stage of an unlimited armaments race; type of new discovery not identified). Compare the testimony of Dr. Vannevar Bush, id. at 171.
of the A-bomb, and it must be concluded that the Special Committee "knew" of the possibility of what would now be called an H-bomb.

The prospect, however, appears to have occupied little of the Committee's time. The approximately half-dozen references are made in passing and are the only ones in some 1112 pages of hearings. Even in these few references opinion varied widely. Perhaps the most influential scientist answered in the negative to a question concerning terrestrial thermonuclear reactions. The emphasis in testimony of a second leading scientist was directed toward unfettered and unclassified research. A third indicated that the light end of the periodic system might be more important than the heavy, and a fourth spoke to the technical feasibility of super bombs. Nevertheless, the emphasis

26 Hearings pursuant to S. Res. 179 started Nov. 27, 1945 and continued through Feb. 15, 1946, with a public record of 573 pages. Hearings on S. 1717 started January 22, 1946 and continued through April 8, 1946 with a total of 539 pages. For a statement of the legislative history of the act see THE ATOMIC ENERGY ACT OF 1946 WITH AMENDMENTS THROUGH THE EIGHTY-THIRD CONGRESS, FIRST SESSION 47-50 (Joint Committee on Atomic Energy Print 1953).

27 When Dr. J. Robert Oppenheimer testified shortly after he had relinquished his wartime post as Director of the Los Alamos A-bomb effort, Senator Hart observed that "all of our talking and thinking thus far has been based on uranium or some other very heavy material as a fissionable material" and asked whether Dr. Oppenheimer visualized "science progressing to the point that much more plentiful and more widely distributed materials may become fissionable and not constitute a danger." In his answer, the doctor referred to Dr. Bethe's theory that the sun's energy derives from a series of fusion reactions involving light nuclei. As to duplicating this process on earth, however, Dr. Oppenheimer responded that it was "conceivable that development of this kind might be carried out terrestrially, but I'm sure I don't know how, and I do not think it an immediate prospect nor a very likely one." And his answer was "No." S. Res. 179 Hearings, pp. 192-193.

28 Dr. Hans Bethe stated the case for unrestricted pure research in respect of the light elements. S. Res. 179 Hearings, pp. 224-225. He also observed that there was "somewhat more to this story" which he could "only mention in an executive session, and which would make the picture more complete." The committee did go into executive session at the conclusion of Dr. Bethe's testimony. Id. at 225, 232.

29 Dr. John von Neumann spoke for the importance of the lighter elements as follows:

"Regarding the developments in nuclear physics, in atomic fission, I think one has to say that the development of the chain reaction and of the fission bomb were enormous engineering tours de force. . . .

"But if nuclear physics had been left to itself, it would not have concentrated upon the upper [heavy] end of the periodic system to this extent. Many scientists who were working in this field claimed that they were stranded at the wrong end of the periodic system.

"It is probable that lighter elements will give more important results in the coming years, so we should concentrate on them." S. 1717 Hearings, p. 217.

30 The following was the comment of Dr. Edward Teller:

"Future bombs may become less expensive, may be easier to handle, and they may have a much greater destructive power. I am convinced that it will not be very difficult to construct atomic bombs which will dwarf the Hiroshima bomb in the same way that that bomb has dwarfed high explosives. In the near future, we can hardly expect that defensive measures will catch up with the means of aggression. Our present military advantage seems great. But the events of the last years show how quickly this situation may change. Only 3½ years of intensive effort were needed to make an atomic bomb. Unless the possibility of a future war can be eliminated, we are going to live in a world in which safety no longer exists." Id. at 275.
 accorded super bomb possibilities was exceedingly small. Indeed, hydrogen possibilities during the spring and summer of 1946, when the McMahon Act was being drafted, were characterized as follows by Atomic Energy Commissioner Sumner T. Pike in a 1948 address:

“Somewhere along this time atomic energy which had been thought of mostly as a material for bombs turned pseudoscientific. This Buck Rogers and Sunday supplement school of science popularizers gave us automobiles and ships powered by uranium in sizes ranging from an aspirin tablet to a baking powder can. I said the Sunday supplement school of writers. I am sorry to have to include quite a few people who most definitely ought to have known better. A former Assistant Secretary of War gave us on paper a bomb a thousand times bigger than the ones we used on Japan, and the head of a midwestern university went the military one better by developing also on paper a contraption which would wipe out half of the United States at one blow.”

Although conclusions with respect to the meaning of the “atomic weapons” phrase are difficult from the legislative history, a twofold legislative intention is consistent with the factors summarized above. In the specific sense “atomic weapon” was used to mean an “A-bomb.” But from the mere possibility, however little emphasized, of a non-A-bomb development, it may also be concluded that “atomic weapon” was used to mean an “atomic energy” weapon, or a weapon utilizing “atomic energy.” If this small step is taken, there is a powerful argument that an H-weapon would be an “atomic weapon.” For atomic energy has been broadly defined in section 18(a) to mean “all forms of energy released in the course of or as a result of nuclear fission or nuclear transformation.”


The reference to the head of a midwestern university is not clear. But Commissioner Pike’s reference to a former Assistant Secretary of War is probably to a statement of Secretary John McCloy before the National Association of Life Underwriters, later printed in 3 Bulletin of the Atomic Scientists 5 (1947):

“I have been told by scientists who are not mere theorists but who actually planned and made the bomb which was exploded in New Mexico that, given the same intensive effort which was employed during the war toward the production of that bomb, we were within two years time at the close of the war of producing a bomb of the hydrogen-helium type, i.e., a bomb of approximately one thousand times the power of the present bombs.”

32 Sec. 18(a) provides that as used in the act, “The term ‘atomic energy’ shall be construed to mean all forms of energy released in the course of or as a result of nuclear fission or nuclear transformation.”

The draft definition of “atomic energy” during the hearings on S. 1717, the McMahon Bill, differed slightly from that in the act as passed. In the original bill, §14(a) of S. 1717,
of terms to describe a nuclear rearrangement or transmutation and clearly includes a thermonuclear transformation (as well as one resulting from nuclear fission). Therefore, if an atomic weapon is used in the act with the reasonable meaning of an "atomic energy weapon," an H-bomb would be as clearly within the term as an A-bomb, and a broad basis provided by the act to control thermonuclear weapons data.

**Literal Interpretation.** The very breadth of the definition of "atomic energy" which achieves this result runs into the difficulty that it proves too much. The difficulties in a literal interpretation were emphasized in what is probably the only precedent for its construction: the 1949 debate over the export of certain radioisotopes. The problem arose because section 10(a), the act's declaration of policy for the control and dissemination of information, prohibits the exchange of information with other nations with respect to the use of "atomic energy" for industrial purposes. The then Chairman of the General Advisory Committee testified before the Joint Committee on Atomic Energy that not only the radioisotopes in question, but a shovel and a bottle of beer could be used for atomic energy as defined. The Joint Committee was told that coal, oil, and people could be considered "atomic energy" within the definition. Under this reasoning carried to an extreme,

79th Cong., 1st sess. (Dec. 20, 1945) read as follows: "The term 'atomic energy' shall include all forms of energy liberated in the artificial transmutation of atomic species." In succeeding drafts this definition was carried forward with the exception that the word "artificial" was stricken.

The May 8, 1946 draft of the bill, which set forth the final definition, separated the earlier language into two phrases, consisting of nuclear fission and "nuclear transformation." See Amendments Intended to be Proposed by Mr. McMahon to S. 1717, 79th Cong., 2d sess. (May 8, 1946) which at p. 3 strikes the original definition and inserts the version adopted as law. At the same time there were inserted in the definition the "in the course of" and "as a result of" phrases which render the definition so broad.

33 Sec. 10(a)(1) provides that "... until Congress declares by joint resolution that effective and enforceable international safeguards against the use of atomic energy for destructive purposes have been established, there shall be no exchange of information with other nations with respect to the use of atomic energy for industrial purposes. ..." Sec. 141(a) of the new bill, note 20 supra, changes this sentence so as to prohibit the exchange of restricted data with other nations except as provided in the act.

34 "Investigation into the United States Atomic Energy Project," Hearings before the Joint Committee on Atomic Energy, 81st Cong., 1st sess., p. 282 (1949) ("No one can force me to say that you cannot use these isotopes for atomic energy. You can use a shovel for atomic energy. In fact, you do. You can use a bottle of beer for atomic energy. In fact, you do.").

35 When the meaning of the definition of atomic energy in the act was raised by Senator Hickenlooper, the following interchange occurred:

Dr. Oppenheimer. . . . coal is atomic energy by this definition; oil is atomic energy by this definition; people are atomic energy by this definition, and surely one must do better than that if one wants to have a sensible export policy.

Senator Hickenlooper. But atomic energy is specifically defined in this act. It has a restricted meaning.
there would be few, if any, forms of energy not comprehended by the
definition. 36

It is possible, of course, that ingenuity may permit an interpretation
of "atomic energy" which would give some certainty to its meaning
and which would separate what should be within the purview of the
act from that which need not be controlled. But even should such a
de facto formula be devised, it would not help, for example, in a
prosecution under the act of someone accused of compromising only
thermonuclear weapons information. 37 Alternatively, each question
of the meaning of "atomic energy" could be met as it arises in light of
the expediencies of that moment. Such was the method of the 1949
radioisotopes matter, and, since the radioisotopes were shipped, they
apparently were not held to be atomic energy. 38 However, the phrase
is an important component of definitions in other parts of the act, so
that the significance of difficulties in interpretation cannot be confined
to the restricted data phrase.

Dr. Oppenheimer. I just read the definition.

Senator Hickenlooper. But people certainly would not be construed as coming under
that definition of atomic energy.

