THE FUTURE OF PLOWSHARE*

John S. Kelly, Director
Division of Peaceful Nuclear Explosives
U. S. Atomic Energy Commission

Since the last general symposium on Plowshare in 1964, significant progress has been made 1) in improving our understanding of explosion phenomenology, 2) in developing suitable explosive designs, and 3) in applying the technology to specific applications in the industrial, public works and scientific areas. The papers to be presented at this symposium will discuss in depth the progress that has been made in each of these areas, and to some degree, what still remains to be accomplished, so I will not attempt to go into detail here. However, I would like to take a few minutes to summarize where the technology stands today, where we believe it is going, and most importantly, how we hope to get there.

In the excavation area, both Cabriolet and Schooner extended cratering experience in hard rock to higher yields. We also conducted Project Buggy, the first nuclear row-charge experiment. Buggy involved the simultaneous detonation of five 1.1 kiloton nuclear explosives, spaced 150 feet apart at a depth of 135 feet. The explosion created a smooth channel about 865 feet long, 254 feet wide and 70 feet deep. Two very significant contributions from Buggy were information on spacing between the explosives and on lip height. Buggy demonstrated that explosives can probably be spaced somewhat farther apart than previously thought without significantly affecting the smoothness of the channel. This could result in considerable savings in future row-charge excavations. We were also particularly pleased that, as predicted, the height of the lips at the end of the ditch was less than half the height of the lips on the sides--some 14 feet versus 41 feet. This is extremely important for the connecting of ditches. The data obtained from Buggy, Schooner and other experiments have been used to extend and refine our predictive capability.

*This paper was delivered by Richard Hamburger, Assistant Director for Technical Operations, Division of Peaceful Nuclear Explosions, U. S. Atomic Energy Commission.

Most dramatic has been the success in developing an explosive for excavation purposes. Based on our success to date, we can assume, due to 1) the amount of scavenging during the venting process, 2) the effect of special emplacement techniques and extensive neutron shielding, and 3) the use of low fission explosives, that the sum of fission products airborne in the radioactive cloud and in the fallout for each nuclear explosive detonated may be expected to be as low as the equivalent of 20 tons. Further, the tritium release may be less than 20 kilocuries per kiloton of total yield, and the sum of the activation products airborne in the radioactive cloud and in the fallout may be expected to be as low as the amounts shown in this chart.

REPRESENTATIVE SET OF INDUCED RADIOACTIVITIES

AT DETONATION TIME

(TOTAL IN CLOUD AND FALLOUT)

	NUCLIDE PRODUCTION, KILOCURIE FOR YIELD OF		
NUCLIDE	100 KT	1 MT	10 MT
Na^{24}	200	800	2000
P^{32}	0.1	0.4	0.8
Ca^{45}	0.01	0.03	0.06
Mn^{54}	0.1	0.3	0.7
Mn^{56}	600	2000	5000
Fe^{55}	0.04	0.15	0.3
Fe^{59}	0.04	0.15	0.3
W^{185}	6	10	14
W^{187}	300	500	700
Pb^{203}	1000	7000	20000
Other	15	20	40

NOTE: This is not a complete list, and the amounts given may be upper limits rather than best estimates.

In the area of completely contained explosions, analyses of Gnome, Handcar and relevant weapons test data have improved our understanding of such things as cavity and chimney formation, fracture characteristics and containment. Using this data, computer codes were successfully developed and are being improved to predict such effects.

Two application experiments have also been conducted jointly with industry--Project Gasbuggy, the first joint government-industry nuclear experiment to investigate nuclear stimulation of a low productivity gas reservoir, and Project Rulison, the second such venture. The technical results of these experiments will be given in subsequent papers. I am happy to be able to add, however, that the results to be presented on Gasbuggy now make it possible to say that it was completely successful in every respect, including stimulation.

Some progress has also been made in the scientific area in using nuclear explosions to create heavy isotopes. The most successful experiments to date have produced fermium-257, starting from uranium-238, a process requiring 19 successive captures and 8 or 9 subsequent beta decays. Eventually, we hope to produce long-lived isotopes of mendelevium, element 102, lawrencium, and even higher atomic numbers.

While the technology has moved forward since 1964, experiments are still needed to improve our understanding of basic phenomenology. We have to examine the effect of greater depths and different rocks on chimneying and cratering mechanisms; and the interaction of multiple explosions still remains to be investigated both in the contained and cratering area. The possibility of enhancing useful effects and minimizing or eliminating undesirable effects remains to be explored.

