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NUCLEAR EXPLOSIONS FOR PEACEFUL PURPOSES

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Few Americans doubt that the United States is engaged in a struggle for survival. Nevertheless, too many of us do not recognize that this struggle is as likely to be resolved by economic and social battles fought over a period of many years as it is by the sudden cataclysm of nuclear war. During the past decade, the attention of the nation has been focused primarily on the tactical position of the United States in a military sense. Obviously, we have not been unaware of the social and economic sides of our conflict with the Soviets. But, we have waged that conflict more with words than deeds, more with enthusiasm than imagination, and more with a view to survival than victory. What is worse, we have tended to neglect an enemy that may, if nuclear war does not come, prove more formidable than any that has yet confronted us or any other peoples. That enemy is the threat of world poverty which stems from the failure to plan adequately for the future material needs of an exploding world population.

THE PRESERVATION OF NATURAL RESOURCES

Whether or not the Soviet Union is a victim of similar myopic thinking, it is clear that the United States, as one of the two major technological powers, must devote a greater part of its total effort to planning for a vastly expanded world population. One method of meeting the problems inherent in the rapid growth of populations is to develop means of exploiting the full potential of the natural resources of the globe. Exploitation in this broad sense connotes the preservation of such natural resources as fresh water, the recovery of mineral deposits that are now submarginal, and the devotion of all natural assets to the uses for which they are most needed and best suited. Achieving these goals will require foresight and the development of new techniques. Thus, one need not be an alarmist, or suggest that we are on the verge of bankrupting our natural resources, to justify a plea for aggressive thinking and prompt action. Nor can we, as a nation, afford to overlook the possibility that the allegiance of countries which remain uncommitted in the present ideological conflict between the United States and the Soviet Union may be swayed by the fact that one of these two powers evidences more interest, and takes greater initiative, with respect to the problem of dwindling natural resources.

Most current estimates of reserves of mineral resources conclude that widespread shortages are not likely to be encountered until the end of the twentieth

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century.[1] In fact, one recent study of fossil fuel resources suggests that present reserves are nearly ten times greater than the requirements anticipated for the next forty years.[2] All experts, however, are not this optimistic. One commentator, for example, in noting that nearly one-half of all the oil and gas ever burned has been consumed since 1940, concludes that "with this fantastic upswing in the rate of consumption of fossil fuels, it is a certainty despite proven reserves, that long before the year 2000 we must be substituting a large amount of nuclear energy for fossil fuel energy."[3] Another expert has suggested that we cannot predict what "consumption will be in twenty-five or fifty years."[4] This suggestion was not prompted by mere academic concern about the accuracy of prophecies. Rather, it was based upon an observation that many depressed peoples, such as the Chinese, presently account for only one-thirtieth as much fuel consumption as Americans; "considering where . . . [the depressed peoples] are and where they intend to go, they represent the possibility of an astronomical increase in the world's energy consumption."[5] Generally, it can be anticipated that the consumption of other natural resources, such as fresh water, will parallel increases in the utilization of fossil fuels.[6] Certainly mineral deposits are consumed more quickly by societies whose industrial growths are reflected in rapidly expanding requirements for electric power. Thus, although a widespread shortage of natural resources is not imminent, we must prepare for the eventual dwindling of supplies of many resources with every means at our disposal.

PROJECT PLOWSHARE

It seems anomalous, but nuclear explosions may provide us with one means for preserving and facilitating the recovery of natural resources that now are being wasted or not fully utilized. The United States has initiated a program to explore the peaceful uses of nuclear explosives. Appropriately, this program has been designated "Project Plowshare."

1. See Weinberg and Wigner, Longer Range View of Nuclear Energy, 16 Bull. of the Atomic Scientists 400, 401-02 (1960).

2. Searl, Fossil Fuels In The Future, AEC, TID 8209 (1960). This conclusion was reached on the basis of compounding of fossil fuel requirements at a rate of slightly over four per cent per year. Reported in BNA, Atomic Ind. Rep., News and Analysis, Nov. 9, 1960 at 6:357, 358.

3. Henderson, Atomic Energy—Its Current Status, Probabilities, and Possibilities, Address before the Annual Meeting of the Association of General Councils, November 17, 1960.

4. Dunning, The Consequences of Power, An Outline of Man's Knowledge of the Modern World 261 (1960).

5. Ibid. One need only note the industrialization of Russia in a period of forty years to be aware of the potential for rapid increases in the consumption of fossil fuels by nations whose present economies are predominantly agrarian.

6. For example, approximately forty per cent of the water used in the United States is consumed by industry, and the proportion tends to increase as industry becomes more highly developed. See Johnson, If We Could Take the Salt Out of Water, N. Y. Times, Oct. 30, 1960, § 6 (Magazine), p. 17.

For most people, the story of Project Plowshare began on June 9, 1958, when Admiral Lewis L. Strauss, then Chairman of the United States Atomic Energy Commission, announced that the ". . . Commission is initiating . . . studies to ascertain the feasibility of . . . [using] nuclear explosives for peaceful purposes."[7] Among other possible applications, the announcement noted that nuclear explosions might be utilized in connection with mining, the recovery of petroleum, or the storage and gradual use of heat contained in subterranean rock structures.

The concept of using nuclear explosions for peaceful purposes actually was not new when Project Plowshare was announced in 1958. Toward the end of World War II, several individuals who had been working on the atomic bomb project of the United States suggested means by which nuclear explosive devices could be employed for research and for producing materials, such as plutonium, not otherwise readily available.[8] However, the need to reserve the then restricted supply of fissionable materials for possible military uses, and the high cost of fission devices, limited speculation and no actual experimentation on peaceful applications was undertaken. When the United States successfully tested a fusion device in 1952, the picture changed and the use of nuclear explosions for a variety of peaceful purposes became a practical possibility. Even then, however, there were only a few individuals who possessed the imagination to foresee the potentiality of this concentrated source of explosive energy. Among them was Camille Rougeron, a retired French military officer, who predicted that constructive uses of fusion explosions would make rapid advances in the ensuing twenty years.[9]

It may seem strange that it took the development of the hydrogen bomb to make most peaceful uses of nuclear explosions sufficiently practical to warrant serious consideration, but there are sound economic and technical reasons for this. Nuclear explosions which derive energy exclusively from a fission reaction involve two major problems which limit the practicability of their utilization for many nonmilitary purposes. First, fissionable material is extremely expensive. Second, the fissioning process induces a great deal of radioactivity in materials immediately surrounding the explosion. If these radioactive materials, known as fission products, are scattered in the atmosphere, they can constitute a serious threat to the health and safety of the public.

On the basis of present technology, these two problems cannot be eliminated entirely in connection with the use of fusion explosions either. It is still necessary to "trigger" a hydrogen device with the heat generated by an explosive

7. Atomic Energy Commission Release No. A-136, June 9, 1958, reprinted in CCH, Atomic Energy Law Rep., New Developments, June 17, 1958, ¶ 9647.

