Indigenous Development of Electronics & Instrumentation

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Preamble

This article brings out in brief the efforts of DAE to develop indigenous electronics and instruments, purpose of the establishment of Electronics Corporation of India Limited (ECIL) and its historical contributions in electronics to the Nuclear Programme, Defence, Aerospace, Security and eGovernance Programmes. The chapter also provides a historical perspective highlighting the key personalities who have shaped the program in the nascent years. Key products/technologies in line with the vision of the corporation and current areas of work are also highlighted.

1. The Genesis

In the late 1940s, Dr. Homi J Bhabha invited a young Stanford returned A. S. Rao to help him with cosmic-ray experiments at the Tata Institute of Fundamental Research (TIFR), Mumbai. Recognizing the vital role of electronics in developing science and technology in India, Bhabha later formed the Electronics Division and appointed A.S. Rao to lead it. Subsequently, the production unit of electronics was shifted from TIFR to Trombay. Rao was made in charge of the Health Physics and Electronics Divisions of Atomic Energy Establishment, Trombay (AEET).

The Genesis of ECIL has its roots in the work undertaken in Electronics Production Division, Reactor Controls Division and Computers Group of the AEET since 1952. Ever since its modest start, the engineers and technicians of AEET steadily undertook the design, development and fabrication of electronic instruments. By late 1960s, AEET had a fairly

large electronic group consisting of nuclear instruments section and a components section, where work was progressed on silicon crystal, compound semiconductors, ceramics, transistors, diodes, carbon resistors, metal-film resistors and tantalum capacitors. Analog and digital computer modules were also made and successfully tested. The requirement of electronic items increased both in variety and volume as the years rolled by and the shifting of operations to some other place had to be considered seriously. Electronic products worth Rs.40 lakhs on pilot basis were produced by 1964-65 in the Electronics Production Division. In consideration of the future development programmes, a full-fledged production on a commercial basis was the need of the hour.

In 1960, the Trombay establishment submitted a project report to Atomic Energy Commission towards embarking on a commercial venture for large scale expansion and diversification of Electronics, Controls and Computers. In the meantime, in 1963, deliberations gave rise to a 'National Committee on Electronics' chaired by Dr. Homi J Bhabha. Dr. Vikram Sarabhai, Dr. S. Bhagavantham, Dr. A S Rao, representatives of Department of Defence and Communications and other user departments were members of this Committee.

Fig. 1: Pandit Jawaharlal Nehru, Dr. Homi J Bhabha, Shri Thaper and Dr. Rao in Electronics Production Division, AEET, Bombay (Mumbai)

The Committee prepared a comprehensive report covering all major areas of Electronics including Computers, Communications, Components and Consumer Electronics. The report was popularly referred to as Bhabha report. Dr. Bhabha, the visionary clearly set the objective on *achieving self-reliance in electronics* so as to put India on par with the developed countries, modernise Indian industry through new technology and open up vast opportunities for Indian scientists and engineers.

After Dr. Bhabha's untimely death, Dr. Vikram Sarabhai took over as Chairman of Atomic Energy commission. Dr. Sarabhai combined the flair for research with the acumen of a businessman and promoted commercialization of the electronic components, instruments and systems (design, production, market and service) which had initially been produced at BARC, that would enable the country to exploit the benefits and fruits of the R&D carried in the field of electronics.

Against this background, Electronics Corporation of India Limited (ECIL) was established in Hyderabad in April 1967 with Dr. Vikram Sarabhai as its Chairman and Dr. A S Rao as its founder Managing Director.

Fig. 2: Dr. Bhabha, Dr. HN Sethna and Dr.AS Rao during the criticality of Cirus Reactor, AEET, Mumbai

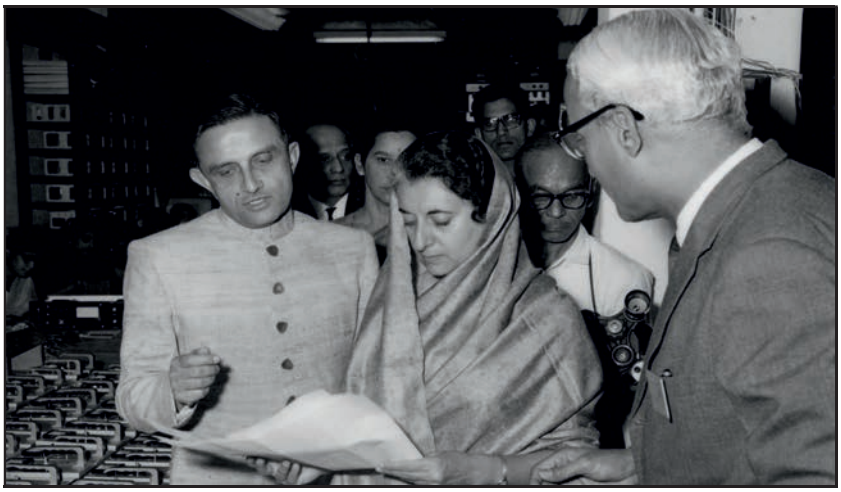

Fig. 3: Dr. Rao along with Dr. Vikram Sarabhai and Smt. Indira Gandhi at Electronics Production Division, BARC

