MARSHALL ISLANDS FILE TRACKING DOCUMENT

Record Number: 183

File Name (TITLE): Plowshare Program

Document Number (ID): 017333

DATE: 1963

Previous Location (FROM): CIC

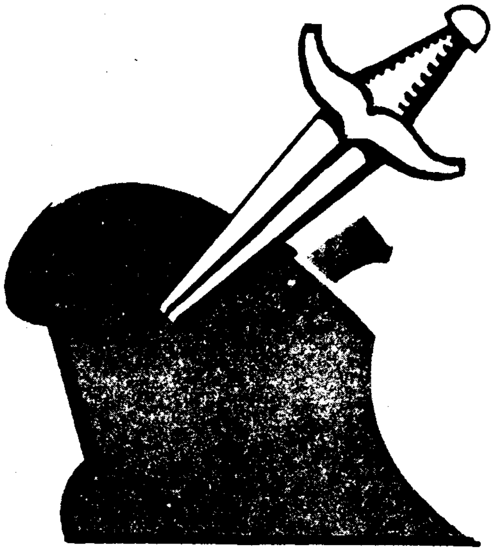
AUTHOR: AEC

Addditional Information: Contains Info on Mike (pg 221)

OrMIbox: 12

CyMIbox: 7

017333



PLOWSHARE PROGRAM

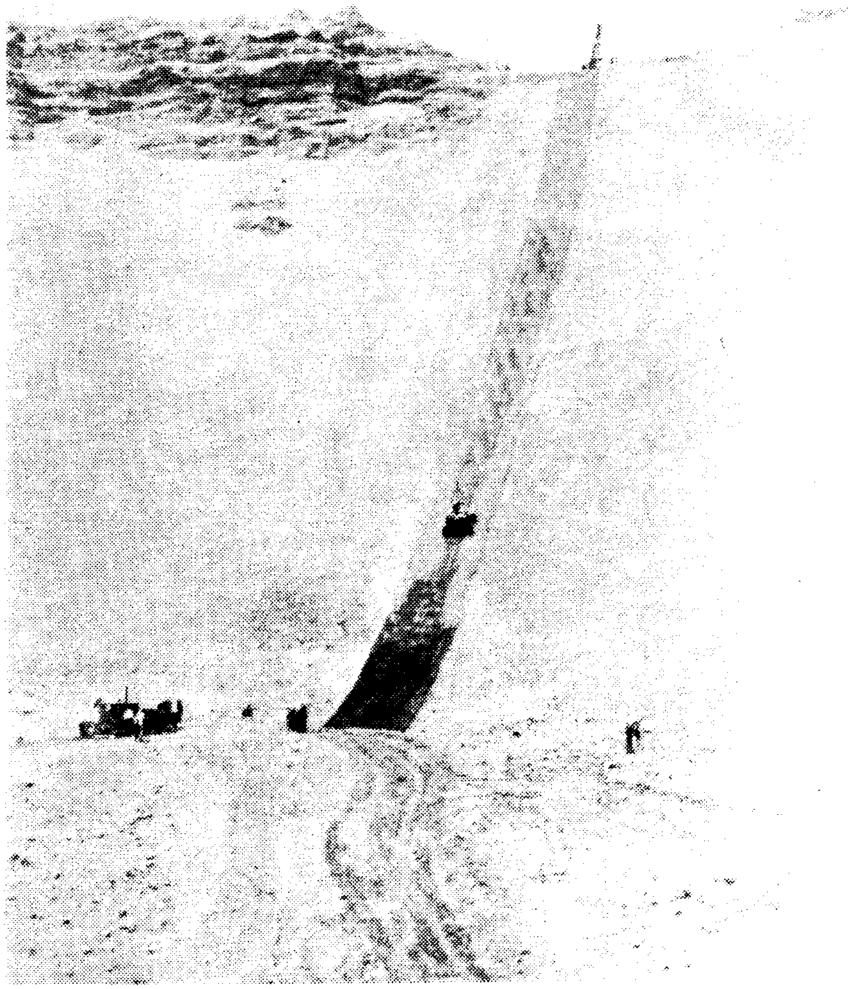
DURING 1963

From the Annual Report to Congress for
1963 of the U.S. Atomic Energy Commission

U.S. ATOMIC ENERGY COMMISSION

PLOWSHARE PROGRAM

Plowshare is the name given to the Commission's program for developing industrial and scientific uses for nuclear explosives. It is



Post-Shot Exploration. Work on the 1,280-foot wide, 320-foot deep Project Sedan crater during 1963 conclusively proved that thermonuclear explosives can be used safely for large-scale earth moving projects as has been envisioned under the AEC's Plowshare program. Created on July 6, 1962, the Sedan crater was first entered during February 1963 and radioactivity was found to be so low that personnel could work on the crater floor with safety. Subsequently, machinery was lowered down the steep bank for exploration of the characteristics of the bottom rubble. The 100-kt nuclear explosive had been buried 635 feet below the Nevada Test Site desert.

based on the idea that the tremendous and relatively inexpensive energy and phenomena released in a nuclear explosion can be used for constructive purposes.

The program encompasses: laboratory research and analyses of data; design, development, and testing of nuclear explosive devices for peaceful purposes; and field experiments. Primary research and development efforts are carried out at the Lawrence Radiation Laboratory, Livermore, Calif. Other research and development is underway at the Oak Ridge National Laboratory, Oak Ridge, Tenn.; the Sandia Laboratory Corp., Albuquerque, N. Mex.; and the Savannah River Laboratory, Aiken, S.C.; and in the laboratories of other Government agencies such as the U.S. Bureau of Mines, the U.S. Geological Survey, the U.S. Public Health Service, the U.S. Weather Bureau, and the U.S. Army Corps of Engineers, and in the Laboratories of several contractors and sub-contractors. Field tests involving nuclear explosives are carried out by the Nevada Operations Office at the Nevada Test Site and at other locations. The San Francisco Operations Office has certain responsibilities for program and policy development, especially concerning the use of nuclear explosives in cooperative projects with industry.

