

**ATOMIC ENERGY AND SPACE RESEARCH
A PROFILE FOR THE DECADE 1970-80**



**ATOMIC ENERGY COMMISSION
GOVERNMENT OF INDIA
1970**

CONTENTS

FOREWORD

PART I. ATOMIC ENERGY

The Programme	3
Milestone Charts	16
Annexures	18

PART II. SPACE RESEARCH

The Programme	27
Milestone Charts	38
Annexures	40

FOREWORD

□ "When nuclear energy has been successfully applied for power production, in say, a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand...." H. J. Bhabha—March 1944.

□ "India should be able to produce all the basic materials required for the utilisation of atomic energy and build a series of atomic power stations, which will contribute increasingly to the production of electric power in the country. These developments call for an organisation with full authority to plan and implement the various measures on sound technical and economic principles and free from all non-essential restrictions or needlessly inelastic rules. The special requirements of atomic energy, the newness of the field, the strategic nature of its activities and its international and political significance have to be borne in mind in devising such an organisation".—From Preamble to Resolution of the Government of India creating the Atomic Energy Commission, 1958.

□ "If you have the picture of the future of India that you are trying to build up, of the power that you require....you will come to the conclusion of the inevitability of our building up atomic power for peaceful purposes from now onwards".... Jawaharlal Nehru—January 1961.

□ "This moment marks a new phase in our technical history. With the commissioning of the Tarapur Power Station, we join the select band of nations which use atomic power for the advancement of human welfare....

"To those who made wry remarks about a cow-dung economy wishing to go in for nuclear energy, Dr. Bhabha convincingly explained the 'technological fall-out' which results from atomic energy, and the impact it has on other fields of economic and scientific activity. In the last 20 years, we have been engaged in building our infrastructure. The developing countries are in the advantageous position of stepping over several intermediate and not-so-essential stages. If the building of the infrastructure itself incorporates higher technology, future progress will be further accelerated. It is this point of view which gives significance to the work of the Atomic Energy Department"—Indira Gandhi—January 1970.

□ “The key to national prosperity, apart from the spirit of the people, lies in the modern age, in the effective combination of three factors—technology, raw materials and capital—of which the first is perhaps the most important, since the creation and adoption of new scientific techniques, can, in fact, make up for a deficiency in natural resources, and reduce the demands on capital. But technology can only grow out of the study of science and its applications. . . .

“ . . . It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind’s greatest enterprise today”—
The Scientific Policy Resolution of 1958 of the Government of India.

* * *

The progress of science and technology is transforming society in peace and in war. The release of the energy of the atom and the conquest of outer space are two most significant landmarks in this progress. Largely due to the consistent national support which the programmes of the Atomic Energy Commission have received since Independence, India is amongst the nations of the world advanced in atomic energy, and is striving for a similar position in space technology and research. There are those who preach that developing nations must proceed step by step following the same process by which the advanced nations themselves progressed. One is often told that such and such a thing is too sophisticated to be applied. This approach disregards what should perhaps be obvious, that when a problem is great, one requires the most effective means available to deal with it.

The seeming disadvantage of a developing nation such as India, which has only a limited existing technological infrastructure to build on, can be an asset rather than a liability. I suggest that it is necessary for us to develop competence in all advanced technologies useful for our development and for defence, and to deploy them for the solution of our own particular problems, not for prestige, but based on sound technical and economic evaluation as well as political decision-making for a commitment of real resources. The traditional approach of planning to provide things like electric power or telecommunication services for a national infrastructure, based on projections of growth from past experience is inadequate. An alternative approach lies in creating consumption centres alongside facilities for supply, as for instance an agro-industrial complex served by a large nuclear power station or a programme for television to the entire countryside using a direct broadcast synchronous communications satellite.

Indeed there is a totality about the process of development which involves not only advanced technology and hardware but imaginative planning of supply and consumption centres, of social organisation and management, to leapfrog from a state of backwardness and poverty.

Nuclear power is today essential for economically supplying energy in large parts of the country, and is moreover the only major supply on which we will need to fall back in perhaps less than 50 years' time. We therefore need to commit ourselves to an appropriate programme of atomic power stations. We cannot hope to gain all the great economic advantages of nuclear power unless we develop a mix of thermal and advanced fast breeder reactors. It is my firm belief that the problems of poverty and regional imbalances in our country cannot be effectively tackled without it.

Several uses of outer space can be of immense benefit to us as we strive to advance economically and socially. Indeed without them it is difficult to see how we can hold our own in a shrinking world. The greatest cost/effectiveness of the uses of outer space occur through large scale applications rather than those of limited scope. A communication satellite can most effectively serve communities dispersed over large areas. Meteorological applications of satellites are likewise most relevant for a global system like the World Weather Watch.

It is possible to develop atomic energy and space research through basic, applied and developmental research in islands largely isolated from the rest of the country, but large scale applications of either for the benefit of the nation cannot be undertaken in isolation. We cannot have 20th century atomic energy or space research with 19th century industry or antiquated systems of management and organisation. There is a totality about modernisation, and in order to gain confidence, we must experiment with our resources even at the risk of failure. We have to rise from an in-built culture within which a major departure from an existing well-proven system and anything which is innovative in character is automatically regarded with suspicion.

There might be many opinions concerning what would be an advantageous course to follow in the short run, but 10 or 20 years from now, when the population of India would be somewhere between 750 and 1000 millions, it can hardly be controversial that we would need a very strong base of science and technology, of industry and agriculture, not only for our economic well being but for our national integration and for ensuring our security in the world. The profile of development, during the present decade, of atomic energy and space research carrying with it advances in fields such as metallurgy, electronics and instrumentation as well as computer sciences has been fashioned to provide a viable future. Advances in science and technology are accompanied by rapid obsolescence

of existing systems. Recognising that we do not wish to acquire black boxes from abroad but to grow a national capability, we should note that our plans have to be continually updated and even the strategy altered as we proceed. In many innovative tasks, forward planning and cost estimates can only be *ad hoc* and this has inherent limitations. Even so, the present document has been brought out in conscious recognition of the need to have national backing for the major objectives of our programme. There are many details, some technical in character, and others at a stage requiring further definition, which have been largely excluded in order that we can convey the broad outlines in terms of commitment of economic and human resources.

It is hardly necessary to emphasise that for projects which take five to seven years to complete, we have to look at least ten years in advance if our progress is not to be halting and results mediocre. The programme that we envisage is ambitious, but achievable. Without a deep commitment to it we shall certainly fritter away our resources.

Bombay,
July 22, 1970.

Vikram A. Sarabhai
Chairman
Atomic Energy Commission

PART I

Atomic Energy

PART I

Atomic Energy

I. The Programme

1.1 Atomic Power

1.1.1 From the early days of the Atomic Energy Commission, considerable thought has been given to the role that atomic energy has to play in the context of power development in India having regard to the availability of various types of energy resources and the capital as well as generating costs of nuclear power as compared with power from other sources. Moreover, taking into consideration the abundance of thorium deposits as compared with uranium reserves in India, an integrated programme of nuclear power was also worked out. The targets contemplated in 1954 by the Atomic Energy Commission, the forecasts made in 1965 by the Energy Survey of India Committee and the revised proposals made by the Atomic Energy Commission in 1968 are as under:

Installed Power in Megawatts—Electrical

Year	As suggested by AEC in 1954	As forecast by Energy Survey Committee in 1965	As proposed by AEC in 1968
1970-71	600	600	400
1975-76	3000	2000	1000
1980-81	8000	5000	2700 (by 1978-79)

The programme has slipped badly in relation to targets that were contemplated in the early 1960s. Many factors have contributed to this. The time frame of only five years within which development has so far been planned in the country since Independence coupled with the absence of adequate national commitment to a long range programme; and difficulties in achieving effective coordination of training and personnel needs, R & D facilities and projects, and the complex industrial infrastructure to back up the programme, are clearly the most important. The early projects at Tarapur and Rana Pratap Sagar have all been with foreign collaboration and the inherent need for external financing and agreement on

international safeguards have involved protracted negotiations leading to major time delays in the past. A revised time table for achieving the target of 2700 MWe by the end of the decade is indicated in the milestone chart included in this document. Realisation of this is, of course, dependent on a national commitment which extends not only till the end of the Fourth Plan, but at least till the end of the decade as we begin the Seventies.

1.1.2 There is a remarkable correlation between the per capita gross national product and the per capita energy consumption for the nations of the world. Developing nations and particularly India are at the bottom of the ladder and the industrially advanced countries at the top. A correlation does not necessarily signify a direct cause and effect relationship but in this case it is an expression of the fundamental necessity of energy to increase human productivity in agriculture, as in industry.

The Planning Commission's estimate of the growth of power by the end of the Fourth Five Year Plan, *i.e.* 1974, leads to a total of 23,000 MWe. The growth rate of consumption of electricity in India during the first three Plan periods has been 12.6%. It is well-known that the economic penalty involved in pessimistic planning of electrical capacity is many times greater than the penalty arising from optimistic planning. Even assuming for the future a conservative growth rate of 12%, the country will need by 1980 about 45,000 MWe of installed capacity.