Dr. Vikram A Sarabhai - Founder Chairman of ECIL

Perhaps no other man could be so versatile, and yet so simple, in his thinking as Dr. Sarabhai who could make plentiful contributions in diverse fields as textiles, nuclear energy, chemical technology, cosmic rays, space research and electronics. His acute awareness of the management needs and his gifted insight into the long-lasting potential value of any programme brought forth recommendations that were practical and immediately advantageous to the country. He had realised that the tool of electronics had to be rapidly and properly developed before the tempo of industrialisation and national advancement could be significantly increased. The contribution of Dr. Sarabhai through his work on the Bhabha Committee probably can be described as one of his most significant services to the cause of electronics.

The twin national objectives of self-sufficiency and self-reliance in electronics received due share of Dr. Sarabhai's vigorous futuristic thinking. Dr. Sarabhai believed that at every stage, our technology has to be one which is completely current with the best that is available. With Electronics holding the key to almost all general national development, he saw in its quick advancement an effective bridge of the "welfare gap".

His thoughts on self-reliance are well captured in his speech in 1970 whilst adopting the annual accounts of ECIL for FY 1970-71.

"The success of your company is all the more creditable when it is realised that the aim in indigenous development of electronic systems, instruments and components was to make the country's nuclear programme self-reliant. Having developed the above products at the Bhabha Atomic Research Centre, a bold decision was taken to set up your company, based entirely on Indian technology. At the time it was taken, the decision was bold indeed, for not many organisations had dared to undertake production of sophisticated items based entirely on Indian know-how. It has now been conceded that the reason why our national laboratories have had difficulties in transferring their process know-how to our industries is the gap between a process know-how and industrial production i.e., production engineering. Your company has successfully bridged the gap as is evident from the consistent quality of its products. The success is noteworthy considering that half of your company's products face competition from private sector companies with foreign collaborations."

Fig. 4: Dr. Rao along with Dr. Vikram Sarabhai

Dr. A.S. Rao - Founding Managing Director

Dr. Ayyagari Sambasiva Rao (Dr A S Rao) was associated with India's atomic energy programme since its early stages. In 1953, he joined the Atomic Energy Establishment, Trombay (after the sad demise of Bhabha in 1966, AEET was renamed Bhabha Atomic Research Centre (BARC)) and was involved in designing and building up the control and monitoring systems for the first nuclear reactor in India, Apsara.

During his tenure as Director, Electronics Group, BARC, he initiated and carried out thorough design, development and engineering programmes on a broad spectrum of electronic materials, professional grade electronic components, semiconductors, industrial, nuclear, medical and electronic test instruments. It was under his leadership that the foundation for indigenous electronics development covering innumerable application areas was firmly laid during the early sixties.

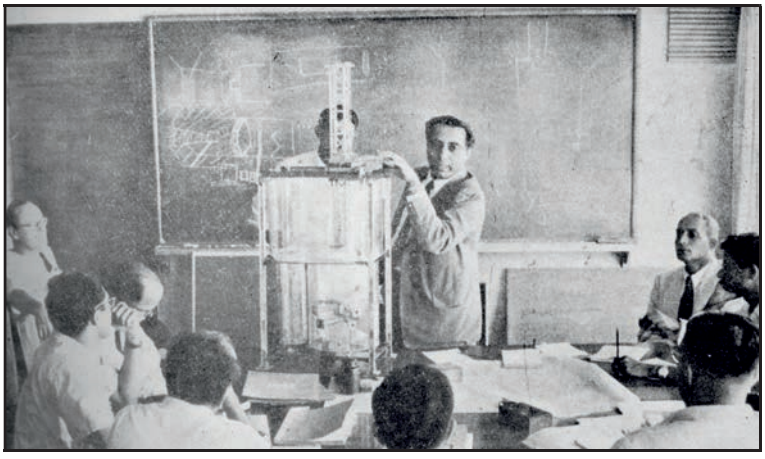

Fig. 5: Dr. Homi J Bhabha during discussions on Apsara design with other scientists

As a member of Bhabha Committee, the blue print for the development of the electronics industry bears Dr. Rao's imprint of practical experience. Dr. Rao provided consistent support to the theme that while foreign collaboration has a useful role to play in certain crucial situations, the main stress has to be placed on indigenous research and development.

