Public Health Service has been parceling out matching grants to the states to help them develop home nursing services. In addition, the Public Health Service is working with the Office of Economic Opportunity in a major new program of training the poor as health assistants. This project is just getting under way, but it is anticipated that it will reach as many as 10,000 persons within a relatively short time. These individuals would be trained to go into homes and perform the various services that might normally be performed by a member of the family. Medicare also provides full reimbursement to hospitals of the costs of developing new forms of service such as extended-care units or home-visiting programs, and it is hoped that the availability of these funds will encourage institutions to experiment.

It is not likely that any of these programs will be sufficiently developed by 1 July to have a major impact on the immediate situation, but their existence does have long-term implications that may help officials resist what might otherwise be public demand for a one-sweep solution, such as a crash program to add more hospital beds. The administration's pet heart disease, cancer, and stroke program—now known as the PHS Division of Regional Medical Programs—which, after a slow start and some budgetary bad luck, now expects to begin offering regional planning grants by late spring, may play a similar role. Like the development of home health services, the heart, cancer, stroke program will be in no position to affect the availability of beds and the delivery of medical services on 1 July. But, again like the home health services, it does represent the beginning of an effort to rationalize American medicine and provide services that are both medically and economically logical. That, in any event, is the theory with which government officials are now consoling themselves.—ELINOR LANGER

Nuclear Carriers: Studies Convince the Skeptics

Although nuclear-powered submarines have been accorded a secure and important place in the U.S. fleet since the mid-1950's, the Department of Defense is only now committing itself to nuclear propulsion for even the Navy's largest surface combatant—the aircraft carrier. Defense Secretary Robert S. McNamara never has questioned the performance of the Navy's first nuclear surface ships, which are the carrier *Enterprise*, the cruiser *Long Beach*, and the frigates *Bainbridge* and *Truxton*; but until recently he has resisted Navy arguments that the effectiveness of nuclear power justifies its greater cost.

McNamara's approval of a recently disclosed plan to build three new nuclear-powered carriers—with greatly improved reactors—is a revealing example of Pentagon decision-making as well as a step toward the application of a more advanced nuclear technology. The carrier decision points up the advantages, and possibly some of the ambiguities, which can result from relying heavily on systems analysis in determining the military force structure.

The decision involved not merely the question of whether nuclear propulsion should be employed but also a question as to the number of carriers which should be built. The Navy now has 15 carriers regularly assigned an "attack" role—that is, equipped to deliver air strikes against enemy forces. Another nine carriers, usually smaller, older ships which are obsolescent for the attack mission, are assigned to anti-submarine-warfare work.

Carrier task forces, each made up of a carrier, its aircraft, and its escorts (and served by auxiliary vessels such as oilers and ammunition ships), are as basic to the Navy as troop divisions are to the Army. Secretary McNamara, at this time last year, was planning to reduce the number of attack carriers from 15 to 13 by the early 1970's. In his judgment, the reduction would be justified for several reasons: the ships and aircraft being introduced to the fleet were more effective than their predecessors; the carriers had been relieved of their strategic alert mission by Polaris submarines; and land-based aircraft were increasing in numbers, range, and effectiveness.

Although a new carrier, quite possibly nuclear-powered, was to be built under the fiscal 1967 budget, three older carriers later were to be retired from the attack fleet. These decisions were tentative, however, and the Navy—which felt that, if anything, the attack fleet should be larger—was free to try to persuade McNamara to change his mind. But, as it turned out, the decision to reduce the attack fleet was abandoned because of a plan proposed, not by the Navy, but by McNamara's own systems analysts.

The role assigned these analysts never has been narrowly defined. Charles J. Hitch, economist and formerly assistant secretary of defense (comptroller), described that role in *Decision-Making for Defense*, published by the University of California Press last October. "It is my experience that the hardest problems for the systems analyst are not those of analytic techniques," said Hitch. "In fact, the techniques we [used] in the Office of the Secretary of Defense are usually rather simple and old-fashioned. What distinguishes the useful and productive analyst is his ability to formulate (or design) the problem; to choose appropriate objectives; to define the relevant, important environments or situations in which to test the alternatives; to judge the reliability of his cost and other data; and finally, and not least, his ingenuity in inventing new systems or alternatives to evaluate."

Inventiveness was brought to bear on the carrier question. Patrick J. Parker, a 34-year-old economist trained at the University of Chicago, had become interested, while on the staff of the Center for Naval Analysis (CNA) in Washington, in a new concept for carrier operations. Parker saw no reason why a full wing of 70 or more aircraft should be provided for each attack carrier, as is the case at present. Instead of having 15 carriers and 15 air wings,

Parker envisaged the possibility of continuing to operate 15 carriers while reducing the number of wings to 12. The Air Force does not have wings for each of its land bases around the world. Aircraft are flown in as needed. So why not treat carriers in somewhat the same manner?

