ATTACHMENT

SUMMARY OF THE PRELIMINARY CARRYALL FEASIBILITY STUDY

A preliminary study, designated Carryall, was made to examine the technical feasibility of using nuclear explosives to cut a highway and railroad pass through the Bristol Mountains in California as part of the U.S. Atomic Energy Commission's Plowshare Program, a research and development program looking toward the application of such explosives for peaceful uses.

Of all the potential civil applications, probably the most certain of accomplishment with large economic gains is earth moving. Over a period of years experience has been obtained in the excavation field from weapons tests which produced craters and from Project Sedan, a 100-KT nuclear detonation conducted as a Plowshare experiment in 1962 at the Nevada Test Site. In addition, well over 100 craters have been created with chemical high explosives in the Plowshare Program. Data from these nuclear and conventional cratering explosions indicate that great savings in cost and time can be made in construction projects requiring large-scale earth moving. Other uses for crater-producing detonations would be open-pit mining, construction of reservoirs, canals, and harbors, and diversion canals for water resources purposes.

On the basis of experience to date, it appears that nuclear devices can be designed and made, with a minimum of radioactivity, at much less cost then presently estimated. Research and development work is being conducted on this phase of Plowshare at the Lawrence Radiation Laboratory, Livermore, which is operated for the AEC by the University of California.

Other research and development work related to the civilian use of nuclear explosives is being conducted at the Sandia Laboratory, Albuquerque, New Mexico; Oak Ridge National Laboratory, Oak Ridge, Tennessee; and the Savannah River Laboratory, Aiken, South Carolina. Work also is underway in laboratories of other government agencies, including the U.S. Bureau of Mines, U. S. Geological Survey, U.S. Weather Bureau, U.S. Public Health Service, U.S. Coast and Geodetic Survey, and U.S. Army Engineers.

In addition to device development work, further nuclear cratering experiments would be needed to permit refinement of engineering data required for the final Carryall design.

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Nuclear Excavation

Cratering

Conventional excavation methods in hard rock require that the material first be shattered by chemical explosives and then excavated by mechanical means. In nuclear excavation, the force of the explosion itself is used not only to shatter the rock but to accomplish the removal of material.

When a nuclear explosive is detonated at proper depth underground, earth and rock are broken and ejected. Some of this material falls back into the resulting crater; virtually all of the remainder falls immediately outside the crater and on the upthrust lip. A small portion of the finer particles is carried up in a large dust cloud and is deposited in the vicinity of the crater and for some distance downwind. The crater dimensions depend on the energy of the explosion, the depth of burial of the explosive, and the properties of the medium.

A row of explosions, properly spaced and detonated simultaneoulsy, will produce a series of interconnected craters to form a channel. This channel will be roughly parabolic in cross section with dimensions and smoothness that depend on the spacing of the charges.

The basic concept is to use the craters produced by nuclear explosions as excavations for large engineering projects. In the Carryall study, the problem was to propose a design for the emplacement and yields of the nuclear explosives so that the craters produced would meet the excavation requirements of the Santa Fe and the Division of Highways, along the section under study.

For detonation of a given yield, the size of the crater formed varies greatly with the depth of burial of the charge. As the depth of burial increases, crater dimensions increase to a maximum at some optimum depth, then decrease until a depth of burst is reached where no crater is formed.

For a given material, crater size is a function of yield and depth of burst. Experimental results to date, including both chemical high explosive and nuclear tests, indicate that crater dimensions scale proportionally with the 1/3.4 power of the yield. This scaling law is used in predicting crater dimensions at large yields.

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With the ability to predict crater dimensions, the next step is to place the craters together in such a pattern that a cut or ditch can result. Such multiple-charge cratering would be required in the Carryall project. The purpose is to produce a smooth cut, with the dimensions and grade required by engineering specifications.

High explosive cratering experiments in alluvium have shown that point charges, spaced at appropriate distances from each other and at the proper depth of burial, will produce a smooth cut when fired simultaneously. Before undertaking Carryall, it would be necessary to perform nuclear row-charge experiments in rock to verify that the charge spacing and depth of burial relationships derived from the chemical HE experiments are applicable to the nuclear case and hard rock.