As far as Dr. Rao was concerned, it was not a case of mere theorising in the name of self-reliance. His deep conviction in this respect became quite apparent when his division at BARC developed into Electronics Corporation of India Limited (ECIL). It soon became a shining example of productionisation of indigenous technologies in many sophisticated areas. The success story that it presented, was often quoted in support of what could be achieved when Indian scientists and engineers were presented with specific tasks according to well identified needs.

Some of Dr. Rao's thoughts on technology and self-reliance from the lectures he delivered in early 1970's are captured below:

"Science and Technology wither when you put wall around them"

"Throughout my life, self-reliance has been the kingpin of my philosophy and shaped my outlook in life. I believe that self-reliance gives individuals and nations great strength and respect".

"Technology transfer is most effective where the development as well as the organisation-culture gap is small, as was the case with ECIL and BARC. There was like-minded innovative culture on both sides and the phase of teething troubles which ECIL had to pass through had been passed by BARC earlier"

"Though technology is a subject that thrills my mind, the welfare and improvement of the standard of living of the common man of the country is what fills my heart with happiness. It has been my ardent desire that the development of technology should be towards this goal"

Dr. Rao was the Managing Director of ECIL since its inception in April 1967 till his retirement in July 1978. Probably, no other founder of Indian Central Public Sector Enterprises is so completely identified with the organisation he created, as Dr. Rao is identified with ECIL. For many, even now, after more than fifty-five years of its establishment, ECIL is Dr.A.S. Rao and vice-versa. This adoration for Dr. Rao goes beyond the boundaries of ECIL as he selflessly worked towards upliftment of the underprivileged. A locality in the vicinity of ECIL is named A.S. Rao Nagar, probably because of the reflected glory that his name brings!

2. Development of Electronics & Instrumentation

Considering the infancy of electronics industry in India, the AEET in 1952 decided to chart an independent course in the field of nuclear electronic instruments, electronic components and systems. The Atomic Energy Commission, in pursuance of its earlier decision to set up a separate commercial unit for production of electronics instruments and with an aim to cater to entire needs of the country, considered advisable that the unit should separate from the Trombay establishment (which was an R&D establishment).

The initial manpower of about 400 dedicated people drawn from Electronics Group of AEET formed the nuclei, around which ECIL grew. This transfer of people enabled continuity of R&D work carried out at AEET and also setting up of the production facility. Subsequently, many divisions were added and re-grouped. The first production divisions were Nuclear and Allied Instruments Division (NAID), Resistors and Capacitors Division (RCD), Semiconductors Division (SMD), Power Reactor Instruments Division (PRID) and Microwave Division (MWD).

BARC-ECIL's contributions to control & automation activity of the nation's nuclear power programme and related activities can be generically grouped as : (i) radiation detectors (ii) nuclear instruments (iii) control systems (iv) support to key projects of BARC & NPCIL (v) support to the conventional power generation programme (vi) operator training simulators (vii) supportive role in all facets of the nuclear fuel cycle, apart from supplying control & instrumentation packages to a major share of Indian nuclear power plants.

It can be stated without exaggeration that BARC-ECIL could provide self-sufficiency in the field of nuclear instrumentation and control, fully complying with the standards laid down by the regulatory boards. The close ties and working relationships maintained with the BARC on one hand and the end-user i.e. NPCIL on the other hand not only helped the pace of product development but also helped generate a synergy whose benefits cannot be easily quantified.

Considering the innumerable products that were developed from the divisions that moved from BARC, the key products developed that are related to nuclear instrumentation, radiation detectors, control and instrumentation, components, computers and IT, and the continued synergy between the BARC and ECIL are highlighted in the succeeding paragraphs.

2.1 Nuclear and Allied Instruments

The main focus in the area of instrumentation at BARC initially and at ECIL later on, has been on radiation measurement and contamination monitoring with respect to whole human body and in the environment covering air and water.

The efforts carried out in the area of instruments can be summarised with generic grouping of nuclear instruments, analytical instruments, measuring instruments, railway products, biomedical instruments, nuclear medical instruments, instruments for defence, industrial instruments, fibre optics, energy meters and security systems.

In the formative years, the nuclear instruments broadly centered around two categories of user requirements of DAE Units – nuclear research applications and health physics instruments. The Nuclear Instrumentation Bin with power supply, a set of functional Nuclear

Instrumentation Modules (NIM) like HV Unit, linear amplifier, single channel analyser, counter-timer etc., detector units like scintillation heads, GM counters etc. formed the first category.

Health physics instruments have been invaluable to ensure safety and protection of operating personnel in nuclear power plants and radiological installations, those handling nuclear radiation equipment in laboratory, hospitals etc. This safety requirement has always been a priority issue for DAE from inception. To ensure conformity to applicable regulatory stipulations of Atomic Energy Regulatory Board, a variety of health physics instruments were developed / productionised and supplied.

