Costing Nuclear Programs

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Direct and analog methods of determining what foreign countries spend on atomic energy for military and peaceful uses.

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How much has the Soviet Union, Communist China, or France spent on its nuclear program? What is the cost of the French gaseous diffusion plant at Pierrelatte or of the nuclear test site in French Polynesia? Is the allocation of funds for these installations proceeding on schedule? How much has West Germany spent on what facets of nuclear research and development? What would it cost India, Israel, or Japan to convert its present program for developing nuclear electric power facilities to production of nuclear weapons? The intelligence community is frequently called upon to supply answers to questions such as these for two primary reasons-to gauge the burden nuclear programs impose on the economies of the countries concerned, and to compare the sizes of different countries' programs.

Attempts to measure the economic burden are usually related to the question whether cost is apt to deter a nation from undertaking or expanding a weapons program. Analysis for this purpose of the pattern of spending also reveals much concerning the nature and probable rate of development of a program. Cost and rate-of-expenditure studies constitute a useful approach to these problems.

Comparison of the size of different countries' nuclear programs is a less cogent reason for estimating costs, and cost comparisons of this kind must be interpreted with great caution. Comparison of probable capacities for production of nuclear materials is the direct and more

appropriate way to get at the relative size of nuclear programs. Size can be measured in megawatts, quantities of plutonium or uranium-235, or numbers of weapons without involvement in complicated problems of monetary conversion. Conversion requires extensive studies of materials, manpower, wages, and productivity in the nuclear industries of the countries compared, and the requisite data, as well as the time, for these are usually lacking.

Two Methods

There are two distinct approaches possible in estimating the cost of a foreign nuclear program. Both are quite useful if their limitations are kept in mind and they are not used to answer the wrong questions. One is the straightforward "documentary" method of examining data made available either by open sources in the country in question-official budgets, press releases, journal articles, parliamentary debates-or through clandestine procurement. This method is particularly well suited to gauging the burden the nuclear program places on the economy. The costs thus obtained, being stated in the country's own currency, can easily be measured against native yardsticks such as gross national product and national income to determine the share of national resources being devoted to the nuclear effort. It is not well suited to comparing the size of the foreign program with that of the United States, because of the monetary conversion problem. And it is not always practicable: the required documentary data may not be available.

The other method is to estimate by analogy, i.e., to start from what it would cost the United States to build and operate the facilities known to exist in the foreign country. This method, if carefully applied, provides a basis for comparing the size of the foreign nuclear program with that of the United States; it is not well suited to determining the burden imposed on the foreign economy. One of its obvious difficulties is imperfect knowledge of what is inside foreign plants protected by strict security measures. Photographic and other types of technical intelligence are useful in identifying the nature, and perhaps the capacities, of the plants, but estimates of their internal layout, equipment, and processes can at best be educated guesses. But these guesses must remain the basis for estimating cost by U.S. standards.

Moreover, even an accurate figure for what it would cost for U.S. technicians, working at the present level of U.S. scientific and technical knowledge and with the resources of U.S. industry at their command, to reproduce and operate the foreign facilities may have little relevance to the question of what it is costing, in terms of man hours and material, for foreign technicians to construct and operate them in their own economies with quite a different-level of knowledge and industrial support. The problems are well illustrated in the case of the French gaseous diffusion plant at Pierrelatte. The official French estimate of the cost of this plant is now 5,037 million francs[1] ($1,028 million at the current rate of exchange), and unofficial estimates have placed it at 6,000 million or more[2] (about $1.2 billion). This is about one-half of the $2.3 billion the United States spent for three gaseous diffusion plants, each of them much larger than the Pierrelatte installation.

It is true one should take into account the huge economies of scale achieved when the initial problems have been solved and unit sizes are increased. This can be attempted by using the cost of early U.S. facilities roughly equivalent to Pierrelatte. In the late 1940s we put $500-$600 million into such facilities; adjustment to present-day prices would bring this up to the neighborhood of $800-$900 million. So even with this adjustment Pierrelatte will cost from 25 to 50 percent more than the analogous U.S. plant, not counting savings for the latter that would result from improvements in technology since the 1940s. It is evident that a price tag put on the Pierrelatte plant on the basis of what it would cost the United States to construct such a facility today, at the present level of U.S. technology, would be so low as to be very misleading.