APPLICATIONS UNDER STUDY

Nuclear explosions can be designed so that the explosion is controlled and the energy made available for a specific purpose. Nuclear explosions can be divided into two broad categories—contained explosions and cratering explosions. Contained nuclear explosions shatter rock underground which could have value in mining and oil and gas production. It also appears that certain valuable radioisotopes can be produced in and recovered from contained nuclear detonations. Most plans for using nuclear explosions for scientific research involve contained detonations. Industrial uses for cratering explosions depend primarily upon using the energy from nuclear explosives to move earth. In this way it appears possible to simplify construction of harbors, transportation and water conveyance canals, and storage reservoirs.

Status and Plans

Primary effort in 1963 was devoted to the development of nuclear explosives for both scientific and industrial use, to research and analysis of data from past field experiments, and to design of future field experiments needed to acquire additional data. No nuclear field experiments were conducted by the Plowshare Program in 1963, except developmental tests of nuclear explosives. The state of development of nuclear explosives with desired characteristics continues to influence the ability of the program to carry out certain kinds of field experiments.

The limited nuclear Test Ban Treaty introduces another factor which needs to be considered in designing field experiments, especially cratering experiments in which a small percentage of the radioactivity produced is vented to the atmosphere. Project Schooner, a proposed 100-kiloton cratering experiment was deferred for the time being because of several factors, including the limited Test Ban Treaty. Project Buggy, a proposed row-charge experiment, is also being redesigned to meet changes in technical requirements. Preliminary concepts of other cratering experiments were also being considered. Project Coach, a contained experiment in salt, was deferred because of the lack of success thus far in achieving a nuclear explosive with the necessary characteristics.

The evaluation of the potential of various Plowshare applications remains much the same as last year.[1] However, additional attention to oil and gas production has made such applications appear more promising.

Domestic and foreign interest in various applications for nuclear explosives increased in 1963. For example, in the latter part of 1963 a group of scientists representing the Australian Atomic Energy Commission reviewed the program in detail to obtain an appreciation of the scientific, engineering, and safety aspects in the use of nuclear explosives. A joint study group was formed with representatives from the Atomic Energy Commission (represented by the San Francisco Operations Office and the Lawrence Radiation Laboratory), The Atchison, Topeka and Santa Fe Railway Co., and the California Department of Highways. This group studied the feasibility of using nuclear explosives to excavate a pass in the Bristol Mountains near Amboy, Calif.

During 1964 it is expected that attention will be given to the development of nuclear explosives which produce less radioactivity, that small-scale excavation experiments will be designed and executed, and that scientific experiments will be carried out. Also research and development will continue, additional industrial applications will be evaluated, and preliminary design of the large-scale experiments discussed in last year's Annual Report will be pursued.

CRATERING EXPLOSIONS

Of the many potential industrial applications for nuclear explosives, excavating earth is the most certain of being accomplished with large economic gains. Conventional high explosives have been used for

---

[1] See pp. 241–263. "Annual Report to Congress for 1962."

about a hundred years to aid in excavation. First, to break up earth and rock so that it could be moved. More recently, they have been used in larger quantities, not only to break up the earth and rock, but to move it. This latter technique is generally known as diffusion blasting and has apparently been most highly developed in the Soviet Union.

It has been recognized since the inception of the Plowshare Program in 1957 that the application of nuclear explosives to most excavation projects depends largely upon the successful development of nuclear explosives with less radioactivity and refinement of cratering technology to permit more accurate cratering predictions.

Cratering explosions can be used to excavate canals, for both transportation and water conveyance, to make highway and railroad cuts, and to make harbors. Other uses include removing overburden in mining operations and constructing water reservoirs.

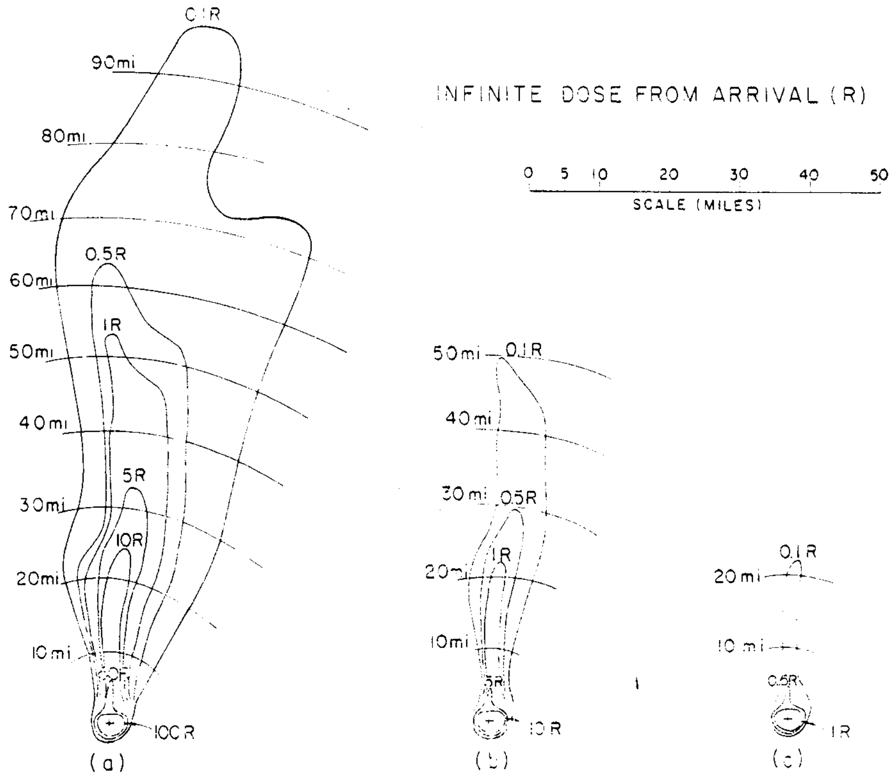
Effect of Limited Nuclear Weapon Test Ban Treaty

The nuclear Test Ban Treaty prohibits weapon tests or any other nuclear explosion in the atmosphere, outer space, or underwater (both territorial and open seas). It permits underground nuclear explosions provided they do not cause radioactive debris to be present outside the territorial limits of the nation under whose jurisdiction or control the explosion takes place. All cratering explosions result, by design, in sufficient disturbance of the surface of the earth to permit some radioactivity to reach the atmosphere. The amount of radioactivity depends primarily upon the yield of the explosive, the depth at which the explosive is emplaced, and the amount of fission which takes place in the explosion. Other factors are the chemical and physical properties of the medium. Upon detonation, the radioactivity produced in the underground detonation region is selectively trapped according to its form in the process of crater formation. That which is released to the atmosphere falls out, mostly near the detonation site, according to the size of the particles to which it adheres, or disperses in the atmosphere.