8. Teller, Introduction, Plowshare Series—Industrial Uses of Nuclear Explosives, University of California Radiation Laboratory, UCRL-5253 at 4 (1958).

9. Rougeron, Les Applications De L'Explosion Thermonucléaire, Ed. Berger-Levrault (Paris, 1956).

fission reaction. However, costs and radiation hazards become *relatively* less troublesome problems when a fusion device is utilized. The hydrogen material which provides the energy for a thermonuclear explosion is plentiful and inexpensive in comparison to the enriched uranium or plutonium necessary for a fission reaction. In addition, a fusion reaction does not create radioactive materials which are comparable in quantity or in longevity to the fission products generated by a fission reaction.[10] Since the same trigger can be used to actuate either a small or a large hydrogen device, the inherent disadvantages of fission explosions, namely costs and radiation hazards, will remain fairly constant factors while the total energy released from a single fusion explosion can be multiplied many times. Thus, the relative cost and the relative radiation hazard of thermonuclear explosions will decrease as the total energy yield of the fusion device used is increased. In effect then, economic feasibility and safety, the two essential criteria for the utilization of nuclear explosions for peaceful purposes, are compatible.[11]

Despite the discussion of potential peaceful applications which followed the successful testing of a thermonuclear device by the United States in 1952, it was military necessity, rather than an effort to explore the feasibility of peaceful uses, which first led to an experiment that provided data directly related to the nonmilitary utilization of nuclear explosions. During the middle fifties, the United States found it necessary to continue to test new types of nuclear weapons. However, public indignation about the hazard of fallout was increasing. In addition, the AEC found that delays occasioned by the necessity of awaiting safe meteorological conditions to test weapons were extremely costly[12] and that weather predictions were not always reliable. As a consequence, the AEC planned an underground shot at the Nevada Test Site for the latter part of 1957. The purpose of the shot "was to develop a weapons testing technique which would eliminate fallout; be independent of weather; and have no offsite effects such as noise, flash, and shock. . . ."[13]

This first underground nuclear explosion, code named "Rainier," took place on September 19, 1957. A fission device containing a charge equivalent to 1700 tons of TNT was installed some 900 feet below the surface of a volcanic rock

10. See Brown and Johnson, Non-Military Uses of Nuclear Explosions, University of California Radiation Laboratory, UCRL-5026 at 2 (1958).

11. Of course, it is not enough to conclude that nuclear explosions for peaceful purposes will be relatively safer as the magnitude of the release increases. Obviously, a satisfactory degree of safety in an absolute sense must be assured. The problem of the hazard of nuclear explosions for peaceful purposes will be discussed presently in greater detail; for the moment, we need only note that the hazard does not necessarily increase in direct ratio with the size of the explosion.

12. See Johnson, Pelsor, Preston, and Violet, The Underground Nuclear Detonation of September 19, 1957—Ranier—Operation Plumbbob, University of California Radiation Laboratory, UCRL-5124 at 5 (1958).

13. Id. at 3.

mesa at the end of a self-sealing horizontal tunnel. The results of the detonation were more favorable than could have been anticipated. There was no blast wave, no fireball, no significant seismic ground shock, and no escape of radiation. Even the problem of the contained radioactivity was less troublesome than had been anticipated. Subsequent excavation showed that nearly all radioactivity was trapped in a glass-like layer of fused rock which formed a thin shell inside the underground cavity. This inner shell collapsed into the bottom of the cavity shortly after the blast and proved to be removable with relative ease. From the standpoint of utilizing such explosions for peaceful purposes, the results of the Rainier test also were promising. The generation and diffusion of heat, the vaporization and crushing of rock, and the creation of an underground cavity, all suggested a variety of peaceful applications that might prove workable.[14]

When the Rainier results were evaluated, interest in Rougeron's dream began to increase rapidly. The AEC released a number of technical papers that described a variety of possible applications of nuclear explosions for peaceful purposes and which also made preliminary analyses of the economics of such uses.[15] As commercial curiosity quickened, the AEC initiated an expanded underground testing program directed more specifically at determining the practicability of various peaceful uses. During the fall of 1958, just prior to the commencement of the United States' unilateral, one-year moratorium on weapons testing, four additional underground shots were detonated in Nevada. These shots varied in size from the equivalent of 65 to 23,000 tons of TNT and produced data[16] which was sufficiently encouraging to lead the AEC to announce its intention to carry out several experiments directed at specific commercial applications.[17]

POSSIBLE PEACEFUL USES OF NUCLEAR EXPLOSIONS

A. *Excavation*: Perhaps the most intriguing possibility for using nuclear explosions for peaceful purposes is that of earth-moving. Nulcear explosions could be employed to create harbors where none now exist, to build waterways,

14. For a detailed summary of the Rainier Test results, see id. at 14-26. Also see Johnson and Violet, Phenomenology of Contained Nuclear Explosions, University of California Radiation Laboratory, UCRL-5124 Rev. I at 8-19 (1958); Kennedy and Higgins, Temperatures and Pressures Associated With the Cavity Produced by the Rainier Event, University of California Radiation Laboratory, UCRL-5281 (1958).

15. See Plowshare Series—Industrial Uses of Nuclear Explosives, University of California Radiation Laboratory, UCRL-5253 at 4 (1958).

16. For a description of these four shots, see Johnson and Violet, supra note 14, at 19-26.

17. See e.g., the AEC's announced plan for Project Gnome, an experiment designed to test the feasibility of trapping heat underground and utilizing it slowly as a source of power, BNA Atomic Ind. Rep., News and Analysis, Feb. 18, 1959 at 5:50, and the announcement of plans for experimenting with the use of nuclear explosions to extract oil from oil shales, id., Feb. 25, 1959 at 5:63.

to dam rivers, and to remove overburden in order to facilitate open pit mining operations. Present estimates indicate that such undertakings could be carried out at a fraction of the cost, and in much less time, than is possible with conventional techniques.

For large energy releases, conventional high explosives are much more bulky than nuclear explosives and more dangerous to handle. The largest charge of dynamite ever used by a western nation[18] for a peaceful purpose was a 1300 ton charge exploded in Canada in 1957 to remove a navigational hazard from an inland waterway near Vancouver. This use of conventional explosives produced only three-fourths as much energy as the Rainier shot, now considered a "baby blast," and was about one-twentieth as powerful as the final underground shot detonated by the AEC in 1958.[19] In addition to the fact that nuclear explosions make it possible to utilize much greater releases of explosive energy, they also afford the significant advantage of vaporizing huge quantities of surrounding materials. In contrast, conventional explosives generally just shatter surrounding materials which then must be removed by normal earth-moving techniques if a cleared excavation is desired. Based upon experiments that have taken place to date, it is estimated that a nuclear explosion equivalent to 100,000 tons of TNT, detonated about one hundred feet below a tamped surface, actually can remove about twenty-five million cubic yards of rock and earth and leave a crater more than one-half mile in diameter and two hundred feet deep.[20]

The money saved by undertaking relatively large excavations with nuclear explosives may be nothing short of phenomenal. Assuming even more conservative crater dimensions than have been suggested as possible, the cost of excavating with a nuclear explosion equivalent to 100,000 tons of TNT is estimated to be approximately one tenth the cost of using conventional excavation techniques.[21] And the cost differential will increase rapidly as larger releases of nuclear energy are employed.[22] In addition to cost savings, there are other significant advantages to using nuclear explosions on large excavation projects. For example, it

18. Beginning in 1956, Red China apparently began to use charges of up to 9000 tons of dynamite for purposes of excavation. See Testimony of Dr. Gerald W. Johnson, Hearings on Frontiers in Atomic Energy Research Before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, 86th Cong., 2d Sess. 62 (1960) [hereinafter cited as 1960 Hearings].