Since gauging the burden on the economy is the principal reason for estimating costs, the analog method should be used only when lack of documentary material makes it necessary. Failure to keep in mind the limitations and proper orientation of the two methods has sometimes led to confused interpretation and unfortunate comparison of their results.

When some documentary information is available but is an insufficient basis for an estimate, analogy may be used as a supplement. Facilities in the country under examination may resemble facilities of known cost in some other country. The known costs, adjusted for evident difference in size or conditions, provide at least something to go on in the absence of hard data. The effectiveness of this mixed method depends on the

ratio of documentary information to analog derivatives and on the comparability of the analog countries in economic, scientific, and industrial development. Circumstances, however, frequently make it the only practical means of estimating the burden imposed by a nuclear program.

These different methods can be illustrated in their application to the nuclear programs of different countries.

The Documentary Method: France

The French case will illustrate the documentary method and also highlight a number of problems encountered in analyzing the cost of nuclear programs-isolation of the military part of the costs, the allocation of joint costs essential to both military and peaceful uses, and the forecasting of probable future expenditures. Work was begun on the case soon after the first French nuclear test in February 1960, with the objective of gauging the burden the program imposed on the French economy.

A wealth of scattered documentary material was found to be available.[3] Data painstakingly assembled from open sources, supplemented by occasional documentary material clandestinely procured, have afforded a reasonably clear picture not only of total annual and cumulative costs but of the allocation of funds to different kinds of activities within the program, to various individual installations, and to capital investment and operating expenses.

Summation of published historical data indicated that by the end of 1964 France had expended some 19 billion francs ($3.9 billion at the official exchange rate[4] on its nuclear program since it began in 1946. The annual expenditures grew from about 5 million francs in 1946 (all in the budget of the Commissariat a l'Energie Atomique at that time) to more than 5 billion francs from all sources in 1964. The sources of funds for the whole period break down as follows:

	PERCENT
CEA budget, loans from the Fund for Economic and Social Development, and income from sales of nuclear products	52
Appropriations for "The Atom" in the Defense budget	34
Investment by Electricit6 de France in nuclear power programs	8
Other: Operational expenses of EDF connected with nuclear power programs, budget allocations to international agencies, transfers from the Ministry of Public Works, and investment by private industry	6

Only about 1 percent of this "estimate" of cumulative expenditure involved any estimation whatever. That amount was necessary "to fill in gaps in some series in the "other" category. The rest is simply a summation of published data. But the 19 billion figure must be regarded as a conservative estimate because it does not include some expenditures for international cooperation, expenditures by the military services from their operating budgets, or more than a small fraction of the investment by private industry in new materials and equipment. We know that such expenditures have been made but have no adequate basis for quantifying them.

The method by which the total expenditure was built up is illustrated by Table 1, covering the period since 1966. The program has grown progressively more expensive as a result of its expanding size, generally rising costs, and greater emphasis on military aspects.

	1960	1961	1962	1963	1964	1965[a]
Payments from CEA Funds[b]	1,071	1,173	1,332	1,472	1,727	(2,186)
Payments from						

Defense Budget[c]	322	570	769	1,646	2,536	(3,135)
Other[d]	288	306	401	483	573	(600)
Total	1,681	2,049	2,502	3,601	4,836	(5,921)

a Appropriations in CEA and Defense budgets. "Other" funds carried at approximately the same rate as in 1964, with allowance for planned increase in expenditure by EDF indicated in Le Monde, 21-22 Feb 65, p. 10.

b 1960-64 CEA, Rapport Annuel, 1964, p. 180.

1965 Budget, Le Monde, 10 Nov 64, p. 10.

c 1960-61, 1964, Le Monde, 17 Jul 64, p. 9.

1962-63, State, Paris, Airgram A-3094, 6 Jun 63, pp. 10-11. Industries Atomiques, 1/2 1963, p. 93.

1965, Assemblee National, Rapport Fait au Nom de la Commission des Finances ... sur le Projet de Loi de Finances pour 1965, Annexe No. 37, Budget des Arm9es, Titre V-Armement, Equipment (Annexe au proc&sverbal de la s6ance du 13 octobre 1964), p. 10.

d EDF investment from: Ambassade de France, Service de Presse et d'Information, N.Y., France and The Atom, Jun 62, p. 16; EDF Rapport d'Activite, Comptes de Gestion, Exercise 1961, p. 11, Exercise 1962, p. 11, Exercise 1963, p. 13; and EDF Travaux d'Investissement, 1964, pp. 4-6.

