

postwar trend in engineering and science education toward more emphasis on fundamental theory and less on applications. Building on foundations laid before the war, the Caltech curriculum provides a common first year for all students, whether headed for science or engineering degrees, and attempts to minimize specialization in the separate branches of engineering.

Of 504 upperclassmen, 376 are registered in the sciences and 128 in engineering. Graduate students are split 381 in science and 297 in engineering.

In recent years, the aerospace industry has cultivated close relations with the science side of the Caltech faculty as well as with the engineers who in an earlier period were more ardently courted. The reason is the obvious one that in missile and space projects basic research and applications have become two sides of the same coin; university scientists and industry need each others' resources.

With the headlong expansion of the aerospace industry in California since 1950, Caltech has lost its unique position as supplier of talent for the upper echelon of the state's premier industry. The University of California at Los Angeles and the University of Southern California in Caltech's own region have become large-scale producers of scientific and professional talent; intensive recruiting over a period of years has brought many engineers and scientists in from other sections including the Midwest, which is particularly sensitive about its own version of the "brain drain" to California. Caltech, for its part, has become an institution with a national reputation and influence.

While it is difficult to establish a direct relation between university research activity and development of technically-based industry, the proposition that education means prosperity is accepted to a remarkable extent in California and this acceptance has resulted in the growth of perhaps the most highly ramified and generously supported education system in the United States.

Emergence of a booming electronics industry in the San Francisco area, for example, is credited largely to the presence of Stanford University and the University of California system which will be discussed in later articles in this space.

But if the economic foul weather signals now being run up are to be believed, the California theory on the rewards of education may be in for a rigorous test.—JOHN WALSH

Project Plowshare: AEC Program for Peaceful Nuclear Explosives Slowed Down By Test Ban Treaty

When the possibility of a partial ban on nuclear testing suddenly opened up last summer, both Americans and Russians, frustrated by negotiations for a foolproof, comprehensive agreement, moved very quickly. Large issues were simplified, elaborate definitions fore-sworn, possible complications bypassed. In one 17-line section of an exceedingly brief document, each state agreed to cease nuclear testing in the atmosphere, in outer space, and underwater, and to forego setting off any other nuclear explosions which would scatter radioactive debris beyond its own borders. With goodwill and hope paramount on both sides, several points of the kind diplomats are fond of spelling out were deliberately overlooked, and many questions were left unanswered. One of these questions was the future of Project Plowshare, the Atomic Energy Commission's program to develop peaceful applications for nuclear explosives.

The test ban is not the only reason for governmental concern with Plowshare. U.S. troubles in Panama have encouraged speculation about nuclear excavation of a new trans-isthmian canal; and, at the same time, slow-starting industrial interest in nuclear explosives is beginning to pick up. The increased interest in Plowshare, coming at a time when the program is being slowed down, has given the AEC a few awkward moments.

Plowshare was established by the AEC at the Livermore Laboratory in 1957, under the leadership of Harold Brown (now director of research and development at the Pentagon) and Gerald W. Johnson, who is still associated with the program. Its present leaders, along with Johnson, are Gary Higgins and Roger Batzel, of Livermore, and John Kelly, director of the AEC's Division of Peaceful Nuclear Explosives. Other Livermore scientists, particularly Edward Teller, have maintained close ties with Plowshare. In addition, there has been considerable interplay between the Plowshare and the weapons research programs, both at Livermore, and at other AEC laboratories and nuclear test sites. A chief and not always unexpressed motive for widespread support for Plowshare has been the desire of nuclear scientists to free the atom from its deep associations with Hiroshima, and to persuade them-

selves that their work could aid, as well as injure, mankind.

Plowshare scientists have begun to work on a variety of uses for peaceful nuclear explosives—unusual mining applications, exploration of the "laboratory" created by the tremendous heat of a contained explosion, the production of new elements. Their favorite project, however—the anchor piece of the whole program—is the perfecting of dramatic earth-moving devices. It is precisely the experiments needed to develop techniques for cheap construction of canals and harbors that appear to conflict with the test ban treaty.

