explained by the box system. The influence of pH on the dissociation curve will vary with the dependence of K_{obs}, K'_1, and K'_2 on pH. A complete analysis would require an extension of the stoichiometric scheme by constructing additional boxes upon each one of the sides of the central box. In every one of these new boxes, the proton dissociation equilibria of each one of the species participating in the oxygen reaction would have to be considered. However, in comparing titrations at different constant pH's, in the range of pH where only the acid dissociation constants operable in K'_{obs} are involved, the curve will shift along the log-L axis without change in shape, but in regions where the acid dissociations affect the observed values of K'_1 and K'_2, the curve will also change shape and therefore its asymmetry will also be affected. In principle each of the thermodynamic constants in this analysis may be directly and independently determined experimentally, whereby the pitfalls inherent in curve-fitting procedures may be avoided. In general, any set of simultaneous reactions can be similarly analyzed.

This is a comprehensive theory dealing with all of the observed properties of hemoglobin simultaneously. The reaction paths considered, with the equations that describe them, can be applied quantitatively to the "apparent" heme-heme interaction, the Bohr effect, the Haldane effects, the heme-linked ionizations, the oxidation-reduction reactions, and the observed dissociation of hemoglobin into subunits; they are in agreement also with the observation that the structure of the reduced hemoglobin tetramer is different from the structure of the hemoglobin-ligand tetramer.

In spite of the considerable amount of work on hemoglobin reactions, a thermodynamic analysis of the data is not possible because there is no complete set of results that includes all pertinent variations of the thermodynamic constraints. Such studies are being undertaken in our laboratories in order to determine the thermodynamic parameters of hemoglobin reactions (*20*).

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News and Comment

Graduate Education: Navy Program in Rocket Astronomy Opens New Horizons to University Scientists

A Navy space research program, which dates back to the pioneer days of rocketry at the end of World War II and, in the intervening years, has won a reputation for solid accomplishment in the new field of rocket astronomy, this fall will begin to play a more active part in the education of astronomers and physicists.

Graduate students, postdoctoral fellows, and faculty members will be able to work with the staff of the atmosphere and astrophysics division of the Naval Research Laboratory (NRL) in Washington by an arrangement under which the National Science Foundation provides grants for the visiting scientists and funds for rockets, satellites, and payloads to be used in their research.

Reciprocal benefits presumably will accrue from the project; the visiting scientists should profit from association with experienced government scientists and from the opportunity to join in rocket-borne experiments, while the regular staff members should be stimulated by what division superintendent Herbert Friedman calls the "give and take" of a graduate school atmosphere.

The new scheme can be numbered among various efforts that have been made in recent years to utilize the resources and staff of specialized laboratories operated or financed by the government to increase the supply of scientific manpower in fields in which the supply is short.

The meeting ground for government and university scientists will be the E. O. Hulburt Center for Space Research, established early this year at the Naval Research Center under the joint sponsorship of the Office of Naval Research—NRL's parent organization—and NSF. The center's permanent staff is made up of researchers in Friedman's division, and some additional professionals and technicians are to be recruited specifically to work at the center.

The Navy's rocket and satellite astronomy program goes back to 1946 and the days when the United States used liberated German V-2 rockets to launch a serious program of research in space.

In the early years of the program, while American-made rockets were getting out of the pinfeathers stage, the V-2 continued to be the standard carrier for the sounding-rocket experiments. Other rockets were tried out as they became available, and by the early 1950's the Aerobee, a liquid-fuel rocket, proved to be generally the most satisfactory for the rocket astronomers' purposes. The Aerobee, which remains the mainstay of the program, can lift a 150-pound payload 150 miles.

The NRL group designed the first astronomy experiments for satellite payloads in connection with the Navy's Vanguard program and, by the sector of the scientific community directly interested in its special field, the NRL group seems to be regarded as consistently in the forefront of this sort of space research.

The group is best known for work on the sun, particularly on the solar spectrum throughout the ultraviolet and x-ray regions.

The rocket astronomy program is operated with a relatively small staff and modest budget—about $2.5 million a year, or a tenth of the total NRL budget for basic research. Friedman's group, however, has the considerable technical and logistical resources of the NRL to draw on and can get help from technicians and consultants in a broad range of specialties. Most of the rockets used in the astronomy experiments are fired at Navy facilities at White Sands Proving Grounds and the Pacific Missile Range, and the fleet can be called on for support of experiments at sea. The program also gets another Navy subsidy of $500,000 to $1 million a year for its small satellite program plus NASA grants.