In technological terms, the theme of development had shifted from the traditional transistor based logic, moving coil instruments and deflection meters to instruments deploying Integrated Circuits. The fabrication techniques and interconnection methods tried to keep pace with the state-of the-art processes. The transition from single sided and double sided printed circuit boards to multi-layer PCBs automatically led to miniaturisation and enhanced reliability. The IC based instruments were replaced by microprocessors-based instruments and later on by those based on Field Programmable Gate Arrays (FPGAs).

The first and foremost Production Division that moved from BARC was named as Nuclear & Allied Instruments Division (NAID) and could aptly be regarded as the 'Mother Division' of ECIL. It not only nurtured the growth of many sophisticated lines of instruments but also gave birth to several diverse product segments that had the potential to establish themselves subsequently as independent business divisions of ECIL. The Television Division and the Communication Division of ECIL were born out of NAID during 1973 and 1980 respectively creating landmarks in the history of ECIL over many decades, the former in household entertainment segment with commercial television receivers and the latter in defence communication segment. A division exclusively for mass manufacturing of Electronic Voting Machines was also born out of NAID in the year 2002 and was named Electronic Manufacturing & Services Division (EMSD).

By 1970, the expertise that Instruments Division had gained was well recognized. IAEA, Vienna released an order for halogen quenched Geiger Mueller Counters to meet the requirements at Atomic Energy Establishment in Cairo, Egypt. The plant was set up successfully to the total satisfaction of the customer and IAEA. *This was the first transfer of know-how from ECIL to an organization outside India.*

During the 1970's, Measuring Instruments Division (MID) undertook indigenous design, development and manufacturing of a wide range of oscilloscopes along with necessary accessories. This product stream occupied a dominant position in the ECIL's product line for over two decades. The first 50 MHz plug-in oscilloscope was introduced in 1970 and the 30 MHz storage oscilloscope in 1973. Further, Department of Electronics, Govt. of India, keeping in view the need of the country's fast growing electronics industry, entrusted ECIL with a project for design, development and manufacture of a high frequency oscilloscope. The first ever indigenous 150 MHz Dual Channel Alternating Sweep Oscilloscope of solid state design with many exclusive features was developed and supplied.

The need and the requirement for new instruments as well as instruments with improved features for nuclear research and radiation safety applications were on the increase during mid-seventies. In addition to Electronics Division, other Divisions of BARC like Radiological Division, Computer Division, Environment Assessment Division also started developing instruments for specific applications. For channelising the development efforts in various Divisions and to streamline the transfer of know-how of such technologies, evaluation and to provide a common platform for feedback, a *BARC-ECIL Coordination Committee (BECC)* was formed in the year 1977 with members drawn from BARC and ECIL.

BECC played a significant role in harnessing BARC-ECIL synergy and effected successful transfer of technology for over 75 instruments that served the purpose of import substitution and combating technology denials espousing the cause of self-reliance as envisioned by founding fathers. Further, the technical expertise gained, helped to cater to unique application requirements of users. Special Nuclear Module and Dual Counter-Timer were developed to meet specific experimental needs of 'Dhruva Reactor' during 1985 and Radon Monitor for AMD, Hyderabad for surface exploration of uranium ore in 1988. It also helped ECIL to embark on the development of a variety of advanced nuclear monitoring systems finding varied applications in important installations in the country and enabled export to customers such as Cuban Institute of Nuclear Research.

Fig. 6: Instruments & systems

Fig. 7: Radiation Monitoring Systems

2.2 Radiation Detectors

Several products such as fission counters, ionisation chambers, boron-coated counters, He-3 filled counters, proportional counters and various sensors were designed, developed and perfected at ECIL. Techniques related to uranium plating, laser welding, BF_3 gas generation and purification methods and boron coating are closely guarded technologies of advanced countries. From the time ECIL was incorporated, focused development activity was carried out in the field of detectors, aimed at reliability, miniaturisation and realising state-of-the-art devices. The depth of experience gained helped ECIL understand and absorb technology obtained from elsewhere very fast. The product about which ECIL can be justifiably proud of in this regard is Self-Powered Neutron Detectors (SPND). Effective import substitutes for Local Power Range Monitoring (LPRM), Intermediate Range Monitoring (IRM) and Source Range Monitoring (SRM) were developed and supplied.

2.3 Controls and Instrumentation

While it might not have been explicitly spelt out, Design, Development, Manufacture, Installation and Commissioning of the Control and Instrumentation packages needed for the national programmes related to nuclear power were the implicitly mandated responsibilities of ECIL - as the production agency for the R&D products of BARC.