Dr. Oppenheimer. I would not wish to construe [the Act] that way... Sena­
tor Hickenlooper. . . . would you say that [those isotopes] are the result of
nuclear fission? Would you say that with respect to these isotopes that have been shipped
abroad, that come from our piles?

Dr. Oppenheimer. The indirect result of nuclear fission, yes.

Senator Hickenlooper. Would you say they are the result of nuclear transformation
if they come out of our piles?

Dr. Oppenheimer. Whether they come out of piles or not, they are the result of
nuclear transformation.

Senator Hickenlooper. I know you are not a lawyer, and I do not intend to argue
the legal point, but those terms are specifically used in defining atomic energy, so that the
law says what atomic energy is, and those things that come as a result of nuclear fission,
as the result of nuclear transformation, therefore, regardless of what anybody says, are
de­fined by law as being atomic energy.

Dr. Oppenheimer. But oil is a result of nuclear transformation. Id. at 287.

36 Somewhat later in the hearing Dr. Oppenheimer carried his previous observations
to a logical extreme by stating that the definition of atomic energy, taken strictly, would
include "every source of energy except tidal power." Id. at 298. If the phrase "in the
course of or as a result of" nuclear transformation is taken to mean of nuclear origin,
essentially all useful energy would be comprehended. The "atomic" origin of our energy
is thermonuclear because the sun is our uniquely important energy source.

37 Most violations of the act are defined in terms of "restricted data" and the only
definition of this term is the statutory one. See, e.g., §§10(b)(2)-(5). See also §16, pro­
viding additional criminal sanctions. Although it is difficult to believe that a duly cleared
and indoctrinated employee of the Commission or of a contractor could consider H-bomb
data beyond the ambit of the act, there should be no possibility of misunderstanding with
respect to the scope of the restricted data phrase.

38 A start toward an interpretation less sweeping than one which would include every
terrestrial form of energy (except possibly tides or winds) was made in the closing part
of the hearing on the isotope export problem. "Investigation into the United States Atomic
Energy Project," Hearings before the Joint Committee on Atomic Energy, 81st Cong., 1st
sess., p. 308 (1949). Compare, however, the complex series of considerations developed
A-bomb Analogy. The authority of the Commission to control thermonuclear weapon information as "restricted data" can be based on circumstances independent of either the legislative background of the "atomic weapons" phrase or the literal wording of the atomic energy definition. The Hydrogen Bomb Print of the Joint Committee on Atomic Energy states that an "A-bomb" would be needed to trigger an "H-bomb":\(^{39}\)

"There are two basic requirements for the hydrogen bomb:
(1) An assembly of materials capable of producing a light element reaction, if sufficiently heated; and (2) a means of heating the materials to the extent necessary. . . . the most promising way to attain such a temperature on earth is through an atomic bomb. Thus, the essential idea is that heavy fissionable material used in A-bombs would explode, thereby heating the hydrogen apparatus, thereby making possible a thermonuclear reaction."

Regardless of how much more energy might derive from the hydrogen apparatus, the thermonuclear components could thus be considered merely as an adjunct or appendage of the initiating A-bomb. By viewing the whole in terms of a modification of the A-bomb trigger, the authority to control thermonuclear weapons data would follow from the unquestioned control over A-bomb information.

These considerations are also applicable to the only other pertinent section of the original act which uses an atomic weapons phrase.\(^{40}\) Section 6(a)(2) grants the Commission authority in the military application of atomic energy to "engage in the production of atomic bombs, atomic bomb parts, or other military weapons utilizing fissionable materials; except that such activities shall be carried on only to the extent that the express consent and direction of the President of the United States has been obtained, which consent and direction shall be obtained at least once each year."

Thus the basic authority to produce H-bombs is almost coterminous with the authority to control H-bomb information.\(^{41}\) The suggested


\(^{40}\) In addition to the use of the phrase in §10(b)(1) and 6(a)(2), discussed in the text, §9(a) provided for the transfer to the Atomic Energy Commission of "all atomic weapons and parts thereof" among other items. This was a housekeeping provision directed to the changeover as of Jan. 1, 1947 from the Manhattan Engineer District to the newly formed Commission, and is not helpful. A subsection added in 1951, §10(a)(3) [65 Stat. L. 693 (1951), 42 U.S.C. (Supp. V, 1952) §1810(a)(3)] prohibits the communication to other nations of restricted data on "design and fabrication of atomic weapons."

\(^{41}\) Sec. 6(a)(2) speaks of the "production of atomic bombs" while §10(b)(1) is drafted in terms of the "manufacture or utilization of atomic weapons."
reading therefore cannot be defeated by asserting that the Commission’s authority to control weapons data has been in excess of the basic authority granted to it. Nor would this conclusion be dependent upon presidential approval: the condition of approval seemingly goes to actual production of bombs, and not to the underlying authority of the Commission so to proceed.

The Commission therefore has now, and from the passage of the act has had, the authority to produce H-bombs—and its control over dissemination of H-bomb information accords H-bomb secrets the sanctions provided in the act for “restricted data.” 42 However, the most compelling basis for these conclusions, the A-bomb analogy, hardly constitutes a construction of the law on the merits of the H-bomb program. It depends on calling an H-bomb an A-bomb for purposes of the act. Apart from legal interpretation, an H-bomb is obviously not an A-bomb, and the argument is one of expediency. Thus the sole phrase in the Atomic Energy Act which has been applicable to the thermonuclear program as such—the “atomic weapon” phrase—furnishes a prime example of the misemphasis and inadequacy of the McMahon Act when examined from the viewpoint of the hydrogen program.

II

Control of Materials

In 1946 control of such substances as plutonium and uranium 235 formed the basis not only of the McMahon Act but of the official United States plan for international control of atomic energy. It is of particular significance, therefore, that the Atomic Energy Act has not provided control over the special materials for thermonuclear reactions (thermonuclear materials) 43 and that substantial doubt exists whether the act could be interpreted to grant such authority. The approach to materials control in the McMahon Act also provides one of the most


43 As a “practical” matter the leverage over thermonuclear materials is considerably greater than absence of legal authority suggests. Thus tritium can be made in atomic reactors, and all non-research reactors are under complete governmental control. Similarly, heavy water, a source material for deuterium, can also be dealt with as a useful moderating medium for reactors. See the H-bomb Punn, pp. 1-2.

Under appropriate circumstances, a material can incorporate “atomic weapons” data, and thereby be controlled under §10(b)(1) whether or not the substance has been determined to be a “fissionable material” under §5(a)(1). An example might be an important component of an atomic weapon in the condition and shape it would be used in the weapon. The discussion in the text concerns materials per se.
characteristic and revealing aspects of the law, and furnishes a technical introduction to the changes which are desirable.

The basis of the materials control provided in the McMahon Act has rested upon terms "fissile material" and "source material." Their definitions\(^{44}\) can be diagrammed as follows:

<table>
<thead>
<tr>
<th>Fissionable material</th>
<th>Source material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. plutonium and enriched uranium</td>
<td>uranium and thorium</td>
</tr>
<tr>
<td>2. any other material capable of releasing substantial quantities of energy through nuclear chain reaction of the material, as determined by the Commission</td>
<td>any other material peculiarly essential to the production of fissile material, as determined by the Commission with Presidential approval</td>
</tr>
<tr>
<td>3. material artificially enriched by any of the above</td>
<td>ores only if the above are contained in a concentration determined by Commission regulations</td>
</tr>
</tbody>
</table>

If thermonuclear materials were to be brought within these sections, it would have to be under the "any other material" provisions, which cannot be invoked until the determinations set forth in the statute have been made. Since the only determination made has been with respect to a heavy element,\(^{45}\) it is quite clear that there is and has been no such control over special thermonuclear materials.

The more difficult question—whether the Commission could assert control by making the requisite findings—turns on the meaning of "chain reaction" in the definition of fissionable material. And since

\(^{44}\) Fissionable material is defined in §5(a)(1) as follows: "As used in this Act, the term 'fissionable material' means plutonium, uranium enriched in the isotope 235, any other material which the Commission determines to be capable of releasing substantial quantities of energy through nuclear chain reaction of the material, or any material artificially enriched by any of the foregoing; but does not include source materials, as defined in section 5(b)(1)."

The definition of source material contained in §5(b)(1) provides that: "As used in this Act, the term 'source material' means uranium, thorium, or any other material which is determined by the Commission, with the approval of the President, to be peculiarly essential to the production of fissile materials; but includes ores only if they contain one or more of the foregoing materials in such concentration as the Commission may by regulation determine from time to time."

\(^{45}\) This determination was that uranium 233 and materials artificially enriched with uranium 233 were "fissionable materials" under §5(a)(1). 13 Fed. Reg. 2220 (1948). Thus the only "fissionable materials" are U-235, U-233, plutonium and materials artificially enriched by them and the only "source materials" are those as set forth in the original statute.
the definition of source material is made in terms of whether it is "peculiarly essential" to the production of fissionable material, the Commission's authority over thermonuclear materials comes down basically to the meaning of the two words "chain reaction."

Legislative History. The legislative history of the "chain reaction" phrase is somewhat easier to follow than the definition of "atomic energy" or "atomic weapon." In the first drafts of the McMahon Act, the "chain reaction" phrase did not appear. In its place was the single word "fission," and had this phraseology been kept, the thermonuclear process would have been completely excluded.

The "chain reaction" phrase, however, was substituted in place of the word "fission." Nevertheless, it is not at all clear that the change was made for any reason connected with hydrogen prospects. Indeed, the testimony of the two witnesses who proposed the "chain reaction" phraseology clearly shows that the substitution as they suggested it was entirely motivated by good reasons raised by the fission process, and not by any intention to make room in the definition for thermonuclear materials.

