The Indian Nuclear Power Program: Myths and Mirages

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THE INDIAN NUCLEAR POWER PROGRAM: MYTHS AND MIRAGES

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MUCH HAS BEEN WRITTEN on whether India, can, should, or will go nuclear, but not much attention has been focused on the planning and performance aspects of the Indian nuclear power program. Planning and performance merit attention because any military potential, perceived or otherwise, is a function of the state of affairs in this area. In addition, it is probably very easy to be misled as to the actual situation because the quality of literature on this subject varies widely. Many studies tend to be very much cut off from reality, not only in their assumptions and arguments but also in their conclusions.[1] Such exercises in misperception tend to give a rather deceptive picture of the actual potential for nuclear weapons by conveniently bypassing significant factors such as safeguards on critical installations and dependence—technological as well as material—on external sources. These factors are important because, as discussed later, reliance on nuclear exporters has its impact by way of stricter safeguards, leaves the program susceptible to other forms of manipulation, and forecloses other possible "options."[2]

It should be mentioned, however, that some good work on the politics of nuclear decision-making in India has been done in which

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1 A good example is the article by Onkar Marwah, "India's Nuclear and Space Programs: Intent and Policy," *International Security,* II:2 (Fall 1977), pp. 96–121.

2 For instance, the only unsafeguarded source for production of plutonium at present is the 40 MWth CIRUS test reactor at Trombay with an estimated annual production rate of approximately 4–6 kg.; the plutonium production by the other reactors (APSARA, ZERLINA) is negligible. *SIPRI Yearbook* 1975, p. 18.

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assumptions have been borne out by events.[3] The present article is an attempt to go beyond the decision-making arena and to assess and evaluate the performance of the Indian nuclear power program. The first section deals with attempts to acquire technological self-sufficiency through a domestic research and development (R & D) program. The second evaluates the planning, construction, and operation of various nuclear and related facilities, and the serious shortcomings that have occurred. The third section deals with the increasing dependence on foreign sources and on stricter safeguards resulting from these shortcomings. No effort has been made to speculate or attempt long-term projections since these would be outside the purview of the present study.

Research and Development

More than two decades have passed since India's nuclear R & D program was started in 1954 and it is an educational experience to consider the cost. Some estimates for the period 1961–1974 have been made: the total Plan and non-Plan investment amounts to Rs. 3,077.3 million (current exchange rate is about eight rupees to the dollar),[4] and the projected outlay (Plan and non-Plan combined) for the Fifth Plan period (1974–1979) was Rs. 2,364.3 million for nuclear research and Rs. 1,725 million for space research—approximately 25% of the total of Rs. 15,682.2 million for R & D during this period.[5]

The economic benefits from this heavy investment in nuclear R & D are relatively unknown since they do not seem to have been worked out—at least not for public consumption. In addition, the situation when viewed in terms of technological innovations does not appear to be very promising either.

One consistent feature of the Annual Reports of the Department of Atomic Energy (DAE) is the promise of imminent breakthroughs that would result in indigenization and import substitution, of which the case of the development of technology for heavy water production is an excellent example. The Bhabha Atomic Research Center (BARC) developed a technology for producing heavy water through the hydrogen sulphide-water exchange process. Construction of the Kota heavy water plant (based on BARC technology) was to be completed in four years, but several technical problems in upgrading the technology to a

3 Ashok Kapur, *India's Nuclear Option: Atomic Diplomacy and Decision Making* (New York: Praeger, 1976).

4 Aqueil Ahmad, "India's Nuclear Age: Dubious Cost-Benefit," *Economic and Political Weekly* (Bombay), X:10 (March 8, 1975), p. 439.

5 *Ibid.* These figures would have to be revised drastically because of inflation and are staggering when compared to the outlay for R & D for other sectors: Council for Scientific and Industrial Research (CSIR)—Rs. 2,548 million (approximately 15% of the total); Food and Agriculture—Rs. 1820 million (approximately 12%); Health—Rs. 217 million (approximately 1%); Family Planning—Rs. 143 million (approximately 0.8%).

commercial scale occurred, resulting in cost escalation and postponement of the completion date. At one stage it was even feared that the plant might never come up.[6] But it was scheduled to reach the precommissioning stage by October 1979, later revised to December 1979[7] —a decade after construction began.[8]

As a consequence all subsequent heavy water plants were planned almost on a turnkey basis (i.e., they were constructed by private contractors with no technical inputs whatsoever by the DAE), with substantial foreign technical collaboration. Plants are being built in Baroda[9] with French collaboration, and at Tuticorin and Talcher with German collaboration.