With proper design, taking the above factors into account, and sufficient distance to territorial boundaries, it appears that some meaningful cratering experiments can be carried out to help develop excavation technology without causing radioactive debris to be present beyond national boundaries.

Major Activities

There were no nuclear excavation experiments in 1963, and the main progress was made in theoretical understanding through laboratory research and high explosive exepriments conducted by the U.S. Army Corps of Engineers' Nuclear Cratering Group and the Lawrence Radiation Laboratory (LRL), Livermore.



Fallout Patterns. The above drawings show, from *left* to *right*, the reduction in radioactivity released from crater forming nuclear detonations as the fission yield of the thermonuclear device is reduced. The pattern on the *left* (a) is similar to that for Project Sedan of the Plowshare program, in which a 100-kiloton thermonuclear device with less than 30 kilotons of fission yield was detonated during July 1962. As a result of development of devices with less fission yield, and through the use of special emplacement techniques, it is believed that, at the present time, the amount of radioactivity released could be reduced to the levels indicated in pattern (b). Work is underway on device development and emplacement techniques to reduce the radioactivity released to the levels shown in pattern (c) which would be about a 100-fold reduction of that actually released by Sedan. These typical fallout patterns indicate the radiation dose a person living outdoors at a particular location for a lifetime could receive. In actual field operations, however, entry into such areas covered by these patterns are controlled so that the population does not receive unnecessary exposure.

Theoretical Understanding of Cratering

The basis for increased theoretical understanding is work conducted in cratering physics at LRL using primarily data from the Sedan and Danny Boy projects, and the pre-Buggy high explosive experiments.

The theoretical model of cratering under development involves conceiving the explosion as producing two primary effects: one, the transmission of the shock wave in all directions, but with a free surface above the explosion, the shock creates a spall, i.e., a lifting off of the

Aerial view of the Danny Boy crater showing radial, fallout collection roads.

surface layers, followed by: two, the expansion of the cavity containing high pressure gases to the point where it intercepts the surface, increasing the amount of material leaving the crater and boosting that already freed by the spalling action of the shock wave. This material then assumes trajectories in which a part of it falls outside the immediate area, thus forming a crater.

Mathematical models to simulate these effects and computer codes are under development, and increased success was achieved in matching this theory to results obtained from field experiments. Among effects to be studied are the differences caused by the type of earth media, especially its particle structure, the effect of the chemical composition of the earth media, and the entrapment of radioactivity.

Additional data are needed from field experiments in different media and at different yields in order to provide input for further theoretical treatments. In particular, it is necessary to obtain data which will allow theoretical understanding of the physics of the simultaneous explosion of a row of charges. Among the most important phenomena in a row of simultaneously detonated charges is the manner in which the cavities created by the individual charges in a row coalesce and the gas pressure from them acts upon the material being thrown out of the crater.

Sedan

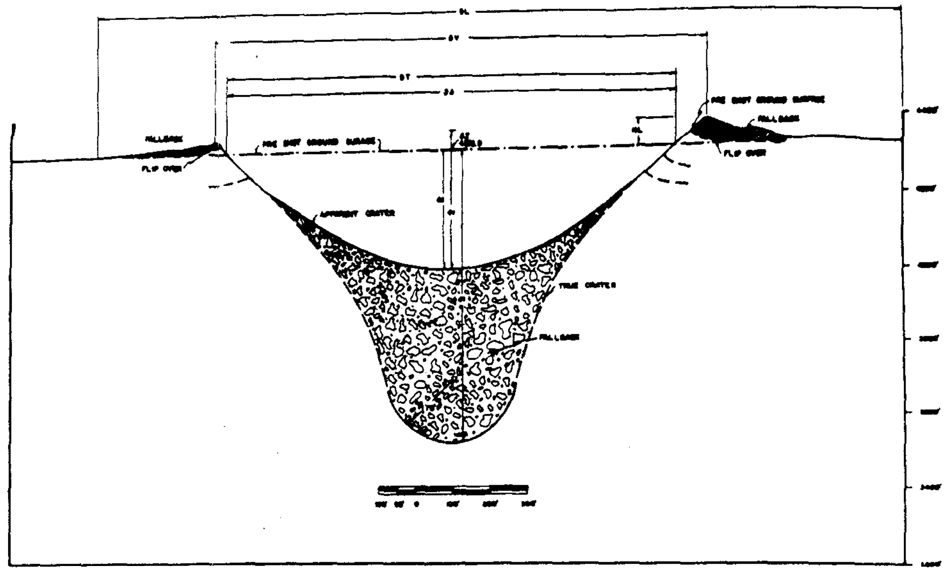
Sedan was a project in which a 100-kiloton thermonuclear explosive was detonated 635 feet underground in alluvium at the Nevada Test Site (NTS) on July 6, 1962. The project was described extensively in the Commission's 1962 Annual Report.[2] During the year, additional data became available and were published with 23 technical reports out of a total of 31 planned having been issued.[3] As indicated above, these data were available for use in the theoretical studies which are underway.

Post-shot exploration of the Sedan crater was begun in February by LRL and the Corps of Engineers' Nuclear Cratering Group. Men, trucks, equipment, and drilling rigs were lowered to the floor of the crater to obtain measurements of the fallback material, radioactivity, porosity, and permeability of the crater. On May 7, 18 representatives of 14 news media organizations visited the Sedan crater. The feasibility of re-entering and working in a crater made by nuclear explosives was conclusively demonstrated in the course of these activities.

---

[2] See pp. 247–250 of AEC Annual Report to Congress for 1963.