In the year 1968-69, 42 per cent of commercial energy consumed in India was based on coal and lignite, 49 per cent on oil and 9 per cent on electricity. By 1973-74, the proportion of these three forms is anticipated to be 35 per cent, 55 per cent and 10 per cent respectively*. If this trend is accepted, the consumption of oil will go up from 84 million tonnes of coal replacement to 152 million tonnes of coal replacement. In the context of our dependence on foreign imports of crude, in spite of development on a high priority of domestic sources which are as yet limited, this will result in major import of petroleum feed stock involving a substantial drain of foreign exchange. The only way of avoiding this situation is to increase the dependence on electricity as a source of energy. While in areas close to coal mines the generation of energy can and should for the time being be based on coal, large regions of the country are removed from deposits of coal by more than 800 km. These regions constitute 35% of the country by area and 30% by population. With the exception of the eastern zone, they include the principal communities engaged in activities needing energy in rapidly increasing quantities for industry as well as for agriculture. The transport of coal to these areas involves major investments on the transport system, for which the requirements of capital are large and the recurring economic penalty

* From the Planning Commission's Paper entitled "A Plan for Energy Development in India"—February 1970.

is substantial. Atomic power clearly provides the most advantageous solution even with single units of 230 MWe, a size small compared with units of 600 to 1000 MWe currently being installed in major atomic power producing countries.

There are several advantages in going in for nuclear power reactors to optimise a grid with hydro and thermal generating units. This arises from the special characteristics of hydel power which is best for peak loads and nuclear power which is best for base loads. Nuclear energy is practically independent of geographical factors, the only requirement being that there should be a reasonably good water supply. No combustion products are created by nuclear plants and consequently it is a clean source of power which does not contribute to air pollution. Fuel transportation networks and large storage facilities are not needed for a nuclear project. And finally, if low cost power units are imaginatively planned, a power consuming complex built round them could provide much needed inputs to the country. Annex. 1 (P. 18) gives the major implications of one such complex which has been considered for Western Uttar Pradesh.

It is worthwhile comparing the role of nuclear power in India according to the revised proposals of the Atomic Energy Commission with the position anticipated in some of the developed countries.

Nuclear Power as Percentage of Total Installed Capacity

Country	1975	1980
United Kingdom ..	15	27
United States of America ..	21	29
West Germany ..		25
Japan ..	15	22
India ..	5	6

Even if the revised Indian target is implemented by 1980, we shall be truly behind other countries advanced in atomic energy.

1.2 The three stages of the Indian Atomic Power Programme

1.2.1 In 1960, the Atomic Energy Commission submitted its first concrete proposals to the Planning Commission for setting up atomic power stations in India. The Atomic Energy Commission made the modest claim that it was "fairly soundly established that the cost of electricity from nuclear power stations" even at that time was "roughly equal to the cost of electricity from conventional thermal stations remote from the coalfields". The Energy Survey Committee appointed by the Government in 1965 clearly expressed the view that nuclear power was already competitive with conventional thermal stations situated more than 600 miles from a coalfield.

1·2·2 In 1960, the Planning Commission endorsed the proposal of the Atomic Energy Commission to launch an atomic power programme and its recommendation was accepted by Government. Amongst the factors that encouraged Government to launch the programme were: firstly, the availability of a group of talented, trained and devoted scientists and engineers at Trombay, who had acquired familiarity with the new technology through the construction on their own unaided effort of two research reactors, APSARA and ZERLINA, and in collaboration with Canada, the Canada-India Reactor (CIRUS); secondly, the location of resources of uranium in Bihar and thorium in the monazite sands of Kerala; thirdly, the success of Indian scientists in establishing the technology of fabrication of uranium fuel elements required for CIRUS; fourthly, the inadequacy of hydel resources and coal and oil resources in the context of India's long term requirements; fifthly, the limited geographical distribution of coal resources in India; sixthly, the significantly lower fuelling cost of nuclear power stations, particularly if the total cost of fuel including the effect of investment on rail transportation were taken into account; seventhly, the possibility of nuclear power stations operating at high load factor in certain grid systems in India, which would contribute significantly to the economics of nuclear power; and last, but not the least, the importance of avoiding obsolescence involved in developing the technology too tardily. In his note to the Planning Commission, Dr. Bhabha, the then Chairman of the Atomic Energy Commission, emphasised the rationale of the Indian programme in the following words:

“Although the initial capital investment needed for nuclear power stations is higher today than that for thermal power stations of the same size, this additional capital investment must be considered necessary for larger purposes than power production. The major fraction of the nuclear power capacity will be installed in natural uranium power stations which are dual purpose stations producing power on the one hand, and plutonium on the other. This plutonium is a concentrated fuel, which is not available from outside as a commercial commodity, and its production is essential in order to enable the country to set up breeder power stations using thorium or depleted uranium for the second stage of its nuclear power programme, which will have to be taken up about five years from now. Such power stations will also be much cheaper in capital cost than the present one, and the indications are that power from these may even be competitive with power from conventional thermal power stations near the coal-fields. It will not be possible for India to take advantage of these new developments five years hence, unless steps are taken now to set up dual purpose power stations for producing plutonium”.

1·2·3 The significance of the production of plutonium for the ultimate power programme of India was thus one of the major considerations for launching a power programme based on the use of natural uranium. This was explained in the following terms by the late Dr. Bhabha in his lecture “On the Economics of Atomic Power Development in India and the Indian Atomic Energy Programme”, delivered on September 6, 1957, in Dublin:

"It has been mentioned that the total reserves of thorium in India amount to over 500,000 tons in a readily extractable form, while the total known reserves of uranium are less than a tenth of this. The aim of a long range atomic power programme in India, must, therefore, be to base the nuclear power generation as soon as possible on thorium rather than uranium. Once concentrated fuel in the form of uranium-235, or uranium-233, or plutonium, is available, it should be possible to generate power in breeder reactors which breed more fissionable material, uranium-233 or plutonium, in the source materials thorium and natural uranium than they burn. Since all power reactors intended for breeding appear to require the use of enriched or pure fissionable material, a self-sufficient programme must provide for the production of such material. As far as India is concerned, we consider isotope separation plants for the production of uranium-235 by the presently known methods out of the question, due to their high cost, and even more because of their enormous consumption of electric power. The best way of obtaining fissionable material appears to be to produce plutonium as a by-product in atomic power stations working on natural uranium".

It is necessary to have roughly 2700 megawatts installed capacity of CANDU type reactors working at 75% load factor to produce 900 kilograms of plutonium per year. This would be sufficient to support a programme of one new 400-500MWe fast breeder reactor every other year during the 1980's.

1.2.4 In selecting in 1963 a natural uranium fuelled thermal reactor, the choice fell on the CANDU type, then under development in Canada, which uses heavy water as moderator and as coolant. This reactor provides maximum economy in the utilisation of neutrons produced through fission. In consequence, from a given supply of uranium, maximum amount of useful energy as well as plutonium can be obtained. The CANDU type reactor with its inventory of heavy water now costing about Rs. 500/- per kg., has a higher initial capital cost of construction, as compared with other types of reactors. The cost of construction of CANDU reactors (of 200 MWe size) under conditions obtaining in Western countries has been approximately US \$ 375 per KWe installed, while that of enriched uranium fuelled light water reactors has been about US \$ 250 per KWe installed. However, in view of its substantially lower fuelling costs, the cost of power generated in CANDU type reactors is more or less the same as power produced in light water reactors using costlier enriched uranium fuel.

The Tarapur Atomic Power Station which was the first to be taken up for the Indian atomic power programme was an exception to the normal pattern decided upon in the early 1960's. There was then in the country, as there is even now in some quarters, considerable argument about the relevance of nuclear power in India on economic considerations. Global tenders were invited for the construction of the Tarapur reactor to demonstrate the point that was held by the Atomic Energy Commission that on cost considerations alone, nuclear power could be fully competitive with power from fossil fuel stations in Western India.

Tarapur was approved with the full knowledge that being based on enriched uranium for fuel and with a domestic programme which at that time did not contemplate the establishment of enrichment facilities, fuel would have to be imported from abroad throughout the life of the station, unless, of course, plutonium from subsequent natural uranium fuelled CANDU reactors was diverted to fuel Tarapur. Operations since the commissioning of Tarapur in October 1969 have fully borne out the economic viability of atomic power in Western India.

1.2.5 The diagram in Annexure 2 (P. 19) explains a strategy which could lead us to sustained growth of power based on nuclear energy on a self-reliant basis. The three stages are:

Stage 1 involves the establishment during the present decade of natural uranium fuelled and heavy water moderated thermal reactors which could provide adequate annual production of plutonium to fuel commercial fast breeder reactors contemplated in the next decade. Simultaneously, prototype advanced thermal reactors as well as fast breeder test and prototype reactors would be constructed to gain practical experience of a new technology.

Stage 2 from 1980 to 1985 would involve the breeding of U-233 from thorium in thermal and fast breeder reactors so as to have an inventory of U-233 to go over to a thorium breeder cycle in the third stage. Simultaneously, thermal and fast breeder concepts based exclusively on the thorium cycle would have to be developed to a prototype stage.

In the third stage beyond 1985, there could be four types of reactors simultaneously in operation, namely, natural uranium fuelled thermal reactors, advanced thermal reactors, plutonium fuelled fast breeders and breeders using the thorium cycle.