International Cooperation from: Ambassade de France, France and the Atom, p. 16; State, Paris, Dsp. 742, 15 Dec 1961; Industries Atomiques, 1/2 1963, p. 93; Le Monde, 26 Jan 1963, p. 22; ibid, 10-11 Nov 1963, p. 2; Journal Ofeiel, 22 Dee 1963, p. 11516; The New York Times, 20 Dee 1963, p. 6; State, Outgoing Airgram CA-2313, 29 Aug 1962, pp. 7-8 of attachment; State, Vienna, Airgram A-247, 23 Aug 1963, pp. 6-7 of enclosure; State, Vienna, Airgram A-570, 27 Nov 1963.

Transfer from Ministry of Public Works: State, Paris, Dsp. 742, 15 Dec 1961. The small remaining portion of the "other" expenditures came from scattered references pertaining to expenditures by private industry.

These annual costs were then related to the French gross national product at current market prices, as in Table 2, to provide an indicator (admittedly imperfect) of the burden on the economy. It was concluded that in spite of sharp increases in costs the nuclear program is well within the capabilities of the French economy.

	1960	1961	1962	1963	1964	1965
Gross National Product at Current Market Prices (millions of francs)[a]	296,223	319,689	356,299	391,837	424,700	453,000
Total Expenditures on Nuclear Program (millions of francs)	1,681	2,049	2,502	3,601	4,836	5,921
Expenditures on Nuclear Program as Percent of GNP	0.6	0.6	0.7	0.9	1.1	1.3

a1960-63 R6publique Frangaise, Minist6re des Finances et des Affaires Economiques, Institut National de la Statistique et des Etudes Economiques, *Annuaire Statistique de la France, 1964*. Paris, Imprimerie Nationale, p. 479.

1964 (Preliminary) State, Paris, Airgram A-1226, 2 Dec 1964.

1965-Estimate.

The Military Share

Intelligence has been asked what portion of these French expenditures went for the development of nuclear weapons. The 19 billion total through 1964 includes, besides expenditures of a purely military character, funds spent on research for peaceful uses, on international cooperation, on electric power production, and on activities essential to both the military and non-military portions of the program. We start with the obviously military appropriations for "the atom" in the defense budget, which we have seen to be about 34 percent of the total, or about 6.5 billion francs. But this is not the entire military share. The CEA annual reports described the defense budget funds as intended "to cover the expenditures of a most immediate. (or direct) military character." That this does not apply to all expenditures for the military nuclear program is confirmed by the fact that investments in facilities known to be exclusively military exceeded total appropriations for "the atom" as of the end of 1963.

Then how much of the 12.5 billion francs from non-defense sources can appropriately be regarded as military? One can eliminate approximately 2.5 billion expended for clearly non-military purposes. This figure includes funds for international cooperation in nuclear development and investment by Electricite de France in equipment for nuclear power stations. (Exclusion of the latter might be debated on the grounds that such stations could produce plutonium.) The remaining 10 billion francs must be regarded as joint costs of military and non-military projects.

Allocation of these funds to military and non-military categories was extremely difficult. A study was made of allocations to such categories as administration, research centers, exploration and mining, ore concentration plants, feed materials and fuel element fabrication facilities, the gaseous diffusion plant, and development of new reactors and chemical separation facilities. The allocations to specific functions were derived primarily from monetary and manpower data available in French documents. As in any attempt to allocate joint costs, a great deal depended on assumptions concerning each type of activity.

In the end, it was considered that another 6 billion francs might properly be charged to military aspects. Adding this to the amounts from the defense budget gives a total of about 12.5 billion francs, approximately two-thirds of the total expenditure, associated with the military side of the nuclear program through 1964. This figure includes funds for both capital investment and operating expenses.