46 See S. 1717, introduced by Senator McMahon on Dec. 20, 1945, 79th Cong., 1st sess. Sec. 1(a) of the original bill stated that "Research and experimentation in the field of nuclear fission have attained the stage at which the release of atomic energy on a large scale is practical"; sec. 5(a)(1) of the original bill defined fissionable materials to include plutonium, uranium 235 and other materials determined by the Commission to be capable of releasing substantial quantities of energy through "nuclear fission of the material." (Emphasis added.) Early in the second session, however, the word "fission" was replaced by "chain reaction." See the draft of the bill dated March 9, 1946 and subsequent drafts. Compare the language of S. 1359, 79th Cong., 1st sess., introduced by Senator McMahon on Sept. 6, 1945, "...it is essential in the interest of national defense, and of the general welfare...that the use and application of energy...by the splitting of an atom (hereinafter referred to as 'atomic energy') be controlled by the United States..." Compare also §6(b)(2) of H.R. 4566, 79th Cong., 1st sess. (1945), introduced by Representative May on Nov. 1, 1945:

"Whenever the Commission determines that any substance in addition to [materials from which the substances known as thorium, uranium (including uranium enriched as to one of its isotopes) and elements higher than uranium in the periodic table, can be refined or produced] is readily capable of or peculiarly related to transmutation of atomic species, production of nuclear fission, or release of atomic energy, it is authorized to extend the application of paragraph (1) to such substance. Notice of such extension shall be published in the Federal Register."

47 The first proponent of the chain reaction phrase in the S. 1717 Hearings was William H. Davis, who suggested that the intent of the definition lay in the control of a chain reaction, rather than the release of atomic energy. As the testimony of Mr. Davis set forth in note 46 below shows, the proposal was made quite without reference to the thermonuclear. In addition, Dr. I. I. Rabi submitted a memorandum prepared by Dean Pegram criticizing the definition of fissionable material as originally drafted in terms of energy release through nuclear fission, the criticism in which was wholly directed at fission energy considerations without regard to thermonuclear energy:

"A conspicuous fault in the bill is the unwarranted use of the word 'fissionable.' It is hardly to be conceived that the bill intends to give the Commission power to assume ownership of all lithium or boron compounds, yet both lithium and boron are fissionable..."
On the other hand, members of the Special Committee themselves on at least two occasions specifically raised the question whether the "chain reaction" idea was sufficiently broad to include a thermonuclear reaction. Both answers were brief, and one amounted to "no" and the second to "yes". If any conclusion be qualified once again in light of the slight attention paid in the hearings to thermonuclear prospects, there is at least some basis for a specific legislative intent to consider a thermonuclear reaction a chain reaction, and therefore to grant the Commission authority under the definition of fissionable material to control thermonuclear materials.

Technical Considerations. There are at least two quite different interpretations of "chain reaction," one of which would include a thermonuclear reaction, and one of which would not. The glossary of No one conceives of lithium or boron being dangerous materials, but U-235 is certainly dangerous. The all important difference is of course, that with U-235 a chain reaction can occur, with lithium it cannot. The potentiality of a cumulative fission by chain reaction is necessary in any explosive material, be it gun-powder, TNT or U-235. Hence in this bill, as much stress should be put on the potentiality of a chain reaction in a material as upon the material being fissionable." S. 1717 Hearings, p. 179 (1946). See also id. at 180. The suggestion made by Drs. Rabi and Pegram was to substitute "materials fissionable by chain reaction" for the "fissionable material" phrase. That the comments were directed solely to the fission process is also illustrated by the further suggestion that "splittable" be used in place of the word "fissionable." Id. at 179-180, 181-182.

48 See the following interchange during the testimony of William H. Davis during the S. 1717 hearings:

Senator HICKENLOOPER. At this point, isn't there another field of atomic investigation at least that the scientists have talked about for a long time, the possibility of creating some reaction by combination as well as by fission? . . .

Mr. DAVIS. That is an idea I didn't think of, in which case you wouldn't use the word "fissionable" at all.

Senator HICKENLOOPER. It occurs to me that it is worth inquiry . . . because there may be other combinations and other methods to which [fission] would not apply.

Mr. DAVIS. There certainly might. I was thinking of what we have in plutonium and uranium-235, which is that upon bombardment with neutrons they release more neutrons than it takes to start them bombarding, and that is the [chain reaction].

Senator AUSTIN. The trouble there is that you haven't got an exclusive definition by such a word or by such conduct because in fact it is not always bombardment that is necessary to release this energy; it may be by absorption.

Mr. DAVIS. Well, my suggestion . . . is . . . to replace "fissionable" [by] "reactive fissile" material, and then define "reactive fissile material" as the bill now does . . . [except that the phrase would read] capable of releasing, or directly connected with the release of, atomic energy through chain reaction. That is my suggestion and it doesn't cover what Senator Hickenlooper had in mind." (Emphasis added.) S. 1717 Hearings, pp. 50-51 (1946).

49 The point appeared fleetingly in testimony of Dr. Karl T. Compton, when again pursued by Senator Hickenlooper and Senator McMahon. The latter referred to a "prospect of development of atomic energy through a combination of lighter elements" and Senator Hickenlooper stated that he presumed that "synthesis may, although I don't know, involve a chain reaction." Dr. Compton responded that "... something along that line [the suggestion of a chain reaction] would cover what Senator McMahon has in mind, because the synthesis in this case is a process that is carried out as part of the program for getting this self-sustaining chain reaction." Id. at 258-259 (1946).
scientific terms in the Senate Report on the McMahon Bill uses it in the broad sense as applicable to "any chemical or nuclear transmutation process in which some of the products of a particular change assist the further development of that change." Dr. Hans Bethe also used the term broadly when he testified before the Special Committee on December 5, 1945:

"How, then, can we ignite atomic nuclei? In other words, how can we start a nuclear reaction which continues on its own power and which releases energy from the atomic nucleus in practical amounts? There are only two known methods to obtain such a so-called nuclear chain reaction: one of these is the nuclear fission on which the atomic bomb is based. The other involves the nuclear reactions which we believe take place in the interior of stars, and which involve light nuclei. . . .

"In the stars . . . we have again a self-sustaining reaction: The energy released from the nuclei produces the high temperatures in the stars, and the high temperature in turn enables the nuclei to get together and to release their energy."

Since one product of a thermonuclear reaction is heat-energy and that product assists the reaction, it is at least arguable that heat-energy might be the "link" corresponding to that provided by neutrons in the fission chain reaction and that "chain reaction" is applicable in this sense to any self-sustaining nuclear transformation, whether by virtue of fission or fusion.

In everyday parlance and in scientific terminology, however, a thermonuclear reaction is not a chain reaction. This distinction follows from the differing physical processes which occur in a fission chain reaction on the one hand, and a thermonuclear reaction on the other.

In theory, if two appropriate light elements are weighed, fused together and reweighed, the fused particle will weigh less than the parts before their combination. If a splittable heavy atom is weighed initially, then fissioned into fragments and the parts reweighed, the combined weight will likewise be less than that of the atom before fission. In each case the loss of weight or mass represents a conversion into energy of huge proportions.

The processes themselves, however, are quite different. In the

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51 S. Res. 179 Hearings, pp. 222-223.
fission chain reaction, the "link" is a neutral bombarding particle, the neutron, which encounters no electrical repulsion in approaching a nucleus. When a neutron strikes a fissionable nucleus, energy is released, and, in addition to various fission products, other neutrons are yielded which enable the reaction to proceed exponentially under appropriate conditions. During the process the atoms not fissioned are substantially unaffected. Relatively few materials are considered capable of sustaining such a chain reaction.

A thermonuclear reaction involves the bringing together of suitable light nuclei: However, nuclei are electrically positive and therefore repel each other. If enough heat is added, this repulsion can be overcome—that is, if the energy of the nuclei can be increased tremendously, some nuclei will have sufficient velocity to approach despite the electrical repulsion. When fusion occurs, great quantities of heat-energy are released, which can raise the temperature of the remaining nuclei so that further fusion reaction is facilitated. The entire material is affected by the heat-energy so produced, and the reaction does not proceed "exponentially" through a series of generations as does the fission chain reaction.53

In view of the common technical understanding that it does not, and in view of the different nuclear reactions involved, doubt exists whether the "chain reaction" term as used in the act can properly be interpreted to include a thermonuclear reaction, and any such doubt in so vital an area as the authority to control special thermonuclear materials must be considered substantial.

There are two consequences of this conclusion. With respect to hydrogen materials, the McMahon Act has failed to provide an unequivocal, minimum basis for the control of such materials. Secondly, the authority to control thermonuclear information by way of parts of the "restricted data" definition is subjected to substantial doubt. It will be recalled that "restricted data" has been defined in terms of three items: atomic weapons, production of fissionable material, and the use of fissionable material in the production of power.54 The two items phrased in terms of fissionable materials do not enlarge the area of thermonuclear data which can be controlled, because (1) no thermonuclear materials have been designated as materials to be controlled under the act and (2) substantial doubt exists whether the Commis-

53 If it be assumed, for example, that each fission nets exactly two useful neutrons for fission of other nuclei, the number of fissions in succeeding generations would be 2, 4, 8, 16 and so forth exponentially.

54 Sec. 10(b)(1).
sion would have authority so to designate them under the definition of fissionable material.

Thus, when the act is examined with respect to the fundamentals of control—that is, over thermonuclear information and special thermonuclear materials—only one phrase in the act is found to have been applicable. That is the "atomic weapons" phrase which authorizes the Commission to treat data concerning the manufacture or utilization of H-weapons as "restricted data." The act cannot be construed with any clarity to confer additional authority for the control of thermonuclear energy. In view of the considerations set forth, the Atomic Energy Act must be considered substantially in default with respect to thermonuclear matters.