Explosive designs suitable for specific applications must be developed. I noted earlier the progress made on the excavation explosive. Similar efforts must be undertaken to design explosives suitable for other applications. In this respect both Gasbuggy and Rulison provided valuable insight into the type characteristics and design trade-offs most appropriate for the gas stimulation application, for example, weighing the costs of using more expensive fuel against savings resulting from reduced product contamination.

Fielding operations must also be streamlined. The single cable emplacement firing technique used by LASL in Rulison was a step in this direction. The radio firing approach being developed by LRL also promises to simplify fielding operations, eliminating the need for ground cable and providing for a more efficient use of equipment and personnel.

The progress made in the non-technical areas of the program has been as significant as the technical advances. In particular, I refer to the Gasbuggy and Rulison projects. As important as the technical objectives was the joint industry-government nature of these experiments. Gasbuggy and Rulison provided invaluable concrete experience in how such cooperative efforts can be realized. Many mistakes were made, as can be expected in any such first undertaking. We, however, have learned from these experiences. More importantly, Gasbuggy and Rulison demonstrated that government and industry can successfully work together to develop this technology.

Another significant development is the increasing interest in the international community--an interest, I might say, which is reflected in the participation in this symposium today. Probably the most graphic example of this interest is the inclusion of an article on peaceful nuclear explosions in the Nonproliferation Treaty, which is expected to come into effect early this year. Article V of that Treaty assures that the potential benefits of the peaceful applications of nuclear explosions will be made available to the non-nuclear weapon states party to the Treaty. It further stipulates that such benefits will be available on a non-discriminatory basis and that the charge for the explosive devices used will be as low as possible and exclude any charge for research and development.

Subsequent to the negotiation of the NPT, the Soviet Union acknowledged that they were pursuing a program in this area and expressed their intention to provide a peaceful nuclear explosion service in conformance with the Treaty. This announcement came in Vienna last April following the first technical talks on peaceful nuclear explosions held between the Soviet Union and the United States.

During the past year, partially as a result of the NPT, the IAEA has become more active in the field of peaceful nuclear explosions. Recently a report was prepared by the IAEA Board of Governors on the Agency's role in connection with nuclear explosions for peaceful purposes. The report concluded, among other things, that the "Agency should approach the subject on an evolutionary basis, devoting its energy initially to the exchange and dissemination of information." Implementing this policy, the Agency is currently planning a panel on the peaceful nuclear explosion technology to be held this coming March.

A third key development in the non-technical area has been the introduction of legislation, during the last two sessions of Congress, to extend AEC's authority to provide nuclear explosion services on a commercial basis. AEC's current authority is limited to projects that have a research, development or demonstration purpose. We contemplate that such a government-provided service would consist of the design and fabrication of the nuclear explosive, its transportation to the emplacement site, supervision of its emplacement in the prepared hole, and its arming and firing. The service would also include appropriate technical reviews, including those related to safety. The user would be responsible, subject to AEC review and approval, for all other aspects of the project, including detailed project definition, preparation of the emplacement site and hole, and operational and safety support.

One of the key factors in the success or failure of our efforts to bring the technology to commercial fruition has been and will continue to be our interaction with the users of the technology in industry, government, or the scientific community. From the beginning we have relied on a continuing dialogue with such groups for guidance and support. We believe that improving and extending this dialogue is essential for the further development of this technology. Accordingly, we have taken a number of steps both to improve communication with users of the technology and to develop more efficient methods of operations to meet the changing needs of the technology as it approaches practical use.

One of the basic steps we have taken has been to reorganize the AEC Plowshare staff both in the field and at Headquarters. Program management responsibility, including that for coordination and cooperation with industry, the public, and other interested agencies and organizations, has been centralized in the Division of Peaceful Nuclear Explosives. In addition, the Nevada Operations Office has established the Office of Peaceful Nuclear Explosives to serve as a central point for working with industry in the design of field operations for joint projects. We believe this reorganization will enable the government to deal more efficiently with our partners in developing this technology.

We also recognize that, if the government's role in providing the technology is to be kept to the minimum, suitable criteria and standards for operations must be developed and published. Government interfaces with the users must be clearly delineated and overall management and operations must be simplified. Effort is underway to accomplish this.