19. The Blanca shot, fired on October 30, 1958, released energy equivalent to an explosion of about 23,000 tons of TNT.

20. See Brown and Johnson supra note 10 at 3.

21. See Testimony of Dr. Gerald W. Johnson, 1960 Hearings 58. This estimate assumes the removal of 13 million cubic yards of earth and rock, and is based on a published AEC charge of $1. million for the cost of supplying, emplacing, and detonating the nuclear device. Costs of site preparation, safety studies, and post-shot precautions were estimated at $2 million. Conventional costs of earth removal, presumably in the United States, were assumed to be $2 per cubic yard. It should be noted, however, that excavation costs are extremely sensitive to local conditions and vary widely. Thus, the cost differential between excavating by using nuclear and conventional techniques would not be as great in areas where labor costs are low and a large labor force is available.

22. The cubic yard cost of utilizing a nuclear explosion equivalent to 1 million tons

is believed that a sea level canal across the American Isthmus could be completed in four years by using nuclear explosions, whereas it is estimated that ten to twelve years would be required to complete such a canal with conventional methods of excavation.[23]

According to the experts who have been responsible for the technical aspects of Project Plowshare, the use of nuclear explosions for earth-moving holds more immediate promise than any other peaceful application being considered.[24] Of course, this type of use still requires a great deal of experimentation,[25] particularly since it raises the problem of radiation safety more graphically than any other peaceful use of nuclear explosives contemplated. Since excavation involves surface shots, or slightly subsurface shots which vent to the surface, it necessarily means the release to the atmosphere of radioactivity. The principal concern in this respect is not so much the increased level of radioactivity in the vicinity of an explosion. Such areas can be controlled by monitoring and by the exclusion of persons for periods of time necessary to allow the radioactivity to diminish to safe levels. The real problem of surface shots derives from the fact that total population exposures will be increased somewhat by any radioactivity that is released to the environment. Keeping total population exposures within acceptable limits is one matter that must be dealt with conclusively before Project Plowshare can proceed very far. Unfortunately, this problem is complicated by the fact that Plowshare applications cannot be treated as isolated sources of radiation. The feasibility of using nuclear explosions for peaceful purposes must be considered and evaluated along with all other sources of ionizing radiation which increase the total dosage to which humans are subjected.[26]

It is believed that the quantities of radioactive materials which would be re-

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of TNT for excavating a crater is estimated at 2 per cent of the assumed cost of using conventional techniques, or approximately $.04 per cubic yard. Ibid. It seems doubtful that conventional earth-moving costs, even in areas where the cost of labor is extremely low, could compete with this estimate.

23. Ibid. Thus, even assuming a large supply of cheap labor that could compete with nuclear excavating techniques on cost, the use of nuclear explosions for extensive projects may nevertheless prove worthwhile.

24. See, e.g., Testimony of Dr. Edward Teller, 1960 Hearings 53. Dr. Teller is the Director of the Livermore Branch of the Lawrence Radiation Laboratory, the installation which has had principal responsibility for overseeing and guiding the development of applications of peaceful uses of nuclear explosions.

25. See Testimony of Dr. Gerald W. Johnson, 1960 Hearings 59-63.

26. Of course, it is important to note that present controls imposed on any types of activities which use sources of ionizing radiation do not contemplate absolute protection for human beings. Since any exposure of humans to ionizing radiation is believed to be deleterious, it would be impossible to permit the use of radiation sources and still assure absolute protection of all individuals. Thus, present control concepts endeavor to achieve a reasonable balance between permitting the conduct of activities which use radiation sources and safety; permissible exposures are set at levels which, on the basis of present scientific knowledge, should produce no discernible injuries. As a practical matter, this test of safety is as strict, if not more strict, than that which we apply to other hazardous industrial activities, as well as to commonplace activities like automobile travel where appalling annual death rates apparently are accepted by the public with equanimity.

leased to the atmosphere from nuclear explosions used for excavating can be kept low. The size, weight, and configuration of nuclear devices utilized for surface or slightly subsurface detonations are of little consequence. Thus, not only may flexibility in the design of devices used in this way make it possible to minimize the amount of fission energy used,[27] but such devices also can be surrounded with neutron absorbing materials, such as boron, in order to reduce the quantity and the radiation half-life of the fission products that are released.[28] Cratering experiments that have been conducted to date suggest that ninety-nine per cent of the radioactivity produced can be trapped underground, and that most of the remainder will be deposited locally on the surface.[29] A one-hundred-ton cratering shot detonated by the AEC in 1958 made no detectable contribution to world-wide fall-out levels at a distance of fifty miles.[30]

When the data derived from these cratering experiments is projected to the use of a ten-million-ton thermonuclear explosion for excavating, the Lawrence Radiation Laboratory experts estimate that a control zone approximately twenty miles downwind, and five miles wide, would have to be maintained for a few days. Apparently, however, the entire area would be safe for occupancy, and a forty-hour work week could be initiated within the immediate crater area, at the end of three months.[31]

Thus, on the basis of present knowledge, it would appear that the radiation hazard problem may not prohibit the use of nuclear explosions for earth-moving projects. Certainly there is every reason to anticipate that technological developments will make such projects feasible from the standpoint of safety. As one expert has put it, "I can say, not with certainty, but with quite a bit of hope, that we can make nuclear explosives for peaceful purposes so clean that the worry about radioactivity . . . may disappear completely."[32]

27. Present estimates are that the fission portion of the energy released from a single thermonuclear device employed for surface excavation can be reduced to well below five per cent of the total energy release. See Brown and Johnson supra note 10 at 4.

28. Id. at 3.

29. See Testimony of Dr. Gerald W. Johnson, 1960 Hearings 59. Of course, if only five per cent of the total energy released were derived from a fission reaction, as could be the case if a large thermonuclear device were used, then only five one-hundreths per cent of the radioactivity, in terms of the energy released, would escape to the environment.