> The Indian participation in these plants is restricted to civil engineering, electrical works, construction of employees' colonies, etc. However, considerable R and D on heavy water still goes on at BARC![10]

In the context of reactor research it is relevant to note that DAE's annual report for the year 1963–1964 stated that the design for a 60 MW, plutonium oxide, enriched uranium oxide fuelled prototype power reactor was at a fairly advanced stage. The following year's report stated that the project had been approved and the sanction of expenditure was under consideration. The next year, however, it was reported that the work on this prototype power reactor had been stopped because the country could "leap frog" on the basis of experience gained in the construction and operation of the Madras and Rajasthan Atomic Power Stations. Seven years later, in 1972–1973, a decision was taken to build a 100 MW thermal research reactor using natural uranium and heavy water, apparently a bigger version of the CIRUS Reactor! It has been aptly observed that "this hardly suggests any leap frogging and in fact looks very much like a technological comedown."[11]

Similar experiences also occurred in other fields of reactor technology. Work has been in progress since 1966 on the problems involved in the use of plutonium in enriching fuel.[12] Investigations on the refuelling of TAPS with plutonium were completed in 1972.[13] In 1968–

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[6] "Nuclear Power: Heavy Water Constraint," *Economic and Political Weekly,* IX:37 (September 14, 1974), p. 1555.

[7] *The Hindu* (Madras) (International Edition), March 25, 1978; *DAE Report 1979–80.*

[8] The cost of Indian-produced heavy water has been given as approximately Rs. 1000/kg., whereas the import price is around Rs. 800/kg. "Even this Indian price is full of hidden subsidies, such as in the form of low interest capital." "Nuclear Power: Heavy Water Constraint."

[9] It was damaged by a serious explosion on December 3, 1977, and according to experts who had gone abroad to arrange for the import of vital equipment damaged in the explosion it would take at least two years before the plant could resume operation. *The Overseas Hindustan Times,* February 16, 1978.

[10] "Nuclear Power: Heavy Water Constraint," p. 1555.

[11] "Atomic Energy: Technological Come-down," *Economic and Political Weekly,* VIII:38 (September 22, 1973).

[12] *Annual Report of the DAE 1966–67.*

[13] *Annual Report of the DAE 1972–73.*

1969 it was also announced that "a revised project report for the production of enriched uranium oxide for the fabrication of fuel elements is under progress,"[14] and the "Sarabhai Profile" of 1970 mentioned "a commitment to a firm program to include . . . development of gas centrifuge technology for U–235 isotope enrichment."[15] But nothing substantial seems to have emerged from these investigations and projects so far, and Indian dependence on the U.S. for enriched uranium fuel for the Tarapur reactor remains as strong as ever. In fact, a 1978 report quoting engineers of the Atomic Energy Commission suggested that the development of a mixed oxide fuel system could take at least four years.[16]

Much has also been written on the utilization of the vast thorium reserves that exist in India, but there have been no large-scale demonstrations of the practical applications of thorium technology so far. Research in this field has been continuing since 1959 when the first thorium fuel rod (called J-rod) for the CIRUS reactor was fabricated.[17] The DAE annual report for 1966–1967 stated that the question of utilization of thorium in various reactors was studied in detail. A pilot plant for the separation of U–233 from the irradiated thorium fuel was commissioned at Trombay in 1970[18] and this had only resulted in making "available tens of hundreds of grams of U–233 for research."[19] In 1977 it was also announced that a test reactor using a half kilogram of U–233 as fuel would be set up at the Reactor Research Center at Kalpakkam.

There have also been feasibility studies of irradiating thorium oxide assemblies and of plutonium production in CANDU reactors.[20] But the fact remains that all this R & D is still on a laboratory scale and there are no immediate plans for any industrial applications for the use of thorium despite the assertion "that with little, if any, change in the Candu reactor it should be possible to burn thorium in combination with either U–235 or plutonium."[21] In connection with the Fast Breeder Reactor (FBR) in 1978, the economics of converting depleted uranium from the spent fuel of the heavy water reactor or thorium from the country's thorium reserves had yet to be worked out on an experimental basis.[22] It would be difficult to overemphasize the significance of this

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14 *Annual Report of the DAE 1968–69.*

15 *Atomic Energy and Space Research: A Profile for the Decade 1970–80* (Atomic Energy Commission, 1970).

16 The mixed fuel for Tarapur would require over two tons of plutonium, which the recently built reprocessing plant would, working at full capacity, take three years to produce. Fabrication of fuel rods and design change in Tarapur would take at least two more years. *Nuclear Engineering International,* June 1978, p. 9.