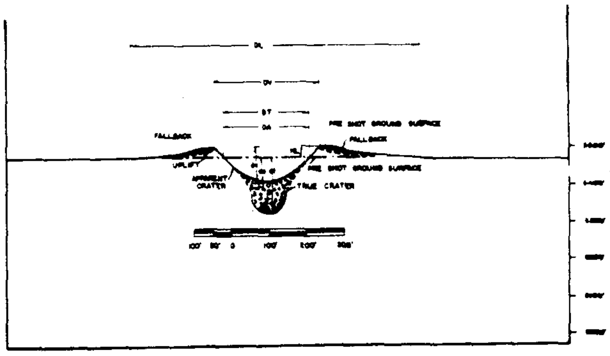
[3] Copies of these reports are available from the Office of Technical Services, U.S. Department of Commerce. Washington, D.C., 20230.



SEDAN

PARAMETERS

	SEDAN	DANNY BOY
DEPTH		
APPARENT CRATER	323'	62'
TRUE CRATER	606'	126'
VISIBLE CRATER	363'	93'
DIAMETERS		
APPARENT CRATER	1220'	216'
TRUE CRATER	1220'	216'
VISIBLE CRATER	1320'	280'
INITIAL CAVITY	350'	72'
BELOW & Z RADIUS	175'	36'
LIP HEIGHT		
FALLBACK	3'	5'
UPLIFT	17'	19'
FLIPOVER	12'	None
VOLUMES		
APPARENT CRATER	6,550,000yd³	33,500yd³
TRUE CRATER	13,918,000yd³	78,580yd³
VISIBLE CRATER	7,800,000yd³	68,700yd³
BULK FACTOR	10-15%	26%
APPARENT CRATER VOLUME PER KT	65,500yd³/Kt	78,560yd³/Kt



DANNY BOY

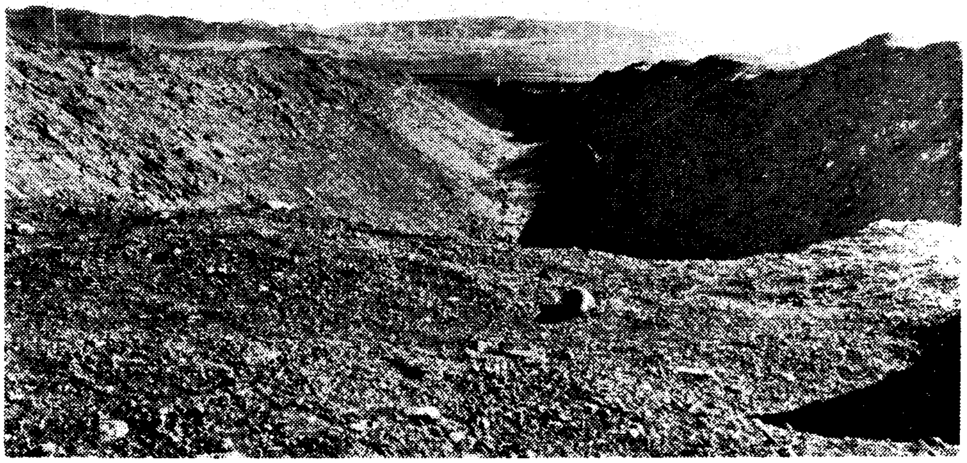
Sedan and Danny Boy. One of the primary Plowshare objectives of Sedan and Danny Boy experiments at the Nevada Test Site was to determine the cratering characteristics of nuclear explosions in alluvium and basalt, respectively. As is shown on the schematic, with the exception of the lip configuration, the Sedan and Danny Boy craters are quite comparable. Apparently, the difference in rock types had very little influence on the resultant craters. The Sedan experiment was conducted at the Nevada Test Site on July 6, 1962, and the Danny Boy event on March 5, 1962.

Danny Boy

Post-shot exploration of the Danny Boy (0.4 kiloton military effects cratering experiment in basalt at the Nevada Test Site on March 5, 1962) crater was undertaken and completed during 1963 by the Corps of Engineers' Nuclear Cratering Group. Data were accumulated on the stability of the Danny Boy crater slope, the suitability of the rubble material as fill, and the nature of the lip area as it would affect foundation and utility design.

Pre-Buggy

High explosive experiments were carried out in January and February and June and July of 1963 at the Nevada Test Site to investigate the spacing of charges in a simultaneously detonated row for excavating a smooth channel. The results showed that when the spacing between charges is equal to 1 to 1.25 times a single crater radius, a smooth channel is produced with a width equal to, or greater than the diameter of a single charge crater. When the spacing is as large as 1.5 times the single crater radius, an irregular channel with somewhat smaller dimensions was produced. Also, experimentally tested with high explosives was the concept of excavating a canal in sections with the last section not throwing large quantities of material back into the previously excavated section.



Row Charge Excavation. One of the phenomena of row charges is shown in the ground level view of a row charge experiment in which 13 one-thousand-pound nitromethane high explosive charges were detonated simultaneously in a 1963 Plowshare program experiment at the Nevada Test Site. Note the virtual lack of throwout at the ends of the channel. This phenomena would be quite important in the construction of canals.

Post-Scooter

In conjunction with the post-Sedan activities, a drilling program was conducted at the Project Scooter (0.5 kiloton high explosive experiment in 1960) crater, which is close to the Sedan crater in order to map the true crater boundaries. Comparison of true crater boundaries is expected to help determine differences between craters produced by high-explosives and craters produced by nuclear-explosive.

Sandia Experiments

The Sandia Laboratory carried out studies of the cratering mechanism using high explosives to obtain data which could then be treated in laboratory analysis. These included studies of:

(*1*) Cratering with vertical emplacement of two charges, fired in close sequence, to examine feasibility of using this technique to excavate through high terrain;

(*2*) Ditch excavation with "row charges" (horizontal emplacement of several explosive units through terrain of varying elevations; and

(*3*) Investigation of the trade-off in reduction of air-blast versus loss in cratering effectiveness by non-simultaneous detonation of the explosive units in a row charge.

Other studies are planned on "area charges" in which several explosive units are located on rectangular grid patterns to determine the feasibility of producing desired horizontal dimensions in a crater using an explosive array of lower total yield than required from a single charge to produce a comparable crater.