30. Id. at 60. The principal reason for this excellent result apparently is the scavenging action of large particles thrown up by the explosion. In addition, a relatively low radioactive cloud, which results from the use of a device that is emplaced some distance beneath the surface, makes it possible to predict meteorological conditions, and hence the local fall-out pattern, accurately. Ibid.

31. Id. at 61. It should be noted, however, that these estimates are based on the application of the data obtained from a 100 ton shot to the use of a 10,000,000 ton shot. Of course, it is not possible to assure the precise accuracy of such an interpolation. Moreover, the estimate does not contemplate that individuals would not be exposed to *any* radiation, but only that exposures would be within what are deemed at present to be safe limits.

32. Testimony of Dr. Edward Teller, 1960 Hearings 51.

B. *Preservation of Water Resources*: Probably the most critical problem of the dwindling supply of a natural resource that confronts us pertains to reserves of fresh water. Recent estimates indicate that by 1975 the United States, for example, will be using ninety per cent of its annual supply of fresh water.[33] This means that many sections of the country will feel shortages long before that time. Other nations, and indeed fairly large segments of the globe, are now plagued by water shortages. Such shortages play a major role in impeding industrial development and agricultural progress. Although the lack of fresh water supplies in some areas is the result of an arid climate, there also are many areas where supplies would be ample if adequate means existed for "banking" the annual "water income." For example, a tremendous proportion of the spring rainfall in the United States runs directly into the sea without being used and without adding significantly to our declining water table.[34] Similarly, many of the world's rivers flow through arid regions on beds of relatively impervious rock. Nuclear explosions could be used to create large storage areas into which some of this unused water income could be directed and drawn upon as needed. Surface reservoirs constitute one type of water bank which could be created. Such reservoirs might take the form of dammed rivers, or of huge surface craters, formed by using nuclear explosives to move earth or to excavate.[35] An even more exciting possibility, however, is the creation of underground reservoirs into which huge quantities of surface water could be diverted and stored without significant loss through evaporation. If, for instance, a nuclear explosion equal to 100,000 tons of TNT were set off under a river bed in an arid region, and the device were placed so that the crushing effect of the explosive energy just reached the surface, calculations indicate that a storage chamber for twelve billion gallons of water would be formed.[36] Such a storage chamber, or aquifer as underground reservoirs are called, would be replenished during periods of spring or storm runoff. Not only could this stored water be pumped directly to the surface as needed, but its presence would tend to raise the water table in the area. In addition, strategically placed aquifers of this type might be used to supplement more conventional systems of flood control.

There are two other possibilities for utilizing contained nuclear explosions to attack the problem of inadequate supplies of fresh water. One is to detonate nuclear devices in a way that will crack natural underground rock barriers which block the flow of subsurface waters to certain areas. The other is to explode nuclear devices in subsurface stratas in which the heat will be trapped;

33. See Johnson, supra note 6, at 17. Of course, this figure refers to the readily available, natural supply of fresh water.

34. Reinow, Robert and Leona, The Day The Taps Run Dry, Harper's Magazine, Oct., 1958 at 72, 75.

35. See Testimony of Dr. Gerald W. Johnson, 1960 Hearings 65.

36. See Johnson and Brown, Non-Military Uses of Nuclear Explosives, Scientific American, Dec., 1958, at 29, 33.

this trapped heat could supply the energy to distill and desalinate brackish inland waters or sea water.[37]

So far, there has been no direct experimentation with these potential means of preserving and increasing present supplies of fresh water. Nevertheless, the possibilities of creating aquifers and of replenishing natural aquifers by facilitating the flow of subsurface waters appear to be particularly promising. The principal concern about safety in connection with these two uses of contained nuclear explosions is the possibility that subsurface waters could become contaminated by radiation. All experiments with underground explosions to date, however, indicate that there may not be a serious problem in this regard. It appears that the radioactive fission products either are trapped in the melted rock, have very short half-lives, or are transported so slowly by underground waters that they become impotent before they have moved more than a short distance from their point of origin.[38]

C. *Recovery of Mineral Resources*: In addition to the possible use of nuclear explosives to remove the overburden from rich mineral deposits that are buried too deep to be worked economically, there are two other possibilities for using nuclear detonations to aid the recovery of such resources. Both involve deep underground explosions which would be completely contained; one would utilize the shattering effect of the immense pressures created by nuclear explosions to facilitate the mining of metallic ores, and the other would utilize the heat generated by such explosions to permit the recovery of petroleum from oil shales.

Underground nuclear explosions could prove particularly valuable in connection with the recovery of metallic ores, such as copper and iron, which occur in concentrated deposits. These ores are not in short supply in the United States at this time, but we already have used our richest known deposits and must rely increasingly on ores which are less economical. Consequently, it is important that we develop more efficient methods of recovery. One relatively efficient method of mining concentrated metallic ores is called "block caving." The block caving method consists of detonating an explosive charge under an ore deposit and thereby destroying the supporting capacity of the underlying rock. If haulage ways are tunneled beneath the unsupported block of earth which contains the ore, the block collapses gradually into the tunnels and makes it possible to recover and haul the ore body to the surface in relatively small fragments. The use of the tremendous energy contained in nuclear explosives would permit the creation of larger, unsupported blocks of ore which could be worked more efficiently than is feasible now.

37. For discussions of the feasibility of trapping the heat of nuclear explosions beneath the surface, and of the economics of utilizing such heat, see Brown and Johnson, supra note 10, at 9; Brobeck, Feasibility and Economics of Power Generation by Nuclear Explosives, Plowshare Series, supra note 8, at 13-16; Reines, Remarks on Containment of Nuclear Explosions, id. at 10-12.

38. See Testimony of Dr. Harold Brown, 1960 Hearings 23-24, and Testimony of W. J. Travers, id. at 33.

Another method of mining mineral deposits deep in the earth is known as the "leaching process." At present this process is employed primarily in connection with copper and sulphur deposits. The leaching process is a relatively cheap recovery method, but it is inefficient in terms of the quantity of minerals that can be obtained from any particular deposit. Surface water is permitted to percolate down through a deposit and then is pumped back to the surface with the ore that has been washed loose. If a large ore deposit were shattered by a deep nuclear explosion and a leaching fluid were pumped through the permeable strata, it is believed that the quantity and concentration of the ore in the recovered fluid could be increased sufficiently to render this mining technique efficient.[39]

The peaceful use of nuclear explosives that has aroused the most interest and has been the subject of most study to date is the possibility of recovering vast quantities of oil that lie trapped beneath the surface in deposits of oil shales and tar sands. Test wells have been drilled and it is estimated that there are approximately six hundred billion barrels of oil in the tar sands which underlie the Athabaska region of western Canada; this is equal to twice the known recoverable reserves of oil in the rest of the world.[40] The Athabaska oil reserves, however, cannot be tapped economically by the use of present techniques. The problem is that the oil contained in the deposits is too viscous to flow freely. If, however, a nuclear device were emplaced through a drill hole beneath the deposits and detonated, it is believed that the viscosity of the oil might be reduced sufficiently to permit recovery by conventional methods. The reduced viscosity of the oil would, of course, be the result of the heat generated by such an explosion. Data from the Rainier test indicates that the moisture content of the tar sands should assure a widespread and even distribution of heat at about 100° C., a sufficiently high temperature to free the oil.[41] There also has been speculation about retorting in place the oil contained in shale deposits. This technique apparently would permit the recovery of a large portion of the oil in such deposits, but it would require maintaining relatively high subsurface temperatures, a feat that now appears to be considerably more difficult than diffusing heat at the moderate temperature necessary to reduce viscosity.