Of the 12.5 billion francs spent on military aspects of the program since 1946, some 9.8 to 10.8 billion were spent during the period 1960-64, after the successful test in February 1960 spurred plans for the creation of a strategic nuclear force.[5] Payments charged to defense budgets accounted for about 5.8 billion of this, as shown in Table 1, and the military share of joint costs during this period has been estimated at approximately 4 billion. The additional billion in the higher figure is designed to take care of expenditures from the regular operating budgets of the armed services that are associated with the development and testing of nuclear weapons but not identified as expenditures for "the atom." The cost, for example, of army, naval, and air transport of personnel and equipment, the salaries and maintenance of military security details, and the cost of military participation in testing or in the development of weapons or propulsion systems cannot be quantified precisely but should be counted.

Future Expenditures

Future expenditures on nuclear programs have in general been estimated on the basis of the past trend in total annual expenditures, what is known of plans for investment in new facilities, estimates of their probable operating expenses, trends in operating expenses at existing facilities, and past relationships between capital investment and operating expenses. Early in 1963 figures for future expenditures on the French nuclear program as a whole were derived by projecting the 1962 budget authorizations s for the program at 33 percent increase per year; the average annual increase in authorizations from 1958 through 1962 had been about 35 percent. The figures thus obtained were found to be roughly comparable to those derived by adding up probable investment in planned projects and probable increases in operating expenses.

Now that what was future at the beginning of 1963 has become past history, we have an interesting opportunity to compare these projections with what happened. We find that authorizations projected for 1963 and 1964 fall in the range between the actual authorizations and the expenditures for those years, as indicated in the following tabulation (in billions of frances):

	1963	1964	1965	1966
Actual authorization	4.5	5.7	5.6[a]	...
Projection (early 1963)	4	5.3	7[b]	9.3[b]
Actual expenditure	3.6	4.8	5.9[a]	...

a Preliminary. Based on budget data.

b Revised at beginning of 1964 as follows: 1965-6 billion; 1966-7 to 8 billion.

The authorizations projected for 1965 and 1966 will undoubtedly prove less accurate. Budget data indicate that expenditures in 1965 will probably be only about 5.9 billion francs, and in 1966 it appears they will be in the range of 6 to 7 billion francs. The margin of error on any forecast tends to increase as the projection moves farther into the future, and it was recognized from the outset that the projected levels of expenditure might not be achieved until later. They have, however, been useful as an approximation for the latter half of the decade.

For the military part of the future nuclear program one begins with the 3,135 million francs appropriated in the 1965 defense budget. To this, if it is assumed that the military share in joint costs will be as high in 1965 as the estimated annual average for 1960-64, can be added 800 million to give a total of 3,935 million francs. This estimate based on appropriations is probably conservative, because in recent years expenditures have tended to run higher than initial budgetary appropriations. Moreover, as the military program increases in size, the military share of the joint costs should really rise over the average of the past five years.

Through 1967, from what is known of plans for investment and weapons development and past relationships between investment and operating expenses, the military expenditures should continue to rise. Completion of the Pierrelatte plant and the test site in the Pacific alone account for some 4.5 billion francs, according to authoritative French sources. Adding the heavy expenditures for weapons testing, construction of facilities for production of lithium[6] and tritium, continued development

of a nuclear submarine propulsion system, completion and operation of the plutonium separation plant at Cap de la Hague, and increased operational expenditures in general, it was estimated that the 3.9 billion figure for 1965 would increase to 4.9 billion in 1967, giving by interpolation some 4.4 billion francs for 1966.

With the completion of a number of important facilities about 1967, annual expenditures on the military program could conceivably decline. It was estimated, however, considering the cost of operating the new facilities and further development of weapons and propulsion systems, that they are more likely to remain at a level oÂ£ about 4.9 billion francs per year through 1970. The sum of the annual amounts then gives a total of 27.9 billion francs, or at the official conversion rate about $5.7 billion, for the six-year period 1965-70.

To this $5.7 billion, rounded to $6 billion, which has become the central figure of the intelligence community's estimate, was attached a margin of error of plus or minus $1 billion, or nearly 17 percent, a range which is considered sufficient for about 95 percent confidence. The lower limit of $5 billion would assume very little increase in annual expenditure above the 1965 level. Some increase is almost certain. The upper limit of $7 billion allows for an excess of expenditures over authorizations in the Second Program Law, possible increases in the military share of the joint costs, and service expenditures that are connected with the nuclear program but not so identified in budget accounts.