1.2.6 The comparative costs (under Western conditions) of different types of nuclear power reactors are as follows:

Nature and size of reactor (size in MWe)		Cost per kw installed (in US \$)	Remarks
CANDU 200 (Douglas Point)	..	375	Equivalent to Rs. 2800/kw (RAPP-1 cost Rs. 3150/kw)
CANDU 500	..	250	
Steam Generating Heavy Water Reactor (SGHWR) 450	..	225	
Advanced Thermal Reactor (ATR) 500	..	210—230	
Light Water Reactor (LWR) 500		200	

In contrast, the cost per installed kw of new thermal plants based on coal under Indian conditions has now been assessed by the Ministry of Irrigation and Power as Rs. 1900. While CANDU reactors of the 200 MWe size are expected to be competitive with fossil stations at places removed from coal fields by more than 800 km., it should be possible to effect economies in nuclear power generation by the following means:

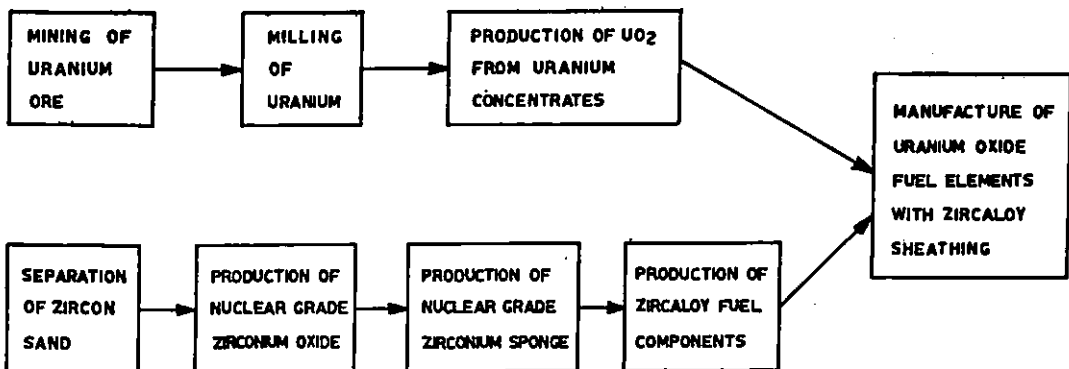
- (a) A substantial reduction of about 33% in capital cost can be achieved by increasing unit sizes from 200 to 500 MWe.
- (b) The switch over to a reactor concept involving the use of boiling light water in the coolant circuit while still using heavy water as moderator can also result in substantial economy in the capital cost as well as in regard to heavy water inventory. Plutonium recycling or low enrichment uranium is likely to be used in the fuel.
- (c) The fuel economy in CANDU reactors can be improved by using Plutonium in booster rods as against the use of cobalt in absorber rods.

1.3 Nuclear materials and special technology for the atomic power programme

1.3.1 The programme for building atomic power stations outlined in Section 1.2 can only be executed if it is supported by other industrial establishments which would need to be set up during the present decade. Within the direct responsibility of the Atomic Energy Commission are establishments for uranium mining, milling and extraction of yellow cake; preparation of fuel elements; production of heavy water; fuel reprocessing for extracting plutonium out of spent fuel; manufacture of zircaloy components starting from mineral sands; electronic and nuclear instrumentation, and control elements.

1.3.2 Natural Uranium Fuel Fabrication.

The manufacture of fuel elements requires a chain of operations as indicated diagrammatically below:



We would need to open a new uranium mine at Narwapahar to augment the supply from the Jaduguda Mine close to it. Moreover, additional capacity for milling the ore and for preparation of uranium concentrates would be required. A combined operation of this kind typically takes from five to seven years to bring to full production, and work would therefore have to start fairly soon. Simultaneously, the capacity at the Nuclear Fuel Complex at Hyderabad would have to be augmented to prepare more zircaloy components and fuel elements.

1.3.3 Heavy Water

Heavy water moderated/cooled reactors to be set up by 1980 would require a capacity for the production of about 400 tonnes of heavy water per year. The average lead time in setting up a heavy water plant is 4 to 5 years. It is therefore necessary to start construction of two additional heavy water plants simultaneously with the commencement of work on new power plants as indicated in the milestone chart (p. 16).

1.3.4 Fuel Reprocessing

Fuel reprocessing plants and waste treatment plants to deal with irradiated material from the nuclear power stations and to recover from them by-products essential for the next stage of the programme are required. It is estimated that two fuel reprocessing plants would have to be built during the decade, in addition to the one under construction at Tarapur.

1.3.5 Enrichment of Uranium

The use of slightly enriched uranium in thermal reactors will result in savings both in capital and fuelling costs. The capital costs per installed kw of the Steam Generating Heavy Water Reactor would be about Rs. 2000/- as against Rs. 2500/- for the 500 MW size CANDU reactor.

In 1960 plants for the enrichment of U-235 were considered out of the question for India due to their high costs as well as their enormous consumption of electric power. This analysis was based on the use of the gaseous diffusion process. Since then, there has been marked progress of the gas centrifuge process which is less expensive to establish and in consequence plants based on the new technology are to be set up in a number of countries.

India is late in interesting itself with serious developmental work for enrichment of uranium-235. This lacuna must be made good in view of the present evaluation of gas centrifuge technology which appears to be of economic significance and within national resources. Substantial Research and Development effort must therefore be devoted to master the sophisticated chemistry and machine technology as well as production of materials which are strong and corrosion resistant, such as carbon filaments, which would be needed for this programme.

1.4 Manpower Requirements

A broad assessment of the manpower needs of the Ten Year programme has been attempted (Annex. 3, p. 20). One factor has been clearly established from past experience, namely, that from the stage at which a trained graduate engineer or postgraduate scientist is available from the universities to the stage at which he can be an active contributor in a Research and Development project or construction effort involved in the atomic energy programme, he requires on-the-job training for a period of three to five years. For the creation of an adequately trained manpower resource, it is imperative to plan, at least ten years in advance the national programme in atomic energy. The requirement of an additional three thousand trained engineers and scientists, about twice that number of technicians and about an equal number of other supporting staff can only be met through utilising fully the available resources of universities, institutes of technology and polytechnics supplemented by specialists programmes provided by the Atomic Energy Commission's establishments, particularly the Bhabha Atomic Research Centre, which conducts the Training School.

1.5 Industrial and other infrastructure

1.5.1 The atomic energy programme is dependent on several factors external to the Atomic Energy Commission's establishments. Repeatedly, Atomic Energy Commission projects have been faced with a situation where the absence of a long term estimate of the demands likely to be made by the atomic power programme has made it impossible for major public sector undertakings or private units to plan their own production and create fresh facilities. For example, Hindustan Steel Limited is being increasingly called upon to supply various types of special steels and alloys for our programme. To the extent that we are unable to commit the requirement for a sufficiently long period, it becomes neither feasible nor economical for Hindustan Steel to plan for our needs. Similarly, Heavy Electricals, Bhopal, will not be in a position to make a long term commitment for the production of large sized turbo generators or to effect economies involved in their manufacture unless it is possible for the Company to know in advance the demand that is likely to arise for equipping such large power stations. It is pertinent to note in this connection that some of the designs and knowhow being acquired by Bhopal for a 235 MWe turbine for MAPP can also be used with suitable modifications for a 500 MWe nuclear or fossil fuel station. A number of other similar examples can be quoted in respect of supply of complicated and costly raw materials and fabricated parts by public and private sector units.

1.5.2 Unless the industrial establishments which would be called upon to supply annually about Rs. 800 crores of equipment for all types of power stations during the decade commencing 1975, prepare themselves during the next three or four years with design capability and trained personnel on the shop floor we would either have no development or go out for external assistance of a magnitude

which is in any case unlikely to be forthcoming. Moreover, the types of equipment required in the late 70's in terms of technology and size should be chosen for development *now* if we are not to fail. What applies to power in general applies equally to nuclear power which should expand at the rate of three times every five years if, by 1985 it is to reach a figure of about 8500 MW, constituting about 12 to 13 per cent of the total generating capacity in the country. Business in supplying components for nuclear power plants alone should be about Rs. 100 crores annually during the latter half of the present decade.

The completion of the Madras Atomic Power Station has been delayed by two to three years on account of the failure to mobilise in time all the national resources required to undertake the project with a maximum of indigenous content. A consortium of undertakings fully committed to the task of backing up the Power Projects Engineering Division of the Department of Atomic Energy for the completion of future atomic power stations in a period no longer than five years, would significantly reduce the heavy incidence of interest during construction and the consequent increase of capital cost of the projects. Economic production of atomic power is crucially dependent on this factor. In our country with scarce resources, it is understandable if every investment is examined in terms of the returns it can bring. It is moreover a good discipline for all of us to have an eye on the capital costs of our first nuclear power stations and the price at which electricity can be sold. But in examining the direct financial aspects, particularly for a project such as the Madras Atomic Power Station which we are for the first time undertaking entirely on our own, let us note that we are not merely building power stations but also creating new national capability of great economic significance in the long run.

1-5-3 A major difficulty that has been experienced in the establishment of nuclear power stations relates to the inadequacy of the existing road and rail system to handle over-dimensioned equipment. A 200 MWe station involves the transport of single pieces of nuclear components having maximum dimensions upto 27' x 24' x 20' and other equipment weighing upto 170 tonnes. These include shield tanks, calandria, end shields, boilers, transformers and turbo-generator components. Over-dimensioned components and parts have to be transported from source locations like Shahabad, Powai, Walchandnagar, Bhopal, etc. The end shields for a 500 MWe CANDU type reactor will weigh about 220 tonnes. Experience so far has shown that unless steps are taken in advance for the creation of the infrastructure of road and rail transport, it will not be possible to handle such large sized equipment. The widening of roads and culverts, strengthening of bridges, etc., involve a considerable amount of work.

1-6 Economic Implications

1-6-1 Nuclear power has been established in Western countries based entirely on economic considerations. A 200 MWe unit would be considered a prototype

reactor for gaining experience for the construction of larger reactors, but under Indian conditions it has now been proved at Tarapur that power from two units of 200 MWe each is fully competitive with that from existing fossil fuel stations in the western region. The Energy Survey Committee recognised this position and has identified regions in the north, west and south of the country as areas where nuclear power is more economic than power from coal fired stations. In all considerations relating to the optimum method of satisfying the country's power needs, the integrated use of coal and nuclear stations providing the base-load and hydel stations providing peaking power must be recognised. Such an integrated study of the optimum mix for serving the power needs of the Northern Electricity Region has been carried out as a sample study and has confirmed that the least cost solution for this region would include nuclear generating capacity. A broad summary of the conclusions reached is found in Annexure 4 (p. 21).