III

Areas for Legislative Change

The discussion of the Atomic Energy Act thus far has been in terms of whether authority has been conferred to assert control over and protection of H-bomb information and thermonuclear materials. It has emphasized the preoccupation of the 1946 act with the process of nuclear fission and the A-bomb and the minimal provision for the light end of the periodic table.

The mere clarification or perfecting of H-bomb controls is deceptively simple: the advent of thermonuclear energy invests even this limited area with substantial new considerations. A substantive amendment to the act, for example, is desirable to assure the Commission's authority over thermonuclear materials, since authority is not provided with clarity by the present provisions for "fissionable" and "source" materials. Of the several formulas which are available to accomplish this purpose, the recent bill to amend the McMahon Act chooses to create a new category of "special nuclear" material, consisting of the presently designated fissionable materials plus others if they are determined to be "capable of releasing substantial quantities of atomic energy." That is, according to the shortened definition of atomic energy in the bill, special material must be capable of releasing substantial quantities of energy in the course of nuclear fission or nuclear transformation.55 The nuclear fission part of this definition amounts to the

55 Sec. 11(t) of the new bill, H.R. 9757 and S. 3690, note 20 supra, defines "special nuclear material" in terms of the materials now designated as fissionable materials; any new materials are to be designated under §51, which provides that before making a determination, "... the Commission must find that such material is capable of releasing substantial quantities of atomic energy and must find that the determination that such material is
original proposal in 1946 for the McMahon Act and would therefore appear to be subject to the same points made when the "chain reaction" phrase was adopted in its place. However, the addition of an alternative criterion of substantial energy release through "nuclear transformation" is new and without question would permit thermonuclear materials to be designated. The definition is so broad, however, that restraint on what materials could be preempted by the Commission would come largely from its discretion, as reviewed by the President and the Joint Committee, rather than from a statutory limitation stated in terms of the technical processes.

Whatever overall formula is adopted, there must be taken into account the differences between thermonuclear materials and the heavy substances upon which the 1946 control provisions were predicated. The categories of "fissionable" and "source" material have represented in part a political classification based upon feasibility of isolating uranium, thorium and plutonium and subjecting them to protective governmental monopoly. Of the materials of interest to the thermonuclear program, however, deuterium can be processed rather easily from heavy water, a substance which has been obtained from ordinary water in ton lots since the 1930's. Tritium can be produced in a fission reactor by the bombardment of lithium, a material of substantial

special nuclear material is in the interest of the common defense and security, and the President must have expressly assented in writing to the determination. The Commission's determination, together with the assent of the President, shall be submitted to the Joint Committee and a period of thirty days shall elapse while Congress is in session ... before the determination of the Commission may become effective. ...

Sec. 11(c) of the new bill amends the definition of atomic energy to mean "all forms of energy released in the course of nuclear fission of nuclear transformation." The language is identical to the McMahon Act except that the "as a result of" phrase is deleted. This appears a substantial improvement. See note 32 supra.

With "special nuclear material" compare the treatment of "prescribed substances" in §18(1) of the British Atomic Energy Act, 1946, 9 & 10 Geo. VI, c. 80, and §2(h) of the Canadian Atomic Energy Control Act, 1946, 10 Geo. VI, c. 37. Deuterium is listed as a prescribed substance in the Canadian act.

See notes 46-48 supra.

The term "nuclear transformation" is broader than "fission" and "fission" is broader than "chain reaction." It is proposed that the President assent to new determinations and that the Joint Committee have a thirty-day period in which to act. See note 55 supra.

An alternative would be to keep the present provisions in effect with respect to heavy elements and to create a new category of "thermonuclear material" to comprehend the key substances of special importance to the hydrogen program. The technical differences between fusible and fissionable material would seem to make it less desirable merely to redefine "fissionable material" so as to comprehend materials capable of releasing energy through "thermonuclear reaction" as well as through "chain reaction" because the light materials would fit only with difficulty into the framework of control designed for heavy fissionable material.

The discussion is based upon and made entirely in terms of the materials and technical considerations set forth in the H-bomb Print.

Id. at 1-2.
commercial usage. Unlike uranium and plutonium, deuterium and tritium are not metals and are not solids. Tritium is dangerously radioactive, and has the short half-life of twelve years, factors which might reduce incentive to private ownership. On the other hand, deuterium is stable and, unless it be a bomb material, does not appear dangerous.

There are also questions of interrelation between the light and heavy ends of the periodic table. Thus heavy water is useful both as a moderator in fission reactors and as a source of deuterium for the thermonuclear program. And the policies may run counter: while a tendency is probable to increase control over thermonuclear materials, it is proposed to relax the governmental monopoly over fissionable materials in favor of private enterprise. The wide range of materials and their interrelation suggest that there may be a shift in the basis for control, a need for more flexible authority for its exercise, and for more emphasis upon assuring the Commission an uninterrupted supply of important materials.

The scope of the other basic control provision—the control of information—hinges on the "atomic weapons" phrase in the definition of restricted data. It may be desirable to amend the definition to make it patent that not only data concerning the "manufacture" and "utilization" but also the "development" of atomic weapons is restricted. Absence of the word "development" is not important with respect to the A-bomb; but it has been recurringy argued that an H-bomb would not be technically feasible or militarily useful—argu-

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60 Id. at 2. The H-BOMB PRINT states at 10 that "Lithium is now used commercially in glass, as a compound in welding fluxes, in storage batteries, in fluorescent light tubes, and as an alloying element."

61 Tritium is classified as "moderately dangerous" in SAFE HANDLING OF RADIOACTIVE ISOTOPES, Handbook 42, U.S. Dept. of Commerce 4 (1949); H-BOMB PRINT, p. 3.

62 In the United States the CP-3 (Chicago Pile No. 3), in Canada the ZEEP reactor and NRX, in France ZOE and the new Saclay reactor, and in Norway the Kjellar reactor are moderated by heavy water.

63 It is an index of the single-minded preoccupation of the McMahon Act with the fission process that proposals to amend the law to encourage private participation in power and other constructive uses of fissionable material have been discussed without reference to possible thermonuclear complications. In hundreds of pages of testimony on the role of private enterprise in atomic power and in thousands of pages of print on this subject, savings provisions for the H-bomb program have not accompanied proposals to amend the act, with the exception of one or two cursory acknowledgments that there was a problem. It is also to be noted that a fission reactor can be a facility for the manufacture of tritium. See ATOMIC POWER AND PRIVATE ENTERPRISE, 82d Cong., 2d sess., p. 17 (Joint Committee on Atomic Energy Print 1952).

64 The declaration of policy for control of information is one of the rare places in the act that can be paraphrased easily in thermonuclear terms. So paraphrased, §§10(a)(1) and (2) provide approximately as follows: thermonuclear weapon data is to be controlled so as to assure the common defense and security; consistent with such policy, the dissemination of information relating to thermonuclear energy is to be encouraged so as to provide the free interchange of ideas essential to scientific progress.
ments which, if correct, would challenge its status as a weapon and therefore control of data concerning it under the "atomic weapons" phrase. It may also be desirable to include an explicit indication that atomic weapons comprehend thermonuclear weapons. The new bill does insert a definition of "atomic weapon," but one less square than desirable: a new definition of the type proposed should choose the most unambiguous terms to spell out that data concerning the development, manufacture or utilization of both atomic and thermonuclear weapons is restricted.

Amendments of this type, however, are directed—as all legislation has been—to the authority to draw (and where and how to draw) the line between restricted and public data. The thermonuclear program raises the equally difficult but unexplored question of how information can be handled within the project to achieve the most enlightened and responsive judgment with respect to important technical possibilities. In speaking of the Joint Committee on Atomic Energy, Senator Henry M. Jackson has regretted that it "did not possess either the information or the intuition to press for a genuine

65 See, e.g., the remarks of Senator Henry M. Jackson, then a House Member of the Joint Committee on Atomic Energy, before the Institute of Industrial and Legal Problems of Atomic Energy, June 28, 1952: "In late 1949, when there was the controversy on the question of whether or not we should really try to build the hydrogen weapon, a very influential group of experts argued against this step. First they said it would be immoral. Then they said, even if making it in self-defense were moral, it could not be built. Then they said, even if it could be built, it could not be delivered. Then they said, even if it could be delivered, it would cost too much. Then they said, even if it would not cost too much, it could do nothing that A-bombs couldn't do." Mimeo. release, from the office of Cong. Henry M. Jackson, June 28, 1952, at p. 4.

The 1954 bill meets this point squarely by redefining "restricted data" to include data concerning the "design" as well as the manufacture or utilization of atomic weapons. Sec. 11(r) provides in full: "The term 'Restricted Data' means all data concerning (1) design, manufacture, or utilization of atomic weapons; (2) the production of special nuclear material; or (3) the use of special nuclear material in the production of energy, but shall not include data declassified or removed from the Restricted Data category pursuant to section 142." In addition a broad definition is provided in §11(i) of the term "design," to include research and development data among other items.

66 Sec. 11(d) of the new bill, note 20 supra, defines "atomic weapon" to mean "any device utilizing atomic energy, exclusive of the means for transporting or propelling the device (where such means is a separable and divisible part of the device), the principal purpose of which is for use as, or for development of, a weapon, a weapon prototype, or a weapon test device."