Under the concept, carriers usually would be deployed with less than the normal complement of aircraft, and additional planes would be flown to the carriers as the situation required. In effect, the carrier would be treated as a forward floating air base. Some naval officers, including Captain E. P. Aurand, formerly one of Parker's CNA colleagues and now an admiral commanding an antisubmarine-warfare task force in the Pacific, were interested in this concept, but the Navy never had proposed it to McNamara.

In February 1965 Parker left CNA and joined the systems analysis staff headed by Assistant Secretary of Defense Alain C. Enthoven, formerly one of Hitch's deputies. Parker and his immediate superior, Deputy Assistant Secretary Russell Murray II, submitted their study of the forward floating base concept to Secretary McNamara. McNamara was immediately interested and had the study sent to the Navy for its reaction.

According to Parker, the Navy accepted the concept, agreeing that more combat power could be obtained for the same cost by maintaining more carriers than air wings. The Navy would prefer larger forces than the 15-to-12 carrier-airwing ratio will provide, but, if given its way, the Navy would go to, say, a 17-to-13 ratio, rather than keep the existing ratio of 15-to-15.

The economic implications of McNamara's decision to adopt the forward floating base concept are important. Of the total cost of an attack carrier system, including the costs associated with escort and supply vessels, the aircraft account for more than half, which is to say more than a half billion dollars. The savings that will accrue over a 10-year period from operating 12 air wings instead of 15 are expected to exceed $2 billion.

Given the same quality of ships and aircraft, the 15 : 12 carrier-air wing force will not equal the potential of a 15 : 15 force for sustained combat; but its potential will be much greater than that of the 13 : 13 force on which McNamara originally had planned, and no additional cost is entailed. (The 15 : 12 plan is made more workable by the fact that not all carriers are deployed at any one time; carriers and aircraft require periodic overhaul, and ship and air crews must be retrained as new personnel join the fleet. Moreover, about 20 percent of the Navy's attack aircraft are not assigned to air wings but are used for combat readiness training.)

Provided Congress gives its approval, the first of the three new carriers will be built under the fiscal 1967 budget. Construction of the other two is to follow in later budget years; these two ships will probably join the fleet by the mid-1970's. McNamara's decision that the new carriers will be nuclear-powered is supported by systems analysis studies conducted by Navy analysts working closely with the Secretary's own analysts.

Agreement on the propulsion question between McNamara and his analysts, on the one hand, and the Navy and its analysts, on the other, is rather recent, however. In the fall of 1963 McNamara and the Navy and their respective analysts were in conflict. Rejecting a Navy recommendation, McNamara decided that, for the carrier project then pending (the ship was later named the *John F. Kennedy*), a conventional oil-burning propulsion system should be used.

Vice Admiral Hyman G. Rickover, director of the Navy's and the Atomic Energy Commission's naval reactor program, was developing a four-reactor system which promised to be about twice as efficient as the *Enterprise's* eight-reactor system. Glenn T. Seaborg, chairman of the AEC, had asked McNamara to reconsider nuclear power as a possibility for the carrier, in the light of successful development of the four-reactor system. McNamara did so, but

The *Enterprise*, the Navy's first nuclear-powered aircraft carrier.

concluded that the additional cost associated with nuclear propulsion was too great. According to his estimates, the four-reactor nuclear carrier would cost about $440 million, compared to about $280 million for a conventional carrier—a difference of $160 million.

Though conceding that a nuclear carrier was superior to a conventional carrier, the Secretary indicated that the superiority probably was marginal, and said that the money required for nuclear power could be better spent on other defense needs.

Decision Assailed

McNamara's decision was assailed by the Joint Committee on Atomic Energy of the House and Senate, which issued a report criticizing his analysis as faulty in its assumptions and unfair in its cost comparisons. According to the committee, the Secretary had assumed that wartime logistics vessels, such as oilers and ammunition ships, would be able to operate unhampered and without losses, as they do in peacetime.

"The defect in this analysis is immediately apparent," the committee said. "We must plan for time of crisis." As the committee observed, a nuclear carrier can carry about 50 percent more aviation fuel and ammunition than a conventional carrier can. Moreover, because the nuclear carrier uses no oil itself, it can supply its conventional escorts with more. Thus, while both nuclear and conventional carriers are dependent on logistics ships, a nuclear carrier can remain longer on combat station before withdrawing for replenishment.