1.6.2 The projected cost estimates for the ten year period for implementing the programme for atomic energy are given in Annex. 5 (p. 23). In the case of several items which involve research and development in new fields, the estimates are *ad hoc*. It is however important to recognise that out of the Rs. 1250 crores that are visualised for the ten year period, fully 915 crores are for projects of direct economic significance contributing to national development. The net value of the products from investments on these projects would annually be approximately Rs. 170 crores. The net additional investment initially in nuclear rather than coal fired stations approximately averages to Rs. 10 crores per year through the decade. But the discounted cash flow analysis over the life time of a nuclear power station in many parts of India shows that the costs compare favourably with coal fired stations, even though the latter require less initial capital per kilowatt installed. The additional initial investment may be regarded as the price we pay at the present time to reach the second and third stages of our atomic power development, when atomic power stations are expected to be competitive both in regard to capital as well as operating costs.

The Research and Development expenditure over the ten year period is likely to be about Rs. 335 crores.

The funds required during the first half and the second half of the present decade are separately indicated in Annexure 5. Note that as against a total of Rs. 365 crores envisaged upto March 1975, the Fourth Five Year Plan which has been recently approved provides for an expenditure of Rs. 254 crores up to the end of March 1974. The provisions in the present Fourth Five Year Plan are indicated in Annexure 6 (p. 24).

Application of radio isotopes can be of very great practical benefit in medicine, in agriculture, in industry, in food preservation and in research. Our atomic power programme would make available a plentiful supply of the basic radioisotopes needed for these diverse applications. However, much effort will be required during the decade to realise these benefits. The expenditure is relatively

modest compared to that required for the rest of the programme of atomic energy. However, the operations are complex and involve sophisticated technologies and industrial establishments. A profile of developments in this field is currently under preparation and should be separately available shortly.

1.7 Summary Conclusions

The starting point has to be a commitment to a firm programme to include:

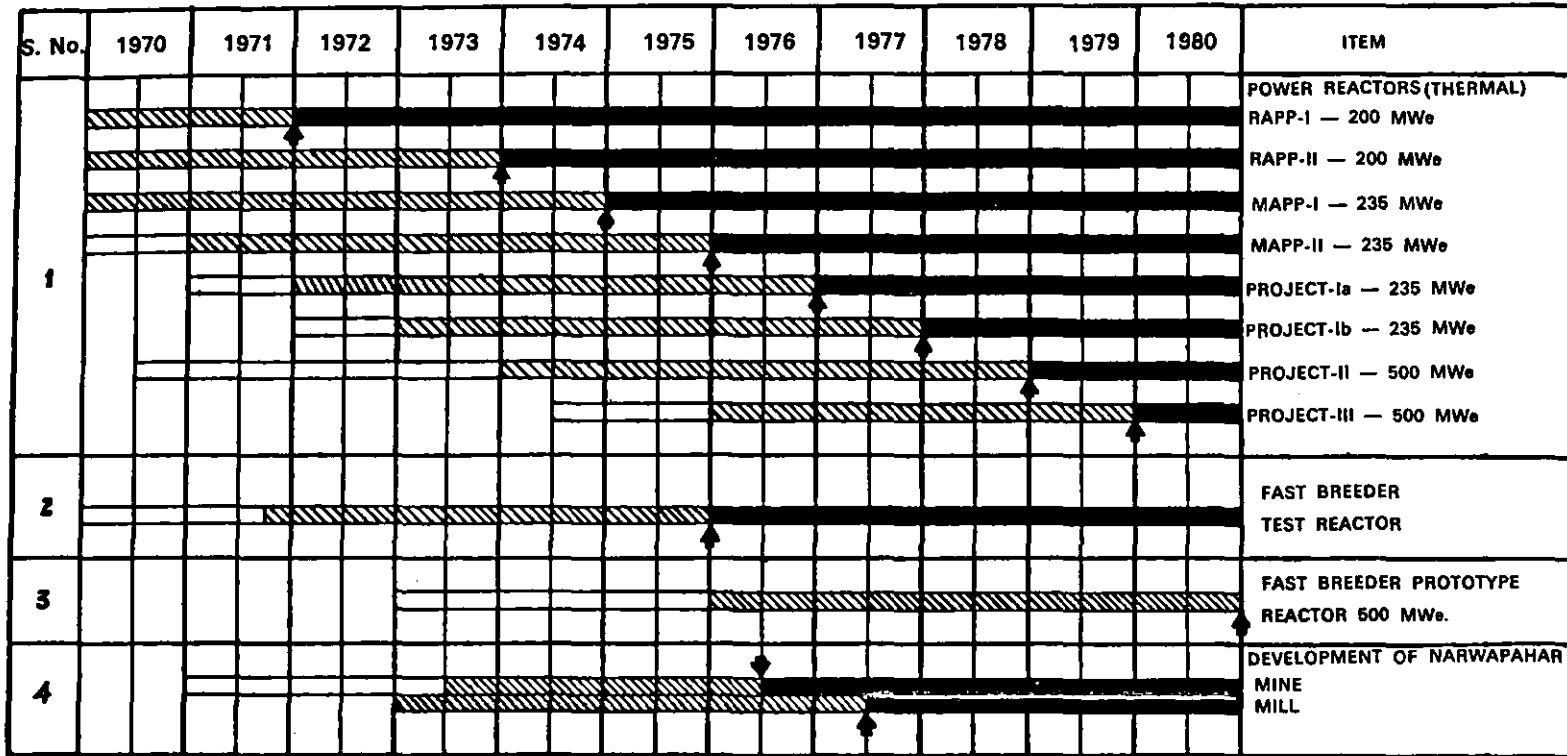
- (a) 2700 MW of nuclear power to be commissioned before 1980. This means approval for four new power stations of 1700 MW for which construction should start during the Fourth Plan.
- (b) Design and construction of advanced thermal reactors of about 500 MW unit size which would lower the capital cost of power stations while still producing plutonium for our future needs in fast breeder reactors.
- (c) Completion of fast breeder test reactor and experience with technology of plutonium enriched fuel, its fabrication and reprocessing, sodium coolant technology and experience with thorium bred U-233 fuel.
- (d) Augmentation of heavy water production to about 400 tons per year to back up the programme for the use of natural uranium in our power reactors.
- (e) Design and construction of a large 500 MW prototype fast breeder test reactor.
- (f) Development of gas centrifuge technology for U-235 isotope enrichment. Development of special materials including carbon filament structures.
- (g) Development of the Narwapahar Uranium Mines and facilities for extraction from low grade ore.
- (h) Early completion of the Nuclear Fuel Complex to manufacture special materials and fuel elements for our programme.
- (i) Creation of adequate facilities for the reprocessing of irradiated fuel and recovery of essential by-products.
- (j) Widespread application of isotopes in industrial processing, food preservation, sterilisation of medical products, medicine and research.

All these will not only require creation, during the Fourth Plan, of one major new atomic energy research establishment, namely the Reactor Research Centre at Kalpakkam, which should have a complement of about 3000 to 4000 by the end of the decade, but also personnel for manning the new projects of industrial importance. One of the most important aspects for the success of the

atomic energy projects would be the development of a new integrated organisation involving the interests of public and private sector organisations in industry which would be involved in fully backing up the programme in all its phases from the production of raw materials to the fabrication of specialised equipment and the erection and commissioning of major plants within a stipulated time frame.

MILESTONES CHART OF MAJOR ATOMIC ENERGY PROJECTS

16



LEGEND

- PREPARATION
- CONSTRUCTION
- COMMISSIONING
- OPERATION

S. No.	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	ITEM
5												NUCLEAR FUEL COMPLEX
												I-STAGE
												II-STAGE
6												HEAVY WATER PROJECTS
												H.W.P. BARODA — 67 TONNES
												H.W.P. KOTA PHASE-I — 100 TONNES
												H.W.P.-III — 67 TONNES
												H.W.P.-IV — 67 TONNES
7												FUEL REPROCESSING PLANTS
												PREFRE-I TARAPUR
												PREFRE-II KALPAKKAM
												PREFRE-III