The use of nuclear explosions for recovering petroleum deposits in this manner does not appear to engender significant problems of safety. The explosions could be contained completely, and apparently there would be no serious problems of contaminated ground water[42] or of induced radioactivity in the oil recovered.[43] Although there have been some very optimistic predictions about the economics of recovering oil in this manner,[44] the most recent analyses sug-

39. For a more detailed discussion of this technique, see Adelmann, Uses of Thermonuclear Explosives in the Mining Industry, Plowshare Series, supra note 8, at 34-35.

40. See Testimony of W. J. Travers, 1960 Hearings 32.

41. See Brown and Johnson, supra note 10, at 8.

42. See Testimony of W. J. Travers, 1960 Hearings 33.

43. Id. at 35-36.

44. See Brown and Johnson, supra note 10, at 8. The authors suggested that recovery

gest that too many unknowns exist at this time to permit precise cost estimates.[45] Nevertheless, the method has enough promise to be of continuing interest to a number of oil companies.[46]

D. *Production of Power*: Still another possible use of nuclear explosives for peaceful purposes, albeit one about which there is not a great deal of optimism at present, is the production of electrical energy through the use of the heat generated by subterranean thermonuclear explosions. The data derived from underground shots indicates that anywhere from one-third to one-half of the energy released takes the form of heat in the surrounding materials. If those materials are a dry medium, it is believed that it may be possible to preserve the heat at relatively high temperatures and to tap it gradually.[47] Tapping the heat could be accomplished by pumping a heat-transfer fluid through the high temperature area beneath the surface. Although this method of using nuclear explosives appears to be theoretically attractive from the standpoint of economics,[48] it involves a number of practical difficulties.[49] In addition, there are those who question the technique largely because it seems inelegant and crude by comparison with present day engineering concepts. Nevertheless, the AEC plans to explore this possible use of nuclear explosives by detonating a small-yield device in a salt deposit in New Mexico during 1961.[50]

AN INTERNATIONAL OPPORTUNITY

Since the problems of improperly used and inadequately exploited natural resources are of world-wide significance, and may have serious implications with respect to the viability of western social and political structures, it is essential that we explore the ways of applying all available tools to the solution of these problems. In this context, the peaceful uses of nuclear explosives that seem to be most promising also are those which would appear to be most conducive to rendering meaningful assistance to underdeveloped nations.

During the past decade, our enthusiasm about the potential benefits of the peaceful uses of atomic energy has tended to blur our evaluation of the real needs of countries that are backward in a material sense. In general, we have thought in terms of nuclear generating stations for nations which have few light bulbs, and of radioisotope laboratories for nations which do not have enough hospital beds. Apart from increased literacy and adequate public health facilities, the first logical step toward the development of backward nations is to assist them to exploit their own natural resources. This means a fuller utilization of

costs might be a little as $1. per barrel. Also see Biehl and Henley, On the Possibility of Using Nuclear Detonations for Increasing the Yield of Oil Wells, Plowshare Series, supra note 8, at 36-41.

45. See Testimony of W. J. Travers, 1960 Hearings 37-39.

46. Ibid.

47. See Brown and Johnson, supra note 10, at 9.

48. See Testimony of Dr. Gerald W. Johnson, 1960 Hearings 64-65.

49. See Brobeck, supra note 37.

50. BNA, Atomic Ind. Rep., News and Analysis, Mar. 23, 1960 at 6:90.

land for agriculture, as well as facilitating the extraction of mineral deposits. Irrigation systems and roads and inland waterways are essential to the production and transport of products and materials that can provide the foundations for industrial development.

Inherent in the use of nuclear explosives for excavating, for preserving and increasing supplies of fresh water, and for exploiting submarginal mineral deposits in nations that do not have highly skilled technicians is an advantage that many peaceful applications of atomic energy do not afford. Most uses of atomic energy, such as the production of electrical energy or the utilization of radioisotopes for industrial purposes, are complex techniques that necessitate the continuing attention of highly skilled personnel. A number of the applications of Project Plowshare, on the other hand, would utilize nuclear energy merely as a means of initiating productive activities of a conventional nature. Using the power of the atom in this manner, therefore, would avoid the necessity of technologically backward countries having to recruit, and maintain on a continuing basis, an elite cadre of foreign technicians. Thus, the use of nuclear explosives for peaceful purposes may make it possible for underdeveloped nations to take basic steps toward industrialization, and to do so rapidly. It will also enable those societies to continue to progress largely by the utilization of their own talents, and, therefore, with self-respect.

Accordingly, it is proposed that the United States promptly take the initial steps necessary to transform Project Plowshare into an international program that will have the primary goal of assisting underdeveloped nations. This will require two fundamental alterations in our present national posture with respect to the peaceful uses of nuclear explosions.

First, we will have to expand and accelerate the present program of research and development. By and large, the United States has been pursuing Project Plowshare slowly and without any apparent conviction. An experiment to create a harbor on the northwest coast of Alaska, first suggested publicly by a government official in 1957,[51] apparently has not proceeded beyond the stage of preliminary planning.[52] The consent of the Canadian government to an experimental attempt to release oil from tar sands in the Athabaska region of Canada had not been sought as of the spring of 1960.[53] And, the program of the United States to develop certain basic data essential to proceeding with Plowshare experiments appears to have been entirely inadequate.[54] The clear

51. See Statement of Dr. Willard F. Libby before the Swiss Academy of Medical Science, Lausanne, Switzerland, reported id., June 18, 1958 at 4:198-99.

52. In January, 1960, a representative of the Lawrence Radiation Laboratory stated that such an experiment "hopefully will be conducted within the next year or two." See Statement of Dr. Gerald Johnson, reported in N. Y. Times, Jan. 28, 1960, p. 12, col. 4.