Starting from the design and development of control systems for the Apsara Reactor, the C&I package for all the operating nuclear power reactors in the country (except RAPS-1 – supplied by Canada and TAPS-1 and 2 – supplied by USA) were designed by BARC/NPCIL and supplied by ECIL, establishing self-reliance and self-sufficiency in this regard. The restrictions placed and the sanctions imposed on India after the Pokhran Experiments of 1974 and 1998 have had minimal impact on this product stream of ECIL. The synergic relationship between BARC-NPCIL-ECIL has been consistently strong and the same is getting extended to IGCAR and BHAVINI in a significant measure.

Servo control devices was an area identified for indigenisation. The servo motors needed for the control rod drive movement and to carry out the emergency shut down procedures of the Apsara Reactor were completely designed and manufactured at AEET.As years went by, new products were added, new technologies implemented, import substitutes realised, products were miniaturised, related diversification was effected and the range of work expanded to touch all the facets of the nuclear cycle, from Exploration and Mining to Reprocessing and Waste Management.

Power Projects Engineering Division (PPED) was carved out of BARC with the designated responsibility of building the nuclear power plants. PPED evolved into Nuclear Power Board (NPB) before taking its present shape as Nuclear Power Corporation of India Limited (NPCIL). ECIL and BARC can be justifiably proud in completing the control and instrumentation of RAPS-2 when Canadians walked away after India tested the nuclear explosive device for peaceful purposes for the first time in 1974.

ECIL supplied the total control and instrumentation systems required for MAPS-1 & 2 and RAPS-1 & 2. The instrumentation was designed by the Electronics Division of BARC and engineering, production, testing and qualification was carried out by ECIL.

The control & instrumentation of NAPS, after a decade of MAPS-1 & 2, again was truly indigenous in concept and construction – realized with joint efforts of BARC, PPED and ECIL. Since the Narora plant was in the seismic zone, all the subsystems and systems had to be subjected to seismic qualification tests.

Concurrent with the control and instrumentation systems design efforts at BARC, ECIL initiated the parallel developmental work related to India's first Programmable Logic Controller (PLC), a path breaking effort of those times at ECIL.

Introduction of computers was a major technological shift in Narora. Computer based displays and replacement of push buttons with keyboards were introduced. Reactor Control Division of BARC played a pioneering role in the design of control systems for nuclear power reactors for computerizing on-line fuelling process for PHWRs. The robots deployed to handle the fuel feeding and withdrawal process were controlled by computers for the first time in India. ECIL's TDC-312 was used for the purpose. A special computer language called Process Control Language (PCL) was developed; the entire fuelling process was meticulously converted into PCL programs. The prototype system developed at BARC was successfully engineered, technologically upgraded, manufactured and supplied to Narora plant. This was the first real time computer system successfully implemented for a critical process in nuclear power plant in India and remains as a landmark in indigenous technology.

Establishment of quality system and production processes to meet the nuclear power plant control and instrumentation requirements was the hallmark of Narora plant equipment. NPCIL was not only the driving force behind the establishment of this world class quality system but also created the requisite facilities like seismic testing facility at ECIL.

A steering committee was set up with members from NPCIL, Reactor Control Division of BARC and ECIL to implement a major technological upgradation for the next nuclear power plants that came up simultaneously at Kaiga in Karnataka (KGS-1&2) and Rawathbhata in Rajasthan (RAPS-3&4) and this committee gave shape to the future C&I systems.

A set of common hardware and software modules which can be used across different reactor control systems was developed by BARC. Concurrent engineering and manufacturing was the hallmark of different computer based systems supplied by ECIL to Kaiga-1&2 and RAPS-3&4.

Concurrent with the development of computer based control systems for these plants at BARC, efforts were going on for the technological upgradation of Programmable Logic Controllers (PLC) and Data Acquisition System developed by ECIL. A variety of features and subsystems were added to the data acquisition system that was rechristened as Computerised Operator Information System (COIS).

Another path breaking work done was the development of electrical Supervisory Control and Data Acquisition (SCADA) System for the monitoring and control of generators and switchyard equipment of nuclear power plant.

The experience gained in developing simulators for thermal power plants came in handy for nuclear plants. ECIL worked closely with NPCIL and supplied Training Simulators for operator training to Kaiga and Rajasthan plants.

ECIL was associated with BARC for the development and supply of control systems required for a special project at Kalpakkam. ECIL supplied the C&I systems and training simulators for the Prototype Fast Breeder Reactor (PFBR) at Kalpakkam. The prototype C&I systems for PFBR were developed by IGCAR and ECIL undertook the engineering, manufacturing and testing of these systems.

ECIL has also taken up the development and manufacturing of the systems required for special applications along with BARC. Further, the 2nd and 3rd phases of the Indian Nuclear Power Programme hold out lots of promises and challenges to ECIL in its C&I Programme.

Fig. 8: Major Products and systems of Controls and Instrumentation

2.4 Components

The development of electronic components was initiated at AEET as early as 1962, much before the Bhabha Committee report was published. ECIL's component activity was an unqualified technical success even if it was not a commercial success. The component base for electronic products in India has been historically weak and it continues to be so.