LEGEND

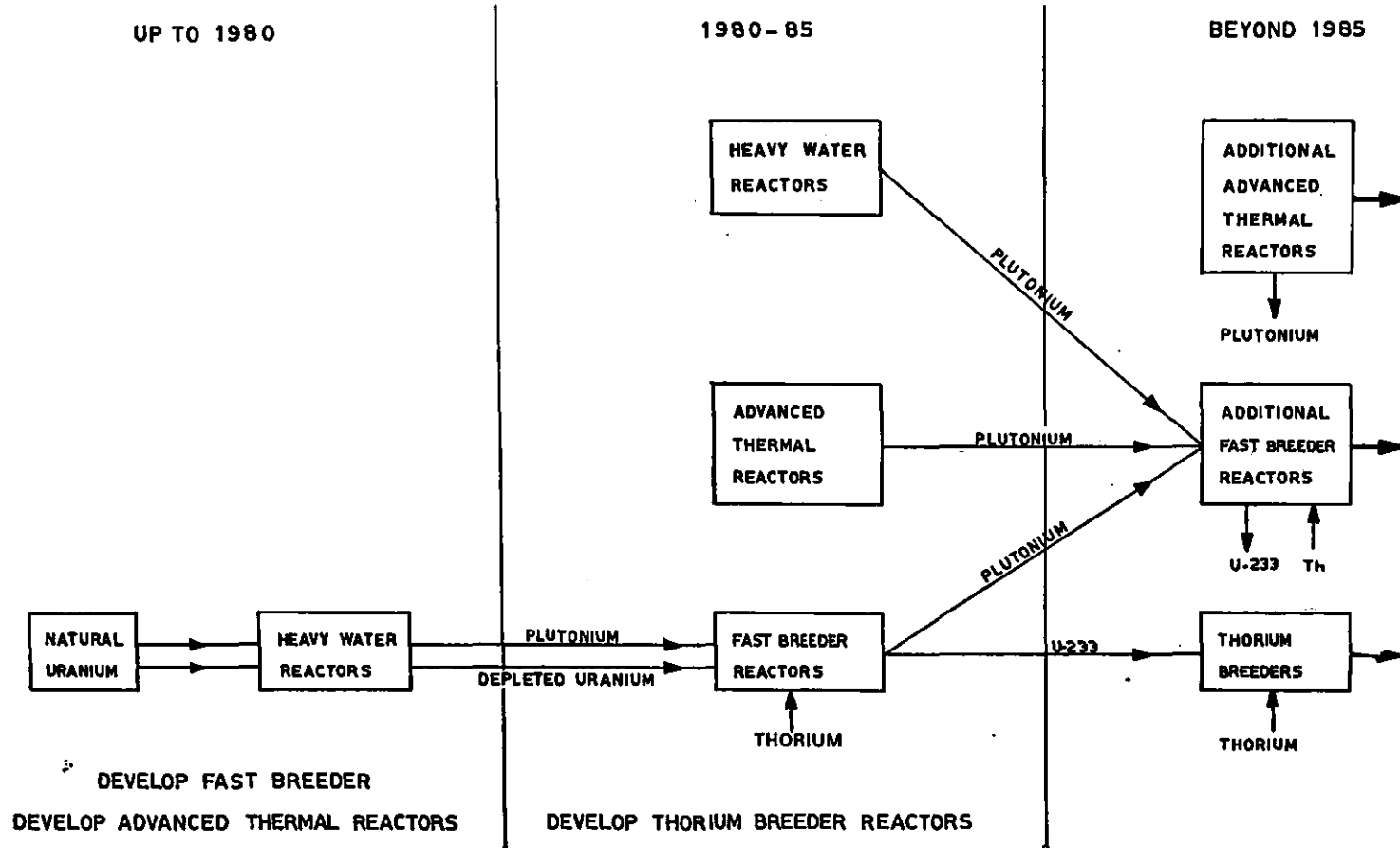
- PREPARATION
- CONSTRUCTION
- COMMISSIONING
- OPERATION

ANNEXURE 1

AGRO-INDUSTRIAL COMPLEX

A good example of the role that nuclear power can play can be seen from our most recent study on the feasibility of an agro-industrial complex in three divisions of western Uttar Pradesh, having collectively a population of about 24 million. We can derive a return of 54 per cent on the incremental investment of approximately Rs.1100 crores with 1200 MWe nuclear power energising 25,800 additional tubewells, producing phosphatic fertiliser using an electro-thermic process (206,000 Te of P_2O_5 /annum), nitrogenous fertilizers using an electrolytic process (370,000 Te/annum of N) and 50,000 Te/annum of fabricated aluminium. Almost half the investment is on what might be termed the infrastructure, involving capital expenditure on augmenting roads and railway transportation, new warehouses, agricultural implements and for providing credit to farmers. The programme would generate all the year round direct employment on farms for 1.4 million persons, resulting in additional agricultural production of 9.4 million tonnes of foodgrains, 1.8 million tonnes of potatoes and 11.2 million tonnes of sugarcane. The increase in gross national product amounts to about Rs.1000 crores annually. The profit to the agriculturist is likely to be about Rs.3300 per hectare after paying full wages for all labour employed. These figures, dramatic and almost incredible can be understood if we recognise that what we have in fact done here is to use nuclear power as a catalyst, through the water that it pumps up, and the fertilizer that it produces, for harnessing through photo synthesis the vast solar energy falling on the plains of India. The example provides a striking demonstration of the impact that the supply of energy can produce in our countryside where the largest number of under-privileged persons of India reside. To realise the potentialities for the accelerated development of our country we need to clearly understand the role of energy and of water and adopt appropriate policies with determination and commitment.

NUCLEAR POWER STRATEGY IN INDIA



ANNEXURE 3

REQUIREMENTS OF GRADUATE SCIENTISTS AND ENGINEERS FOR THE ATOMIC ENERGY PROGRAMME (1970-80)

Year	Power Stations	Reactor Research Centre	Fuel Manu- facture	Other Projects	Replenish- ments for loss	Total
1971 ..	170	50	20	—	100	340
1972 ..	220	80	20	—	100	420
1973 ..	120	80	50	25	100	375
1974 ..	40	100	40	105	100	385
1975 ..	50	120	—	—	100	270
1976 ..	—	120	—	—	100	220
1977 ..	—	100	—	35	100	235
1978 ..	—	60	—	—	100	160
1979 ..	—	—	—	—	100	100
1980 ..	—	—	—	40	100	140
Total ..	600	710	130	205	1000	2645

ANNEXURE 4

SUMMARY OF THE CONCLUSIONS OF THE STUDY OF THE OPTIMUM MIX OF NEW POWER PLANTS TO SERVE THE NEEDS OF THE NORTHERN ELECTRICITY REGION

The study was made for the year 1978-79 for the Northern Region, assuming a system peak demand of 7700 MWe. In order to determine the optimum mix of generation of the various types, thermal, nuclear and hydel, the following alternative schemes of generation with regard to proposed plants were studied:—

Station	Alternatives							
	I	II	III	IV	V	VI		
Thermal			MWe					
Satpura Extension	—	250	—	—	—	—		
Palana & Sawaimadhopur ..	260	—	260	260	260	260		
Obra Extension II	550	550	550	550	550	550		
Western U.P.	700	700	1100	1100	120	623		
Bhatinda I	200	200	200	200	200	200		
Bhatinda II	—	—	200	200	—	—		
Jagadhri	400	—	400	—	200	200		
Rajpura	—	—	200	200	—	—		
Delhi (new)	—	400	—	400	—	—		
Nuclear								
Western U.P.	400	400	—	—	600	400		
Punjab/Haryana	400	400	—	—	600	400		
Hydel								
Maneri Bhali II	105	105	105	105	105	105		
Yamuna IV	27	27	27	27	27	27		
Dehar II	242	242	242	242	242	242		
Thein	—	—	—	—	350	350		
Lakhwar	—	—	—	—	150	—		
Biyasi	—	—	—	—	68	—		
Khare	—	—	—	—	36	—		
Mahi	—	—	—	—	55	—		
System Costs	147.9	149.2	152.3	152.2	146.3	143.4		
(Rs. Crores per year)								
Investment	868	891.2	771	772	888.8	863.4		
(Rs. Crores)								

It can be seen from the above table that Alternative VI, which includes two nuclear stations of 400 MWe each in Western U. P. and Punjab/Haryana and the somewhat uncertain Thein project in addition to other thermal and hydel stations, is the most economical. If, however, Thein does not materialise by 1978-79, Alternative I is the most economical. This also has 2 nuclear stations of 400 MWe in Western U.P. and Punjab/Haryana, but the Thein project has been replaced by additional thermal generation in Western U.P.. (+ 75 MWe) and Jagadhri (+ 200 MWe).

**DISCOUNTED CASH FLOW ANALYSIS OF ALTERNATIVES
CONSIDERED FOR NORTHERN GRID
(NUCLEAR REACTORS—CANDU)**

Alternative	Investment	Annual System Costs	Present value (for 25 years) of annual system costs at			Present value of total expenditure (for 25 years) (1) + (3)		
			8%	10%	12%	8%	10%	12%
	1	2	3			4		
(Rupee in crores)								
I	868	148	1579	1342	1160	2447	2210	2028
II	891	149	1590	1352	1168	2481	2243	2059
III	771	152	1622	1379	1192	2393	2150	1963
IV	772	152	1622	1379	1192	2394	2151	1964
V	889	146	1558	1324	1145	2447	2213	2034
VI	863	143	1526	1297	1121	2389	2160	1984

Note: Each of the six alternatives meets the peak demand as well as supplies the total requirements of energy. However, the capital costs and the annual operating costs are different for each of the alternatives. In comparing the economics of these alternatives, one ought to select that alternative which is the least expensive one. Yet since different amounts have to be spent at different times, for a proper comparison one should calculate present discounted values of the costs of these alternatives. In this procedure we assume that it is possible to put away money in a bank and earn a fixed interest at say 10%. Thus Rs. 110 spent next year is equivalent to putting Rs. 100 this year in the bank, earning an interest of Rs. 10 for a year, and then spending Rs. 110 next year. Similarly, Rs. 121 spent two years from now is equivalent to having spent Rs. 100 this year. Thus expenditure incurred in different years can be reduced to equivalent expenditures incurred this year. We can reduce the different streams of expenditures of the different alternatives to comparable equivalent expenditures to be incurred now. Obviously, the alternative which involves the least amount of expenditure today is the most economical alternative available.