The phrase "device utilizing atomic energy" has been a basic term of art in the 1946 act (see notes 85 and 89 infra) but appears to have been superseded in the 1954 bill by the new concept of a "utilization facility." See §11(v). Of a number of other questions there are two unnecessary ones raised by defining atomic weapons in terms of weapons utilizing atomic energy so as to include thermonuclear weapons: (1) the definition of atomic energy may not have met the objection that it is vague and indefinite (see notes 34-36, 38 supra); and (2) it is too indirect—it should not be necessary, to confirm that H-bomb information is restricted, to examine three different definitions (those for restricted data, atomic weapons and atomic energy). If a definition is considered desirable, it should very clearly and specifically refer to thermonuclear weapons. See note 37 supra.
hydrogen effort until late in 1949."\(^{67}\) His comment suggests the question of how fully informed the President may have been—and the defense establishment, the Military Liaison Committee, and other groups which were established to act as safeguards in the conduct of our atomic energy program. How, in the first place, can a responsible official assure himself that he is aware of all significant technical potentialities and how, in the second, can all the appropriate officials and agencies be most effectively informed?

It is a matter of concern that virtually all the legislative attention accorded thermonuclear energy to date has concerned provisions—such as all those discussed above—which deal with authority for the "containment" of thermonuclear energy. No less important, but virtually ignored in both the 1946 act and the recent bill, is legislation affecting the "attainment" of thermonuclear objectives. The vital importance of this field has largely emerged since the McMahon Act was passed in 1946, when there was a general belief that a "lasting peace had been accomplished, that we would enjoy an atomic monopoly for some years, and that there would be international control of atomic weapons."\(^{68}\) An initial approach is explored below to three of these affirmative areas to which the 1954 amendments make either no or only passing reference: new military developments, the establishment of atomic requirements, and the encouragement of peaceful and constructive thermonuclear development. The still broader question of the relative emphasis in legislation accorded thermonuclear energy is discussed in the concluding section of the article.

**New Development.** A number of provisions in the atomic energy law are directed broadly at the fostering and encouraging of the physical sciences. While these provisions are of the utmost importance,\(^{69}\)

\(^{67}\) See mimeo. release from the office of Cong. Henry M. Jackson, June 28, 1954, at p. 4: "[The Joint Committee on Atomic Energy] has, I believe, demonstrated a uniquely non-partisan and constructive approach to a great national problem but I equally believe we would do certain things differently given the advantage of hindsight. In particular, I regret that we did not possess either the information or the intuition to press for a genuine hydrogen effort until late in 1949."

\(^{68}\) Statement of Sterling Cole, Chairman, Joint Committee on Atomic Energy, mimeo. release dated April 7, 1954, at p. 1.

\(^{69}\) See, e.g., the statement of Gordon Dean, then Chairman of the Commission, in "Second Independent Offices Appropriations for 1954," Hearings before the Subcommittee of the Committee on Appropriations, 83d Cong., 1st sess., p. 376 (1953): "May I respectfully request the committee to consider where this country would be with the present thermonuclear-weapon program if there had not been available a few years back the fundamental knowledge of nuclear theory, the nuclear constants of the isotopes, and all the other data needed to cope with this extraordinarily difficult problem. Without that accumulated knowledge it is inconceivable that we could have planned and executed the tests
they are to be distinguished from the development of new military applications of atomic energy. The hydrogen program belongs in the latter category, and it is at the slighting of this subject that the most serious criticism of the act can be directed.

The basic provision in the act dealing with military development is section 6 (a). This section authorizes the Commission to "conduct experiments and do research and development work in the military application of atomic energy." Since "atomic energy" is construed to include thermonuclear energy, the section clearly confers developmental authority upon the Commission.\(^\text{70}\) There are also two pertinent organizational provisions. A statutory Division of Military Application was established within the Commission and the "development . . . of bombs" is one of the items within the purview of the Military Liaison Committee.\(^\text{71}\)

This slight attention in the act may be contrasted with the reliance placed upon pre-eminence in special weapons for the defense of the free world. It has become an axiom of the cold war that we rely on our scientific and technical advantage in special weapons to offset our adversaries' superiority in conventional military armament. Yet, as the thermonuclear program shows, this reliance in turn is greatly dependent upon new developments, and a lag can jeopardize the very posture of our defense and that of the West.\(^\text{72}\) There may or may not be further scientific developments which affect a "qualitative" change in our capacity for deterrence and defense; they may or may not be yielded by the field of atomic energy; and they may or may not be military in nature—indeed, one can hope for qualitative advances in constructive applications of atomic energy. It would, however, be

and other accomplishments in this effort in the 3 years since the Presidential directive to accelerate development. This is of course a spectacular example of research's contribution."

\(^{70}\) See also §§3(b) and 3(a) which authorize the Commission to conduct in its own facilities research and development activities relating to such broadly defined fields as "nuclear processes" and the "theory and production of atomic energy." In addition, the term "research and development" used in §6(a) is defined by §18(e) to mean: "... theoretical analysis, exploration, and experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes."

These provisions are unaffected by the corresponding §§31 and 32 of the new bill.\(^\text{72}\) Secs. 2(a)(4)(B) and 2(c).

\(^{72}\) Cf. former President Truman's State of the Union Message, note 2 supra, at p. 238: "But when the Soviets produced an atomic explosion . . . we had to broaden the whole basis of our strength. We had to endeavor to keep our lead in atomic weapons. We had to strengthen our Armed Forces generally and to enlarge our productive capacity—our mobilization base. Historically, it was the Soviet atomic explosion in the fall of 1949, 9 months before the aggression in Korea, which stimulated the planning for our program of defense mobilization." Emphasis added.
extraordinary if the significant consequences of atomic energy had been exhausted in the first few years of its study. And it is increasingly unacceptable that significant new technical developments be known to other nations and not to the United States.

A first step in supplementing the present law might be an explicit statement of objectives in the technological race for discovery. Such a declaration might suitably recognize our stake in pursuing new developments and the importance of the rate and scale of their development. However our goals might be phrased, they should seek—as a minimum—the achievement and the maintenance of a superiority in development at least commensurate with our scientific and technical advantage over other nations. And the goal might more effectively be stated in terms of decisive leadership.

The legislative role in implementing objectives of this kind is a difficult one, and one not limited to the atomic energy field. Civil defense and the ballistic missile may represent other examples. How is responsibility defined, where the responsibility is for boldness and daring? How can adequacy of a developmental effort be measured

73 There is little on the statute books dealing with research and development for military uses. In 1952 acts facilitating "the performance of research and development work by and on behalf of the departments of the Army, the Navy, and the Air Force" were passed. 66 Stat. L. 725-757, 5 U.S.C.A. (1953 Supp.) §§235b-235h (Army); id., §§475g-475m (Navy); and id., §§625b-628h (Air Force). The legislation, however, appears to meet only a few special problems: facilitating the appointment of research advisory committees; the employment of alien scientists and technicians; long term research contracts; governmental facilities for development; indemnification against liability for injury or damage where insurance coverage was not available; and a simplified voucher procedure. Neither in this facilitating act, nor in the authority of the services to undertake research and development, are there affirmative standards of achievement or standards of responsibility. See the report accompanying the above bill in the House, H. Rep. No. 548, 82d Cong., 1st sess. (1951).

74 With respect to long range missiles, see the comment of Lt. Gen. James H. Doolittle: "As a result of their own intensive effort, together with what they took from the Germans who, during World War II, led in this field, it is extremely likely that the Soviets are ahead of us in the development of the long-range ballistic missile." "Defense in the Air-Atomic Age," Address by J. H. Doolittle before the Jewish War Veterans of the United States of America, mimeo. text Jan. 13, 1954, at p. 6.

75 A major part of the problem is that the more revolutionary the idea, the less is success assured and the greater the inertia. See the following testimony with respect to the inception of the wartime atomic energy effort:

"The Chairman. I understand Doctor . . . that when Fermi and Pegram went to see you people in the Navy on March 17, 1939, they came away from that conference much discouraged, and that it was as a result of that discouragement that they got in touch with Dr. Sachs, who in turn got in touch with the President. . . .

"Dr. Gunn. I think that is a fair deduction from what happened. You gentlemen must realize that this picture looks a great deal different today than it did look then. Here was a group of scientists who had been looking for something like this, but we didn't quite believe it. We didn't object in the least to the conversion of nuclear energy. It was conceded that energy was there all right, but the chain reaction . . . was distinctly something that placed us in the position of being 'from Missouri.' We weren't sure of it."
in terms of our defense? The thermonuclear program epitomizes the need for detailed legislative attention in this field, which appears to be a new legislative frontier that remains quite unexplored.

**Requirements.** The provisions dealing with the establishment of military requirements are perhaps the most consequential of the act. We have been forced to direct the bulk of our atomic energy efforts to military application. And military requirements, of course, control the scope and scale of effort.

As a practical matter, the thermonuclear program could have been directed and managed in every nontechnical respect by establishing thermonuclear objectives under the requirements sections of the act—or left undirected and uncontrolled by absence of such requirements. As a legal matter, however, the powers and responsibilities with respect to military requirements are more uncertain.

The "requirements" provision with respect to "fissionable material" appears tersely as the last sentence of section 4 (c) (2): "The President shall determine at least once each year the quantities of fissionable material to be produced under this paragraph." In addition, section 6 (a) (2), which grants authority to the Commission to "engage in the production of atomic bombs" provides that "such activities shall be carried on only to the extent that the express consent and direction of the President" has been obtained at least once each year.\(^76\)

If "atomic bombs" be again construed to include thermonuclear weapons, section 6 (a) (2) is, nevertheless, inadequate because the pertinent part appears in the form of a limitation on the power of the Commission, rather than an affirmative obligation imposed on the officials charged with our defense. If there has been an affirmative duty, it would seem to be under the quoted sentence in section 4 (c) (2). But since no thermonuclear material has been designated a "fissionable material," this provision has been entirely directed at the A-bomb with no applicability to thermonuclear matters. The responsibility for developmental items, as contrasted with production, is still more vague. One of the few statements with respect to the practices followed indicates that while production requirements are approved

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Emphasis added. Statement of Dr. Ross Gunn, Technical Adviser to the Naval Administration of the Naval Research Laboratory, S. Res. 179 Hearings, p. 370.