Analog Method: China

The costs of the Communist Chinese nuclear program have been estimated entirely by analogy, because very little useful documentary information is available. Documentary materials and official public statements have helped to identify and describe some of the facilities, particularly some of the early research facilities, but have given no indication of cost. Most valuable in identifying and describing the nuclear installations has been Nationalist aerial photography.

Once the Chinese installations are identified and described, they have been related to roughly comparable facilities in Western countries as a means of estimating costs. For example, photographic evidence

suggests that the Chinese reactor at Pao-t'ou is very similar to the G-1 at Marcoule in France. Information released by the French CEA in 1960 indicated that the original cost of the G-1 reactor was 8 billion (old) francs, approximately $16 million, so the one at Pao-t'ou was estimated to cost $15 to $20 million.

Estimating thus on the basis of roughly comparable Western facilities, it has been concluded that by late 1964 the Chinese Communists had invested at least $500 to $600 million in their nuclear program, including the substantial Soviet grants for equipment and technical assistance prior to 1960. If the ratio of capital investment to total expenditure is roughly similar to such ratios in some Western countries, the total cost of the Chinese program through 1964 may have been about $1 billion. At a guess, the operating expenditures in 1964 could have run $50 to $75 million.

These cost estimates, made on the basis of very sketchy information, are less precise than those on any other country's program. Moreover, the dollar total is undoubtedly an inadequate measure of cost to the Chinese economy in terms of scarce technical talent, materials, and industrial capacity. It is, however, in line with costs elsewhere in the world; our estimate of what France spent in the period before its first nuclear test is approximately $1.1 billion.

Mixed Method: USSR

Estimates of the cost of the Soviet nuclear program have been made by a mixed method. In the early 1950s, when it was first undertaken to measure the burden of the program on the Soviet economy, considerable effort was devoted to studying Soviet budgets in the attempt to identify nuclear allocations. This effort was largely unsuccessful. The hybrid method was consequently employed, using Soviet data on activities not identified as connected with the nuclear program but believed relevant and supplementing these where necessary by analogy with U.S. costs.

A description of Soviet facilities was obtained from the interrogation of former prisoners of war who had worked in or near them, and particularly from German scientists and technicians taken to the USSR

in 1945 and used in the nuclear program until the early 1950s. Papers delivered in the 1958 Geneva conference on peaceful uses and displays at the Soviet exhibition in New York in 1959 also provided some limited information. Photographic and other technical intelligence contributed further to the description.

As installations were identified and described, their construction costs were estimated from Soviet data on the cost of other industrial construction. Known Soviet electric power costs were applied to estimates of their power consumption. Soviet cost data were available for some of the chemicals used in the program. The cost of uranium, which accounts for a substantial portion of Soviet operating costs, was estimated from information on the cost of extracting and milling other minerals and from trade data on imported ore and concentrates. Soviet wage data were helpful in estimating personnel costs. But investment in R&D facilities could not be estimated from intelligence data; it was therefore assumed to have about the same relationship to investment in production facilities as in the United States.

One of the major deficiencies was in data on the cost of equipment for the production installations. To fill this gap, U.S. Atomic Energy Commission contractors were given descriptions of the plants and asked to estimate the cost of equipping them, breaking this down in considerable detail. These detailed estimates in dollars were converted into ruble costs by comparing U.S. price lists with available Soviet lists of prices and specifications for well over 100 different commodities and activities related to the nuclear program.[7] The different ratios were then weighted according to the relative importance in the program of the commodities or activities in question.

Early in 1961 it could thus be estimated that the Soviet nuclear program had required through mid-1960 a cumulative expenditure of about 100 billion 1955 rubles, about 40 billion in capital investment and about 60 billion for operating expenses.

Since 1961 additional intelligence has made possible improved estimates of the capacities of both previously existing and new production plants. The gap in information on R&D facilities has been partially filled by analyzing fragmentary information on the number of personnel employed at some R&D centers. A recent estimate places cumulative expenditures on the Soviet nuclear program through mid-1965 at 19 billion new rubles (the new ruble equals 10 pre-1961 rubles), about 6.5

billion for plant and equipment and about 12.5 billion for operating purposes. Current spending is estimated at about 2 billion rubles annually, or approximately 1.1 percent of GNP.