53. See Testimony of John A. McCone, 1960 Hearings 9.

54. See Testimony of Gerald W. Johnson, id. at 61-63. Dr. Johnson's description of the experiments which the U.S.S.R. and Communist China have been conducting with conventional high explosives, in order to develop basic data on cratering and containment, suggests that the Plowshare program of the United States will suffer for lack of similar information.

implication of statements by United States scientists who have been developing the technical concepts of the peaceful uses of nuclear explosions is that Project Plowshare, for one reason or another, has lacked sufficient support by the government.[55] Theoretically, Plowshare now constitutes a promising means of raising the living standards of underprivileged peoples. However, the theory must be proved, and the practical techniques developed, by an aggressive program of research and experiment. Failing such an effort, any public expression by the United States of altruistic international objectives for the peaceful uses of nuclear explosives will run the risk of promising more than we can hope to fulfill.[56]

The other fundamental step necessary to transform Project Plowshare into an asset of United States foreign policy is an expansion and a clarification of the ultimate objectives of our effort to develop the peaceful uses of nuclear explosions. The publicity given to Project Plowshare by the United States thus far has been characterized by vagueness with respect to long-range goals and has been developed through statements which have been anything but reassuring to people who fear *any* additional exposure to radiation and increased stockpiles of nuclear weapons.

In August of 1958, at Geneva, the United States made a presentation of Project Plowshare to the Second United Nations International Conference on the Peaceful Uses of Atomic Energy. Unfortunately, the presentation appeared to be more of an apologetic afterthought than a well conceived attempt to convince other nations of the theoretical promise of nuclear explosions for peaceful purposes. Plowshare was discussed by three members of the United States delegation. The two United States speakers who possessed international scientific reputations dealt with the peaceful uses of nuclear explosives briefly while discussing other subjects.[57] None of the three delegates enunciated clearly any long-range objectives of the Plowshare program. Particularly, they did no more than imply that nuclear explosions might afford a safe and practical

55. See e.g., Testimony of Dr. Edward Teller, id. at 53. During the course of his statement, Dr. Teller said: "I believe that *if* we get the full support of our Government . . . to explore this particular frontier . . . Plowshare will become the first great economic success among the frontiers of peaceful atomic energy." Ibid. (Emphasis added.) Also see Testimony of Dr. Harold Brown, 1960 Hearings 25.

56. It is, of course, essential to avoid overselling the potential of Project Plowshare. Unfortunately, the United States made this error in connection with the Atoms-for-Peace plan announced by President Eisenhower in 1953. The Eisenhower announcement seemed to promise that electricity produced by nuclear energy would change the world into a Garden of Eden; although our intentions undoubtedly were honest, our failure to fulfill the hopes created has not enhanced the prestige of the United States.

57. After an extensive discussion of controlled fusion reactions, Dr. Edward Teller directed attention to Plowshare merely as "another way in which thermonuclear energy can be made to serve peaceful and constructive purposes." Reported in Atomic Industrial Forum, The Forum Memo 23 (Oct., 1958). Dr. Willard Libby, then a member of the Atomic Energy Commission, mentioned Plowshare during a Conference session on Progress in the Use of Isotopes. Id. at 24. The United States conference paper which presented the details of Project Plowshare was delivered by Dr. Gerald W. Johnson.

means of assisting underdeveloped nations to begin to utilize the full potential of their natural resources. Worst of all, each of the three United States speakers made the tactical blunder of referring to the use of "bombs" for peaceful purposes.[58] As a consequence, the presentation of Project Plowshare by the United States at the Geneva Conference was received coolly and with concern on the part of most participating nations.[59]

Despite the initial mishandling of Project Plowshare on the international scene, it may not be too late for the United States to correct the misunderstandings and apprehensions that have been created. We should now take the logical step of announcing that the United States has adopted a policy of proceeding with an accelerated and expanded program of research and development on the peaceful uses of nuclear explosions principally as a means of assisting underdeveloped nations to make *rapid* advances toward increased productivity, industrial growth, and improved living standards. In order to make the goals of this new policy as clear and as acceptable to other nations as possible, such an announcement should be both cautious and forthright in a number of respects.

First, the announcement should carefully describe the theoretical concept of the use of nuclear explosives for peaceful purposes and explain how explosions might be employed to increase supplies of fresh water, to facilitate the extraction of mineral resources, and to expand systems of transportation. Second, the announcement should emphasize that peaceful uses of nuclear explosions are still in the developmental stage and that a great deal of experimentation remains necessary in order to confirm present calculations with respect to safety and economics. In this regard, we should publicize in advance the experiments we plan, invite representatives of all nations to observe such experiments, and publish all data developed relevant to safety, costs, and technological results. Third, the announcement should stress the distinction between the peaceful uses program and any continuing program of the United States to test nuclear weapons. This distinction should be emphasized by divorcing the administration of the Plowshare program from personnel engaged in the military aspects of the atomic energy program of the United States,[60] as well as by a greater degree of declassification of information concerning peaceful nuclear explosions.[61] Fourth, our stated policy on Plowshare should be characterized by a consciousness of safety problems and by generosity toward nations that require assistance. To these

58. Id. at 23-24. In fact, Dr. Johnson is reported to have stated that "any old bomb would do."

59. For a brief summary of reactions by various nations, see The Forum Memo, supra note 57, at 25. E.g., V. S. Emelyonov, the head of the Russian Delegation, stated: "Mr. Johnson said 'bombs'—therefore, they must be radioactive and a hazard to health."

60. It is interesting to note that Project Plowshare is still administered by the Atomic Energy Commission's Division of Military Applications. Although this may be practical from a developmental point of view, doubtless it is not very reassuring to nations who may feel that the Plowshare program, in reality, is a part of our weapons program.

61. For a discussion of the practicability of declassifying Plowshare data, see p. 19 infra.

ends, we should make it clear that as individual peaceful uses of nuclear explosives are proved to be safe and economically practicable, we plan to allocate a liberal portion of the total number of explosions that can be employed consistent with safe world-wide radiation levels to nations that request such uses for purposes of economic development. We also should express our intention to impose only those charges for the services of the United States, such as for designing, emplacing, and detonating devices, and for evaluating and controlling health and safety problems, as are consistent with a particular nation's ability to pay. Finally, our Plowshare announcement should state explicitly that, at such time as adequate controls are developed to assure that nuclear devices designed for peaceful purposes cannot be misused, we are prepared to have the Plowshare program placed under international supervision.[62]

Unquestionably, this proposal contemplates a rather bold step by the United States. As such, it raises a number of policy problems and, no doubt, will encounter resistance on a variety of grounds. Although it is not possible to deal in detail in this article with all of the problems involved,[63] it is possible to identify and make a few observations about the major drawbacks of the proposal that are likely to be cited.

THE MAJOR PROBLEMS OF FOREIGN ASSISTANCE THROUGH PROJECT PLOWSHARE

A. *Safety*: Perhaps the most serious question that will be raised about any use of nuclear explosions for peaceful purposes is the possible hazard to the health and safety of the public. Since any nuclear explosions will add some radioactivity to the general environment, and since any exposure of human beings to ionizing radiation is believed to be deleterious, the safety issue is of vital import. Nevertheless, as we have seen, a number of experts believe that the radiation safety problems engendered by the peaceful uses of nuclear explosives are controllable within

62. There already have been suggestions for internationalizing Project Plowshare. Dr. Edward Teller and the National Planning Association's Special Project Committee on Security Through Arms Control both have recommended international supervision and conduct of the peaceful uses of nuclear explosives; unfortunately, neither recommendation was very precise on how this could be achieved. In 1959, the authors suggested that Project Plowshare might be an appropriate undertaking for the International Atomic Energy Agency, but noted that the Agency, at that time, did not have a "cadre of individuals technically qualified to deal with the intricacies of nuclear detonations." See Berman and Hydeman, The Research Frontier, Saturday Review, Sept. 5, 1959, p. 56-57. There has been no indication that the International Atomic Energy Agency has taken any initiative along these lines.