17 *Annual Report of the DAE 1959–60.*

18 *Annual Report of the DAE 1970–71.*

19 N. Srinivasan et al., [Report on] *Pilot Plant for the Separation of U–233 at Trombay* (Bombay: BARC, 1972), p. 3.

20 *Annual Report of the DAE 1971–72.*

21 Hugh C. McIntyre, "Natural Uranium Heavy Water Reactors," *Scientific American,* 233:4 (October 1975), p. 27.

22 *The Times of India* (Bombay), December 18, 1977.

technology, considering that the conversion of thorium to U–233 for the third stage of India's nuclear power plan was an integral part of the second stage, which was originally scheduled for the 1980–1985 period.[23]

As with most of the reactor work in the country, the Fast Breeder Test Reactor (FBTR) Project at Kalpakkam in Madras is also based on the transfer of know-how and agreements for technical consultancy with the French Commisariat à l'Energie Atomique (CEA).[24] In 1970, the DAE tried to study the possibility of replacing the plutonium-enriched uranium fuel in the FBTR with a wholly indigenous mix of plutonium and natural uranium but the results were indifferent. So, as envisaged, the first charge of enriched uranium will indeed have to be imported from France.[25]

Consequently there is very little if any evidence to sustain the belief that the massive investment in nuclear R & D in India has resulted in significant breakthroughs in advanced technology. Attempts at indigenous development from existing technology also seem to have met with very limited success and have more often than not proven to be more expensive than direct imports—a situation that in no way justifies the large investment on R & D so far.

Planning, Construction, and Operation

The construction of nuclear power stations and other infrastructural facilities has been based on extremely optimistic assumptions and, as a consequence, the cost estimates and target dates for the commissioning of various facilities have been subject to repeated revision. The vastness of the difference between the original estimates and actual performance seems to confirm the belief that the estimates were formulated without any basis and with only one objective—to "sell" the project by making it look as attractive as possible. Tables 1 through 5 demonstrate this fact rather vividly.

It is obvious from Tables 1 and 2 that there have been delays of three years or more in the estimated and actual completion of power reactors. The Tarapur Station is an exception, but it was constructed on a turnkey basis by General Electric (U.S.). These construction schedules also compare rather unfavorably with the Canadian experience—the construction of the Douglas Point reactor and its commissioning were delayed by six months because of "teething" troubles in this first reactor. All subsequent reactor stations have been brought into operation "within days of the original target."[26]

[23] *Annual Report of the DAE 1970–71.*

[24] *Annual Report of the DAE 1972–73.*

[25] K. C. Khanna, "India's Nuclear Option: AEC Back in Business," *The Times of India,* October 15, 1971.

[26] For example, the reactor constructed at Gentilly "was brought into operation slightly over 4 years after the first sod was turned and within days of the original target" while that at Pickering "within a fortnight of the schedule set.." *Atomic Energy of Canada Limited* (AECL), *Annual Report* 1970–71, p. 4.

TABLE 1: Target Dates of Beginning Operation of Thermal Reactors (by date target was set)

	1965	1968	1970	1971	1977
TAPS	1968				1969
RAPP I	1969	1971	1972		1973
RAPP II		1972	1974	1975	1978
MAPP I			1975	1976	1980
MAPP II			1976	1977	1981
NAPP I			1977	1978	1982
NAPP II			1978	1979	1983

SOURCES: 1965: *Annual Report of the DAE 1965–66.*
1968: *Annual Report of the DAE 1968–69.*
1970: *Atomic Energy and Space Research: A Profile for the Decade 1970–80* (Atomic Energy Commission, 1970).
1971: H. N. Sethna et al., "Integrated Planning of Nuclear Industry" (Paper presented at the Fourth International Conference, Peaceful Uses of Atomic Energy, Geneva, 1971).
1977: *Performance Budget of the DAE 1977–78.*

TABLE 2: Other Projects

	1967	1970	1977
Reprocessing Plant Tarapur	1972	1974	1977
Reprocessing Plant Kalpakkam		1976	1982
Fast Breeder Test Reactor		1976	

SOURCES: 1967: *Annual Report of the DAE 1967–68.*
1970: *Atomic Energy and Space Research: A Profile for the Decade 1970–80* (Atomic Energy Commission, 1970).
1977: *Performance Budget of the DAE 1977–78.*
1982 date for Kalpakkam: *SIPRI Yearbook* 1977, p. 47.