Chariot

The decision whether or not to proceed any further with Project Chariot, a study of a nuclear excavation experiment on the northwest Alaskan coast near Cape Thompson, continued to be held in abeyance pending the results of future field experiments. The Commission withdrew its application for a withdrawal of the land from public domain and reduced the area for which it has special use permits. Camp facilities at the Chariot site were transferred to the Office of Naval Research on May 7 for use by its Arctic Research Laboratory. The camp facilities will continue to be available for limited use by the Commission for its continuing studies on the effect of world-wide radioactive fallout on the arctic ecology.

Future Excavation Experiments

The design of future excavation experiments continued during 1963 with input from the research program helping to further define the types of information needed and thus influencing the concepts of these projects. Site selection for Project Schooner (100-kiloton excavation experiment) progressed to the point where a preferred site was located in southwestern Idaho. However, because of certain considerations such as the limited nuclear Test Ban Treaty, the Commission deferred Project Schooner in favor of concentrating on the development of nuclear explosives with less radioactivity, smaller scale experiments in excavation, and experiments in scientific and other engineering applications.

Concepts of small-scale excavation experiments are presently under development by LRL to provide data on point-charge and row-charge detonations. Such experiments probably would be conducted at the Nevada Test Site and because of their relatively small size, they would not require elaborate preparations.

Large-scale experiments will be necessary to confirm extrapolations of theory to yields of 100 kilotons and above. Plans for such experiments will continue to be developed.

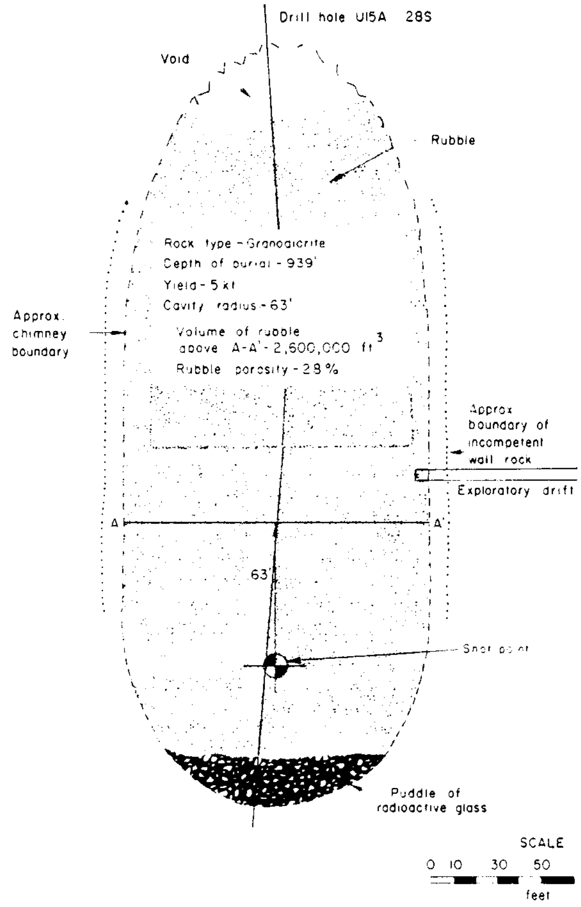
Since a row of nuclear explosives has never been simultaneously detonated, experiments in this area are particularly necessary. There are four main variables in the basic phenomena of using row charges:

(*1*) Dimensions of elongated craters as a function of yield, depth of burial, and spacing of charges;
(*2*) Amount of radioactivity vented from such detonations;
(*3*) Effect of uneven terrain on crater size and slope stability; and
(*4*) Effect of cratering through different media.

The code name Buggy is now associated with the experiment which would study the first two variables. Galley is the code name now associated with the experiment which would be designed to study the last two variables. The magnitude and location of these experiments have not yet been determined.

CONTAINED EXPLOSIONS

One clearly proven use for contained nuclear explosions is scientific research. Nuclear explosives used in an underground environment constitute a new and unique scientific laboratory. Most experiments being designed to make use of the tremendous number of neutrons produced in a nuclear explosion, which is many orders of magnitude higher than that available from any other known neutron source. Because of the tremendous flux, it appears possible to produce some isotopes of the very heavy elements which cannot be made in any other way. The neutrons also can be used to study neutron spectroscopy, fission processes, neutron-neutron reactions, and other areas essential to the field of nuclear science. Many experiments may not be possible by any other means. The extremely high temperatures and pressures created hold interest for investigating basic chemical reactions which cannot be otherwise accomplished.



The effects of a contained nuclear explosion in granite are illustrated in the schematic cross section (on the left) of the Hardhat site. Postshot investigations revealed a cavity radius of 63 feet and a chimney height above the shot point of 281 feet. Rock in the chimney was broken sufficiently to allow undertaking a block caving mining experiment. Donald Rawson, Lawrence Radition Laboratory geologist, examines (in the photograph below) broken granite in the chimney produced by the nuclear detonation. Rawson's position is 89 feet above the shot point and 10 feet inside the chimney.

The Hardhat experiment, together with the experience gained in Projects Rainier (a 1.7-kiloton explosion in tuff) and Gnome (a 3.1-kiloton explosion in bedded salt) has provided sufficient information to warrant undertaking a pilot-scale industrial project.

The most promising industrial applications for contained nuclear explosions are those involving the development of our natural resources. These concepts include breaking up ore bodies for mining by block caving or in-situ leaching methods; producing crushed rock for large construction projects, and fracturing gas and petroleum bearing rock formations to increase production or make production possible from otherwise unrecoverable reserves.

Phenomena of Contained Explosions

Understanding of the phenomena associated with contained explosions is based upon empirical studies of past detonations, development of instrumentation to follow explosion history from detonation through cavity growth to cavity collapse, and development of theory and computational techniques to handle the data.