63. Clearly, the administration of a program which offers nuclear explosions to other nations would involve a number of practical problems such as the charges to be imposed, the priorities system to be employed, the establishment and application of criteria pertaining to which proposed uses are worthwhile, the allocation of devices between domestic and foreign use, and the implications in terms of the long-range diplomatic and economic goals of the United States. Admittedly, these problems will be complex and difficult to resolve, but they are by no means insuperable.

reasonable limits, and that further developmental efforts may increase the degree of safety that can be assured.[64] While much experimentation remains necessary in order to prove these postulations conclusively, it also is essential that the radiation safety question be kept in proper perspective. An excellent statement of the kind of perspective we should maintain with respect to all activities that involve the use of sources of ionizing radiation has been made by a leading expert on the problem of radiation protection:

> The concept of a permissible level of radiation rests on a general assumption. This is that we cannot in practical daily life avoid all risks but must endeavor to regulate our activities in such a way that the risk from any given source is not unacceptably great. The degree of acceptability varies. For example, we accept tens of thousands of deaths caused by automobiles as balanced by the convenience and speed of transportation. On the other hand, two or three deaths from smallpox would be regarded as a great threat and would lead to emergency measures for control.[65]

This simply is another way of saying that while it is appropriate to expend considerable effort to minimize the radiation hazards that may result from the use of nuclear explosions for peaceful purposes, it also may be appropriate to assume some additional risk to the health and safety of the public if the counterbalancing benefits that can be derived from such explosions appear to be sufficiently meritorious. Thus, the possibility that Project Plowshare may engender some additional risk of radiation injury should not automatically be viewed as a bar to the program; rather, the risk involved should be just one element, albeit a very weighty one, in every determination of whether any particular use of nuclear explosives for a peaceful purpose is worthwhile.

B. *Security*: Two principal security issues are raised by a United States policy of making peaceful nuclear explosions available to other nations. Both relate to security in the broad context of international relations. One is the effect which the announcement of such a program by the United States will have on the negotiation of an agreement to terminate the testing of nuclear weapons by the four major atomic powers. The other is the question of whether some degree of participation in the detonation of nuclear explosives for peaceful purposes will assist nations that do not yet have nuclear weapons to acquire a weapon capability and thereby hamper efforts to achieve nuclear disarmament.

The Geneva discussions on the cessation of nuclear weapons tests have proceeded on the basis of an agreement in principle between the United States

64. See discussion p. 7, 8, and 11 supra.

65. Statement of Shields Warren, M.D., Scientific Director, Cancer Research Institute, New England Deaconess Hospital, reprinted in Employee Radiation Hazards and Workmen's Compensation, Hearings before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy, 86th Cong., 1st Sess. 157 (1959).

and the U.S.S.R. that the use of nuclear explosions for peaceful purposes would be permitted.[66] There has not, however, been any agreement on the important matters of numbers of explosions for peaceful purposes or of the means of assuring that allegedly peaceful detonations are, in fact, for peaceful purposes and do not have military significance. Concern has been expressed that the United States might complicate and confuse the issue of stopping weapons tests by proceeding to experiment with the peaceful uses of nuclear explosives,[67] as well as provide the U.S.S.R. with an excuse for resuming the testing of nuclear weapons. Admittedly, the United States would take calculated risks along these lines if it proceeded with an accelerated Plowshare program. However, the progress of the test cessation discussions to date has not been very encouraging, and it may be that the degree to which the negotiations might be further impaired no longer justifies postponing an imaginative expansion of our Plowshare program. Certainly if the United States were to declassify Plowshare data extensively, divorce the program from administration by personnel who are concerned with military programs, and invite representatives of all nations to observe all Plowshare experiments, there would be no legitimate basis for the Soviet Union to question the peaceful motivation for the program.[68] In fact, if the United States were to take these steps, the Russians might even feel compelled to do likewise and disclose more fully the goals and status of, and the data developed in connection with, their experimental program of utilizing high-yield chemical explosions for peaceful purposes.[69]

Discussions on the issue of disarmament have been pervaded by concern over the possibility that more and more countries may acquire nuclear weapons. This possibility, frequently referred to as the "Nth country" problem, is disturbing because a greater diffusion of nuclear weapons capability could upset international stability and increase the mathematical chances of a nuclear war. Thus, a significant question posed by a proposal to make nuclear explosions for peaceful purposes available to nations which do not now possess nuclear weapons is whether doing so will accelerate the development of a weapon capability by such nations. It is assumed, of course, that the United States, in pursuing such a program, would not make the explosive devices available to Nth countries; rather, it is contemplated that the United States would maintain control by

66. See Testimony of John A. McCone, 1960 Hearings 10.

67. See Testimony of Dr. Henry D. Smyth, id. at 14-16.

68. Obviously, the Russians might derive some temporary propaganda value from an expanded United States Plowshare program, but we have learned to live with that type of problem during the fifteen year history of the Cold War. Perhaps it is time that we also learn to accept temporary setbacks in national prestige if that is necessary in order to achieve a significant long-term gain.

69. Apparently, the U.S.S.R. has been pursuing an extensive experimental program of utilizing high-explosives for peaceful purposes. See Johnson, The Soviet Program for Industrial Applications of Explosions, Lawrence Radiation Laboratory, UCRL-5932-T, reprinted in 1960 Hearings 69-81. Although it is not clear whether the Soviets have employed nuclear detonations for similar purposes, their chemical explosion program will provide them with excellent experience for doing so. Id. at 76-77.

designing, emplacing, and detonating the devices for such countries. Nevertheless, it must be anticipated that countries which are the recipients of such services will expect to participate in these activities and be thoroughly apprised about the devices employed. A recent evaluation of this problem by Dr. Edward Teller, a man who should be extremely sophisticated about all its implications, suggests that participation by Nth nations in peaceful nuclear explosions need not necessarily enhance their weapon capabilities.

