so sure about that. . . . We are going to find out. The orphan has been placed on Dr. Hornig's doorstep. We are going to find out whether he is going to adopt him or get rid of him."

In short order, the Committee then returned to Holifield's demand for a "national policy in this high energy field that is more definite in point of planning the project and time period. . . ." To which Hornig returned to his position that "what we can have is a set of guidelines as to what is scientifically profitable as we go ahead viewed at any given time, but it seems unavoidable, simply because the funds are so large, that this policy will be subject to constant modification as the budgetary situation changes from year to year and as the scientific situation changes."

The chair repeated that it was not satisfied with the reply, and Hornig stated: "I understand your concern and will do what I can to sharpen up our views for your guidance."

In general, the new science adviser performed well in his congressional premiere. Though often pressed by the committee to an extent that might have induced a less temperate soul to indulge in sharp rejoinder, he was never harsh, but neither was he ever unduly deferential. When he didn't have an answer at hand, he freely admitted it, and when he disagreed with the committee, he didn't seem to spare them that fact.

On one occasion, though, he found himself in a rather embarrassing position. Addressing himself in his prepared statement to an interdepartmental energy study which is looking into the politically volatile issue of national policies regarding atomic energy, oil, gas, and coal, Hornig stated that the study was progressing: "All told, nearly 100 technical papers were prepared for internal use of the Energy Study. These were reviewed by more than 150 qualified technical reviewers and by about 225 members of 22 special ad hoc committees. . . . By the end of last summer, the team . . . had produced a preliminary draft on the order of 1200 pages in length. . . . In order to make this material more useful for the purposes of overall analysis and intercomparison, an effort has been made to reduce its size while maintaining its high quality. A re-draft, on the more manageable order of 600 pages in length, is now ready for further review by the 10 participating agencies.

"The present situation therefore is that we nearly have in hand a scholarly review of the subject. What is missing is clear-cut findings and conclusions," Hornig explained.

To which Chairman Holifield recalled that last year, when Hornig's predecessor, Jerome B. Wiesner, was asked about reports that the administration was going to make an energy study, he replied, " 'Yes, sir, it will be a small one.' " Hornig then assured Holifield that the report would be completed this spring, and Holifield assured Hornig that a "return engagement" with the committee would take place.

—D. S. GREENBERG

California: Aerospace Industry Has Meant A Second Gold Rush; Climate and Education Get Credit

Los Angeles. In the sharpening regional competition for economic development through research-based industry, California has been widely regarded as representing both the standard and the ideal. A growing number of people, here, however, are suggesting that their state's silver cloud may have a dark lining.

Basis for this apprehensiveness is the dependence of much California industry on government business. This is not a new source of worry for Californians, who suffered fairly painful periods of adjustment after World War II and the Korean War. But, in the last year or so, well-informed people have begun to read signs of some unfavorable long-term changes in the state's economic climate.

Talk of economy in general in Washington and, specifically, of cuts in spending on defense and space, in which California plays a leading and lucrative role, has created an atmosphere of uncertainty probably unmatched since the nuclear weapon systems race between the United States and the Soviet Union began in earnest more than a decade ago.

More particularly, the expected leveling off of expenditures on intercontinental-ballistic-missile systems in the mid sixties—with the maturing of the Polaris, Minuteman, and Titan programs, for example—would presumably cut the growth rate of the state's bellwether airframe-electronics industry. Development work on new weapons systems, which is expensive and involves large numbers of engineers and scientists, has already tapered off to some extent.

Predictions that the pattern of expenditures for weapons will be altered in the direction of more arms for conventional warfare and less for the big systems does not reassure California planners. Manufacturers in the Midwest and East have experience in producing vehicles, ordnance, and soft goods, and in some cases boast a competitive advantage over the West Coast.

Also disquieting to Californians is the clamor that has been raised in the past two years in Congress and by the legislators' constituents over the concentration of defense and space spending in a relatively few states. Since California has taken a long lead over other states as a defense contractor in the era of complex weapon systems, California has become the principal target for critics of concentration on the grounds that such federal spending represents an investment which has broad and perhaps irreversible economic effects (*Science,* 29 March 1963).

Californians find the possibility of a political assault behind a "fairer shares for all" banner particularly worrisome now.

The decision to award the contract for the TFX all-service fighter to General Dynamics for production in Texas and the cloudy future of manned bombers, and of tactical and support aircraft, has made the outlook for California's aircraft industry less than brilliant. The manufacture of commercial jet transports has not proved the boon to employment and profits that many expected. And the placing of a checkrein on NASA spending by Congress last year has forced the California space industry to modify its expectations for snowballing growth.

For all these reasons, Californians now seem to be taking a close look at their state's present situation and its prospects in the light of changing federal policy and national trends.

While California officials and industrialists are discussing potential difficulties with some somberness these days, it is, with employment and business activity in the state at record highs, no time for sackcloth and ashes. Observers from states with less dynamic economics may well wish they could exchange their problems for California's. But to understand the local tendency to see trouble prefigured in present prosperity it is necessary to appreciate the California statistics and the California context.

Governor Brown stated the case in a

recent message to the California legislature when he described a booming state economy but predicted an unemployment problem exacerbated by a decline in defense spending.

Next year the work force in California is expected to grow by some 200,000 workers, thus sending total employment above 7 million for the first time. Unemployment is also expected to grow from an average of 411,000 in 1963 to about 425,000 this year to stay at about 6 percent, or a shade above the national average.