Actual capital outlay on power reactors has been far more (nearly double in some cases) than initially estimated (see Tables 3 and 4). Outlays on the construction of a standardized 220 MWe Pressurised Heavy Water Reactor (PHWR) of the RAPP–I type have shown a consistent increase—from Rs. 732.4 million (RAPP–I), to Rs. 942.6 million (RAPP–II), to an estimated Rs. 1,040.5 million for NAPP–I. In this respect too comparison with the Canadian performance is relevant since there is no record of cost overruns even in their (first) Douglas Point reactor, which was completed in 1965 within the 1959 figure of $81.5 million *despite* devaluation of the Canadian dollar.[27]

The massive escalation in the cost of reactor construction has resulted in an increase in the price of output ranging from more than threefold for Tarapur to sevenfold for RAPP–I (see Table 5).

Despite repeated claims that the indigenous infrastructure was increasing its capacity to manufacture equipment and achieve self-

[27] AECL, *Annual Report* 1964–65, p. 9.

TABLE 3: Estimated Actual Capital Outlay on Power Reactors (in millions of rupees)

	1964	1968	1977
TAPS	485*		971.2
RAPP I	340*	525*	733.4
RAPP II		581.6*	942.6
MAPP I and II			2034.8*
MAPP I and II			2098.9*

SOURCES: TAPS 1964: *Annual Report of the DAE 1964–65.*
RAPP I 1964: *Annual Report of the DAE 1963–64.*
1968: *Annual Report of the DAE 1968–69.*
1977: *Performance Budget of the DAE 1977–78.*
* Estimated figure.

TABLE 4: Expenditure Estimate for the Decade 1970–1980 (in millions of rupees)

	1967	1970	1977
Heavy Water Plants		950[a]	1728[b]
Nuclear Fuel Complex	100	130	733.8
Thermal Reactors (1,000 MWe)		1300	2774.6
Fast Breeder Test Reactor and Reactor Research Center, Kalpakkam		500	534.2[c]

SOURCES: 1967: *Annual Report of the DAE 1967–68.*
1970: *Atomic Energy and Space Research: A Profile for the Decade 1970–80* (Atomic Energy Commission, 1970).
1977: *Performance Budget of the DAE 1977–78.*
[a] For plants with a production of 400 tons of heavy water annually.
[b] For plants with an annual production of 300 tons of heavy water.
[c] Expenditure for the *years 1975–1978 only.*

TABLE 5: Price of Output

	1964 (est.)	1977
TAPS	3 p./KWH	13.38 p./KWH
RAPP I	2.64 p./KWH	18.21 p./KWH

SOURCES: 1964: *Annual Report of the DAE 1964–65.*
1977: *Performance Budget of the DAE 1977–78.*
NOTE: p = paise; 100 paise = 1 rupee.

reliance, etc., in relative terms such statements are not borne out by the facts.

> A major constraint that has been faced in implementing the nuclear power projects is the difficulty in getting major nuclear components manufactured in shops within the country in the time schedule required for the project. . . . In some instances there was inadequate response from industry. . . .[28]

[28] H. N. Sethna and M. R. Srinivasan, "India's Nuclear Power Program and

But in other cases "it was found difficult to locate one manufacturer having all facilities to complete the job . . . (hence) . . . the Department had to spend considerable time to achieve the end result. *It would have been easier to import them*"[29] (emphasis added). And, as if this was not enough, as late as "the period 1972–76, many *inadequacies in the design and equipment choice* in auxiliary systems were noticed and extensive engineering was required to be done to improve these deficiencies"[30] (emphasis added). The direct consequence of this attempt to superimpose sophisticated nuclear technology on a basically collaboration-dependent industrial infrastructure has been that "the investment costs are higher than for coal fired stations. Moreover, the gestation period for a nuclear power plant built hitherto has been 8 to 10 years."[31]

The experience in operation and maintenance of power reactors also demonstrates the far from satisfactory performance prevailing in these sectors of the nuclear program.

> The Tarapur reactor was planned on the basis of a 80 per cent load factor on Tarapur. As a result, if Tarapur is out of action there is a sharp cut in the availability of power . . . which cannot be made up from any alternative source. Inevitably, therefore, there has been enormous political pressure . . . to keep the Tarapur plant operating at any cost.[32]

The cost of this "flogging" has been heavy:

> the reactor system has aged rapidly, with leaking valves and joints, clogged pipes, corroded equipment and bewildered operators. Transformers get burnt, feeder lines trip, steam mains burst, instruments behave erratically. Yet the slogan has been: "run the plant at any cost."[33]

In the case of RAPP I too: "unit availability factors since commencement of commercial operations in December 1973 were 58% in 1974 and 43% in 1975 . . . output has been relatively low until mid-1976."[34] The overall performance situation so far seems rather bleak—the over-

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Constraints Encountered in its Implementation," [IAEA-CN-36/385 (VII)] (Paper presented at the International Conference on Nuclear Power and its Fuel Cycle, Salzburg, Austria, May 2–13, 1977, hereinafter referred to as the Salzburg Conference).