It should be recognized that devices employed for peaceful nuclear explosions are not effective weapons. As Dr. Teller has stated, "they are related to military explosives like a passenger car is related to a tank. The principles . . . are similar. The execution is quite different, and the technical knowledge obtained from one is only indirectly relevant to the other."[70] The continued classification of nuclear devices employed for peaceful purposes, therefore, may not be an essential concomitant of preventing the diffusion of nuclear weapon technology to Nth countries. In discussing the possibility of declassifying peaceful nuclear devices, Dr. Teller has said:

> The secret of nuclear explosives is far less secret than we hoped and than we believed. I think we should not disclose our advanced concepts of nuclear explosives for wartime purposes. But the general principles cannot be kept secret. It is only these general principles which need become known. One could choose the design of peaceful explosives in such a way as to disclose a minimum of the information that is useful for bomb design.
>
> The hints which we are giving that way I believe will not be very significant. . . . I also believe that in disclosing the information we need not explain in detail how we perform our calculations, how we construct our theories. We merely say that the black box into which we put our nuclear explosive is no longer black. Here it is; we can open it. This part serves this purpose and this part serves that purpose. This is the sequence of events that occurs during an explosion.
>
> We need not tell people: This is how we perform our difficult calculations in detail. If we make disclosures in a discriminating way, I think we can assure everyone.[71]

It would appear, then, that while problems of national and international security may be significant factors to be considered before the United States initiates a

70. Testimony of Dr. Edward Teller, 1960 Hearings 52. Dr. Teller, who frequently is credited with the development of the hydrogen bomb for the United States, probably is as conversant with the implications of the design and development of nuclear weapons as any man alive. Dr. Teller went on to suggest the fundamental difference between what he described as "deliverable" weapons and "clumsy, big, heavy" nuclear devices used for peaceful purposes. Ibid.

71. Testimony of Dr. Edward Teller, 1960 Hearings 54. It may be worth observing that Dr. Teller is a scientist who has never been known to take a relaxed attitude toward matters of national security.

program which offers peaceful nuclear explosions to foreign nations, the nature of these problems, like the problem of safety, suggests that we proceed with caution rather than not at all.[72]

C. *Public Emotion*: A third major problem raised by a suggestion that we use nuclear explosions for peaceful purposes stems from the fact that the whole concept tends to appall people. Strong initial opposition on purely emotional grounds may well be encountered by a proposal to make nuclear explosions available to foreign nations. The relatively fresh recollection of the use of nuclear weapons against civilians at the end of World War II, public fears of deformed future generations, disagreement among scientists about the effects of fall-out, and a feeling that any nuclear explosive is in fact a weapon, have led even sophisticated individuals to make an intuitive assumption that the pursuit of Project Plowshare is unwise and unjustified. The possible adverse emotional reaction of the public to peaceful nuclear explosions was both expressed and described in a recent statement by Dr. Henry Smyth:

> Even if our use of nuclear explosions for peaceful purposes promises to contribute significantly to our material welfare, I still question its political advisability in terms of international understanding and peace. . . . I have a feeling, based on watching reactions for a long time . . . that reactions to these atomic explosions . . . are not rational reactions. . . . It is for this reason that I am suggesting that the simplest way to avoid trouble is to avoid using these nuclear explosions for peaceful purposes, at least for a period of years. . . . It requires a high degree of sophistication to distinguish between a device that you say is not a weapon but is a nuclear explosion, and a device that you say is a weapon and you can drop on somebody and blow him to pieces.[73]

It would be foolhardy to deny or underestimate the import of Dr. Smyth's statement. But, it may be more foolhardy to forego the potential benefits of the peaceful uses of nuclear explosions without making a considerable scientific and public relations effort.[74]

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72. As Dr. Teller has observed in this respect: "Had we been governed by *utmost* caution, then we would not have disclosed to the world nuclear reactors either. In that case, history would have passed right by us, and we would be now left behind." Ibid. (Emphasis added.)

73. Testimony of Dr. Henry D. Smyth, Chairman, University Research Board, Princeton University, and former member of the Atomic Energy Commission, 1960 Hearings 15, 16.

74. Senator John O. Pastore expressed this point of view in response to Dr. Smyth's testimony before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy during 1960. Senator Pastore said: ". . . I am a little amazed that a scientist like yourself, and an educator like yourself, is sweeping under the carpet all of the possibilities and the potentialities of exploration of this great science, even for the benefit of mankind, because you are afraid that such peaceful exploration would arouse the suspicion of some people who would not believe us anyway." 1960 Hearings 17.

The problem in terms of emotional reactions is largely one of reassuring and educating the public. There is no inherent reason why people cannot learn to accept the use of nuclear explosives for peaceful purposes, just as they have learned to accept the necessity of chemical explosives, and are learning to accept the essentiality of nuclear power, as tools that may play a vital role if the increasing needs of a rapidly expanding world population are to be met. Obviously, the United States cannot expect immediate and widespread acceptance of Project Plowshare solely on the basis of announced plans and objectives; there are too many peoples who are ready and willing to mistrust our motives. If, however, we set forth our Plowshare program in terms and o: conditions that will reassure those nations which do have confidence in us, and avoid giving those who do not trust us any justification for overt action, we will have created an atmosphere in which it will be possible for the United States to prove its good intentions.[75]

CONCLUSION

The world has come a long way in the twenty years that have passed since World War II began. For two major segments of the earth's population, allegiance to radically different political ideologies has become relatively fixed. At the same time, a large bloc of politically uncommitted nations has emerged from the penumbra of colonialism. The peoples of these newly emergent nations are well aware of their material insufficiencies and are eager to improve their lot. It is essential that we help them do so, if not to acquire their allegiance, at least to maintain their neutrality.

Raising the living standards of the underprivileged peoples, however, is not going to be a simple matter of providing them with conventional types of aid. Financial loans, medical training, disaster relief, and past concepts of simple technical assistance may not suffice to keep standards of living at present levels, let alone to improve them. The present rate of growth of the population of the world will impose greater and greater pressures on existing sources of supply. Lacking the means to expand their own productive capacities, whether it be for food, raw materials, or consumer products, the underdeveloped nations will become ever more dependent upon, and an ever greater burden to, materially advanced countries. In addition, the "have-not" nations also will become increasingly dissatisfied with the material disparities which exist between them and the "have" nations. It is reasonable to suggest, then, that our obligation to advance underdeveloped countries may no longer be merely a matter of social

75. During the Joint Committee's 1960 hearings on Plowshare, Senator Pastore suggested that such an atmosphere might be created if we "invite all the scientists of all the world to come here as observers and see what we are doing . . ." Ibid. If Dr. Teller's views are correct that it may be possible to declassify Plowshare data extensively without jeopardizing international security, we could go even further than Senator Pastore has suggested to reassure other peoples. Rather than inviting scientists from other nations merely to come and observe, the United States might ask a selected group, particularly from the neutralist bloc, actually to participate in the Plowshare program.

conscience; rather, it could become a matter of political and cultural survival.

The rapid advances which science has made in the past two decades have provided us with new means for exploiting our environment in ways that can meet the physical needs of the future. What remains is for this generation to use these technological advances with vigor and imagination. The use of nuclear explosives for peaceful purposes appears to afford one relatively promising means of achieving a greater utilization of the natural resources that are potentially available to us. It would be unfortunate indeed if the United States, out of *excessive* caution, failed to explore this possibility completely.