Geological studies of the post-shot environment and their interpretations have yielded significant results. Maximum cavity radii were determined for 35 explosions, and a method for predicting cavity radii as a function of yield and depth of explosion has resulted. Such radii now can be predicted within 10 percent for any single rock type. Furthermore, experience in tuff, alluvium, salt, and granodiorite shows that the rock type affects the cavity radii by only 20 percent. The cavity usually collapses shortly after formation. In the case of Gnome, however, relatively little of the cavity has collapsed because the salt formation was strong and plastic enough to arch without breaking. However, in the case of tuff and granodiorite, a chimney of broken rubble is formed after cavity collapse. The chimney of broken rock is roughly cylindrical and extends above the shot point to a height of about 5 times the original cavity radius, if the detonation is of a sufficient depth. Cavities formed from detonations in alluvium have collapsed within a few minutes. In alluvium a depression crater is created at the surface almost immediately after cavity collapse.

Special instruments have been developed and used to measure shock effects of underground explosions in tuff, alluvium, granodiorite, and salt. The peak shock pressure, the velocity of the shock wave, and the velocity of the material behind the shock wave have been measured as a function of the time. Two instruments, developed during the past year, are noteworthy. One of these is a small, inexpensive gauge to measure the peak pressure found in a shock wave 20 to 30 feet from a typical underground nuclear detonation.

The other instrument is a gauge that measures continuously the velocity of the shock front at distances up to 400 feet from the detonation point. A cable is stretched down a hole pointing toward the center of detonation. As the shock wave spreads out from the explosion, it crushes the cable progressively. The point of crushing is measured continuously by an electronic circuit in a small canister and this information is sent to a remote recording station.

The development of instruments to measure the characteristics of strong shock uses such equipment as an air gun that fires a 3-inch-diameter flat-ended aluminum projectile into a target of similar shape. The impact causes a shock wave to pass into the target. Instruments to be tested can be installed in the target and their response to the shock wave recorded electronically.

One result of this program has been the adaptation of the instrumentation and calculational procedure for early determination of the yield of many underground detonations.

Gnome

A 29-minute film on Project Gnome, the first nuclear detonation exclusively for peaceful purposes, was made available for public showing during the fall of 1963 (see Appendix 8 for description).

Project Gnome was carried out on December 10, 1961, at a site about 28 miles southeast of Carlsbad, N. Mex. A nuclear explosive producing energy equivalent to about 3,100 tons of TNT was detonated at the end of a tunnel bored into a rock salt formation 1,200 feet underground. The wealth of scientific data derived from Project Gnome to date is contained in 22 technical reports which are available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., 20230.

On December 10, 1962, the first anniversary of Gnome detonation, 28 news media representatives toured and photographed the multicolored Gnome cavity. The cavity temperature was about 120° F. with relative humidity of about 60 percent.

Coach

On August 1, the Commission postponed the conduct of the Project Coach detonation at Carlsbad, N. Mex. This detonation was originally planned for 1963. It involves using a nuclear device to produce neutron-rich isotopes of known transplutonium elements and possibly to produce elements heavier than those yet discovered. Postponement of the Carlsbad detonation was caused by technical difficulties related to developing a suitable neutron-producing nuclear device. Further work on the device is underway at the Lawrence Radiation Laboratory at Livermore, Calif.

Preparation for the Carlsbad detonation has been underway since the completion of work on Project Gnome. In October 1963 the site and facilities near Carlsbad were placed on a standby basis, with a minimum number of caretaker personnel, to await the outcome of the device development work.

The use of a nuclear explosive for producing transplutonium elements involves exposing a target, such as, uranium 238, to the intense neutron flux produced by nuclear reactions. The nearly-instantaneous multiple neutron capture results in isotopes with higher atomic numbers and greater masses than the target element. Using nuclear explosives, the target undergoes neutron exposures equivalent to years of irradiation in the highest flux nuclear reactor and also avoids the barriers formed, in reactor irradiation, from the production of isotopes with short half-lives.

For Coach a special nuclear explosive is required to produce an intense neutron flux with relatively low total yield. Development of such a device has been underway since late 1962 with tests being continued at the Nevada Test Site.

Experimental Results

The potential of the nuclear explosive approach to producing transplutonium isotopes was shown by the Mike event, a high-yield thermonuclear explosive fired at Eniwetok in November 1952. The debris from the explosion was found to be rich in transuranium elements, including two new elements, einsteinium and fermium (atomic numbers 99 and 100), plus new isotopes of plutonium, americium, curium, and californium. Other high-yield thermonuclear tests have produced heavy elements, but in lesser amounts than the Mike event.

On November 27, 1962, in the Anacostia event, a thermonuclear device being developed for Project Coach was fired underground at the Nevada Test Site. One of the objectives achieved was to ensure that the target would be subjected to a uniform neutron flux, thus making data analyses less ambiguous. Radiochemical analysis of the debris showed that elements at least through mass number 246 were formed in quantities comparable to those from Mike.

Other Development Work

Two other aspects of Project Coach are being pursued. First, prompt sampling techniques were developed to provide samples of debris from the detonation region immediately after the detonation. The technique collects samples brought to the surface through a pipe leading from the detonation region. By this method it should be possible to obtain small quantities of isotopes with very short half-lives. Prompt sampling combined with samples obtained by core drilling into the cavity region within a few days after the detonation will be the means used to look for new elements and new isotopes of known heavy elements. Second, in order to recover significant quantities of transplutonium elements, the special nuclear device must be detonated in a medium that facilitates mining recovery operations. Salt is one such media, therefore the same area that had been previously used for Project Gnome was selected for Project Coach. Material from the Gnome cavity has been studied as a part of the work to determine possible mining and chemical processing techniques.

Hardhat

The Department of Defense experiment Hardhat (4.5 kiloton military effects test detonated 950 feet underground on February 15, 1962, at the NTS) was of particular interest to the Plowshare program because the granodiorite in which the explosion took place is typical of the media in many mining situations. This explosion formed a cavity about 63 feet in radius which collapsed about 11 hours after the detonation. On collapse rock above the cavity fractured by the explosion caved progressively upward forming a chimney of broken rubble to 280 feet above the detonation point. About 220,000 tons of granodiorite were fractured.