29 S. Challappa et al., "Experience in the Manufacture of Nuclear Equipment in India" [IAEA-CN-36/462 (VII.3)] (Paper presented at the Salzburg Conference).

30 Sethna and Srinivasan, "India's Nuclear Power Program." For instance, almost two-thirds of the unavailability of power at RAPP I was due to problems with the imported steam turbine and another 23% resulted from the failure of components in the primary heat transport (PHT) system. J. C. Shah et al., "Experience from the Construction and Operation of Tarapur and Rajasthan Nuclear Power Station" [IAEA-CN-36/360 (VII.3)] (Paper presented at the Salzburg Conference).

31 J. C. Shah, "Experience from the Construction."

32 "Tarapur Atomic Power Plant: Falling Apart," *Economic and Political Weekly*, IX:20 (May 18, 1974), p. 774.

33 *Ibid.*

34 J. C. Shah, "Experience from the Construction."

all station cumulative load factor achievement through December 1977 was 38.9% for RAPP I, and 30.5% and 47.4% for TAPS I and II respectively.[35]

With regard to refuelling-cum-maintenance outages, the Tarapur experience shows their critical dependence on availability of trained manpower.

> In the absence of support from trained crews from vendors or experienced maintenance contractors considerable effort has been expended in obtaining and training men from other units of the Department of Atomic Energy as well as from *thermal utilities* and *even from the Armed Services*[36] (emphasis added).

Even normal refuelling operations in its two reactors are said to have taken almost twice as long as is usually required.[37] One direct consequence of lack of proper maintenance has been that personnel have been exposed to very high levels of radiation (see Table 6), and workers from other sectors have had to be inducted for work in high radiation areas. It has also been maintained that "often personnel have been authorised to receive very high doses of radioactivity. There have been known cases of fatalities . . . from radition induced cancer."[38]

TABLE 6: Cumulative Radiation Exposures of Tarapur Station Personnel

Year	No. of Persons Exposed	Exposure (rems)
1969	399	43
1970	550	153
1971	622	444
1972	1,558	2,338

SOURCE: P. Abraham et al., "Safety Experience in the Operation of a BWR Station in India" in *Proceedings of a Symposium on Principles and Standards of Reactor Safety* (Vienna: Julich, IAEA, 1973), pp. 459–471.

NOTE: The limit specified for radiation exposure by the ICRP for workers is 5 rems/year; at this rate the number of personnel required at Tarapur would be 500. In 1972, station personnel received a dose of 2,383 rems. If there had been a staff of 100 (the number required by BWR's of the same type in other countries), each worker would have received an exposure of approximately 24 rems—roughly five times the permissible dose.

Exposure levels are high because radioactive waste releases have been much higher than originally expected and the capacity of the station radioactive waste system has proved inadequate (see Table 7).

[35] *Nuclear Engineering International*, 23:270 (April 1978), p. 27. Consequently the Indian performance in nuclear power generation (45.6%) compares rather unfavorably with Europe (56.8%), U.S. (54%), U.K. (55%), Canada (53.5%), and Japan (53.5%).

[36] J. C. Shah, "Experience from the Construction."

[37] *The Times of India*, August 5, 1974.

[38] "Tarapur Atomic Power Plant: Falling Apart."

TABLE 7: Environmental Releases: Tarapur Station

Year	Liquid Wastes Activity Released (Ci) (excluding 3H)
1969	14.9
1970	79.5
1971	442.0
1972	356.4

Year	Solid Wastes Volume (M^3)	Activity (Ci)
1969	109.0	198.6
1970	103.3	201.5
1971	116.2	14,277.6
1972	132.6	13,913.8

SOURCE: P. Abraham et al., "Safety Experience in the Operation of a BWR Station in India."

NOTE: The Station had expected an annual liquid radioactive waste release of only about 8 curies (Ci). The maximum annual discharge of liquid wastes was estimated to be 72 Ci on the basis of maximum permissible concentration in effluents (stipulated to be 10^{-7} Ci/ml), in contrast to the 442.0 ci and 356.4 Ci actually released in 1971 and 1972 respectively.