Compare the conclusion of the Report of the Joint Committee on Atomic Energy to the Congress of the United States, S. Rep. No. 1041, 82d Cong., 1st sess., p. 7 (1951): "If the Committee has a single general comment to offer, it is this: Greater boldness and more scientific and technical daring should be brought to bear upon the program."

\(^76\) See note 41 supra.
by the President, requirements for specific developmental projects are not.\textsuperscript{77}

Both the failure of the present provisions to avoid substantial lag in the thermonuclear program, and the continuing need for leadership in special weapons\textsuperscript{78} suggest reappraisal of the requirements pro-

\textsuperscript{77} Brig. Gen. K. E. Fields, Director of the Division of Military Application, explained practice with respect to requirements as follows: “The requirements covering our production efforts are established by the Department of Defense based on capability estimates previously furnished by the Commission. The yearly production program itself is approved by the President. The requirements for specific weapon developmental projects, on the other hand, are also determined by the Department of Defense, but after joint evaluations by the Department of Defense and the Atomic Energy Commission as to the feasibility and military worth of these projects.” “Second Independent Offices Appropriations for 1954,” Hearings before the Subcommittee of the Committee on Appropriations, 83d Cong., 1st sess., p. 441 (1953).

\textsuperscript{78} The discussion in the text is undertaken entirely in terms of our defense policy, and it would seem either that staying ahead in nuclear weapons is necessary or the entire military posture of the United States appears to be wrong.

The Mike test shot of the fall, 1952 Ivy test series produced a crater of maximum depth of 175 feet and a diameter of approximately one mile. See text of the motion picture public release, Operation Ivy, set forth in 100 Cong. Rec. 4237 (April 2, 1954). Such effects emphasize anew the potentialities of tactical H-bombs to destroy the bases from which an enemy could launch attacks of mass destruction against the United States. The cratering characteristics of the H-bomb could be exploited, for example, to knock out airfields with a completeness that might prove a major element of our defense.

The pioneer publication to spell out the potentialities of atomic weapons in great quantity for tactical use against the enemy’s power to retaliate appears to have been William L. Borden’s \textit{There Will Be No Time—The Revolution in Strategy} (Macmillan, 1946). See, e.g., pp. 113-115: “... it is said that after each of the great powers has accumulated enough bombs to reduce the others’ cities, additional bombs will be redundant. Numerically superior American armaments deriving from our present head start in production would therefore count for nothing, and victory in an atomic war would go to whichever side was the aggressor....

Such is the saturation argument, one which has been naively espoused by most nuclear scientists and many military experts as well. The fallacy is obvious; it lies in thinking of the atomic bomb primarily as a strategic rather than as a tactical weapon. ... Even if the enemy possessed a stockpile of 8,000 bombs, and only 2,000 would suffice to destroy our economy, 12,000 American bombs could not only bring victory but also attract to their scattered emplacements the brunt of a surprise attack. ... no power on earth can theoretically prevent a future aggressor from singling out American cities as his first objective. But as a practical matter, if our dispersed military system is strong enough, he will seek its destruction first. To act otherwise would impair his chances of winning and assure the obliteration of his own cities. The United States may therefore have an opportunity to extinguish the aggressor’s forces before widespread damage overtakes our home front. Should the war last long enough for industrial production to influence the result, an opponent might still hesitate to take the initiative in attacking civilian concentrations for fear of reprisal in kind. Each atomic bomb deployed for a counterattack means that it, and not a city, will form the important enemy objective. A bomb can retaliate immediately unless destroyed. Civilians are powerless to create the tools of retaliation except over a considerable period of time. For America, then, superior armaments mean maximum security in both of its aspects, winning victory and salvaging cities. Our head start in atomic know-how will remain priceless long after foreign powers have attained a saturation level of armament theoretically enabling them to devastate our centers of population. If the head start is lost as the world armaments race progresses, however, an opponent could strike at all our military positions and still have bombs to spare for simultaneous use against American civilians.”
visions. The practical problem would seem the following: who assumes responsibility and leadership for an item (such as the thermonuclear program) as to which the military is uncertain of its military worth and the scientists are uncertain of its technical feasibility? Who takes the initiative when the military interest is affected

See also the June 14, 1952, speech of the late Senator Brien McMahon, then Chairman of the Joint Committee on Atomic Energy, and the last speech he delivered before his death: "There can be no greater deterrent to war than our capacity to launch a countering offensive against the airfields and staging points and naval bases from which Stalin could launch an atomic attack against American cities and industry.

"If he should strike, our best and surest means of halting the blows against our cities lies in countering blows aimed at his atomic bases. This means an all-out counter-attack—a counter-attack compressed in time to the absolute maximum. Every day that an enemy atomic base were to stay in existence might mean a lost American city—a city that could be saved if the base were at once destroyed with finality. The hydrogen bomb, if available to us in quantity, could do this job as nothing ever before conceived by man could do it. The prospect would not be lost on Stalin.

"Five years ago neither the professional soldiers nor the atomic scientists foresaw what will turn out to be the great military revolution—the use of atomic energy as firepower in the hands of troops, sailors, and airmen against enemy troops, sailors, and airmen. It was this revolution that brought about the requirement for great numbers of atomic bombs. No matter how many we might come to possess, we would need and could profitably use far more—in the event we were attacked. . . . It seems to me perfectly obvious that the hydrogen weapon will have, in case of conflict, a revolutionary impact upon the conduct of war by reason of its tactical uses. We must cut down the lead time in our thinking."

Partial text of address, mimeo. release from the office of Senator Brien McMahon, June 14, 1952, at pp. 2-3.

79 In the requirements provisions cited in the text, the new bill essentially makes only those changes which are uniformly undertaken throughout the bill. Thus the word "bombs" in §6(a)(2) is changed in the corresponding §91(a)(2) of the new bill, to "weapons," and "fissionable material" in §4(c)(2) is replaced by "special nuclear material" in the renumbered §41(b). The latter change will be a constructive one when thermonuclear materials are designated as "special nuclear materials."

80 The statement of Sterling Cole, Chairman, Joint Committee on Atomic Energy, dated April 7, 1954 listed some of the arguments against proceeding with an accelerated hydrogen program during discussions prior to the January 31, 1950 decision of the President in the following terms:

1. There was doubt concerning the technical feasibility of such a weapon.
2. It was feared that building such weapons, should they prove feasible, would detract from the strength of our position in fission weapons.
3. Some questioned the military worth of large-yield thermonuclear devices.
4. It was feared that concentration of money and—more importantly—people, on this program would detract from the speed with which improvements in our fission bomb program could be made.
5. To many, the prospect of developing such potentially devastating weapons was morally repugnant.
6. Development would involve an expenditure of large sums of money."

The statement also notes that "After vigorous debate at the highest levels of the Government, the situation that confronted the President was this: (1) A majority of the Atomic Energy Commission advised against proceeding with a large-scale and vigorous effort on development of the hydrogen bomb; (2) the General Advisory Committee also advised against so proceeding; (3) the Joint Committee on Atomic Energy favored proceeding; and (4) a special subcommittee of the National Security Council favored proceeding; the Secretary of State and the Secretary of Defense recording favorable votes."
by costs and facilities subject to wide variation which in turn are dependent on the extent of the military interest?81

81 Who "originates" significant changes in goals or major new types of effort? Who should? See the testimony of General Bradley, Chairman of the Joint Chiefs of Staff, with respect to the origination of the 1952 A-weapons expansion program amounting to some $4 billions:

Mr. THOMAS. Where did this expansion program originate, General? Did it originate with the Joint Chiefs of Staff? . . .

General BRADLEY. Mr. Thomas, I do not know the exact origination.

Mr. THOMAS . . . Where did this new superimposition [of new construction and plant capacity] come from, General, if you know?

General BRADLEY. I do not know who put it down on paper first, but these expansion programs and the increased need for A bombs have been under discussion in the Joint Chiefs of Staff ever since I have been a member from 1948.

Mr. THOMAS. That is the information we want. In other words, it came out of the Joint Chiefs of Staff.

General BRADLEY. I say, I do not know whether they started it or not. I do not know whether the Atomic Energy Commission started it or who started it, but we all feel this way about it." The Supplemental Appropriation Bill for 1953, Hearings before Subcommittees of the Committee on Appropriations, 82d Cong., 2d sess., p. 61 (1952).

Compare the recent decision of the Commission to construct a power reactor capable of yielding at least 60,000 kw. The decision was announced October 22, 1953 by Commissioner Murray in part as follows:

"Until recently defense demands have limited large scale nuclear power efforts primarily to military propulsion projects, such as submarine reactors. But the world situation, as well as the evolving progress of reactor technology, now call for a great change of pace. With this in mind the Commission has decided that it is time for full-scale construction . . . I am very glad to be able to tell you officially today that the Commission has embarked on a program to construct a full-scale power reactor." U.S.A.E.C. Mimeo. release, Remarks prepared by Thomas E. Murray, Commissioner, October 22, 1953, at p. 5.

