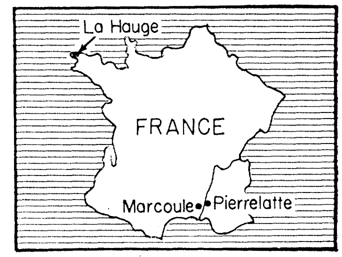

The French Bomb: How Much Technical Fallout?

London. Students of the interplay between science and public policy will find today in France a significant example of major technical effort undertaken for nontechnical reasons. It has just been decided that for at least six more years France will continue to commit a large fraction of her scientists and engineers—to say nothing of money and materials—to building a credible, all-French nuclear deterrent. By the end of 1970, in other words, France hopes to be a thermonuclear power.

The first 5 years of the effort will end 31 December, and the regime of President Charles de Gaulle saw fit this fall to ask parliamentary ratification of an outline plan for elaborating nuclear-armed forces, both tactical and strategic, during the years 1965 through 1970. The Chamber of Deputies of the Fifth Republic accorded this ratification 3 December by a vote of 278 to 178.

France plans to spend, in each of the next 6 years, an average of $2 billion on the equipping of its strategic and tactical nuclear forces, and another $700 million on other capital expenditure for defense. Perhaps another $2.5 billion will go for salaries, supplies, and other ordinary operations. These expenses may appear modest, but France's population is only one-fourth that of the United States and its per capita gross national product is only half the U.S. figure. Hence, the projected French expenditure is the equivalent of $40 billion annually in the U.S., or close to what America spends.

Defense Program

General de Gaulle stated in a press conference of 25 July that the program was expected to yield nuclear and thermonuclear weapons with total explosive power of 40 megatons by 1970. Here are some of the elements of the program:

1) On the atolls of Mururoa and Fangataufa, 19,000 kilometers from France and 1100 kilometers southeast of Tahiti, more than 600 soldiers, airmen, foreign legionnaires, Polynesian construction workers, and atomic technicians are building a center for testing thermonuclear weapons. On Hoa atoll a 3000-meter jet runway is being built so that supplies from France can be channeled through Hoa without disturbing the tourist economy of Tahiti.

2) The first of four cascades of the gaseous-diffusion plant at Pierrelatte on the River Rhône began functioning this fall, it was announced on 11 November. By means of this stage the content of uranium-235 is increased from the 0.7 percent found in nature to 1.85 percent. A second stage, which will increase the U^{235} content to 6 percent, may be completed during 1965. The third and fourth stages, which will provide still higher U^{235} content, are scheduled for completion by 1967.

3) It has been decided to build the Celestin reactor, specially designed to produce tritium by irradiating the atoms of lithium-6 that are present in the far more abundant lithium-7. An appropriate plant for chemical separation of lithium-6 from lithium-7 will be built. The three reactors at Marcoule, which produce plutonium, cannot produce much tritium.

4) A heavy-water plant will be built, to produce the deuterium needed for a fusion reaction with tritium.

5) Besides the chemical separation plant at Marcoule, another is being built at La Hauge, near Cherbourg, partly to handle the plutonium created in the civilian power reactors.

6) Construction of four Polaris-style nuclear submarines, each to carry 16 thermonuclear missiles, is now foreseen, but the first will not be operational until 1970. The other three will come into service in 1972, 1973, and 1974, respectively.

7) The thermonuclear missiles to be carried aboard the submarines must be developed, tested, and miniaturized at least in time for manufacture to coincide with completion of the vessels. For the three "modernized" army divisions planned for 1970, miniaturized tactical weapons must be developed.

8) The force of about 62 Mirage IV jet bombers is expected to be completed in 1966. The bombers, designed to be refueled from KC-135 jet tankers purchased from the United States, are expected to be capable of swooping from high to low altitudes, out of the range of radar, to release 60-kiloton plutonium bombs over sites in western Russia.

9) For the past 2 years, according to French Defense Minister Pierre Messmer, it has been understood that there would be a gap between the time the Soviet air defense nets would end Mirage IV's usefulness as a strategic bomber and the commissioning of the Polaris-style submarines. France decided against building an air-to-ground missile to fill this gap and chose to build approximately 35 medium-range thermonuclear ballistic missiles, to be located in silos on French territory. These missiles, called *sol-sol ballistiques stratégiques*, are being adapted from the missile to be fired from the submarines, with the difference that plutonium, rather than U^{235}, will initiate fusion.

Scientific and Industrial Implications

In the months that led up to the vote of 3 December, *Le Monde*'s scientific correspondent, Nicholas Vichney, reviewed some aspects of the "*force de dissuasion*": the tritium project (22–24 February); the isotope-separation plant at Pierrelatte (28–30 November and 1 December). According to Vichney, science, technology, and industry in France can derive some direct and

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indirect advantages from the *force de frappe* as conceived. But outside the area of civilian central-station nuclear power plants, these advantages appear to be limited, not at all commensurate with the resources committed for the French nuclear arm.

After examining specific demands for electronic equipment, Vichney reported these findings. In the plants for producing nuclear material the emphasis was on safety, not innovation. In the acquisition of computers for studying bomb characteristics, the accent was on speed, and so the equipment was bought in America. In any case, creation of a French computer industry rivaling that of the United States is too big a job to be accomplished as a by-product of *force de dissuasion* orders. In the equipment for nuclear tests sites, about the only salient technical innovation is the high-speed camera, whose commercial exploitation has already begun. Equipment for the Mirage IV bomber—such as the antimissile radar or the emitters of signals to throw off ground radar and the electronic instruments of approaching fighters and missiles—is not likely to have many applications. The computers for controlling missiles before launch and providing them with the information that will get them to target must operate with special speed aboard a Polaris-style submarine, because the missiles must get off before an answering missile can zero in. Nonetheless, the computers to be used in France are of a classic model, directly inspired by American technique. Inertial guidance equipment to be placed aboard the missiles will probably have applications in the navigation of satellites, planes, and submarines. Integrated circuits will be required in the computers that are to be flown inside the missiles, but this requirement will not, of itself, suffice to introduce manufacture of integrated circuits into French industry. The special instruments to be used for tracking missiles as they are launched were developed not for the *force de dissuasion* but earlier, as part of an abandoned air defense system; they will not have an application in aeronautics, only in the launching of satellites.

The development of alloys for nuclear reactors or ballistic missiles, and growing knowledge of techniques for producing the vacuums needed for the gaseous-diffusion plant at Pierrelatte, certainly have produced some by-products of use to industry, Vichney acknowledges. So, perhaps, may the work on the barriers in Pierrelatte's separation chambers. But it is doubtful that the diffusion plant at Pierrelatte will be of great help to the French nuclear power industry when it finishes supplying the currently envisaged number of warheads by about 1972, Vichney calculates. The Pierrelatte plant may be able to produce about 60 tons per year of uranium with U^{235} content of 3.5 percent. Thus, it might be able to produce enough U^{235} to operate six reactors producing about 330 megawatts of electrical power each. This total of 2000 megawatts is less than the amount France must add each year to its electrical power capacity. Further, it is calculated that the cost of U^{235} from Pierrelatte will be something like 3 times the U.S. cost of $12 a gram. Even if Pierrelatte were expanded to produce U^{235} for a European market, it has been estimated that the cost would still exceed the cost of U.S.–produced U^{235} by 30 percent. And that such an expansion will be undertaken appears doubtful in view of the development of power systems based on "breeder" reactors, which consume only limited quantities of enriched uranium.

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