Radioactivity

The radioactivity generated in deep cratering explosions is distributed primarily in two ways:

A. Most of the activity is trapped by particles of debris buried in the rubble and fallback in the crater or on the lip.

B. A much smaller fraction, including those products which are gaseous at early times, escapes to the surface and is scavenged by the particles in the dust cloud, and deposited as "prompt" fallout. More than 90% of this "prompt" fallout falls within five miles of the detonation.

From deeply buried cratering detonations there is essentially no contribution to "world-wide" fallout.

The relative amount of activity which escapes and is deposited as "prompt" fallout depends mainly on how deep the explosive is buried compared to the depth of the resulting crater. As the depth of burial increases, the "prompt" fallout continues to decrease and ultimately reaches a point of complete containment.

The decrease in radioactivity escape with increasing burial depth is an important factor which will be considered in the nuclear engineering requirements of Carryall.

As no rows of nuclear charges have been fired to date, more data are required on radioactivity escape from

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such multiple-charge detonations. For purposes of the Carryall Feasibility Study, it was assumed that escape from single and multiple-charge detonations having the same ratio of depth of burst to depth of crater will be equal for any given yield.

Air Blast and Ground Shock

The air blast and ground shock resulting from underground nuclear explosions are of concern as possible damage producing effects.

Air Blast:

Nuclear detonations for cratering purposes can cause damage close to the detonation site due to direct blast wave, at intermediate ranges due to refraction or "ducting" of the blast wave in the troposphere, and at long ranges due to refraction in the ozonosphere. Propagation and intensification (focusing) of these long and intermediate blast waves is a function of wind speed patterns in the upper atmosphere. Day-to-day variations in the ozonospheric winds cause considerable variability in the magnitude of the blast pressures experienced at any point downwind in the sound ring. These variations as well as the seasonal variations are predictable once the local weather patterns are well established.

Operationally, direct air blast damage is controlled by isolation of the shot site, and the intermediate and long range problems are solved by choice of firing times when wind conditions are such that the blast will be below the threshold of damage.

Ground Shock:

Large yield nuclear detonations may cause damage to nearby structures and other cultural features by inducing ground motion at a point where structures are located. In general, the intensity of ground shock is dependent on the yield of the detonations, the distance to vulnerable works, the geology of the area, and the types of structures or facilities involved.

Transmission of the seismic waves between the shot point and structures of interest is dependent on the type and characteristics of the rock formation through which the waves must travel and discontinuities between formations.

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The type of material on which a structure is located and the nature of the structure itself have a significant effect on the damage which may be sustained. Much higher velocities and displacements are observed at the surface of deep alluvial deposits than in rock. The design and construction of structures determine their response to the velocities, displacements and frequencies of the ground motion.

Full evaluation of the potential hazards from ground motion in the Carryall case must await detailed geologic investigations of the area and a thorough survey of the location and kinds of structures in the immediate vicinity of the site.

Carryall Study Results

If the cut were to be excavated as indicated in the study, 23 nuclear explosives would be required, with individual yields ranging from 20 to 200 kilotons, and a total energy release of about 1,830 kilotons; this includes detonation of a separate explosive to solve a drainage problem. The study examined the possibility of firing a row of charges in two separate detonations, each group comprising about one-half of the total nuclear charge required, in order to reduce air blast and seismic shock. The number of explosives, however, that would be detonated at one time and the sequence of detonations would have to be determined by further studies. The study also indicated the yield, location, and depth of burial of the explosives to produce a relatively uniform trench or cut with a bottom grade approximating the desired highway and railroad grades.

Access roads would be constructed into the pass as soon after detonation as possible to permit surveys and explorations. Maps of the trench and adjacent areas would then be prepared and detailed design of the railroad and highway facilities would proceed essentially in the same manner as for a conventional construction job.