On the same day the following statement was released by Sterling Cole, Chairman of the Joint Committee on Atomic Energy:

"When the Joint Committee on Atomic Energy first saw the President's proposed budget on atomic energy for the coming year, we realized that it made no provision for getting on with development of a full-scale atomic power plant. As a result of our review of this situation, we got into touch with the House Appropriations Committee and explained the situation to them. Through the close co-operation of the two committees there was included, entirely on Congressional initiative, an authorization to permit the start of construction this year of our first atomic power plant. The Members of the Joint Committee and Congressman Phillips and his colleagues on the House Appropriations Committee can take real pride in having been the originators of this first major step toward realization of the benefits of the peacetime atomic power. It is gratifying indeed to see the Atomic Energy Commission moving so swiftly in carrying out the will of Congress in this project." Emphasis added. Partial text of mimeo. release dated October 22, 1953.

See also the N.Y. Times account of the Fifteenth Semiannual Report of the Atomic Energy Commission:

"The hydrogen bomb references were purposely vague. Without mentioning the type of bomb upon which it had been at work since 1952, the commission said that it had been conducting 'weapon' research in a special laboratory employing 1,500 scientists at Livermore, Calif. The laboratory is being run for the commission by the University of California.

- "Those familiar with the Commission's operations noted today that it was at Livermore that Dr. Edward Teller, the noted atomic scientist, had completed work that reached a climax in November, 1952, with the world's first explosion of a hydrogen device. . . .

- "The laboratory at Livermore was set up on the recommendation of the Joint Congressional Committee on Atomic Energy as a special establishment to supplement nuclear weapons work at the Los Alamos and Sandia laboratories in New Mexico." N.Y. Times, Jan. 31, 1954, p. 1:2 and p. 58:4.
As a first step, the statutory authority of the President over thermonuclear requirements and his affirmative responsibility with respect to their establishment should be made clear beyond question. Secondly, since the President would normally seek the advice of the Department of Defense and the Atomic Energy Commission, it may be desirable to impose a statutory declaration of their responsibilities with respect to military worth and technical feasibility. Finally, the thermonuclear program raises the question whether a high level review should not be required of important development items, and the scope and scale of their prosecution. Thus, members of the Joint Chiefs of Staff, the Military Liaison Committee, the Commission and the General Advisory Committee might state annually whether they are satisfied with the adequacy of the weapons and development programs, with a copy to the President and the Joint Committee on Atomic Energy. The alternative to high level review and recommendations would appear the most precise definition of responsibility with respect to both military requirements and objectives for new development.\(^\text{82}\)

**Constructive Uses.** It is perhaps not surprising that the legal status of any peaceful and constructive uses of thermonuclear energy must be improvised under the 1946 act. At least prior to the statements of Senators McMahon and Hickenlooper, of "some hope, in time,"\(^\text{83}\) it had been said many times that no constructive uses were possible—a position which, if true, would render thermonuclear developments unique in scientific history by having potentialities solely destructive in nature.

There can have been no real question, however, of the authority of the Commission to prosecute the development of constructive applications. The research sections of the act have granted the Commission power to undertake research and development activities relating to such broadly defined areas as "nuclear processes" and the

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\(^{82}\) In addition, the Chairman of the Atomic Energy Commission could be made a statutory member of the National Security Council. See Remarks of Rep. Sterling Cole, mimeo. release from his office dated Feb. 11, 1954, at p. 3.

\(^{83}\) See notes 5 and 6 supra. See also the statement of Dr. Kenneth S. Pitzer, former Director of Research, Atomic Energy Commission, in "What's Wrong with the Atomic-Energy Program," U.S. News and World Report, May 9, 1952, 56 at 58:

"Q. Is the hydrogen bomb, if any, to be of any peaceable use?"

"A. The so-called thermonuclear process might conceivably have some peaceable use, although it is pretty vague."

"Q. But it might be controlled?"

"A. It might, yes. I'm not even going to postulate how it might, but I never like to say that something is impossible—there have been too many people who have predicted something was impossible and within 10 years somebody did it."
It would also appear that there have been under the McMahon Act major areas open to non-governmental development, because key prohibitions in the act against private activity have contained exceptions for research and development activities under section 3.85

Beyond research and development, however, the 1946 act has been vague. It is difficult to see how any apparatus for the constructive application of thermonuclear energy could avoid using "equipment or devices utilizing . . . atomic energy" (if atomic energy be taken in the broad sense of nuclear transformation).86 However, no regulations with respect to the "equipment or device utilizing . . . atomic energy" phrase have been promulgated since inception of the act. The act also makes unlawful the ownership by any person of any "facilities for the production of fissionable material."87 The _H-bomb Print_ of the Joint Committee on Atomic Energy states as follows:88

"There are three possible reactions involving the heavy hydrogens: (1) a deuterium-deuterium reaction (i.e., two nuclei of deuterium fusing to produce tritium, a proton, and energy or helium, a neutron, and energy); (2) a tritium-tritium reaction

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84 Sec. 3(a) authorizes and directs the Commission to make arrangements for the "conduct of research and development activities relating to (1) nuclear processes; (2) the theory and production of atomic energy, including processes, materials, and devices related to such production. . . . (4) utilization of fissionable and radioactive materials and processes entailed in the production of such materials for all other purposes, including industrial uses. . . ."

Sec. 3(b) authorizes and directs the Commission to conduct through its own facilities activities and studies specified in §3(a). Secs. 3(a) and 3(b) are renumbered as §§31 and 32 but otherwise are substantially unchanged in the new bill.

85 Under §7(a) it has been unlawful, with exceptions not relevant, for any person to "manufacture, produce, or export any equipment or device utilizing fissionable material or atomic energy" or to utilize atomic energy with or without such equipment or device, except under commission license. No license could permit any such activity if fissionable material were produced incident to such activity, except as provided in §§3 and 4 of the act. The concluding sentence in §7(a) has stated that: "Nothing in this section shall be deemed to require a license for the conduct of research or development activities relating to the manufacture of such equipment or devices or the utilization of fissionable material or atomic energy, or for the manufacture or use of equipment or devices for medical therapy."

Sec. 4(b) has made it unlawful for any person to own facilities for the production of fissionable material except to the extent authorized by subsection (c). Sec. 4(c)(1) has excepted from the Commission's exclusive ownership facilities useful in the conduct of research and development activities in the fields specified in §3. Compare also §6(b) ("It shall be unlawful for any person to manufacture, produce, transfer, or acquire any equipment or device utilizing fissionable material or atomic energy as a military weapon, except as may be authorized by the Commission. Nothing in this subsection shall be deemed to modify the provisions of section 4 of this Act, or to prohibit research activities in respect of military weapons, or to permit the export of any such equipment or device.") Emphasis added.

86 See the discussion note 32 supra.
87 Sec. 4(b). See note 85 supra.
88 _H-bomb Print_ at p. 1.
(i.e., two nuclei of tritium fusing to produce helium, two neutrons, and energy); and (3) a tritium-deuterium reaction (i.e., a nucleus of tritium and a nucleus of deuterium fusing to produce helium, a neutron and energy).”

These equations raise the speculation that a device in which thermonuclear reactions took place at an appreciable rate could provide a source of neutrons (one equation indicates the production of protons). If it is assumed that such a terrestrial thermonuclear apparatus—a "thermonuclear reactor"—might provide a neutron source, and if it is further assumed that plutonium or U-233 might be made therefrom if one chose to do so, it would still not follow that such a thermonuclear apparatus would be a facility for the production of fissionable material. However, section 18 (g) defines "facilities for the production of fissionable material" to mean any "equipment or device capable of such production . . . as determined by the Commission."89 Thus it is possible upon the set of hypotheses made that thermonuclear reactor could be determined by the Commission to be under the prohibitions of the act.

Finally, it would appear that data concerning peaceful and constructive uses of thermonuclear energy has not been restricted. It will be recalled that the only part of the "restricted data" definition applicable to thermonuclear matters was the "atomic weapons" phrase, because the other two parts of the definition depend upon "fissionable material," and the Commission has not sought to classify thermonuclear material under them (and question exists whether they would have the authority to do so).90 It would seem to follow that if such constructive and peaceful applications were not "weapons" within the meaning of section 10 (b) (1), data concerning them would not be restricted by the Atomic Energy Act.

It would further seem that the possibility of a use which would be advantageous to the military would not be sufficient to sanction classification as a "weapon." Were such construction proper, almost every aspect of our industrial strength would be a military weapon.91

89 Sec. 18(f) provides that the term "equipment or device utilizing fissionable material or atomic energy" shall be construed to mean "any equipment or device capable of making use of fissionable material or peculiarly adapted for making use of atomic energy and any important component part especially designed for such equipment or devices, as determined by the Commission."

90 See the discussion on this point at the conclusion of Part II supra.

91 The new definition of "atomic weapons" in H.R. 9757 and S. 3690, quoted in note 66 supra, seems to make such a distinction. Compare the testimony of Dr. Karl T. Compton in the S. 1717 Hearings at pp. 268-269 (1946):

"Suppose that back when most of you were children and I was a young man, about the time the automobile came in, the War and Navy Departments had said, 'Well, this
The act itself argues against such interpretation. Because of the direct interrelation between power and bomb materials in the fission process, the "production of fissionable material" and the "use of fissionable material in the production of power" phrases occupy a special place in the Atomic Energy Act. Production of power was considered "75% of the way" to the A-bomb. Nevertheless, the 1946 act did not rely upon the "atomic weapons" provision to cover data concerning nuclear power for peacetime use, and it is difficult to avoid the force of this analogy in construing "atomic weapons" with respect to the light end of the table.