Solid wastes had to be stored in drums that were difficult to handle not only because of high radiation levels but also because special tools and machinery needed for such jobs were lacking, thereby increasing personnel exposure.[39]

It is likely that backfitting (retrofitting) to handle the excessive radioactive wastes is one factor contributing to the cost escalation of the Tarapur Station. In addition to the cost factor, it has also been reported that Tarapur has been operating at a level lower than its generating capacity because of its "inability to remove spent fuel from the reactors at the plant's spent fuel storage tanks which were filled up beyond their design capacity."[40] A conspicuous feature of the program that merits attention is the lack of detailed information on the safety aspects of reactor operation experience. Nevertheless, the figures in Table 8 are illustrative.

Delays, Dependence, and Safeguards

The gap between promise and performance, between R & D and industrial applications, indifferent results and often futile attempts at import substitution have resulted in continued foreign dependency and, as a consequence, the inevitable acceptance by scientists of foreign safeguards. When the CANDU reactor type was adopted as the standard

39 P. Abraham et al., "Safety Experience in the Operation of a BWR Station in India" in *Proceedings of a Symposium on Principles and Standards of Reactor Safety* (Vienna: Julich, IAEA, 1973), pp. 459–471.

40 *Overseas Hindustan Times*, May 4, 1978.

TABLE 8: Industrial Safety

Tarapur (Power Station)	1970	1971	1972
No. of disabling injuries	19	10	20
Man days lost	75	36	108

Trombay (Research Establishments) up to December 31, 1973	
No. of disabling injuries	68
Man days lost	988

SOURCES: Tarapur: P. Abraham, et al., "Safety Experience in the Operation of a BWR Station in India." Trombay: *Annual Report of the DAE, 1973–74.*

reactor system to be constructed during the first stage of the Indian nuclear power program, the argument advanced in its favor was that this would ensure self-sufficiency and eliminate dependence on external sources of supply. The main factor in this decision was that the CANDU reactor uses natural uranium as fuel, thus doing away with reliance on Western supplies of enriched uranium, which is used as fuel for Boiling Light Water Reactors (BWR) of the type installed at Tarapur. Since the CANDU reactor uses heavy water both as a coolant and as a moderator, it was also decided to set up heavy water plants to ensure self-sufficiency in the domestic requirements for heavy water. Not only were the attempts at evolving indigenous technology for heavy water production not very successful (as is evident from the experience with the Kota plant discussed earlier), but also the inordinate delays in the completion of subsequent plants being built with foreign collaboration have made the goal of self-sufficiency in heavy water supplies look highly futuristic.

Considering that each of the reactors at Rajasthan, Madras, and Narora (there are two at each station) would require an initial charge of approximately 230 tons of heavy water and an annual replenishment of approximately 25 tons, it is obvious from Table 9 that self-sufficiency in this vital material is nowhere in sight! In fact, despite the im-

TABLE 9: Target Dates for Completion of Heavy Water Plants (by dates targets were set and revised)

	1970	1977	1978
Baroda (67.2 MT/year)	1975	July 1977	April 1979
Kota (100 MT/year)	1976	December 1978	end 1979
Tuticorin (71.3 MT/year)	1976	December 1977	March 1978
Talcher (67.2 MT/year)	1976	July 1978	February 1979

SOURCES: 1970: *Atomic Energy and Space Research: A Profile for the Decade 1970–80* (Atomic Energy Commission, 1970).
1971: *Performance Budget of the Department of Atomic Energy 1977–78.*
1972: *Performance Budget of the Department of Atomic Energy 1978–79.*

port of 200 tons of heavy water from the Soviet Union, the *Performance Budget of the DAE 1978–79* candidly admits that "the date of criticality for the second unit of the Rajasthan Atomic Power Project is July 1978 *subject to the availability of heavy water*" (emphasis added).

It is very interesting to survey the gradual acceptance of stricter safeguards by Indian scientists. The DAE has not widely publicized this acceptance but has maintained the facade of growing independence. The bilateral safeguards (1963) agreement with the U.S. was subsequently revised to open Tarapur (TAPS) to bilateral inspective by the IAEA. Not only have U.S. inspectors had unrestricted access to TAPS but the IAEA has also sent inspection teams whenever it wanted.[41]