Brown singled out the aerospace industry as a crucial area for the state because between 1950 and the present about six out of every ten new jobs created have been in the aircraft-missile-electronics sector. Aerospace employment rose from a total of about 99,000 in 1950 to 471,000 in 1962. Now the growth of the aerospace industry has slowed, says Brown, to the point that it can no longer absorb a majority of the new workers in each year's bumper labor crop. In-migration to California is estimated at more than 1500 persons per day.

There is little question that up to now, at least, it has been a matter of as goes the aerospace industry so goes California. And the figures on geographical distribution of federal expenditures clearly indicate the magnitude of military and space expenditures in the state economy.

A Defense Department study shows that of the $25 billion in military prime contracts it awarded in 1962, California garnered $5.9 billion worth or 23.9 percent. Some 54 percent of California's military business was in missiles and 14 percent in aircraft.

The same report, *Five Year Trends in Defense Procurement—1958 to 1962*, also indicates that about 40 percent of the $6.1 billion in prime contracts for military experimental, developmental, test, and research work (EDTR) went to California. While nobody has established a direct relationship between EDTR work in an area and resultant production contracts, it has become something of an article of faith among those interested in regional economic development that one leads to the other and that the presence of a "university-industrial" complex is the essential catalyst.

The aerospace industry, which is concentrated in the Los Angeles Area, with a secondary center south around San Diego, provides at least circumstantial evidence to support the popular theory. And so does the complementary electronics industry complex in the San Francisco peninsula and bay area, where Stanford and the University of California at Berkeley seem to have served as germinating forces.

People who have watched the aircraft industry in California develop and then evolve into the aerospace industry tend to explain the rise of the industry in terms of a simple formula: climate plus Caltech.

The California Institute of Technology at Pasadena, as a matter of fact, appears to have been a kind of service academy for the aircraft industry. Most people date Caltech's era of influence from 1921 when Robert Andrew Millikan resigned from the University of Chicago to come to Pasadena as administrative head of the Institute and head of a new research laboratory in physics. Basic educational policy in Caltech's forerunner, little Throop Institute, an arts and crafts school established in the 90's, however, seems to have been set in the early years of the century by men such as George Ellery Hale, first director of the Mount Wilson Observatory and a Throop trustee. Hale saw a future for Throop as a first-class science and engineering school. In 1907 Throop shed its normal school, academy, and elementary school and became a college of technology, awarding B.S. degrees in electrical, mechanical, and civil engineering. By the time Millikan moved to the West Coast, Caltech had taken its present name and the trustees were committed to fostering first-class instruction and research in science and engineering by recruiting first-class men.

Millikan, Hale, and Noyes

The early growth of Caltech was heavily influenced by the triumvirate of Millikan, Hale, and Arthur Amos Noyes, who came from MIT to Caltech as director of chemical research. Caltech's plant, faculty, and reputation grew rapidly and began to attract the support of industry, foundations, and private benefactors. In the late 20's the Guggenheim Graduate School of Aeronautics was established with a grant from the Guggenheim Foundation. Caltech had boasted a wind tunnel since 1917, but little serious first-rate work was being done in aerodynamics at Caltech, or indeed elsewhere, until the establishment of the Guggenheim school, which was soon to achieve distinction and to become the institute's chief contact point with the aircraft industry.

In the late 1920's also, the distinguished German aerodynamicist Theodore von Karman, who was then at the technical institute at Aachen, visited Caltech and helped design a new wind tunnel. In 1930, as the political atmosphere in Germany worsened, von Karman was persuaded to emigrate and become full-time director of the Guggenheim lab.

In the same period, Donald Douglas and other pioneers in the aircraft industry were attracted to the Southern California littoral because of its good climate for making and testing airplanes. The 1930's was a period of rapid development in both aeronautical theory and design, and as Clark B. Millikan, now director of the Graduate Aeronautical Laboratories recalls, the Caltech aeronautics lab and the aircraft industry "sort of grew up together," as many Caltech graduates moved into engineering and administrative jobs in the industry.

In the mid-1930's von Karman and his associates began the experimental work on rocketry and jet propulsion which was to influence heavily Caltech's wartime role and also put the Institute in the van of research on emerging aerospace problems and lead to the establishment of the Jet Propulsion Laboratory (*Science*, 6 March 1964).

The war not only spawned JPL but resulted also in the colonization efforts by JPL faculty and graduates in the new aerospace industry. Most conspicuous, perhaps, was the setting up of a private company to fabricate the JATO (jet assisted takeoff) units by von Karman and his associates, a company which became the Aerojet General Corporation of the General Tire and Rubber Company, and was the 12th biggest defense contractor last year. Another notable example was the Ramo Wooldridge research and engineering firm formed by two Caltech graduates.

At Caltech, the postwar period has brought a spectacular growth in government-sponsored basic research and a rise in the proportion of graduate students to undergraduates. In 1958 there were 703 undergraduates and 555 graduate students, while in 1963 the numbers had moved toward balance, 697 undergraduates and 678 graduate students being on the rolls.

Emphasis on graduate training is reflected in the figures showing that 82 percent of the graduates in the class of 1963 went on to graduate school.

In its undergraduate curriculum, Caltech appears to have anticipated the

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 foresworn, 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 themselves 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 expolsives. 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.