The total cost of a nuclear carrier and its aircraft, over the life of the ship (25 to 30 years), is estimated by the Navy at only 3 percent more than the lifetime cost of a conventional carrier and its aircraft, the committee noted. It considered McNamara's estimate that the initial investment cost of a nuclear carrier would exceed that of a conventional carrier by $160 million to be misleading. The figure included $32 million for the fuel cores on which the ship would operate for 7 years. Included, too, was $37 million for a squadron of planes—an extra squadron to take advantage of the nuclear carrier's spaciousness.

Aircraft costs obviously are unrelated to the costs of nuclear propulsion, the committee observed. Furthermore, it said, the Navy had no plans to put an extra squadron of planes on the ship. The extra squadron would have increased costs by an estimated $308 million over the life of the ship—or almost two-thirds of the incremental cost which McNamara had attributed to nuclear power.

The committee cited the advantages claimed by the Navy for a nuclear carrier. Principally, these included not only reduced dependence on logistics support but also virtually unlimited endurance for cruising at high sustained speed and greater flexibility of deployment. Some $400 million had been spent during the previous 8 years on extending submarine reactor technology to surface warships, the committee said. "Despite rapid technological advancement and the proven superior performance of our first nuclear surface vessels, no plans exist today for the future utilization of nuclear power," it said.

McNamara, though usually able to overwhelm congressional critics with facts and arguments supporting his positions, appeared, to some observers at least, to have emerged second-best from his encounter with the Joint Committee on Atomic Energy. In this instance, the kind of cost-effectiveness analysis which often had been his strong point in the past had proved less than convincing. McNamara stood accused, by a committee generally respected as competent and serious, of having used faulty arguments to support a decision to build a costly, yet obsolescent, weapon system.

The Secretary, who showed signs of sensitiveness to the criticism, never foreclosed the possibility that future carriers would be nuclear-powered. On the contrary, he spoke warmly of the effort to develop more economical naval reactors, and noted that studies of the relative merits of nuclear and conventional carriers were continuing.

McNamara said his own conclusions, which would remain tentative until he had received a more definitive study by the Navy, was that the nuclear carrier would enjoy a substantial advantage in (i) unusual situations where a carrier task force had to travel a long distance for a very limited action, and (ii) in "quite exceptional" circumstances where a conventional carrier would require frequent refueling. "Translated into the contingency that we face, these [circumstances] would occur very infrequently," McNamara said.

In August 1964, McNamara asked the AEC to proceed with the development of the two-reactor system, which, as it turns out, will be used for the first of the new carriers. This system, developed by the AEC's Bettis Atomic Power Laboratory in Pittsburgh, operated by the Westinghouse Electric Corporation, was to further reduce the cost of nuclear propulsion, particularly the operating costs. The fuel cores for the two-reactor system are expected to last 13 years—four times as long as the first cores used by the *Enterprise* and nearly twice as long as those that would have been used in the four-reactor system.

Meanwhile, the Navy, which has tried hard in recent years to make systems analysis an integral part of its process of program development, was gaining further insight into the operational advantages nuclear power affords. The Navy's studies, which McNamara and his staff now seem to find convincing on the whole, have indicated that the nuclear ship's principal advantage over its conventional counterpart of the same size is an ability to launch more attack sorties before having to "go off the line" for replenishment of fuel and ammunition.

Sortie Output Stressed

The studies have shown that a conventional carrier, to be able to generate the same number of sorties as a nuclear carrier, would have to be about one-fourth again as large, or it would require service by more oilers. The two-reactor carrier's initial investment cost of $427.5 million might exceed by $77 million or more the cost of a conventional carrier of comparable combat potential. However, the studies indicate that, over a 10-year period, the cost differential for the two ships (operating as well as construction costs) declines to, say, $50 million in favor of the conventional carrier. Moreover, it is conceded that even after every effort has been made to equalize the two ships' combat effectiveness, the nuclear carrier is still somewhat the better.

(The two-reactor carrier will cost more to build than the four-reactor carrier proposed in 1963, but this is a reflection of a general rise in ship construction prices. The cost attributable to nuclear propulsion has declined by a few million dollars.)

According to Parker, the Navy studies have indicated that in one important respect the nuclear carrier has been overrated. At one time, he said, the Navy stressed the nuclear carrier's ability to speed to a crisis spot—to arrive much earlier than a conventional

carrier could. Analysis has suggested, however, that in most situations the nuclear ship's advantage would be measurable in hours, not days.

To many naval officers, the fact that the nuclear carrier has now received the blessing of favorable cost-effectiveness studies must seem of quite academic interest. The Navy reports that the *Enterprise,* operating off Vietnam in the South China Sea, has been launching 20 percent more attack sorties than the conventional carriers have been launching. The very circumstances which, 2 years ago, McNamara felt would be "quite exceptional" have become routine since the raids on North Vietnamese and Viet Cong targets began in February 1965. Carriers of the U.S. Seventh Fleet have been engaged in sustained combat operations and have required frequent replenishment. The Navy's analysis of the nuclear carrier's value—heavily influenced by the intuitive judgment of experienced naval officers—appears to have been better than the early judgments by McNamara and his analysts.