ANNEXURE 5

COST ESTIMATES OF THE ATOMIC ENERGY PROGRAMME

S. No.	Item	Funds Required		
		1970-80	1970-75	1975-80
(Figures in Rs. crores)				
1.	2700 MWe			
	a) 1000 MWe constructed or under construction	130.00	101.00	29.00
	b) 1700 MWe new			
	3 x 235 MWe	230.00	44.00	186.00
	2 x 500 MWe	275.00	5.00	270.00
2.	Design of 500 MWe advanced thermal reactors ..	5.00*	5.00	—
3.	Fast Breeder Test Reactor & Reactor Research Centre			
	a) Fast Breeder Test Reactor	} 50.00*	29.00	21.00
	b) Sodium Coolant Technology			
	c) Thorium Bred U233 fuel			
	d) Reprocessing	5.00	3.00	2.00
4.	Heavy Water 400 T/year including 167 under construction and 233 additional	95.00	75.00	20.00
5.	500 MWe Fast Breeder Reactor	125.00	—	125.00
6.	Development of gas centrifuge technology and special materials (carbon filament)	110.00*	10.00	100.00
7.	Development of Narwapahar Uranium Mines ..	18.00	4.00	14.00
8.	Nuclear Fuel Complex	13.00	13.00	—
9.	Fuel Reprocessing Plants for Plutonium	23.00	9.00	14.00
10.	Bhabha Atomic Research Centre	165.00	65.00	100.00
11.	Isotope Applications	6.00*	2.00	4.00
Total		1250.00	365.00	885.00

* Ad hoc estimates.

Anticipated Revenue from Industrial Projects in a Full Year

					Rs. Crores
1.	Sale of power				126.00
2.	Heavy Water				20.00
3.	Fuel Production				20.00
4.	Plutonium				4.00
Total					170.00

ANNEXURE 6

PROVISIONS INCLUDED IN THE FOURTH PLAN (1969-74) FOR ATOMIC ENERGY

S. No.	Item	Fourth Plan provision
		(Rs. in crores)
1.	Nuclear Power Stations	135.00
2.	Fast Breeder Test Reactor and Reactor Research Centre ..	15.00
3.	Heavy Water Projects	32.88
4.	Nuclear Fuel Complex	18.18
5.	Fuel Reprocessing Plants	7.64
6.	Bhabha Atomic Research Centre	17.32
7.	Variable Energy Cyclotron.. .. .	5.18
8.	Radio Telescope Station	0.24
9.	Atomic Minerals Division	3.00
10.	Aided Institutions	5.67
11.	Public Sector Undertakings (ECIL & UCIL)*	4.64
12.	Housing	6.95
13.	Other Miscellaneous items	2.21
		253.91

* ECIL—Electronics Corporation of India Ltd.
UCIL—Uranium Corporation of India Ltd.

PART II

Space Research

PART II

Space Research

1. Space Research Programme

1.1 About 15 years after the first steps taken for the establishment of an atomic energy programme in India, the subject of exploration of outer space was allocated in 1961 to the Department of Atomic Energy. There was at that time considerable interest amongst the many Indian scientists and institutions researching in equatorial aeronomy (including meteorology), cosmic rays, astronomy and geodesy. Quite early it was decided to establish the Thumba Equatorial Rocket Launching Station (TERLS), a sounding rocket range on the geomagnetic equator at Thumba, near Trivandrum in South India. It consciously laid emphasis on creating facilities which would permit a study of problems in aeronomy in the region upto 200 km. which is below the operational level of satellites. It was felt that this would be particularly appropriate, since the programme could be conducted with small sounding rockets involving a modest budget. Moreover, the scientific results would have a direct bearing on a better understanding of meteorology which is of great practical significance to the Indian economy.

1.2 It was clear at the outset that space research could not progress without the simultaneous development of advanced space technology. As a beginning, an arrangement was concluded in 1964 to manufacture in India, under licence from a French firm, a two-stage rocket capable of reaching an altitude of about 150 km. with a payload of approximately 30 kg. The manufacture of these rockets was established provisionally at the Bhabha Atomic Research Centre pending the setting up of a special Rocket Fabrication Facility (RFF) at Thumba. A Rocket Propellant Plant (RPP) was also set up at Thumba to make solid propellant blocks under licence from France.

Space technology was acquired under licence from abroad only as a means to buy time, and simultaneously a major R & D establishment was created to advance developments in the years to come. In 1965, the Atomic Energy Commission approved the setting up of the Space Science & Technology Centre (SSTC) on Veli Hill by the side of the Thumba Equatorial Rocket Launching Station. The principal responsibility of the Centre is

- (i) to conduct research and development (R & D) on systems and their components required in Space Research, and

- (ii) to carry out prototype design and pilot production of equipment resulting from its R & D activities.

The systems and their components include the rocket vehicle, scientific payloads and back up experiments, instrumentation, telemetry for both communication and command, and ground support systems. The Centre also undertakes prototype production.

The diversity of scientific and technical disciplines involved in the conduct of the work at the Centre necessitates that its personnel are drawn from diverse fields of specialisation. In order to build effective teams of workers to carry out technologically complex and mostly target-oriented projects, an appropriate organisational structure has been devised.

The most important task of the Space Science & Technology Centre is to develop indigenously a satellite launch capability. This is of relevance not only for scientific exploration, but also for many applications of outer space in the fields of communications, meteorology and remote sensing. The first launch that would be attempted in 1974 would be to place in a near circular orbit at about 400 km. a satellite of about 30 kg. The launcher which is being designed, designated SLV-3, would have four stages and would weigh approximately 20 tons. The length of the vehicle would be about 21 meters. The vehicle would be powered by solid propellants and the diameter of the first stage would be 1 meter. The vehicle would need control and guidance using inertial systems. Special materials and methods of construction involved in advanced aero-space engineering are being developed for use in the rocket motors.

Propellants of high performance are now produced and these have been flight tested in smaller rockets. Electronics and instrumentation, which can stand extreme environmental conditions such as acceleration many tens of times the force of gravity, needed for the SLV-3 mission, are flight tested in the current programme with sounding rockets. Moreover, extremely rigorous procedures are involved for quality assurance at all stages of procurement and construction and also for testing the components and subsystems under flight simulated conditions.

SLV-3 would be followed in the period 1975-79 by satellite launch vehicles using more powerful motors and it is the objective of the Space Science & Technology Centre to develop by the end of the 1970's a launch vehicle capable of putting a 1200 kg. satellite into synchronous orbit at 40,000 km. This is the type of capability which is needed to fully exploit, on our own, the vast potential arising from the practical applications of space science and technology.

The development of systems as complex as a satellite launch vehicle and a satellite needs understanding in depth and complete mastery of the technology of each subsystem which is involved. The thrust of the programme

at the Space Science & Technology Centre during the past three years has been to grow this capability through a number of individual projects, each by itself modest in character, but progressively involving increasing technological complexity and sophistication. RH-75, RH-125 and its multistage combination as well as India-made Centaure rockets have all been successfully completed; RH-100 along with its Dart combination in the configuration designated 'Menaka' useful for meteorological observations, is nearing completion. RH-300 would be flight tested within the next few months from the new SHAR range at Shriharikota in Andhra Pradesh near Madras.

Space research has steadily gained momentum and today not only are complete two-stage rockets made entirely in India but also sophisticated payloads for investigation of the upper atmosphere and for the study of X-Ray Astronomy. While a total of 205 sounding rockets were launched from TERLS during the past six years, almost 75 are expected to be launched during the current year.

1.3 A most important practical application of space research is the use of satellites for telecommunications. When a satellite is in a circular equatorial orbit at a height of about 35,900 km., the earth appears stationary to it and a large part of a hemisphere is visible to it. Two widely separated points in the area of visibility can establish high quality reliable telecommunication links through the "synchronous" satellite. A communication satellite can also be used for the dissemination of television pictures over a wide network of T. V. receiving stations, thus providing an effective medium of mass communications to isolated communities.

To enable India to gain competence in global satellite communications, the Experimental Satellite Communication Earth Station has been established at Ahmedabad by INCOSPAR with assistance from the U.N. Special Fund.

At the present time the Indian Space Research Organisation (ISRO) is deeply interested and involved in an evaluation of the benefits that a synchronous satellite can provide for national needs of point to point communications, for mass communications through direct broadcast television to promote national integration as well as the economic development of isolated communities, for meteorological observations covering the vast Indian Ocean and for assisting navigation. Just for one application, namely, the provision of broadband communications for reaching through television half a million villages of India, it can be shown that using satellites the investment would be much less than what would be required with conventional technologies. Where capital funds and foreign exchange are crucial bottlenecks, the deployment of a satellite communication system based on a largely indigenous effort in electronics can make all the difference to a national decision for adopting the most effective and persuasive means as yet available for mass communications. Indeed it is estimated that with an annual investment equivalent to about Rs. 35 crores one can provide community

television to all the 560,000 villages in India over a five-year period. This would incidentally generate a strong industrial base in electronics providing employment to about 120,000 qualified scientists, engineers, technicians, managers and other administrative personnel.

1.4 Weather is by its very nature world-wide. This means that, in order to have an adequate picture of today's weather, it is necessary to have observations from all over the world from an adequate network of stations uniformly distributed over the earth's surface. Without such observations it is only possible to have a partial picture, and this places limitations on our ability to understand the global behaviour of the atmosphere, to test new theories about its behaviour and to forecast the future weather. The limitations become more and more serious as the period of time for which the forecast is required becomes extended; for a forecast for more than a day or two ahead it is in fact necessary to have observations from a whole hemisphere, if not from the whole globe.

