Project BOMEX: Biggest Weather Study Yet

The Barbados Oceanographic and Meteorological Experiment (BOMEX), announced by U.S. government officials last week, illustrates strikingly how environmental science has become very big science indeed, demanding new forms of scientific organization and investigations of unprecedented size and sophistication. For BOMEX, which will take place during May, June, and July over a 90,000-square-mile ocean area east of Barbados in the West Indies, is regarded as the largest, most complex, most difficult single effort that has yet been undertaken to understand the weather.

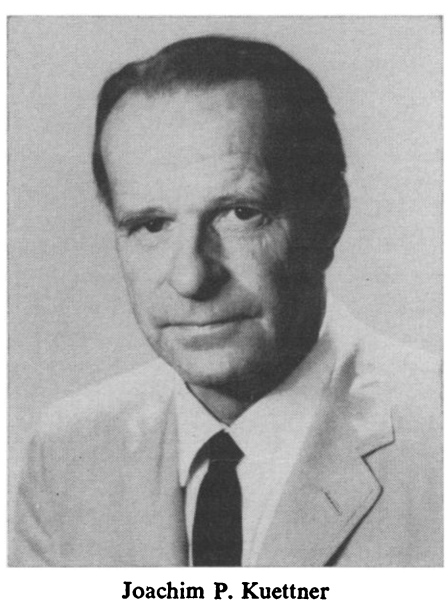
To set up this $18-million experiment, it has been necessary to draw on the scientific and other resources of seven federal agencies, seven independent research laboratories, and 19 universities. Further, BOMEX will involve the use, in integrated fashion, of a remarkable array of instrument platforms—eight satellites, including one in synchronous orbit 23,000 miles above the earth; 24 aircraft, flying at altitudes of 100 feet to 60,000 feet; ten ships, including several of the most sophisticated oceanographic vessels afloat; a dozen instrumented buoys; and "FLIP," a highly stable, 355-foot-long instrumentation barge which can be upended by the flooding of its ballast tanks, so that observations can be made at the surface and at various depths.

The experiment, to be led by the Environmental Science Services Administration (ESSA), is the first of a series of very-large-scale research projects planned by the nations of the world as part of the Global Atmospheric Research Program (GARP). GARP, in turn, is directed toward achieving a truly global system of weather observation—a "World Weather Watch." Its objective is to mount, by the mid-1970's, a worldwide experiment demonstrating the feasibility of accurately forecasting the weather for 2 weeks or longer.

The goal of BOMEX is to gain new understanding of the interaction of the air and tropical oceans, a primary process in determining atmospheric circulation and world weather systems. Joachim P. Kuettner, director of BOMEX, at a Washington press conference, described this process. "Most of the heat received from the sun," he said, "is stored in the tropical oceans between the latitudes of 30 degrees North and 30 degrees South, a region representing half the earth's surface.

"In contrast," he continued, "the earth loses heat by radiation almost uniformly at all latitudes, so heat has to be transported from equatorial regions to higher latitudes. Strangely enough, this transport is not done by the ocean, but primarily by the atmosphere. This process, of which relatively little is known, seems to occur in three stages. First, the energy in the ocean transfers to the atmosphere in a turbulent boundary layer about 6000 feet thick. Most of this energy moves from ocean to air as latent heat in the form of water vapor. Next, the energy finds its way from the boundary layer to the upper layers of the troposphere. Finally, it is transported to higher latitudes by fast-moving air currents, sometimes in the nature of jet streams."

According to Kuettner, until the mechanisms by which these processes occur are understood, accurate weather forecasts extending over more than a few days will be impossible. BOMEX will investigate in detail the exchange of energy between ocean and atmosphere and the vertical and horizontal spreading of these energies. Also, a mathematical model, based on observations made by satellite and conventional means, will be developed in an attempt to predict sea-air interactions within the experimental area.



Joachim P. Kuettner

By providing an exceptional array of data-gathering facilities, BOMEX will afford unusual opportunities for scientists at universities and independent laboratories, allowing them to do research which they could not otherwise dream of undertaking. Eugene Bierly, director of meteorology programs at NSF, observes that researchers who have had to base their mathematical models and other theoretical studies on unverified assumptions will now get the chance, in BOMEX, to test their work in the real world.

Some 85 separate research studies are to be carried out as part of BOMEX. These investigations will be conducted by scientists from the participating federal agencies; from institutions such as the National Center for Atmospheric Research (NCAR) and Woods Hole Oceanographic Institution (WHOI); and from universities such as Yale, Chicago, Michigan, Oregon State, Texas A&M, and Miami.

The organizational complexity of BOMEX is illustrated by the multiplicity of agencies and institutions that have major operating responsibilities in the program. For example, four federal agencies (ESSA, the Navy, the Coast Guard, and the Bureau of Commercial Fisheries) will be operating ships, and as many as eight agencies and institutions (including NCAR, WHOI, and two universities) will be operating aircraft.