The components that were developed and produced indigenously were wire wound resistors and wire wound potentiometers of single turn which were used in entertainment electronics. The pioneering spirit nurtured by Dr. Bhabha enthused the Electronics Division of AEET to commence ab-initio developmental work on electronic components notwithstanding the fact that there was neither the required knowledge nor the required equipment readily available with the establishment.

There was a healthy interaction of ECIL's team with VSSC for production of space quality resistors. This resulted in the production of established reliability Metal Film Resistors (MFRs) for which lot of procedures and practices had to be formalised and documented. This work had enhanced the prestige of ECIL and earned accolades in realising excellent import substitute for Metal Film Resistors.

The developments were seriously curtailed by the globalisation forces and the inability of the company for making large scale investments for mega volume production levels.

Fig. 9: Components manufactured at ECIL

2.5 Computers & Information Technology

The investment on computers was truly an 'investment on people' as Dr. Vikram Sarabhai prophesised way back in 1971. Computers and Information Technology are areas wherein the contributions of ECIL have had a nation-wide effect in terms of skill generation, technology base creation and nurturing of high calibre techno-managerial talent which played a pivotal role in the IT revolution in the country in the years to come. Apart from scoring several 'firsts' in the country in terms of computer hardware development, ECIL's achievements in system software development and application software development are accomplishments of the highest order. If one could go back in time and assess the quality and quantum of work done 35-40 years back, the accomplishments are truly breathtaking.

21st January 1969 is a red letter day in the annals of Indian science and technology - it was on this day that the first Indian built electronic digital computer was commissioned by Dr Vikram Sarabhai at BARC.

Fig. 10: Dr.A.S.Rao with Dr.Vikram Sarabhai and Dr.H.N Sethna during launching of first indigenous computer, TDC-12 at BARC

Fig. 11: TDC-12

3. ECIL -Business Environment Over the Years

The primary activities for ECIL mandated in its formative period, were to productionise the components, instruments and systems developed and engineered at AEET. Ever since its formation, ECIL had a remarkable growth in size, turnover, product range and the number of persons employed despite being the first ever undertaking of its kind in the field, based entirely on indigenous know-how. Between the period 1967 to 1977, ECIL achieved an annual growth rate of nearly 80%. The company attained breakeven operations within three years of formation, making a maiden profit of Rs. 1.4 million during 1970-71, the fourth year of operation.

From the process of transferring know-how from BARC to ECIL, many useful lessons have been learnt, which related to the most favourable conditions required on both sides, the givers and the receivers. One of them is that technology is most effective where the development gap as well as organisation-culture gap is small, as was the case with ECIL and BARC. There was like-minded innovative culture on both sides and the phase of teething troubles which ECIL had to pass through had been passed through by BARC earlier.

Fig. 12: The First Board (from left to right: Shri N.B.Prasad, Shri M.A.Hadi, Dr.A.S.Rao, Dr. H.N. Sethna, Dr. Vikram Sarabhai, Dr. Brahm Prakash, Sri Rai Mathai)

The pioneering efforts of BARC and ECIL resulted in several products that positioned the company as a torchbearer of the electronics and IT revolution in India. EC-TV and EC computers were the flagship products during the 1970's. This phase was characterized by an explosion of indigenous products, infectious enthusiasm, a young workforce and growth in manpower.

During the 1980's there was all-round development of electronic industry in the country. So, to be competitive in the market and to achieve faster growth, 'leap frogging' strategy by importing know-how in selected areas was being pursued. Hence, R&D focus shifted from basic equipment and components to high end products and systems to meet the specialised requirements of the customer.

During 1990's, liberalisation and privatisation unleashed fierce market forces. With the high cost of development and given the inherent limitations of public sector, surviving in a highly competitive field with products of in-house development became extremely difficult. R&D necessarily got limited to adaptive R&D and R&D for niche market, having specialised requirements.

The impact of the process of globalisation and the economic liberalisation was being acutely experienced by ECIL from 1995-96 and the growth of the company was tapering off. Though the company was registering profitable results in the period 1992-1997, the margins came down drastically and the stresses of competition were intense, both from the multi-national companies (MNCs) and the private sector. The company incurred a loss in 1997-1998 and 1998-99 resulting in eroding net worth of the Company. The company was on the brink of sickness and had to be reported to BIFR.

The problems got accentuated in the year 1998-99, when ECIL was included in the Entities List by the U.S. Department of Commerce implying total clamping of embargoes on exports to ECIL on all items of U.S. origin. Several other western countries followed suit and the operations of the company in the year were adversely affected.