The best example of the growing submissiveness of the Department of Atomic Energy, however, is the gradual tightening of safeguards to be applied to the Rajasthan Atomic Power Project (RAPP I and subsequently RAPP II). In the original safeguards agreement negotiated by Bhabha for RAPP I, Canadian inspection was restricted to *first generation* fissile material and was tied to the supply of Canadian uranium. Also, India had equal inspection rights on the Canadian Douglas Point Reactor, thereby achieving the "principle of political equality."[42] It has also been held that Bhabha wanted the safeguards on RAPP II "to be even freer than the RAPP I agreement."[43] Bhabha's untimely death in 1966 deprived India of a brilliant international negotiator. It was under the Chairmanship of Vikram Sarabhai that the Atomic Energy Commission accepted tougher safeguards for RAPP II under which IAEA inspectors (instead of Canadian) were to implement safeguards to be applied to *all generations* of fissile materials. Even the use of Indian uranium was safeguarded.[44]

Much later, despite Canada's unilateral termination of nuclear cooperation after the 1974 nuclear explosion, India did not repudiate the bilateral right of Canada to inspect RAPP I (commissioned 1972), or the IAEA's authority to maintain its supervision of both reactors, including RAPP II, then still under construction. Because of the suspension of Canadian cooperation and lack of heavy water supplies, the commissioning of RAPP II (due in early 1975) was delayed by three years. In 1976, the Soviet Union signed an agreement with India for the supply of 200 tons of heavy water conditional on the latter signing a safeguards agreement with the IAEA,[45] a price that was paid in September 1977. Although details of the agreement have not been disclosed

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41 *Nuclear Engineering International*, September 1977, p. 11.

42 Ashok Kapur, *India's Nuclear Option*, p. 196.

43 *Ibid.*, p. 194.

44 *Ibid.*, p. 135. See also IAEA, Canada and India Agreement relating to safeguards provisions. Signed September 30, 1971. *Treaty Series* (New York: United Nations, 1975), vol. 798, no. 11378, pp. 155–174.

45 At the stage of detailed negotiations, the deal got bogged down as Moscow reportedly demanded that all nuclear plants, and not Rajasthan alone, be opened for inspection to ensure that heavy water supplied for one reactor was not used at any other. *Indian Express*, March 18, 1977.

publicly in New Delhi by the government, unofficial sources point out that fuller safeguards have been accepted not only for RAPP II but also for RAPP I.[46] Some sources maintain that the agreement categorically prohibits India from undertaking PNE's and includes multiple point safeguards,[47] restrictions India had been trying to resist since its nuclear program began in the 1950s.[48]

This agreement also seems to have put into jeopardy the Indian fast breeder reactor program, which, if fuelled by plutonium from the RAPP reactors, would automatically come under IAEA safeguards. In this context it is worth mentioning that the Pilot Reprocessing Plant at Trombay, with a capacity of 60 tons U/yr,[49] has not been operating since 1972 and is undergoing decontamination, repairs, and expansion.[50] Protocols exchanged between India and the U.S. subsequent to the 1963 agreement provided for the construction of a Reprocessing Plant at Tarapur (capacity 100 tons U/yr) to extract plutonium from the Tarapur spent fuel. India was entitled to keep a certain percentage of this production as nuclear fuel mix and sell the balance to the U.S. Accordingly, U.S. approval was obtained on the designs submitted before construction of this plant was started. To operate the plant, India was said to have been seeking an agreement similar to the one the U.S. has with Japan.[51]

Conclusion

In a wider perspective, execution of the Indian nuclear program can be viewed as an attempt to superimpose a highly advanced technology over a basically collaboration-dependent industrial-economic infrastructure. Implementation of the program has involved massive cost overruns in terms of capital outlay and excessive delays in the execu-

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46 Ashok Kapur in *Indian Express,* December 23, 1977; and Col. R. Rama Rao in *Overseas Hindustan Times,* April 6, 1978.

47 This means that if the heavy water or the plutonium produced from the plant is used in another installation, it too would be placed under international safeguards.

48 It was earlier thought that the Nuclear Fuel Complex (Hyderabad) would not be able to supply sufficient fuel for the reactor by the time it was ready to be commissioned. But because of the heavy water wrangle there is sufficient fuel now. *Indian Express,* March 21, 1977.

49 *Nuclear Engineering International,* 21:239, February 1976, p. 24.

50 This plant was operational for a period of nearly eight years (1964–1972). Of the stockpile of plutonium obtained from this plant, 21.8 kg. was used for fuelling the PURNIMA test reactor at Trombay, an unknown amount (up to 20 kg.?) for the 1964 explosion and other experimental purposes. It could perhaps be maintained that there would still be enough plutonium in the inventory to fuel the Fast Breeder Test Reactor (FBTR) now being constructed at Kalpakkam, whose requirement is 54.26 kg.