It is hoped that canals can be built, for example, by producing a series of overlapping holes ("craters") with nuclear explosives. The explosives, placed some distance underground, would loosen the earth and expel it in a single operation. Enthusiastic predictions for the future of this technique, however, have considerably outrun experience with it. Only one full-scale cratering experiment has so far been undertaken—the Sedan shot of July 1962 (*Science*, 5 October 1962)—and many more shots would be needed before the knowledge and precision required for an actual excavation job could possibly be attained. The problem is that although underground explosions are not prohibited by the treaty, the cratering shots are not strictly "underground." And, at the present state of development of the explosive devices used, it is thought that further shots would violate the treaty in another way, by producing radioactive debris that might contaminate the atmosphere beyond our borders. Blasting projects other than canals, such as a proposal by the Santa Fe Railroad and the California Highway Department to study the possibility of blasting a pass through a California mountain, would run into the same difficulty.

As a result of these uncertainties, and the desire of the government not to risk antagonizing the Russians, the AEC has had to alter its plans for Plowshare. All large-scale cratering experiments planned for this year have been postponed, although small excavation tests and fully contained explosions for scientific purposes will be allowed to continue. In addition, more attention will be given to developing explosives with a low fission-to-fusion ratio (the "clean bomb"), so that nuclear excavation experiments free of both diplomatic and radioactive fallout can eventually be performed.

The cessation of costly cratering shots is reflected in a lessened budgetary request, from \$13½ million in fiscal 1964 to \$11 million in fiscal 1965. The program has always been a small one, however—only \$40 million has been spent on it since 1957—and the AEC believes in general that the political and financial restrictions will not limit it too severely. In several recent public statements AEC officials have made it clear that they expect the 140 or so scientists, engineers, and technicians working on Plowshare to remain, and that they believe significant work can still be carried out, in the field as well as in the laboratory.

Plowshare Politics

Others are not so sure. Plowshare occupies a place in the competition of cold war ideologies somewhat comparable to the place of medieval relics in the battles of competing religious sects. The importance attached to Plowshare by both politicians and scientists and the extent to which they believe it damaged by treaty restrictions tend to be in inverse ratio to their judgment of the treaty's desirability. This was apparent back in 1960, during the 3-year nuclear testing moratorium (the first time Plowshare was inconvenienced by efforts for peace), when the Joint Committee on Atomic Energy held hearings on all peaceful uses of atomic energy. Henry Smyth, chairman of the University Research Board at Princeton, told the committee that "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." Edward Teller, on the other hand, one of the scientists least in favor of a test-ban treaty, consistently has appeared as one of the most fervent proponents of Plowshare. "We can make harbors, we can make sea level canals, we can deflect rivers, we can throw off overburden from . . . deep mineral deposits, and increase our wealth and the wealth of other nations," Teller told the Senate Foreign Relations Committee during its hearings on the test ban last August. ". . . All this can be done. But there will be some measurable radioactivity, and this treaty prohibits the deposition of any radioactivity outside the territory of the United States." Indicating the variety of his anxieties, Teller went on to describe the treaty as a document "whose main point is to

bar knowledge, to prohibit knowledge that we need now for our defense and it also interferes with knowledge which we may acquire otherwise in the future, and which we may want for scientific purposes . . ."

Now the AEC, like the American eagle, wields an atomic sword as well as a peaceful plowshare, and arguments about the relative merits of Plowshare and the test ban tend to leave it in a somewhat peculiar position. In the first place, it is the fountainhead of the conflicting views, since most of the scientists involved on both sides belong to the AEC in one way or another—as past or present employees, contractors, advisors. Second, since the AEC is in the business of promoting all atomic activities, applications as well as research, it has a mandate to push ahead as far as possible, and it is understandably unenthusiastic about having its enterprise curtailed. Underlying these dilemmas is the fact that, unlike the State and Defense departments, the Atomic Energy Commission is not exactly part of the political administration. It occupies a hybrid position, part independent agency, part executive affiliate. AEC commissioners are theoretically "nonpolitical" appointees, although the custom has arisen of having a 3-2 ratio favoring the party in power. But the camaraderie and political loyalties that make most high-level appointees fall into line behind an administration program do not always operate in the AEC.