The satellite is ideally suited to serve as an observation platform for meteorology. It is situated high above the atmosphere, and as the earth rotates beneath it, the satellite sensors can view every area on the globe, including those that are inaccessible to man and those where weather stations cannot be installed on a practical basis. Satellites orbiting at low altitude can view the earth with greater detail while those further out can view larger areas of the earth, though often with lesser clarity. Over dense conventional networks their surveillance is supplementary, over the oceans they cast sparse data into a meaningful framework of broad-scale motion. While surveying the atmosphere with their own cameras and sensors they can collect data by interrogation of horizontal sounding balloons, ocean buoys and remote land-stations, and can communicate these data to processing centres. They have varied utility—apart from their capability of disseminating weather analyses and forecasts over the world, there is no reason why more sophisticated and direct sensing devices, for example to sound the vertical distribution of temperature and humidity, cannot be part of these observing platforms.

1.5 A most significant development in space research has been in the field of remote sensing of earth resources from orbiting satellites. This is of great interest to geologists, geographers, agriculturists, hydrologists and oceanographers. In the Indian programme this has particular relevance to the detection of the snow cover over the Himalayas and the surface temperature of the Indian Ocean, two factors which appear to be vitally connected with the precipitation of rainfall over India during the monsoon. Moreover, detection of diseased trees and crops over large areas is potentially of great practical significance to agriculture and forestry.

The milestone chart (page 38) of the programme of space research indicates the special initiatives to be taken and facilities as well as competence which will have to be created.

2. Space Technology

2.1 Much has been established at the Space Science & Technology Centre during the past four years to undertake the responsibility of designing and building multistage satellite launch vehicles. An area in which special emphasis requires to be given is for sophisticated control and guidance systems. This involves the design and development of optical, magnetic and inertial type sensors and control components of electro-mechanical, magnetic, pneumatic and hydraulic types and associated special electronics. Moreover, fibre glass, strip-wound and helically welded rocket motors as well as special materials for aero-space use are required to be carried from pilot plant to the stage of large scale fabrication.

Special facilities and new groups of trained personnel to construct scientific and communication satellites and to environmentally test them are required early. The personnel engaged in space research are growing rapidly as is indicated in the table below :

Year	Total
1965	110
1970	2500
1975	4500
1980	7000

2.2 It is decided to launch the first Rohini Scientific Satellite (RS-1) by mid 1974 using SLV 3 vehicle. The satellite, quasi-spherical in shape and weighing a total of about 30 kg. will be launched into a near circular orbit at 400 km. altitude from SHAR launching range. The structure, on-board data processing, power, command and telemetry systems will weigh about 25 kg. the rest of the weight being allocated to one major scientific payload and a few technological payloads. The technological payloads include a large variety of sensors to measure different performance parameters of the satellite. The house keeping along with all the on-board data will be telemetered to ground. The satellite will also have the capability of being commanded from ground. It will be powered by solar cells and standby batteries.

Elaborate ground test facilities which include solar simulation chambers, thermo vacuum chambers, vibration tables, shock testing facilities and operational life time evaluation facilities are in the process of being installed at SSTC for testing the satellite and the different sub-systems. Facilities for sophisticated packaging in super clean rooms and special fabrication techniques are being developed.

3. A Domestic Communication Satellite

3·1 National development and the development of communications in a country are necessarily interdependent. It is the increase in the amount of information transfer and the speed with which it is disseminated that leads to rapid development, especially in the modern world where development is very much technology oriented.

3·2 The introduction of television in India has until recently enjoyed low priority. Indeed, in adopting television, India stands almost the lowest amongst the nations of the world, including developing nations. This is largely attributable to four principal factors. First is the non-recognition of television as one of the most powerful media of mass communication, and therefore of direct relevance to development. Second is the inherently higher unit cost of a TV receiver compared to a receiver for sound broadcasting. In consequence, unless community TV is organised, it cannot reach the vast majority of our population. Third is the absence of broad-band tele-communication links throughout the country, or even between the major cities. These are necessary to provide national programme. And fourth is the large dependence, in the past, on importation of equipment and components for broadcasting or reception of television programmes.

3·3 The advent of synchronous communication satellites has a special relevance to developing nations which have not still acquired an extensive infrastructure of tele-communications with older technologies. Even though an optimum system in the future is expected to have ground tele-communications as well as satellite tele-communications, there are unique opportunities for optimising a system in respect of its cost and effectiveness where the existing investment is relatively small. India can profit from this situation provided it can use satellite communications for its national needs meaningfully and with imagination.

3·4 Three years ago, the Indian Space Research Organisation of the Department of Atomic Energy, which is responsible for promoting the peaceful uses of outer space, organised a study of the cost and significance of a synchronous satellite to link together isolated rural communities and distant centres of population in India through a powerful national system for mass communication using television. It was felt that there is necessity to gain insights on the manner in which television can be used as a direct instrument for promoting the developmental tasks of Government, so that it can be regarded as *an investment rather than an overhead*. The Krishi Darshan Programme was organised in 1967 in collaboration with All India Radio, Indian Agricultural Research Institute and the Delhi Administration through the establishment of community television receiving sets in 80 villages around Delhi.

3·5 Parallel with this, a study was conducted to determine the most cost-effective method of deploying a nationwide TV system. This study was conducted

by Indian experts drawn from various establishments and departments of Government. The study had the benefit of experience shared by NASA of USA and participation of specialists from many industrial and educational organisations. The study showed that the most cost-effective method would be one that utilised a satellite for direct broadcasts to remote villages and also for rediffusion through terrestrial TV transmitters—in short, a hybrid system. Such a system could provide television services to all of India's 560,000 villages and cities through community viewing sets.

3-6 For undertaking a programme to provide television nationally on the scale indicated, it would be necessary to rely largely on Indian expertise and indigenous supply of hardware. To use it effectively as a means of promoting national integration and development, experience requires to be gained on the side of content and programming, in applications to education, agricultural extension, promotion of family planning and national integration. Moreover, insights on managerial and technical questions related to the operation and maintenance of television sets in rural areas, often with no established electric supply, would need to be gained.

3-7 In order to do this and to gain practical experience, an agreement has been concluded between India and USA which will enable India to utilise, for a period of one year around 1973, NASA's ATS-F satellite to beam instructional TV programmes through one video channel accompanied by two audio channels to villages and cities in various parts of the country. This project—called the Satellite Instructional TV Experiment (SITE) — will provide the necessary experience and help in developing Indian personnel and facilities. The responsibility for the ground segment of this experiment and for programming will exclusively be that of India.

3-8 SITE would involve about 5000 villages located in clusters of about 400 each and spread over West Bengal, U.P., Rajasthan, Delhi, Kashmir, Gujarat, Maharashtra, M.P., Orissa, Bihar and Tamil Nadu. One community TV set will be located in each of these 5000 villages and instructional/educational programmes produced in India will be beamed via the satellite from the earth station located in Ahmedabad and possibly also from Delhi and Bombay. This project will tie in with AIR's plans of installing TV transmitters in Srinagar, Bombay-Poona, Calcutta, Madras and Kanpur-Lucknow.

3-9 Following the experiment, which will provide a systems test of broadcast satellite TV for national development and enhance our capability in the design, development, manufacture, installation, operation and maintenance of ground segment, it is proposed that we go further and establish our own domestic satellite system. Such a system, it is proposed, will utilize a multipurpose satellite for providing nationwide TV coverage and tele-communication links between at least the four major cities of India. As proposed by ISRO, the national satellite

could be launched around 1974-75 and will have the capability of transmitting simultaneously three video channels (each accompanied by a number of audio channels) and 3600 high quality telephone channels. While it will be necessary to build the first such satellite (INSAT) abroad, it is proposed that 30-40 Indian engineers will be involved in this task in association with the foreign contractor. Typically three satellites are built before one is launched, and it is proposed that these engineers will construct the next two satellites in India using the maximum amount of Indian components and sub-systems. While the first synchronous communications satellite (in 1974-75) will have to be launched by a foreign agency, ISRO should have the capability to launch a communication satellite around 1980 when a replacement is required.

3-10 The ISRO proposal for a national TV coverage using INSAT includes 20 terrestrial TV transmitters, probably located in State capitals and large cities. These stations will be connected to the national hookup via the satellites, so that they can relay either their own programme or one of the three national programmes originating through the satellite. Nationwide coverage is theoretically provided as soon as the satellite is in place in 1974-75. However, it is recognised that national coverage has no meaning unless a very large proportion of the population has the opportunity to view the programmes. Therefore, the proposal also suggests the installation of at least one TV set in every village in the country. It is estimated that the deployment of one set in every village will take about 5 years at the rate of 100,000 each year from 1975 onwards. The cost of community TV sets and the TV broadcast ground installations for the period 1975-80 is not included in the Department's estimates presented in this document.

3-12 The economics of INSAT can be judged by the fact that through a mere 25% utilization of the tele-communication capability on board the satellite it will be possible to earn revenues of about *Rs. 80 crores a year*, i.e. roughly Rs. 400 crores over a five-year period. Besides this, of course, are all the benefits of a national TV system.

4. Sriharikota Range (SHAR)

4-1 The Indian Space Research Organization (ISRO) is establishing a satellite launching station at Sriharikota island situated about 19 km. east of Sullurpet in Nellore District, Andhra Pradesh. This island is along the east-coast with the Bay of Bengal on one side, Pulikat lake and shallow backwaters of the Bay of Bengal on the other. It is 100 km. from the metropolitan city of Madras by road. An area of approximately 12,000 hectares on the island which is elliptical in shape has been earmarked by the Andhra Pradesh Government for the Satellite station. It provides a coastal length of about 21 km. and has a breadth of about 8 km. It is a forest area having casuarina and eucalyptus trees and practically no habitation. There is no fishing in this area and the backwaters of the sea provide safety for range operations.