The steps taken by the company to locate alternate sources and the R&D initiatives taken to develop some of the sub-systems denied by advanced countries took time to fructify. The period 1997-99 witnessed several challenges for ECIL that threatened the very existence of the company.

Concurrent with approaching the parent department and the Government of India for extending help to the company to tide over the crisis, ECIL took several corrective steps to strengthen its operational base, organisational restructuring and business development. Support from DAE, coupled with demand for fuzes for Indian army, concurrent NPP and general elections during the period helped the company to consolidate and proved vital for the recovery and resurgence of the company. As a result of corrective measures with refocused approach on special electronics, the company achieved a total turnaround in three years' period 1999-2003, in both quantitative and qualitative terms. Since than the company operations have been profitable. The turnaround was recognized and rewarded by various organistions in the form of Awards given to ECIL.

The Fourth Decade (1997-2007) was characterized by more rapid advances in technology with a higher degree of obsolescence not witnessed hitherto. Increased meshing of technologies of computer hardware and software as an integral part of the design of electronic equipment and systems. In the new era of open technological competition that was being experienced on account of liberalization of economy, a conscious shift of product mix from standard applications to special applications, covering the domains of Atomic Energy, Defence, Space, Civil Aviation and applications for societal benefits was undertaken.

The unique ability of ECIL to effectively deploy computer hardware and software technologies on all varieties of electronic equipment in instrumentation, control & automation, RF communication, telecommunication, antennas etc., has been of great advantage to ECIL in harnessing the requisite skills to effectively combat technology denials from time to time.

Further, to strengthen R&D, a Technology Development Council comprising of various experts from DAE and ECIL was formed to approve and review R&D Projects pursued with grants from DAE. ECIL further recognized the advantages of working closely with national R&D institutes of repute. This paved the way for development of a number of advanced technology products and systems in collaboration with various Defence Labs, Department of Space, Ministry of Communication and Information Technology etc.

In the last decades, ECIL has grown into a company with an average turnover of Rs 1500 Cr. In line with its Vision and Mission, the company is currently focusing on high technology and low volume projects of national importance in the chosen areas of electronics and activities in Nuclear, Defence, Aerospace, Security, IT & e-Governance.

4. Contribution to Other Key Sectors

A brief account of the genesis, current work and contributions to sectors other than nuclear is given in the following paragraphs.

4.1 Defence

Immediately after the Chinese war in the early nineteen sixties, the need for indigenous development of several electronic systems and products for defence applications was keenly felt. Variable Time Fuze was a product chosen by Dr. Bhabha for development at AEET. The development and user trails were successful and Electronic Fuze became a reality. It was decided by Dr. A.S Rao and other senior colleagues at BARC that Electronic Fuze will be productionised at ECIL. This was the entry point for ECIL into the Defence arena.

The early seventies were a period when the need for indigenisation of electronics was strongly felt by Indian Defence. Marconi, UK was the only company in the world known then to manufacture Personal Locator Beacons (PLB). PLB, operating on three international distress frequencies became a reality in mid-1976. In fact, the PLB radio was awarded an 'Import Substitution Award' in February 1987. The supplies to Defence continued till 1994 after which PLB was phased out in view of reliable satellite communication.

Sound Ranging System towards identifying the type of guns like 135 mm / 155 mm or mortars by signature analysis from a distance of 15-20 km was developed. Expendable Bathy

Thermograph (XBT) was developed for Navy, based on Naval Physical & Oceanographic Laboratory (NPOL) knowhow. Automatic data handling systems, encompassing 150 consoles were delivered to Air Force by end of 1990.

Today, ECIL harnesses its expertise in electronics and communication technologies to meet India's defence needs on land, sea and air. The portfolio includes C^4I systems, radiocommunication products, electronic fuzes, antenna products, satellite communication systems, sensors and actuators, stabilization platforms, electronic warfare systems, communication intelligence systems and crypto solutions.

Fig. 13: Major Defence Products

4.2 Aerospace

ECIL's Aerospace Division was established in 1968 when ARVI Satellite Communication Group was constituted by Chairman, AEC, by drawing experts from various organisations to design, develop, manufacture, install, test and commission the country's 1st INTELSAT Class-A Earth Station Antenna at ARVI, Pune for providing the gateway for overseas communications. The MASEG R&D group of ISRO was merged with ECIL in 1972 and Antenna Products Division was formed to take up commercial production of microwave and earth station antennas.

In recognition of its domain expertise, ECIL was awarded the design, manufacture, supply, installation, testing and commissioning of 32M Deep Space Network IDNS Antenna for the country's first unmanned Lunar Mission (Chandrayaan-1) and Mars Orbitor Mission (Mangalyan) programmes of ISRO. This high precision antenna was installed at Bylalu near Bengaluru.