The effects of these conflicts were clearly visible at the Joint Committee on Atomic Energy's most recent hearings on Plowshare, on 25 February. Perhaps it was a series of tactical errors, as one commissioner later suggested, and not a reflection of underlying ambivalence, but the witnesses gave a rather muddled exposition of the issues raised for Plowshare by the test ban. Every admission that the program would in fact be slowed down was extracted only after the most painful questioning by the congressmen, as if the commissioners were very sorry to have to confess it and had not yet faced the issue squarely themselves. The official belief that Plowshare was essentially uninjured by the test ban turned out to be strangely difficult to defend. AEC chairman Glenn Seaborg kept repeating, for example, that the budget cut would have no effect on the morale or interest of Plowshare scientists. "It is not a dying project," Seaborg insisted, "but a perfectly healthy

one." To inhabitants of Capitol Hill, who have mastered Washington's immutable law that budgets of healthy agencies go up, not down, this was mystifying news. "Would it be equally healthy if we cut it by 40% again next year?" inquired Representative Craig Hosmer (R-Calif.).

Whatever its inner doubts on the Plowshare-test ban question, compared to the Joint Committee the commission is a model of solidarity. The jurisdiction of the Joint Committee extends exactly as far as the atom, and the role of the committee has traditionally been to push new atomic energy programs on a sometimes reluctant commission. JCAE chairman John Pastore, however, a loyal administration Democrat from Rhode Island, overcame the despair a man in his position might reasonably feel at seeing any atomic program cut. Pastore took the occasion to emphasize that, even without the treaty, the practical application of nuclear explosives to a project such as a canal would still be a long way off. Representative Hosmer, on the other hand, an opponent of the test ban treaty, took a far less relaxed view of its effects on Plowshare. Hosmer, to use his own words, was "shocked and amazed" when Seaborg reported that it would take about 5 years from the time cratering experiments were renewed before a canal job could actually be undertaken.

Canal Crises

The adequacy of the present Panama Canal has been a matter of sporadic debate for some time, and the sudden crisis in U.S.-Panamanian relations has spurred congressional interest in finding a replacement for it. Pastore, in fact, introduced a resolution calling on Congress to provide for a study of a new canal, and the Senate Commerce Committee began hearings on it last week.

The cost estimates for nuclear excavation of a canal are staggeringly low. Gerald Johnson, head of the Plowshare program at Livermore, estimated in a recent letter to Senator Pastore that, by nuclear methods, a sea-level canal could be constructed 110 miles east of the present canal (a route known as Sasardi-Morti) for \$770 million. The lowest cost alternative with conventional methods, according to Johnson, would be conversion of the present canal, which currently operates on locks. This would cost an estimated \$2,286,900,000. "In addition to being

cheaper," Johnson wrote Pastore, "the nuclear excavated canal was projected to have a width of 1000 feet as compared with 600 feet for the conversion of the present canal."

Even allowing for the vast uncertainties on which such calculations must depend, unless the figures are monumentally in error, the savings from nuclear excavation would be substantial. The money angle, however, is probably the least of the uncertainties facing a canal project: others are whether (or when) research will be able to minimize radioactivity from such explosions to the point where they can be safely carried out, and whether we will be able to persuade the "anti-imperialist" inhabitants of proposed canal sites that they want an American-inspired canal, nuclear or not, across their territory. Finally, it is clear that unless radioactivity can be fully eliminated, any canal project would require an amendment to the treaty, since by definition it involves nuclear explosions outside U.S. territorial limits. Although that time is still far off, it appears likely that the U.S. would seek a formal treaty revision when it arrived. In the meantime, however, whenever it is decided to renew cratering shots to develop the necessary technology, officials hope that informal international participation in the U.S. effort can be substituted for formal treaty amendment.