4.2 The object of this station is to provide a suitable range for launching scientific and technical satellites using multi-stage rockets. This work cannot be undertaken by the existing range at Thumba since Thumba Equatorial Rocket Launching Station (TERLS) has a small area surrounded by thickly populated villages, and for the important reason that a satellite should be launched in the eastward direction. Secondly, there is a necessity for having a big range for flight testing of single and multi-stage rockets being indigenously developed for our space programme. This calls for considerable safety zone around the launching base.

4.3 It is proposed to put up a Rocket Propellant Plant for manufacture of large size boosters and a static and high altitude test facilities at SHAR. This will facilitate handling and transport problems connected with large size boosters. The work of SHAR is intended to be taken up in 3 phases. In phase one, a sounding rocket launch facility will be put up and used for carrying out flight tests of our Rohini rockets developed at the Space Science & Technology Centre, Thumba. It is expected that this facility would be available by December 1970.

4.4 In the second phase to be completed by December 1971, the range will be developed further for flight testing of large sized multi-stage vehicles and necessary tracking and telemetry systems will be available for performance tests. In the third phase of the programme, the various facilities required for handling the satellite launch vehicle, long range tracking radars, high power ground telemetry stations, computational facilities, communication and control centre, will all be provided. This will be made ready by 1973-74, to handle full scale satellite launch operations.

5. Economic Implications

5.1 The principal objectives of the space programme of the Atomic Energy Commission are to develop indigenous competence for designing and building sophisticated hardware involved in space technology including rockets and satellites for scientific research and practical applications, the use of these systems for providing point-to-point communications and a national TV hook-up through a direct broadcast synchronous satellite; and the applications of satellites for meteorology and for remote sensing of earth resources.

5.2 All these will involve considerable effort in research and development. Annex. I (p. 40) gives the estimate of the funds required to be invested for acquiring this capability in the course of the next 10 years. The returns from this investment through expanded point-to-point tele-communications facilities alone can be as high as Rs. 80 crores per year from 1976 onwards. To this will have to be added the tangible benefits expected to arise out of reliable weather forecasting in the shape of saving of human life, property, crops, etc. A national TV net-work based on synchronous satellites will provide benefits by promoting agricultural

productivity and contributing to family planning, etc., apart from fostering national integration. Along with these, the country will acquire much needed capability in rocket technology, vital to national security.

5.3 It is pertinent to note that all the benefits outlined above can be acquired with an outlay of Rs. 10 to 20 crores per annum over the next 10 years. Annex. II (p. 41) gives the provisions during the Fourth Plan for space research.

6. Conclusions

6.1 Our space research programme thus involves the establishment of the following for the decade 1970-80:

- (a) Augmentation of the facilities for R. & D. at the Space Science and Technology Centre to be able to build scientific and communication satellites and to environmentally test them.
- (b) Facilities at the Space Science & Technology Centre for the development of inertial guidance systems and on-board miniaturised computers.
- (c) Development (at SSTC, TIFR and ECIL) and construction of high performance missile tracking radars and PCM communications systems for installation at SHAR and in the Andamans for the satellite programme.
- (d) Construction of a plant for manufacture of large solid propellant blocks at SHAR and a facility for static testing of these propellant blocks on the ground and under simulated high altitude conditions.
- (e) Completion of a rocket fabrication facility at Trivandrum for manufacture of large sized rocket casing and hardware for rocket motors including the development of special materials for rocket motor systems.
- (f) Development by 1973-74 of a launcher which would be of four stages, burning solid propellant, capable of putting into orbit a satellite of about 80 kg. payload. This would be followed by development of more advanced rocket systems capable of putting 1200 kg. payloads into synchronous orbits.
- (g) Fabrication of communication satellites by 1975 capable of providing high quality point to point tele-communication service between metropolitan areas and direct broadcast of television.
- (h) Development of sensors and techniques for remote sensing.

6.2 The constraints on the development of space technology are related to the development of men and teams familiar with the new sophisticated technology. With a growth rate of 50 to 100 per cent per year, we still need about three years before we can reach the minimum critical size for successfully implementing large scale projects of space technology.

**MILESTONE CHART OF
MAJOR SPACE RESEARCH PROJECTS**

MILESTONES CHART OF MAJOR SPACE RESEARCH PROJECTS

S. No.	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	ITEM
1	[Hatched bar from start of 1970 to end of 1972]											AUGMENTATION OF FACILITIES FOR R & D AT SSTC FOR BUILDING SCIENTIFIC & COMMUNICATION SATELLITES & ENVIRONMENTAL TESTING
2	[Hatched bar from start of 1970 to end of 1973]				[Hatched bar from start of 1974 to end of 1978]							DEVELOPMENT OF INERTIAL & IN-FLIGHT GUIDANCE SYSTEMS FOR ROCKETS & ON-BOARD MINIATURISED COMPUTER
									[Hatched bar from start of 1979 to end of 1980]			
3	[Hatched bar from start of 1970 to end of 1973]											DEVELOPMENT OF HIGH PERFORMANCE MISSILE TRACKING RADARS & P C M COMMUNICATION SYSTEMS
4	[Hatched bar from start of 1970 to end of 1972]			[Hatched bar from start of 1973 to end of 1975]								SOLID PROPELLANT PLANT AND TESTING FACILITY AT SHAR
							[Hatched bar from start of 1976 to end of 1977]					
5	[Hatched bar from start of 1970 to end of 1970]	[Hatched bar from start of 1971 to end of 1972]										ROCKET FABRICATION FACILITY FOR LARGE SIZED ROCKETS
	[Hatched bar from start of 1970 to end of 1971]		[Hatched bar from start of 1972 to end of 1973]									

38

LEGEND





- PREPARATION
- CONSTRUCTION

ABBREVIATIONS

- SSTC — SPACE SCIENCE AND TECHNOLOGY CENTRE
- PCM — PULSE CODE MODULATION
- SHAR — SHRIHARIKOTA RANGE

S.No.	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	ITEM
6												SLV-3 SATELLITE LAUNCH VEHICLE DEVELOPED AT SSTC. 30 Kg-400 Km CIRCULAR ORBIT.
7												RS-1 ROHINI SCIENTIFIC TECHNOLOGICAL SATELLITE DEVELOPED AT SSTC 30 Kg-
8												SITE. DAE-NASA ITV EXPT. NASA ATS/F SATELLITE INDIAN GROUND SEGMENT 5000 COMMUNITY RECEIVERS
9												INSAT-1 INDIAN NATIONAL COMMUNICATION SATELLITE FIRST BUILT & LAUNCHED—U.S. SECOND & THIRD BUILT AT SSTC 1200 Kg-40,000 Km.
10												SLV-SYN DEVELOPED AT SSTC FOR LAUNCHING 1200 Kg. TO 40,000 Km. CIRCULAR ORBIT

LEGEND

-  — PREPARATION
-  — CONSTRUCTION
-  — OPERATION
-  — LAUNCH

ANNEXURE I

COST ESTIMATES OF THE SPACE RESEARCH PROGRAMME

Sl. No.	Item	Funds required		
		1970-80	1970-75	1975-80
				(Rupees in crores)
1.	Augmentation of facilities for R. & D. at SSTC for building scientific and communication satellite and environment testing	5.00	5.00	—
2.	Development of inertial & inflight guidance systems for rockets and onboard miniaturised computer ..	2.50	1.25	1.25
3.	Development of High Performance Missile Tracking Radars and P.C.M. Communication Systems ..	3.75	2.00	1.75
4.	Solid Propellant Plant and Testing Facility at SHAR..	15.70	12.45	3.25
5.	Rocket Fabrication Facility for large sized rockets ..	2.00	2.00	—
6.	Development of SLV-3 satellite launch vehicle ..	3.50	3.50	—
7.	Development of Scientific Satellite	3.00	1.00	2.00
8.	Expansion of Experimental Satellite Communication Earth Station including Satellite Instructional Television Experiment (SITE)	4.25	4.25	—
9.	Development of Communication Satellite	27.00	2.00	25.00
10.	Development of Satellite Launcher (SLV-SYN) ..	15.45	—	15.45
11.	Operational requirements:			
	(i) Thumba Equatorial Rocket Launching Station..	10.00	4.60	5.40
	(ii) Experimental Satellite Communication Earth Station	2.25	0.75	1.50
	(iii) Rocket Propellant Plant	5.00	2.00	3.00
	(iv) Space Science & Technology Centre	36.00	10.00	26.00
	(v) Rocket Fabrication Facility	9.00	3.00	6.00
	(vi) Sriharikota Range	20.00	8.00	12.00
	(vii) Indian Space Research Organisation	0.60	0.20	0.40
	Total..	165.00	62.00	103.00

ANNEXURE II

**PROVISIONS INCLUDED IN THE IV PLAN (1969-74)
FOR SPACE RESEARCH**

Sl. No.	Item	Fourth Plan Provision
		(Rs. in crores)
1.	Indian Space Research Organisation	0.14
2.	Experimental Satellite Communication Earth Station (including Satellite Instructional Television Experiment but excluding assistance from United Nations Special Fund)	4.84
3.	Thumba Equatorial Rocket Launching Station (including Housing Colony)	4.50
4.	Space Science and Technology Centre (including rocket development) ..	14.22
5.	Rocket Propellant Plant (including expansion and binder unit)	1.50
6.	Rocket Fabrication Facility	3.20
7.	Sriharikota Range	2.70
	Total ..	<u>31.10</u>
NOTE : Shown as Plan Provision		15.02
	Shown as Non-Plan	16.08
	Total ..	<u>31.10</u>

Published by the Publications Officer, Department of Atomic Energy, Government of India, 1, Chhatrapati Shivaji Maharaj Marg. Printed by R. Subbu at TATA PRESS Ltd. 414, Veer Savarkar Marg, Bombay-25.