The estimate of 19 billion rubles expended through 1964 is probably conservative. Recent information indicates, though not conclusively, that the ruble-dollar ratio used for estimates of capital investment may have been a little low. Moreover, the estimates themselves probably do not make adequate allowance for cost of modernization, conversion to new processes with improved technology, or complete replacement of facilities. An offsetting factor, however, is that in recent years improved mining and refining methods may have reduced the cost of Soviet feed materials somewhat more than estimated. The annual distribution of capital expenditures is difficult to determine; estimates have been based primarily on observed construction times and on analogy with experience in Western countries. In spite of these deficiencies, the estimates are considered good indicators of the magnitude of outlays for the Soviet nuclear program.

Presentation and Interpretation

As we have pointed out, the costs of foreign nuclear programs are best studied in the indigenous currency, so they can be related to units of national accounting and expressed as a percentage of a native measure of the economy. In U.S. intelligence studies, however, they must be expressed in dollars. If told that West Germany spent about 3.4 billion marks on its nuclear program through 1964 or that the annual nuclear expenditure in Japan as of 1964 was 30.7 billion yen, the reader immediately asks, "How much is that in dollars?" For this reason costs derived in indigenous currencies are frequently converted to dollars at official rates, as in the following tabulation:

COUNTRY	ESTIMATED TOTAL EXPENDITURES TO END 1964	YEAR PROGRAM STARTED	ESTIMATED EXPENDITURE IN 1964
			Percent of

	Million US$		Million US$	1964 GNP in Current Prices
West Germany	850	1956	185	0.2
Italy	580	1952	78	0.2
Japan	460	1954	85	0.1
Sweden	310	1945	45	0.3
India	220	1954	63	0.2
Israel				

Although the official exchange rates may not accurately reflect differences in the purchasing power of money spent on the nuclear industry in the United States and in the country concerned, the dollar figures at least have the merit of being readily understandable and can be reconverted to the original currency with ease. And conversion to dollars for purposes of presentation does not affect our measure of the burden on the economy; the percentages of GNP in the table were computed entirely in the indigenous currencies.[8]

Along with the desire to have the cost of foreign nuclear programs stated in dollars goes a tendency to compare the results of the conversion. It should be remembered, however, that when the conversion has been based on official exchange rates rather than ratios derived from study of relative productivity, the comparisons can be only rather crude measures of relative size.

Even if comparative costs could be accurately expressed in the same terms, a further difficulty in comparing size is that different programs are not homogeneous; aggregate costs do not reflect differences in the

nature of the programs. West Germany, for example, has spent nearly as much on its nuclear program as France had by the time of its first test, or nearly as much as we estimate for Communist Chinese expenditures through 1964. Yet West Germany has no nuclear weapons program at all. Its program has been oriented strongly toward education, research, and technological development aimed at developing low-cost, high-quality equipment, particularly reactors for electric power and for ship propulsion. The table shows that India has spent only about one-fourth as much as West Germany on its nuclear program. It is true that the Indian program is much smaller than the German one, but although it is thus far oriented toward peaceful uses, it is so balanced that it now has all the facilities needed to produce the fissionable materials for a small weapons program. Such facts as these, which become apparent through examining the allocation of funds to various types of installations and activities, are not indicated in the overall costs.

Collection Requirements

As we have seen, the method of estimating the costs of nuclear programs, and to some extent the usefulness of the estimates, is usually determined by the availability or lack of documentary material. The more documentary evidence there is, the more the intelligence problem becomes the traditional one of painstakingly collecting, combining, and analyzing the data. It is a matter of indifference to the cost analyst whether the documentary materials were overtly published and procured or obtained by clandestine collection. A great deal of documentary information on the costs of nuclear programs is published openly.

Unfortunately, the fact that information has been published abroad in the official report of a foreign atomic energy commission or electric power monopoly or perhaps in a trade journal does not necessarily mean that it is available to the analyst in Washington. In most of our diplomatic missions abroad the publications procurement officers have that responsibility merely as an addition to other duties, and they must look for publications for a wide variety of consumers. Even if the analyst knows of a specific publication and submits a request for it, the delay before he actually gets it may be considerable; but often he does not

even know that such-and-such a publication exists and therefore cannot request it.