The BOMEX project office appears to have been successful over the past 18 months in fitting all the various participants into a well-integrated plan. This has had to be a matter of gentle persuasion, however, for participation has been voluntary. And ESSA, though it has been the lead agency, has not controlled project funding and has had to look to other agency participants for sizable contributions to the BOMEX budget. (Of the $18 million which will have been spent on BOMEX by the time the experiment is completed, $4.5 million will have gone into buying instruments and other project preparations, while $13.5 million will have covered such major costs as those for ship and aircraft operations and data reduction.)

Although ESSA's administrator, Robert M. White, has described BOMEX as an outstanding example of interagency cooperation, he evidently is not eager to strain his luck in the future. White was a member of the Commission on Marine Science, Engineering, and Resources which recently recommended establishment of a National Oceanic and Atmospheric Agency. "NOAA" would be made up principally of ESSA, the Coast Guard, and the Bureau of Commercial Fisheries; and it would coordinate, as the President might direct, interagency programs in civilian meteorology and oceanography. Among other reasons it gave for establishing the new agency, the commission said NOAA would offer the "major advantage" of providing consolidated planning and operating capabilities for the large-scale field experiments expected to follow BOMEX.

—LUTHER J. CARTER

Arms and the Scientists: A Long Dialogue Continues

The national debate on Sentinel is the first example I know of a military system being a matter of public debate not confined to a small group of experts or advocates of a special cause.—Professor Jack P. Ruina of M.I.T., a former top Pentagon weapons adviser, at recent Senate ABM hearings

Earlier in the cold war the technical and strategic pros and cons of a new military system could not have been aired with the fullness which has lately marked the discussion of ABM capabilities and potential countermeasures against such a system.

David E. Lilienthal, first chairman of the Atomic Energy Commission, made this point in a recent CBS public affairs program when he contrasted the ABM debate with conditions prevailing two decades ago when the decision to develop the hydrogen bomb was made. Lilienthal, who opposed development of the H-bomb, commented on the decision and its effect on the arms race. "Well it's easy," said Lilienthal, "to look back and say you were right, but now we're going through another cycle. . . .

"Now we're having a public debate about another issue of this kind, and it's casting a lot of light on public policy. The H-bomb should have been discussed that way."

Certainly there is a new freedom in discussion of weaponry in comparison with the early postwar period, when the military secrecy lid was kept clamped down with wartime tightness. But it is unclear to what extent more open discussion has actually affected key strategic decisions or the process by which they are made.

Debate on the ABM, in fact, seems to be following a pattern set during a succession of crucial debates on weapons and arms control, in which a group of university scientists, who established themselves as weapons experts during World War II, have sought to influence the dialectic of the arms race.

Over the years there has been a certain continuity in arguments and in personalities. Hans Bethe, Nobel-prize-winning theoretical physicist, played a key role in the work of American scientists mobilized during World War II and was a dominant figure among those who argued that it was possible to develop a detection system adequate to police a nuclear test ban. And it was Bethe, collaborating with physicist Richard L. Garwin, who produced an article, published in the March 1968 issue of *Scientific American*, which provided a prime public source of information for opponents of the ABM. Bethe and Garwin discussed in detail offensive tactics and aids to penetration of the putative "thin" ABM shield, and thus markedly raised the level of sophistication of subsequent debate.

More open discussion of both technology and strategy is not the only change which occurred during the debates over the hydrogen bomb and the continental air defense system and during the long gestation of the test-ban treaty. The Pentagon and the White House developed greater "in-house" capabilities in dealing with weapons evaluation and strategic policy. Most notable were the creation, after the Sputnik I scare, of the Advanced Projects Research Agency (ARPA) and the Directorate of Defense Research and Engineering (DDRE). Of increasing importance during the period were such semi-detached advisory organizations as the RAND Corporation and the Institute for Defense Analyses. The "think tanks" at first concerned themselves with technical problems but soon evolved a capacity to advise on strategic questions. The emergence of the "defense intellectuals," offering analyses of policy questions, inevitably gave government policy-makers a source of advice which could be set against the advice of university scientists. The academic scientists were mostly natural scientists whose claim to authority lay originally in their expertise in developing weapons and their understanding of weapons effects. The scientific strategists were mainly mathematicians and, especially, economists, who evolved an even more dismal science by thinking about the unthinkable in a professional way.

Academic scientists also institutionalized their government advisory activities in groups such as the President's Science Advisory Committee (PSAC) and the National Academy of Sciences' Committee on Science and Public Policy, but it is fair to say that members of these groups have felt themselves to be, as the saying goes, on tap rather than on top.

In the debate on the ABM, the dissenters who received most public notice have been men like the former Presidential science advisers James R. Killian, George B. Kistiakowsky, Jerome B. Wiesner, and Donald F. Hornig (*Science*, 21 March), all of them products of the wartime incubator of statesmen of American science. All of them, also, can be placed in what Robert Gilpin, in his book *American Scientists and Nuclear Weapons Policy*, calls the "school of finite containment." This group excludes the unilateral disarmers. As Killian said in the recent ABM hearings before the Senate Foreign Relations subcommittee, it is "essential to preserve the deterrent." But the finite