Early in 1963, a Plowshare mining experiment at the Hardhat site was successfully completed. The experiment provided information on the use of nuclear explosives to break and crush mineral deposits preparatory to extracting the ore by conventional, block-caving techniques. The re-entry drift was driven completely through the rubble-filled chimney at a level 90 feet above the shot point. Two standard mining draw-points were installed and more than 2,700 tons of broken rock were withdrawn in a simulated mining operation. No hazardous amounts of radioactivity were encountered. The results are considered sufficient to allow undertaking an industrial scale project next.

Shoal

Project Shoal was a contained 12 kiloton nuclear explosion conducted 1,200 feet underground in granite near Fallon, Nev., on October 26, 1963. Shoal was conducted as part of the Vela program which is directed by the Advanced Research Projects Agency of the Department of Defense to improve the capability of detecting, locating, and identifying underground nuclear detonations. The phenomena of this explosion will be of great interest to the Plowshare program.

The Plowshare program sponsored a U.S. Bureau of Mines add-on experiment to the Shoal detonation to measure the extent and type of shock-induced permeability changes in rock formations. Data from this experiment will be used by the Bureau in a study on the feasibility of using nuclear explosives in petroleum and natural gas production.

Dribble

The Plowshare program expects to obtain information from the Vela program Project Dribble decoupling experiments in Mississippi. Dribble is planned as three underground nuclear detonations (Salmon, Sand, and Tar events) in the Tatum Salt Dome 20 miles southwest of Hattiesburg. (See Military Applications Section of Part Two.)

The Plowshare program will also sponsor a structures response study as an adjunct to the Salmon event (proposed 5 kiloton explosion at a depth of 2,700 feet). Prior to detonation, several small frame and concrete block buildings will be constructed and instrumented near the Salmon site.

Future Experiments

The next logical step in developing industrial applications for contained nuclear explosions would be a demonstration or prototype project. In such a project, additional experience would be sought as well as confirmation of existing theory. It would not be expected that the first project necessarily would have practical commercial value. Therefore, a mineral property would be sought in which actual production and economic data could be obtained. The possibilities for feasibility studies include:

(*1*) Block caving mining of the rubble-produced chimney;
(*2*) In-situ leaching of minerals in a chimney rubble column;
(*3*) Enhancing petroleum or natural gas production by increasing reservoir diameter or interconnections and through increasing the porosity and permeability of the producing area;
(*4*) Producing aggregate (broken rock for construction purposes) from chimneys which are allowed to progress to the surface; and
(*5*) Creating a chimney for disposal of industrial or other wastes.

NUCLEAR EXPLOSIVE DEVELOPMENT

Development of nuclear explosives for peaceful purposes continues along two separate lines. First, nuclear explosives are needed which have special effects, such as high neutron fluxes for scientific experiments; second, nuclear explosives which obtain less energy from fission are highly desirable for excavation experiments. Beginning with fiscal year 1963, the Plowshare program began to sponsor separately and to fund for device tests being conducted at the Nevada Test Site specifically for its needs.

Considerable success continues to be achieved in developing nuclear explosives which obtain less and less of their energy from fission; that is, less and less radioactivity is produced which needs to be controlled either through design of the experiment, such as by deeper burial, or through operational measures, such as the use of exclusion areas and awaiting proper meteorological conditions. In addition to reduction in amount of fission energy in explosives, studies are also underway to develop design and emplacement techniques which may further reduce the amount of the radioactivity which escapes from the crater. It now appears possible to reduce the radioactivity released from a crater to the point where the area to be controlled should not exceed the area which would have to be controlled for other safety reasons, such as blast effects.

Design of an explosive with an adequate neutron flux for the production of heavy elements has still not achieved its objective. However, increased understanding of device performance was achieved during the year which provides some confidence that a successful device can be developed to produce heavy elements.

Progress in both types of nuclear explosive development has had a major influence on the rate and kind of experiments that can be carried out.

Other Research and Development

Certain research and development activities in the Plowshare program apply equally to cratering or contained explosions. These are safety research and studies of fields of applications in which both cratering and contained explosions may be used.

Safety Research

The Plowshare program benefits from other Commission research and development activities. For example, a part of the research conducted in the Biology and Medicine program makes a major contribution to the safe use of nuclear explosives. A new program which is expected to be especially valuable to cratering explosion safety is the Fallout Studies Program recently established at LRL. See also pages 252–253 of the AEC Annual Report to Congress for 1963.

In addition, the Plowshare program supports certain safety related research, which might be termed "applied research", and contributes to the Long Range Safety Program of the Nevada Operations Office. This latter program, in turn, provides the Nevada office with the ability to review the safety of experiments and projects and to make operational plans to protect the public during nuclear operations.

Research sponsored by the Plowshare program during the year included studies on the movement of radioactivity in ground water to permit assessment of any contamination of aquifers in the course of either cratering or contained detonations. For example, a hole was drilled in the vicinity of the Aardvark weapons test event at the Nevada Test Site to determine the effect of the detonation on water levels as a function of time. Laboratory studies of the flow of water in a confined aquifer have been made in the Hydrologic Laboratory of the University of California, in Berkeley, and by the Texas A & M Research Foundation.[4] Using these data, theoretical studies have been made which indicate that radioactive contamination of ground water is not likely to be a problem in any envisioned application.[5]

Studies in the long range safety program included the response of buildings and other structures to ground motion from nuclear explosions. Holmes & Narver, Inc. of Las Vegas, Nevada, and Roland F. Beers, Inc. of Alexandria, Va., under contract to the AEC's Nevada Operations Office, are engaged in these studies.

Application Studies

The Geological Survey is conducting a theoretical study on the application of nuclear explosions to the development of water resources. This study covers the technical and economic feasibility of employing nuclear explosives to develop and conserve both surface and underground water. Ideas under investigation include: (*a*) fracturing rock to improve the recharge of aquifers by surface waters; (*b*) fracturing rock to interconnect and increase the capacity of aquifers; and (*c*) creating surface reservoirs.

The U.S. Bureau of Mines is investigating the application of nuclear explosives to mining, petroleum and natural gas production, and shale oil production. Feasibility studies currently under way cover removal of the overburden from an orebody to facilitate subsequent mining by open pit methods; leaching of minerals from an orebody shattered and rendered permeable by a nuclear explosion; and under-

---

[4] The Texas A & M study is in report UCRL 13074. available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C., 20230.