At the same time that some of Plowshare's earth-moving activities are being curtailed, however, industrial interest in other uses of nuclear explosives—particularly in their commercial application to mining and gas production—is on the rise. Most of the overtures are still in preliminary stage, but some companies in the Western states are reported to be on the verge of asking the AEC to cooperate with them in making test detonations. Detonations for these purposes would be fully contained, and there would be little or no risk of violating the treaty.

It would not be surprising to see the AEC, after its first disappointments are overcome, concentrating on industrial and scientific uses of nuclear explosives that will not embarrass the government. Though less dramatic than canals and mountain passes, this work is no less potentially revolutionary; a few scientists have argued from the beginning of Plowshare that its emphasis should be on these opportunities. In sum, if because of the test ban the AEC is beating swords into plow-

shares at a somewhat slower rate than formerly, there is no reason why it cannot nonetheless continue to beat them steadily.—ELINOR LANGER

Announcements

Esso Research and Engineering Company is sponsoring a group of scientists which organized last month to "help in the **analysis of the carbon compounds of the carbonaceous chondrites**." The group invites other scientists who can contribute meteoritic material or help in the analysis to contact the chairman, W. F. Libby, director of the Institute of Geophysics, U.C.L.A., Los Angeles, California.

A national headquarters for the American Federation of **Information Processing Societies** has been established in New York. The new offices were set up in an effort to provide "a full-time, year-round point of contact between the profession and the general public." The federation is located at 211 East 43 St., New York 17.

Meeting Notes

Warsaw, Poland, will be the site of the 15th **international astronautical congress**, 7-12 September, sponsored by the International Astronautical Federation. The congress will include meetings on technical problems of manned lunar exploration. The call for papers has been issued; triplicate copies of a 500- to 800-word summary must be submitted to the appropriate session chairman. The chairmen are listed at the beginning of the forthcoming events section in this issue. Deadline: 15 April. (Further information on the congress is available from the International Astronautical Federation, 250 rue Saint-Jacques, Paris 5, France.

The Franklin Institute will present its second annual **organic solid state** symposium 25 May in Philadelphia, Pa. It is designed for research chemists and physicists in the field. Advance registration is required. Deadline: 11 May. (M. M. Labes, Franklin Institute Laboratories, 20th and The Parkway, Philadelphia 3)

Papers are invited for presentation at the fourth general meeting of the **International Mineralogical Association** 14-22 December, in New Delhi, India.

Symposiums will be held on natural and synthetic zeolites, and on carbonatites, kimberlites, and their minerals; sessions will also take place for presentation of papers of general interest. Deadline for submitting titles and abstracts: 31 May. (Zeolite papers: J. V. Smith, Department of Geophysical Sciences, University of Chicago, Chicago, Ill.; carbonatite papers: H. von Eckermann, Edeby, Ripsa, Sweden; general papers: M. S. Krishnan, National Geophysical Research Laboratory, Osmania University, Hyderabad 7, India)

Scientists in the News

Gerald R. MacLane, chairman of the mathematics department at Rice University, has been appointed head of the division of mathematical sciences, Purdue University, effective 1 July.

The Institute of Electrical and Electronics Engineers has elected as president **Clarence H. Linder**, a retired vice president of General Electric Company.

Bruce A. Reese, former chief scientist in the U.S. Army's Nike-Zeus anti-missile program, has been appointed associate director of the Purdue University Jet Propulsion Center. He recently returned to Purdue after a 2-year leave of absence spent as technical director at the Redstone Arsenal, Huntsville, Ala.

Robert Griffith Page, associate professor of medicine at the University of Chicago, has been appointed associate dean of the university's division of the biological sciences.

Isidor I. Rabi, Higgins professor of physics at Columbia, has been chosen to receive the 1964 Priestly memorial award from Dickinson College. The prize and \$1000 honorarium honoring Rabi's "contributions to the welfare of mankind through physics," will be presented 19 March.

Elizabeth Dexter Hay, at Harvard, has been appointed the first Louise Foote Pfeiffer associate professor of embryology at the school.

Robert C. Little, professor of physiology at Seton Hall College of Medicine and Dentistry, has been named chairman of the physiology department at Ohio State University's medical college, as of 1 April.