In view of these considerations under the 1946 act, it is striking to examine both the extent and the manner of change accorded treatment of any constructive applications by the new bill. The latter creates the new category of "special nuclear material," so defined as to permit the designation and control of fusionable material as well as those determined to be "fissionable," and this term is substituted throughout the act in place of the prior term. A production facility is thus redefined as one capable of the production of "special nuclear material" and a utilization facility is restated as one capable of making use of "special nuclear material." Secondly, the key exemption from control provisions in favor of research and development activities has been deleted and new prohibitions against utilization of special nuclear material have been inserted. Finally, the special nuclear material phrase

internal-combustion engine looks as if it ought to have a very great military significance, and we will classify that information and develop it for our military purposes in trucks, tanks, and maybe airplanes—if they were envisaged at that time.

"I think it is clear to everybody that under those conditions our great automotive industry never could have been developed to anything like the strength that it is now."

92 See the S. 1717 Hearings, p. 86 (1946):

Senator JOHNSON. Mr. Chairman, if the Secretary will permit me, I should like to go back to the difficulty of dividing the wartime from the peacetime uses of uranium or atomic power. The scientists told us that when you used uranium for power, you were 75 per cent on the way to its use as a bomb. In other words, when we use coal for power, the ashes are practically worthless; but when we use uranium for power, the residue is the very thing that we need to create bombs. That makes all the difference in the world, and so the two are tied together so closely that we ought to recognize that fact in any legislation which we propose, which we handle.

Secretary FORRESTALL. There is no question about that.

93 A "production facility" (§11(p) of the new bill) is defined in improved but basically similar terms to a "facility for the production of fissionable material" in §18(g) of the 1946 act and a "utilization facility" (§11(v) of the bill) replaces "equipment or device utilizing fissionable material or atomic energy" in §18(f) of the 1946 act. In both definitions "special nuclear material" is substituted for "fissionable material." See note 85 supra.

94 Although the exception with respect to ownership of "production facilities" is kept in §41(a) of the new bill in the same terms as §4(c)(1) of the act, the exception contained in §7(a) for facilities utilizing atomic energy is deleted. See §101 of the new bill and note 85 supra. Sec. 101 also prohibits transactions with respect to utilization and production facilities except in accordance with the licensing provisions of the act.
has been inserted in the two parts of the restricted data definition which were originally designed to accommodate the close interrelation between fission power and fissionable material production, with the result that all data concerning the "production of special nuclear material" and the "use of special nuclear material in the production of power" would be restricted.

Any conclusions in this field must be qualified by the vagueness of the subject matter. In the author's opinion, however, the constructive application of thermonuclear energy is the most challenging aspect of atomic science and may prove of extraordinary significance. It can be speculated, for example, that power and electricity from the fission reactor may be transitional to power from nuclear fusion. Could the latter be accomplished, energy on a scale sufficient to satisfy the most ambitious of man's projects could be directed to his beneficial use. An effort, however, of large proportions in men, money and materials would undoubtedly be necessary to explore and develop this hope.

In any event, the subject would seem to command a significance apart from whatever its technical prospects may prove to be. The United States has been forced to develop and to be preeminent in hydrogen bombs of great destructive potential. Since it has been, there would seem to be a large and related national stake with respect to development and preeminence in the constructive aspects of this new energy force. Just as the legislative provisions in the act dealing with defense can be sharpened, there would appear every reason for correspondingly explicit emphasis upon constructive goals for thermonuclear energy.

There would also seem to be raised a number of new questions and problems. Is responsibility for leadership in this field to be vested in the government or in private industry? Is exploitation by private enterprise to be encouraged? What steps should be taken from the outset to assure fair and equal opportunity to participate? Who should own development equipment and materials?

These issues are speculatively far beyond any legislative intent with respect to the 1946 act. And their treatment would appear profoundly changed by the new bill. It is possible that this change is intended, but without any manifest emphasis accorded it. It is more probable that the result is the unintended consequence of changes in the act undertaken primarily for other purposes. If constructive uses be an important subject, the 1954 bill appears to represent the most

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95 See notes 65 and 92 supra.
recent evidence of the continuing preoccupation of our program with fission at the expense of emphasis upon and attention to thermonuclear development.

IV

The Issue of Primacy

The issue which underlies legislation concerning the thermonuclear program is one of primacy: is the H-bomb or the A-bomb to be the principal weapon of deterrence and of defense? Assuming we are to have them, are they to be an A-bomb or an H-bomb Army, Navy and Air Force? Which weapon could more effectively counter bases that otherwise might be the springboard of attacks of mass destruction against the United States?

The former Chairman of the Atomic Energy Commission, Gordon Dean, has testified that the $4 billion A-bomb expansion program voted in 1952 is to enable us to meet our minimum security requirements four years earlier than otherwise would be the case. If four years corresponds to four billion dollars in respect of our A-bomb requirements, how much is time worth in the considerably more powerful field of hydrogen energy?

Will the study of light or heavy elements contribute more to our comprehension of the physical sciences? Will fusion or fission yield our chief hope for constructive benefits from atomic energy?

In terms of attention accorded by law, each of these issues has been overwhelmingly weighted in the McMahon Act against the thermonuclear. The Atomic Energy Act of 1946 and its framework, concepts and issues are directed to nuclear energy in the sense of the A-bomb and nuclear fission with a preoccupation that future historians of the early years of the atomic age may find extraordinary. In the ther-

96 The Supplemental Appropriation Bill for 1953, Hearings before Subcommittees of the Committee on Appropriations, 82d Cong., 2d sess., p. 5 (1952): "We could, of course, meet this demand eventually with the facilities we now have on hand or are building. But we would meet it much later. This new expansion is designed to reach the minimum military stockpile requirement at least 4, and possibly 5 years earlier than would otherwise be the case—4 years in which I think we can be sure the Soviet Union will not be idle."

Compare the testimony of General Bradley, former Chairman of the Joint Chiefs of Staff: "... this program is by no means an all-out one." Id. at p. 60.

97 See the remarks of Dr. von Neumann cited note 29 supra. See also GLASSTONE, SOURCEBOOK ON ATOMIC ENERGY, §14.137, p. 409 (1950): "If, before 1939, nuclear physicists had been urged to express an opinion as to the probable direction in which the successful release of atomic energy might be realized, it is extremely doubtful if they would have thought it to be by fission. The general feeling was that it would prove more practical to obtain energy by the combination, or fusion, of light nuclei than by fission of heavy nuclei."
monuclear field, on the other hand, there has been legislative default. If the discussion in this article is borne out, the McMahon Act has not been an act for the development of thermonuclear energy: the indications are that we are a number of years behind where we might be in thermonuclear development. It has not been an act for the control of thermonuclear energy: only one provision in the act apparently has applied to the control of thermonuclear energy as such. Nor has the McMahon Act been one for the encouragement of peacetime benefits from the light elements: the act has a seeming gap with respect to the thermonuclear and specific peacetime goals. The act has missed at least an extraordinarily important—and perhaps the dominant—aspect of atomic energy.

In view of the one-sided preoccupation of the 1946 act with fission energy, it is remarkable that substantive new amendments set forth in 1954 seek to discharge legislative recognition of the advent of thermonuclear energy merely by redefining several terms in the 1946 act. Even this attention to hydrogen energy is accorded indirectly: thermonuclear reactions, weapons and materials are nowhere specifically mentioned. Language engrafted onto an A-bomb act passed in 1946 for a different process involving different materials would seem to misjudge the impact of the hydrogen program and may have the effect of a present judgment that the A-bomb and the fission process continue to be the center of emphasis and interest. Indeed, one might at least as logically pass a new act directed entirely toward the thermonuclear, but which would contain in passing a few phrases sufficiently broad to include the fission process.

Conflict in emphasis is not necessary. If a thermonuclear weapon capability adequate to the common defense and security is an objective, there could be expressed a corresponding goal for A-weapons. If military applications of thermonuclear energy are to be developed at a rate adequate to our security, the scope and scale of A-bomb development could be similarly stated. In one respect, however, the thermonuclear objectives might be more emphasized than fission goals. Since we have been forced to develop the destructive potential of hydrogen bombs, there may be particular incentive to recognize our national interest in exploring every hope there may be for beneficial applications of thermonuclear energy.

These considerations for a substantially new approach are under-

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98 In retrospect it may not be considered helpful that the "atomic weapons" phrase covers H-bomb development. The breadth of the term has helped mask the substantially new issues posed by the thermonuclear program.
scored by a tempo of development, both peacetime and military, much faster than has been anticipated.\(^9\) Both the Chairman of the Joint Committee and the former Chairman of the Commission agree that we have underestimated Russian progress.\(^10\) But the even more serious question is whether we have not underestimated ourselves across the board and—by previous standards—the ease of exploiting nuclear energy.

With the passage of time and with new advances in the technology of nuclear weapons, the capacity for destruction increases. With the advent of thermonuclear energy, the point has been passed when the issues at stake increase by degree—the increase has become exponential. Since 1946 the line between our military requirements and our moral hopes has become more emphatically drawn than ever. The extraordinary difficulty in drafting new legislation is hardly limited to the problem of providing for thermonuclear materials and processes, and their interrelation to nuclear fission, difficult as those problems are.

Nevertheless, the need for realistic legislation with respect to thermonuclear energy is clear. But thermonuclear energy must be accorded the perspective and the awful prestige which are its due. Though falling short of meeting all the problems, fresh and searching legislative effort is a basic first step which is completely within our power and our duty to take.


\(^10\) Compare Gordon Dean, as quoted by The Evening Star, Washington, D.C., Sept. 24, 1953, p. A-1:2: “... we have consistently underestimated the Russians ... ” with the statement of Chairman Cole “... the Soviet hydrogen test occurred sooner, a good deal sooner, than most officials in Washington have anticipated. So let us acknowledge the fact plainly: We still seem to underestimate the Soviets—just as in 1949 we were caught by surprise by Stalin’s first atomic bomb.” Mimeo. release from the Office of Cong. Sterling Cole, Oct. 12, 1953, at p. 1.