If all types of collectors were kept aware of the need for documentary information on the cost of foreign nuclear programs they might pick up and forward useful material they ran across by chance in the course of other activities. Clandestine source materials, both documentary and of an incidental conversational variety, have proved useful both in filling gaps in overt information and as an aid in interpreting overt data. Sometimes they have lent credibility to overt materials that otherwise would have been disbelieved until confirmed at a much later date.

The supplementary method of estimating cost by analogy, used when the documentary materials are not adequate, depends on collection of a different sort. Photography and other types of technical intelligence often make possible the description of facilities that is necessary before attempting an analog estimate.

Collectors should think of the cost analyst as an insatiable sponge who welcomes data from any source on either the over-all costs or particular allocation of funds, for investment or operation, to any installations or activities connected with nuclear programs almost anywhere in the world.

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1 Doe. No. 568, Assemblee Nationale, Premiere Session Ordinaire de 1963-64, Rapport Fait au Nom de la Commission des Finances, ... sur le Projet de Loi de Finances pour 1964, Annexe No. 37, Rapport sur les Credits du Ministere des Armees (Annexe au prices-verbal de la seance du 9 Octobre 1963), p. 40.

2 Le Monde, 4 Dec 64, p. 2.

3 Among the more important source materials were the annual reports of the Commissariat a 1'Energie Atomique (the French atomic energy commission) and of Electricite de France (the nationalized power industry), official press releases, budget data published in the Journal Officiel de la Republique Francaise, committee reports contained in official documents of the French National Assembly, press coverage of parliamentary debates on appropriations, and articles in numerous professional and trade journals.

4 On 1 January 1960 a new franc equal to 100 old francs was introduced.

Cost data in old francs were converted to new francs at this rate. Dollar comparisons use the official exchange rate of 1 new franc=$0.2041.

5 A *Profet de Loi Programme Relative d Certains Equipments Militaires* of 8 December 1960, which scheduled funds during the years 1960-64, has come to be called the "Program Law," or "First Program Law" now that a "Second Program Law," approved by the French Parliament late in 1964, provides for continuing the development of the strategic nuclear force during the years 1965-70. Intelligence estimates frequently compare the period of the first program law with the future.

6 Much of the work done during 1960-62 on the costs of the French program was based on authorizations rather than actual expenditures because data on expenditures then available did not permit a breakdown as to either source or allocation of funds. Inasmuch as unallocated authorizations are simply carried over to the next year, the lag in expenditures was not a serious handicap in measuring costs over a fairly long span of years. Since the middle of 1963, however, estimates have been based on expenditure data; even the estimates for earlier years have been recalculated on the basis of additional expenditure data now available for those years.

7 Research during 1958-60 indicated that a 1955 ruble-dollar ratio of about 5:1 was appropriate for capital costs, reflecting average ratios of about 6:1 for labor and materials and 4:1 for equipment. (For certain types of equipment the ratio was as low as 2:1 and for others it exceeded 5:1, but for a major portion it was about 4:1.) For operating costs an average of 10:1 was derived from widely varying ratios for a number of inputs. (The 1955 ruble-dollar ratio for uranium concentrates produced in the USSR was estimated at about 12:1. The ratio for industrial wages was about 4:1 or 5:1, with labor productivity assumed to be about half that in the United States. On the basis of comparative rate schedules the ratio for electric power was 15:1, though this probably understates the difference in plant efficiency. The ratio for chemical products was generally about 10:1.)

8 Sufficient indigenous documentary material was available to permit fairly precise cost estimates for the nuclear programs of West Germany, Italy, Sweden, India, and Japan, both total costs and allocations among various installations and types of activities (except that information on investment by private organizations was in all cases inadequate, making all the estimates conservative). For the Israeli nuclear program, however,

the estimates were reached by a mixed method, using some cost data released by Israeli sources (particularly early in the program), descriptions of the facilities obtained from observers and visitors, and analogy with the costs of similar facilities in other countries. In estimating the cost of a chemical separation plant, for example, should Israel elect to construct one, use was made of detailed information India has released on the costs of its chemical separation plant. It was assumed that Israel could buy the equipment for the plant at about the same price that the Indians paid. Indian construction costs were adjusted according to the difference in costs for labor and cement in Israel.

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