51 *Nuclear Engineering International,* November 1977, p. 11. Some sources maintain that these efforts have been unsuccessful. Consequently, the disclosure in the Annual Report of the DAE 1977–78 (which does not make clear where the spent fuel came from) that the Tarapur plant has begun reprocessing operations would lead one to believe that the fuel being reprocessed came from the CIRUS reactor.

tion of the various projects. These problems seem to have resulted at least in part from indifference in planning and lack of detailed cost analyses of the various projects as indicated by the drastic revision of estimates soon after their initial announcement. From all this a marked tendency towards ad hoc decisions and the near total absence of any sustained long-term planning can perhaps be inferred. The only such exercise was the "Sarabhai profile" (*Atomic Energy and Space Research: A Profile for the Decade 1970–1980,* AEC 1970), but even this seems to have been nothing but a hasty attempt at what could be called bureaucratic journalism since various schedules and estimates announced in this report began to be revised not even a year after its release.

Such practices have been the rule rather than the exception and seem to have been further encouraged by a near total lack of public debate on the economic, safety, and environmental effects of the development and growth of nuclear energy in the country. The little debate that did take place has been an elitist exercise among scientists, particularly at international conferences and symposia.[52] This lack of debate is partly the fault of the Indian press, intellectuals, and members of parliament among whom very little discussion seems to have occurred, and that more in terms of the military options than the actual performance of the industry itself. Some of the blame would also fall on the bureaucracy, which in view of the heavy investment in this sector has failed to provide a substantial basis for public discussion. It is also interesting to note that the foregoing analysis has been undertaken mostly on the basis of the annual reports of the DAE and papers presented by the nuclear scientists at various international conferences and symposia. It is a matter of speculation as to how much is being hidden by bureaucratic politics.[53]

The vast gap between planning and execution has, along with the increasing magnitude of the program, eventually led to an increase in foreign dependency in certain critical sectors like heavy water production and supply. Coupled with the obvious reluctance of the scientist-bureaucrat to admit lack of satisfactory progress despite the heavy in-

[52] For example, there has been a lack of detailed information and discussion on the safety aspects and environmental consequences of RAPP. RAPP uses Lake Rana Pratap Sagar for its coolant water supply and for the discharge of its low level wastes. The lake is also the source of drinking and irrigation water in the area as far as Kota, a city located 35 km. downstream. A heavy water plant whose most dominant waste is likely to be tritium, whose intake causes cancer, is also being constructed on the site. See P. R. Kamath, "Backfitting the Site to Changing Radiation Environment" (IAEA–SM–169/32) in *Proceedings of a Symposium on Principles and Standards of Reactor Safety* (Vienna: Julich, IAEA, 1973), pp. 345–354. Similarly, the decision to locate the Narora Atomic Power Project (NAPP) in a seismic zone is also questionable.

[53] As an illustration, it would be useful to refer to Chapter 9 of Ashok Kapur's book in which he "directs attention to a process of bureaucratic politics where individuals holding public office are the actors," with reference to the internal debates on the NPT. *India's Nuclear Option,* pp. 190–207.

vestment and a near autonomous style of functioning,[54] this dependence has led to the inevitable acceptance of stricter safeguards.

The shift in emphasis by the suppliers of nuclear material from political to technological control has made the situation more acute. If the trend set by the recent IAEA safeguards agreement on RAPP I and II (which was a result of lack of sufficient heavy water supply from domestic sources—a situation not likely to improve in the near future despite the claim by the Chairman of the AEC that India would be self-sufficient in its requirements for heavy water "within the next two years")[55] continues India could very well end up having all its future nuclear establishments under IAEA safeguards[56] without going through the formal (and essentially political) motions of signing the NPT.

It is a fascinating exercise to view the top echelons of Indian nuclear technocrats as propagandists or public relations men who have used a combination of cliches like "self-reliance," "indigenisation," "vast future potential" (so dear to underdeveloped countries—including India) and scientific-technical jargon, to carry out relatively freely a program that probably deserved a critical evaluation at all stages right from its inception.

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[54] In a slightly different context, Indian nuclear decision-making has been aptly described as "a product of a coalition of political and scientific czarism." Ashok Kapur, *India's Nuclear Option,* p. 207.

[55] *The Times of India,* June 11, 1977.

[56] This would also continue in the future generation of fast breeder reactors since they would be fuelled by plutonium derived from the spent fuel of the present generation of nuclear reactors. For example, both nuclear power stations that have been commissioned so far, TAPS and RAPP, are already under IAEA safeguards (the former under U.S.-IAEA).

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