The group has been instrumenting an average of 15 Aerobee rockets and two satellites a year, but it can also bid to "hitchhike" on spacecraft launched by the National Aeronautics and Space Administration. Astronomy experiments aboard NASA's Explorer VII and ill-starred Rangers I and II were NRL products, and the group is also putting hardware aboard NASA's solar observatories and orbiting geophysical observatories.

The continuing independence of the Hulburt Center program appears, at first blush, to be something of an anomaly at a time when most people equate the national space effort with NASA. A substantial part of spending on space, however, is not accounted for in the NASA budget, big as that is. The space budget of the Defense Department, to cite the chief non-NASA program, approached $1.5 billion last year, not including funds for the development of military missiles which are also used in space. Most of these funds go into research on military applications, but a substantial amount supports basic research. While the smaller programs generally cooperate rather than compete with NASA, there is no doubt that interagency frictions and rivalries remain, if only because NASA arrived on the scene late and in such a big way.

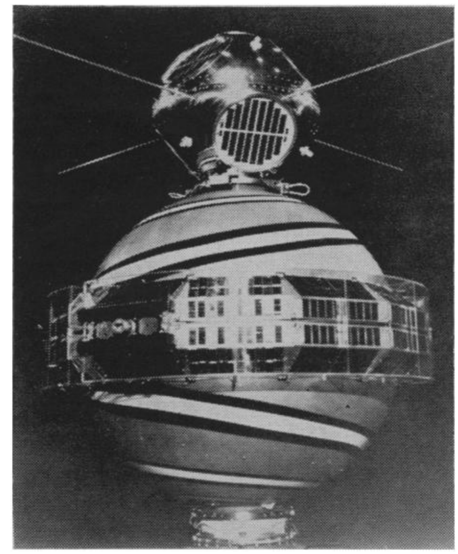
The firmly established and productive NRL rocket astronomy program was not included in the gathering of space programs under the wings of NASA in 1958. But the NRL group was radically affected by the rise of NASA, for when the Navy Vanguard space sciences program was shifted to NASA, about half the astronomy group, almost all of them concerned with upper-air research, went along. NASA recruiting is vigorous, but the real lure in this case seems to have been the prospect of bigger boosters to abet their research in the ionosphere.

Those who stayed behind were concerned mainly with astrophysics, and the gaps in the group's ranks, with Navy approval, were filled largely with people with like interests. As a result, the group, which numbers about 50 scientists, engineers, and technicians, has concentrated even more on astrophysical experiments conducted above the atmosphere through the use of rockets and satellites. The new research associates will be expected to participate in these experiments, which include solar ultraviolet and x-ray spectroscopy and photometry, solar x-ray and ultraviolet imaging experiments, experiments to map the white corona, stellar photometry in the far ultraviolet, and x-ray astronomy.

Research appointees will be selected by a review board composed of representatives of the Hulburt Center and the astronomy section of NSF. Appointments will normally be for a year, although tenure for other lengths of time may be arranged according to circumstances.

Plans call for the appointment of six to ten visiting scientists the first year. NSF has set aside some $800,000 to defray the costs of hardware and services for the researchers, plus funds for stipends and other costs.

While NSF has supported a variety of science education programs in cooperation with federal agencies, the new agreement with NRL seems to



[U.S. Navy]

Pickaback solar radiation satellite.

mark the first time the foundation has underwritten a formal program for graduate and postgraduate training and education in a particular discipline in another federal agency.

A shortage of astronomers, on the one hand, and the accomplishments of the NRL center group seem to have persuaded NSF officials to launch the program. Under the informal rating system that operates inside Washington science, the Hulburt program gets high marks. Observers always seem to mention that Friedman, the center's chief scientist, and Richard Tousey, its head of rocket spectroscopy, are members of the National Academy of Sciences. And though probably exaggerated, there is a feeling current that, national science politics and prejudices being what they are, it is easier for a camel to go through the eye of a needle than for a government scientist to be elected to the National Academy.

NSF's concern over the state of astronomy appears to be related to the split in the profession brought about in part by the emergence of rocket astronomy. While much work is still done from observatories on the ground and by radio astronomers, a new realm has been opened to those who send their instruments above the limiting boundaries of the atmosphere aboard sounding rockets or satellites.

Friedman says that about half the astronomy graduates now go into ground-based observation, and that the other half, plus recruits from physics, work on problems amenable to research through rocket astronomy.

University researchers in this branch of astronomy, however, lack the rockets and the elaborate logistical support needed to get their experiments off the ground. University researchers, therefore, have much to gain through association with the Hulburt Center.

Scientists at the center are interested in establishing closer relations with the universities, not only to recruit new men to a fruitful field of research but also because it is generally agreed that basic research and graduate education go hand in hand, and that a community of scientists is refreshed and stimulated when teaching and learning are going on within it.