Fallback material from the explosions in the bottom of the trench is expected to be shattered rock fragments ranging in sizes up to two feet in diameter. No particularly difficult settlement problems in the fallback material are anticipated. The roadbeds would be topped with a mantle of alluvium excavated east of the nuclear excavation. Loose rock and potential slide material would be scaled from the sides of the trench during construction of the highway and

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railroad, and adequate rock fall buffer zones would be provided along each side. These measures would eliminate potential hazards which might result from subsequent rock fall from the edges of the pass.

Subsequent construction of the highway and railroad roadbeds would be performed by conventional construction methods and equipment. One roadway of the divided freeway would be located along the bottom of the trench. The other roadway would be slightly higher on the north slope and the railroad correspondingly higher along the south slope. Initial freeway construction would provide for four traffic lanes (two in each direction) with space for ultimate expansion to a total of eight lanes, with a standard width median. The railroad would be about 22 feet higher than the adjacent eastbound highway lanes to minimize headlight glare.

Drainage Crater

An unusual solution is proposed for a drainage problem near the east end of the proposed cut, where it crosses below the flow line of an intersecting desert wash. The conventional solution would be to divert this flow eastward to a point where it could be passed below the highway and railroad grades by means of bridges. Instead, it is proposed to excavate an additional and separate nuclear crater upstream from the pass to capture the intermittent flow. This crater would have a capacity at least twice that required for the heaviest thunderstorm experienced in the area. Between storms the stored water would be dissipated by evaporation and possible seepage.

Safety Aspects

Based on past experience and the limited knowledge available for the study concerning details of the site, the study group indicated that the project could be executed safely.

Fallout

It appears at this time that, owing to the remote location of the site, protection of the public from harmful radiation can be assured.

Air Blast and Ground Shock

Close-in air blast at Amboy, the nearest community, is estimated, on the basis of currently available data, to

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be between 0.9 and 4.3 millibars. In this range, it is possible that a few windows might be broken, but very unlikely that any more severe damage from air blast would result. Distant air blast is estimated to range from 0.65 to 2.8 millibars, well below the threshold for damage under wind conditions favorable for shooting. Therefore, it is concluded at this time that air blast would not present a major obstacle to the project.

The velocity of ground shock predicted at Amboy would be between 6 and 10 centimeters per second. The threshold for minor damage to residential structures is about 8 centimeters per second. Therefore, some minor damage might be expected at this range.

It is emphasized that pre-shot site investigation of the local geology and further nuclear cratering experiments would provide much more information than is presently available, allowing a much more refined estimate of these effects from nuclear row shots.

Further Studies Needed

If it were decided to proceed with further consideration of such a project, the next phase would require additional site investigations to verify assumptions used in the study. These investigations would include geologic surveys, detailed mapping of the route, drilling of exploratory holes, and a survey of the exact number and location of all inhabitants and structures in the entire area. Detailed safety studies would also be required. These include the location of the water table for assessment of the possibility of ground water contamination, and direct and long range air blast studies and weather observations at the site to measure the frequency of suitable conditions for detonating safely. A ground shock and seismic study would also be required to determine the largest total detonation that could be safely made. These and other studies would be needed to evaluate in detail conditions under which the project could be undertaken with safety for inhabitants, vegetation, livestock, and motorists.

The AEC would not undertake such a project without complete assurance that it could be conducted without hazard to the public safety. Operational safety procedures normally employed by the AEC in conducting nuclear detonations would be utilized for operational control and safety during the nuclear detonation phase of the construction.

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The above studies, supplemented by results from future nuclear cratering experiments to be conducted as part of the Plowshare excavation program, would serve to refine the tentative design of the project. Carryall could not be conducted without data from these prior experiments.

Schedule

If such a project were initiated, the study group envisages a schedule of approximately five and one-half years for its completion. If undertaken, investigations and engineering design would take place in 1964, major pre-shot construction in 1965, and the nuclear detonation could be planned for 1966. The remaining time would be required for post-shot surveys, design, grading and construction of the railroad and highway, with the pass open to traffic possibly in 1969. This study is only one of feasibility. There is no proposal for undertaking such a project. The time schedule given, therefore, is hypothetical.