In any event, the question of nuclear propulsion for carriers has been settled. The question which remains is whether other major new combatant ships shall be nuclear-powered, as the Navy has proposed. A nuclear-powered guided missile frigate costs about 50 percent more than a conventional frigate, or about $150 million, compared to $100 million. Only modest reductions in this differential are foreseen.

McNamara has made it plain that, at the current price, he regards the nuclear frigate as a bad bargain. So far he has withheld the $20 million appropriated by Congress last year for purchase of "long lead-time" equipment for such a frigate. The only nuclear ship that has been built under the McNamara regime is the frigate *Truxton,* which was included in the fiscal 1962 defense program on the initiative of the House Armed Services Committee.

Although their cost is admittedly great, nuclear ships may offer operating advantages as yet unsuspected. Harold Brown, former director of defense research and engineering, expressed concern a few years ago that cost-effectiveness studies tend to evaluate the effectiveness of nuclear ships in terms of deployment concepts developed through years of experience with conventional ships. "I think this prejudices the case against the all-nuclear Navy and prejudices it unfairly," Brown said. "It is quite possible that entirely different concepts and tactics will evolve."

As Brown's remarks suggest, the next real breakthrough in the use of nuclear ships may come from collaboration between naval forces afloat and systems analysts ashore—all working to develop and test new concepts which can exploit to the full the advantages peculiar to nuclear propulsion.

—LUTHER J. CARTER

Announcements

The Commerce Department's Environmental Science Services Administration has created a committee to coordinate government research efforts on **turbulence in clear air**. Such turbulence, which appears without visible warning, presents problems in aircraft operations. The committee is composed of representatives of the Defense Department, Federal Aviation Agency, NASA, NSF, the Agriculture Department, the State Department, and ESSA. Jack J. Catton, director of operational requirements and development plans for the Air Force, is chairman.

The departments of chemistry and physics at the University of Tennessee have combined efforts to offer a graduate program leading to the Ph.D. in **chemical physics**. Students may participate in theoretical or experimental research. The program is open to people with a bachelor's degree in either physics or chemistry. Additional information is available from the Department of Physics or the Department of Chemistry, University of Tennessee, Knoxville.

Grants, Fellowships, and Awards

The University of Miami will provide grants for up to 50 U.S. and foreign undergraduate students to participate in a course on fundamental concepts in **environmental and planetary sciences**, 17 June to 22 July. The awards will include tuition and fees, round-trip travel to Miami, and $60 a week for subsistence. Applicants need a background equivalent to 3 years of college training in physical sciences and in mathematics through advanced calculus. Advanced courses in theoretical mechanics, electricity, and modern physics are desirable. The course will emphasize fluid dynamics in the context of geophysics and planetary physics. Application deadline: *1 May.* (S. Fred Singer, School of Enviromental and Planetary Sciences, University of Miami, Coral Gables, Florida 33124)

The University of Virginia will offer eight graduate courses in field **biology** between 17 June and 25 August at the Mountain Lake Biological Station. A limited number of NSF fellowships are available: postdoctoral, for research, stipend $1300; predoctoral, for supervised research, stipend $500; postgraduate, for field biology training, stipend $400. Deadline for applications: *1 May.* (J. J. Murray, Jr., Department of Biology, University of Virginia, Charlottesville)

Courses

The University of Texas Institute of **Marine Science** will offer courses 9 June to 6 August on marine microbiology, geology, and chemistry; ecology of fishes; estuarine ecology; and adaptive mechanisms in marine animals. Applications should be made by letter and should include an official transcript and letters of recommendation from two faculty members. Applicants should state their career objectives and their housing requirements. Deadline: *1 April.* (Director, Institute of Marine Science, Port Aransas, Texas 78373)

McGill University and the National Research Council of Canada will sponsor a course on molecular and cellular aspects of **immunobiology** 4–15 July. Attendance will be limited to 80 to 100 pre- and postdoctoral participants. The fee is $75 for people from universities and government, $300 for those in industry; room and board will cost $15.50 a day. Stipends are available for graduate students. Application deadline: *15 April.* (A. Sehon, Department of Chemistry, McGill University, Montreal, Quebec)

Meeting Notes

Papers are invited for a conference on **nuclear and particle physics**, scheduled for 21–23 September at the University of Glasgow, Glasgow, Scotland. Outlines: 300 words; deadline: *30 June.* [N. MacDonald (nuclear physics) or I. S. Hughes (particle physics), Department of Natural Philosophy, The University, Glasgow, W.2]

Advance registration for the meet-