How the universities feel about this is a more complicated question. Undoubtedly, there has been some suspicion engendered by proposals to use government laboratories for graduate education. Some of the dubious fear that the idea might be pushed to extremes, even to the creation of degree-granting federal universities.

The present NRL-NSF program hardly seems to tend in this direction. The research appointee working at Hulburt Center would submit his thesis at his own university, where he would have satisfied all other requirements for his degree. The arrangements are similar to those which have applied for several years in other government-operated or -supported facilities, notably those financed by the Atomic Energy Commission.

The AEC programs were originated in a period when nuclear technology was classified, and the agency brought in university students and faculty members in the cause of spreading nuclear science education to the universities. Though the AEC monopoly on materials and machines for research was broken in the mid-fifties, and the AEC became a big patron of nuclear research in the universities, providing project grants and fellowships and subsidizing equipment purchases, the agency also maintained sizable programs of nuclear science education in its own installations and contract labs. These programs are generally cooperative in character, through arrangements made with a university or group of universities such as the Associated Midwest Universities, linked to Argonne National Laboratory, or the southeastern universities which are tied to Oak Ridge National Laboratory through the Oak Ridge Institute for Nuclear Studies.

One of the best known proponents of more direct federal participation in science education is Alvin M. Weinberg, director of the Oak Ridge National Laboratory. He argues that the federal government is a big consumer of scientific and technical manpower and has an obligation to help produce that trained manpower.

In a widely discussed lecture presented at an NSF colloquium in 1962 [*Science* **136**, 27 (6 Apr. 1962)] Weinberg said that "Big Science, by weaving itself intimately into the fabric of science education, can help alleviate the manpower shortage which Big Science has created."

While not ruling out the federal university as a possible response to a critical need, Weinberg said, "One scheme which appeals very much to me is for the big laboratories to set up joint institutes with existing neighboring universities. The general plan would be to make the very best basic research scientists at the federal laboratories professors at the universities. These individuals, if carefully chosen, could convert an average institution into a true center of excellence. . . ."

Although this suggestion would undoubtedly appeal to underdeveloped universities striving to expand and improve their graduate programs in science, general proposals for basic changes in government-university relations seem to have been received apprehensively in the universities.

Security and Academic Freedom

Most university researchers are more than willing to work on government-financed basic research projects in their own university labs, but there seem to be a series of stock objections to working, even on the same projects, in government laboratories. First, there is the argument that federal labs are mission-oriented and that therefore, even in the case of basic research, there are inevitably restrictions and bureaucratic pressures on the investigator.

Then there is the feeling that security requirements conflict with academic freedom, though even in weapons laboratories today a good deal of unclassified basic research is carried on. In the case of the Hulburt Center, security clearances are required of the research appointees because the lab is located in a restricted area, but the center's work is completely unclassified, and results are published promptly.

University scruples may also be based partly on economics. Graduate education is a kind of apprentice system in which the graduate student, as he progresses, is relied on as a source of willing and inexpensive labor. Universities, not surprisingly, are reluctant to invest effort and money in a graduate or postdoctoral fellow and then lose him to a federal lab just at the time the investment should start to pay off.

Recognition of these sore points has moved the agencies to deal tactfully with the sensibilities and the exchequer of the university. In the NRL program, typically, grants to support the research appointee are made through his university; if the researcher is a predoctoral student his thesis adviser is named principal investigator on the grant and probably is made a consultant to the center. And overhead payments also are made to universities. In these ways the agencies strive to befriend the universities rather than to offend them.

In practice, while arrangements for graduate and postgraduate training are available in several agencies—the National Institutes of Health and the National Bureau of Standards are the sites of small programs and NASA may not be far behind—there are certainly no signs of a concerted effort to turn the government laboratories into graduate education mills.

In the loftier realms of science policy, the most recent definitive word seems to have been said in 1960 by the panel on basic research of the President's Science Advisory Committee, in its report "Scientific Progress, the Universities and the Federal Government."

The panel put heaviest emphasis on strengthening basic research and graduate education inside the universities and directly affiliated laboratories, but in one section of its report it noted, "In some fields of science, leadership is no longer clearly with the universities. . . ." In these areas, the panel suggested, industry, government, and the universities should seek ways to cooperate, and it went on to say that "Perhaps the simplest notion—and one of the best—is that it should be possible for research scientists in governmental or industrial laboratories to contribute to the graduate programs of nearby universities. This happens now, of course, but it should happen much more often; all parties should be eager to expand the practice."

As for recent developments, it is understood, apropos, that the Federal Council for Science and Technology is organizing an ad hoc panel to look into the matter of how government laboratories might be better used to bolster graduate education.—JOHN WALSH