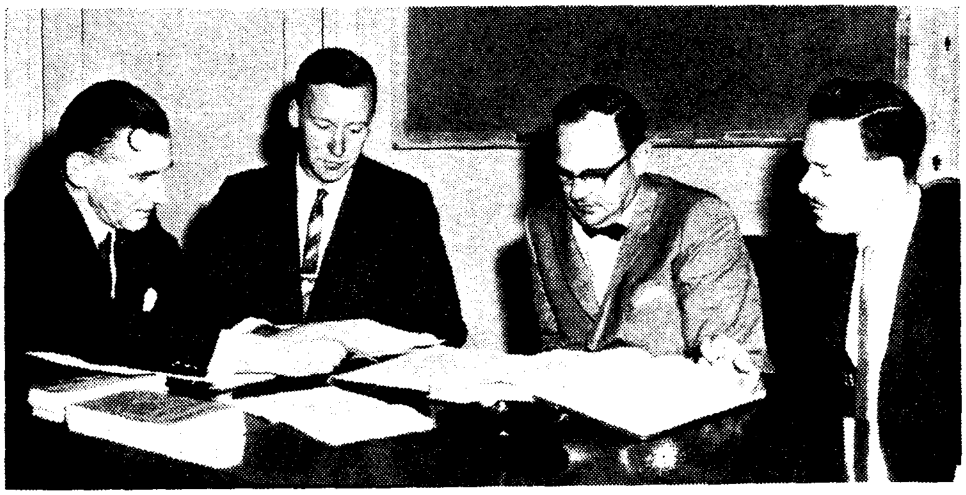
[5] One of these theoretical studies is included as Appendix IV to report UCRL 7350, which is also available from the Department of Commerce.

ground mining of an orebody which has been fractured by a nuclear explosion. Other feasibility studies are being made on using nuclear explosions to stimulate production rates from oil and gas fields of low permeability. Application of nuclear explosives to production of oil from the Nation's vast reserves of oil shale now appears somewhat more encouraging.

PROGRAM DEVELOPMENTS

Australian Review of Plowshare

In response to a Commission invitation, three scientists representing the Australian Atomic Energy Commission were in the United States from September 1 through October 24 to gain a first-hand appreciation of the scientific, engineering, and safety aspects of the use of nuclear explosives for constructive purposes with a view toward assessing the advantages and hazards of their possible use in Australia.



Australian Visitors. Three Australian government scientists made an eight-week tour of AEC facilities during 1963 to acquaint themselves with various peaceful applications of atomic energy. Photo shows the officials during a summary discussion with John S. Kelly, Plowshare Program Director. Shown (*left to right*), are Mr. E. B. Pender, Senior Executive Engineer, Civil Engineering, Snowy Mountains Hydro-Electric Authority; Dr. A. R. W. Wilson, Head, Technical Policy Section, Technical Administration, Australian Atomic Energy Commission; Mr. Kelly and Dr. E. K. Carter, Supervising Geologist, Geology and Geophysics, Bureau of Mineral Resources.

The Australian visitors were: Dr. A. R. W. Wilson, Head, Technical Policy Section, Technical Administration, Australian Atomic

Energy Commission; E. B. Pender, Senior Executive Engineer, Civil Engineering, Snowy Mountain Hydroelectric Authority; and Dr. E. K. Carter, Supervising Geologist, Geology and Geophysics, Bureau of Mineral Resources.

During their eight-week visit, the Australians were given an intensive review of all the technical phases of the Plowshare program. The group visited the San Francisco Operations Office, the Lawrence Radiation Laboratory, Livermore; the Nevada Operations Office and Test Site, and other Commission facilities.

Carryall Feasibility Study

Officials of The Atchison, Topeka and Santa Fe Railway Co. approached the Commission in 1963 on the possibility of using nuclear explosives to excavate a cut in lieu of digging a tunnel through the Bristol Mountains north of Amboy, Calif. The Santa Fe Co. is interested in the cut for realigning a portion of their road bed through the region, and in addition California's Division of Highways is interested in rerouting U.S. Highway 66 (Interstate 40) through the cut.

A joint feasibility study group, comprised of staff members from The Santa Fe Co., the California Division of Highways, and the Commission's San Francisco Operations Office, with technical participation by LRL, has examined the feasibility of this idea. The joint study was assigned the name Carryall. In its final report, a summary of which was issued December 23, 1963, the group concluded that the project would be technically feasible.

The proposed pass through the mountain would be about 10,000 feet in length and would involve cuts up to 350 feet deep. About 60 million cubic yards of rock would be excavated.

One interesting result of the study was a possible new application—the creation of a large crater to serve as a sump to collect in dry areas excess water from flash flooding. The use of such a sump in a normally dry stream bed to collect excess water would eliminate the need for large bridge structures.

West Virginia Atomic Energy Committee

In late 1961, Governor William W. Barron of W. Va. appointed an Atomic Energy Committee to assess the technical merits of the Plowshare program in the development of his State's resources and to recommend a position which the State should adopt with respect to the Plowshare program.

In their September 15, 1962 report, the Committee recommended that West Virginia cooperate with the Commission by offering facilities and sites in the State for Plowshare experiments.

Corps of Engineers Participation

Close collaboration between the U.S. Army Corps of Engineers and the Commission on the development of nuclear excavation technology which began in 1962 [6] continued throughout 1963.

Under the 1962 agreement, the Commission is responsible for nuclear device development, execution of nuclear cratering experiments, and development of the basic theory of cratering. The Corps of Engineers is responsible for execution of a corollary chemical high explosive cratering program and development of the requisite data on engineering and construction problems. A Corps of Engineers' group is located at the Lawrence Radiation Laboratory, Livermore, which carries out the Corps' part of the joint program. The ultimate objective of this joint program is to develop a capability to employ nuclear explosive construction techniques on the Corps of Engineers' civil works projects.

---

[6] See pp. 262–263 of 1962 Annual Report.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price 15 cents

U.S. GOVERNMENT PRINTING OFFICE : 1964