We are also developing a number of planning guides to help industry understand what the government requirement will be for joint projects. Guides on management procedures and safety planning are currently being prepared. In addition, guides will be developed on:

a. Nuclear operations procedures
b. Engineering, construction & support consideration
c. Public acceptance
d. Security and classification considerations
e. Site acceptability considerations

The development of suitable radiation standards for products recovered with the aid of nuclear explosions is another area we are actively pursuing. The Oak Ridge National Laboratory is currently investigating possible exposure pathways to the public from such products and the amount of radiation exposure which might result. We believe such information will permit the progressive and timely development of regulations which are related to the specific condition prevailing at the various stages of development.

We also recognize that there is a very real requirement for seeing that the technical data in the program is made available to the users as expeditiously and as fully as possible. Accordingly, efforts are underway to improve and facilitate the dispersion of technical data generated under the Plowshare program. Open files on projects Gasbuggy and Rulison have already been established at the USBM Office of Mineral Resource at Denver, Colorado; the USBM Bartlevsille Petroleum Research Center at Bartlesville, Oklahoma; and at the University of Nevada, Las Vegas, Nevada. This practice will be followed for subsequent experiments.

In addition, a considerable amount of other data has been identified of interest to the program and action is being taken to make more of this data available to industry. Classification is, of course, part of this question. However, almost all of the data on the explosion effects is unclassified. In addition, on a case by case basis, we have declassified diameters, yields and other characteristics of the nuclear explosives themselves, for example, data on the radioactivity in natural gas. Some data, however, because of security reasons, still remains classified. We are in the process of reviewing this data, and hope eventually to declassify all data not related to the internal design, operation and manufacture of the explosive. Specifically, we hope to declassify all pertinent data on explosive characteristics, such as yield, diameter size, weight, costs and external explosion effects such as debris, neutron flux, etc. Our objective is to declassify all pertinent data and make it available as expeditiously as possible so that industry and others will have everything required to assess the technical and economic factors of any particular project and to evaluate independently the public health and safety considerations.

In addition to the dissemination of technical data, steps have also been taken to make all pertinent cost data available. This past December a paper was presented at the AIF Annual Conference on the Costs of Plowshare Projects, and a report on the hardcore costs of projects Gasbuggy and Schooner was also published. We view these reports as part of a continuing effort to be updated as projects are conducted.

As I indicated above, our relationship with the user, whether it be industry, government, or the scientist, is basic to the successful development of the Plowshare technology. If we are to meet your needs, we must continue to work with you and exchange ideas.

Accordingly, it is in this vein that I would like to offer for your consideration a somewhat different approach to the development of various applications. Specifically, I would like to invite the users or potential users to join with us in developing programs of such breadth and length as to see an application through to the complete evaluation of its potential. In this I believe we need to design multi-year programs to solve the technical, administrative, and sometimes legal problems that exist as barriers to such development. Such programs, I believe, should scope out the developmental functions and costs associated with a particular application. They should consider such things as the sequence and nature of developmental experiments; appropriate related explosive development and testing; the creation or adaption of the necessary conventional production and distribution plants and equipment; and the definition of codes and standards for product use. These total development costs could then be weighed against the potential benefits to be obtained from the use of a developed technology, for instance, the potential increase in natural gas supply and consequent benefits that would be passed on to the consumer. Such an application approach has the added advantage that each project would be viewed in light of its contribution to the development of the total application and not as an individual technical achievement.

In a sense, this is the approach we have been following informally. It certainly is consistent with our current project-oriented effort. However, we believe that such an application-oriented approach as described above would permit both the user and the government to delineate more clearly the potential returns from their investment in the technology. The need for more precise cost-benefit analysis is becoming crucial as government funds for research and development become more scarce and the intensity of the competition for these funds increases. I believe Plowshare can meet both the cost-benefit and the environment tests and prove its worth. I further believe realistic, achievable, and challenging goals will help us in this endeavor.

Accordingly, in closing, I urge you to join in establishing meaningful goals for Plowshare. Now is the time for defining our aims--for determining where and how we are going to go.

We can have natural gas from nuclearly stimulated wells flowing into pipelines by 1975!

We can recover oil from oil shale and copper from low-grade deposits in this decade!

The development of definitive programs to achieve these goals--and achieving them--will require the best efforts of all of us here. I urge all of you to accept this exciting challenge--to give your best efforts to making Plowshare a reality in this decade.