ECIL has partnered with Department of Space in all its endeavours starting from Satellite Instructional Television Experiment (SITE) to the moon mission project Chandrayaan-1. As a technology collaborator of the Department of Space, ECIL delivered several types of earth station antenna systems for communication, tracking, telemetry, command and monitoring for both Low Earth Orbit (LEO) Satellites and Geo Stationary Satellites.

ECIL has established ground station at Antarctica to receive satellite data and networked with National Remote Sensing Centre (NRSC), Hyderabad and National Centre for Antarctica & Ocean Research (NCAOR). Goa. An Imaging Major Atmospheric Cerenkov Experiment Telescope (MACE) was built for BARC and was assembled at the campus of Indian Astronomical Observatory at Hanle.

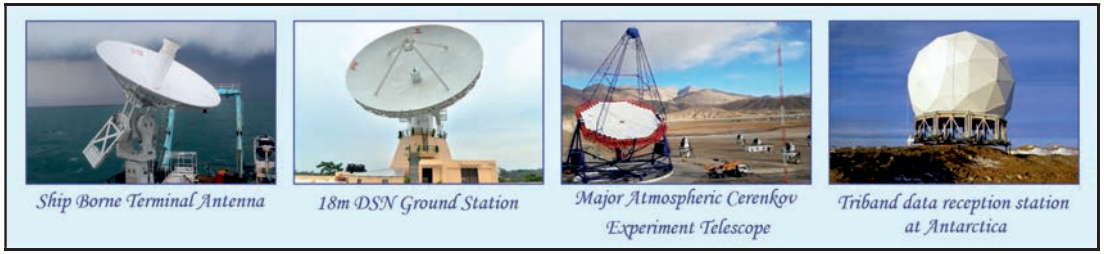

Fig. 14: Major Products for Aerospace sector

The vertical continues to provide products/solutions for DSN, satellite communication and research antennae. It is foraying into CFRP based antenna systems.

4.3 Security Sector

It is a matter of pride that the indigenous security product stream was pioneered in India by ECIL. The development of closed circuit television monitor, the basic entity of the security system was started in 1970 and ECIL commissioned its first system at Security Press, Dewas. For monitoring the launch operations of SLV II in 1982, ECIL developed and delivered a CCTV system to SHAR, ISRO.

Over the years, the company made great strides in the security sector by developing expertise over a wide range of products spanning detection, protection and mitigation aspects of the security solution encompassing perimeter protection, video surveillance with advance analytics, personnel access control, vehicle access control, explosive detection, fire alarm, CBRN protection, personnel / baggage and container scanners technologies.

An integrated security system for the Commonwealth Games at New Delhi, as well as security systems for the Indian Parliament, several state secretariats and VIP residences have been established by ECIL. Leveraging the state-of-the art technology and the experience, ECIL is presently executing various security projects for vital installations.

Fig. 15: Major Security Products

4.4 IT and e-Governance

ECIL in close association with BARC was instrumental in building the digital computer named Trombay Digital Computer TDC-12. The configuration of the 12 bit TDC-12 system

was a modest-4k ferrite core memory, 12-bit processor and a teletypewriter as the input / output device.

TDC-12 for scientific real-time and business applications was followed by TDC-312, TDC-316, TDC-332. The first microcomputer in the country developed by ECIL was released in the year 1978, it was called Micro 78.

In the days of proprietary software, ECIL had to develop its own Operating Systems, language processors, utilities, conversion programs and several application packages. ECIL developed the complex and mission critical Automatic Data Handling system (ADHS) for Air Defence Ground Environmental System (ADGES). This system was intended to identify the nature of the aircraft hovering on the Indian skies and take appropriate counter measures.

Banking applications were also pioneered by ECIL. Front office automation software BASIS was very popular with Banks. Criminal data analysis was carried out by Indian Police with the help of ECIL's systems. Flight data analysis developed by ECIL was used by Indian Airlines to process flight information related to Air bus aircraft. The availability of this indigenous system helped avoid transportation of the flight record data abroad for analysis.

The Directory Enquiry System, the Dial 100 systems are other noteworthy systems developed by ECIL for use by DoT and Police.

Secure Network Access System (SNAS) and Integrated Threat Management Appliance (ITMA) are the two indigenous network security products from ECIL to protect the enterprise network from internal and external cyber-attacks and other threat vectors.

ECIL which had been focusing on commercial data processing applications and hardware sales shifted its focus to e-Governance applications and other applications for societal benefits like Information Dissemination Systems for Agricultural and Market Yard applications. The torch-screen Kiosk received country-wide recognition.

Statewide automation of Road Transport Authority at Kerala and the Sales Tax Automation project implemented in Maharashtra are realized through sizeable Wide Area Networks.

4.5 Electronic Voting Machine (EVM)

If TVs and Computers were ECIL's flagship products once, it is Electronic Voting Machines (EVMs) today. EVMs stand as a shining example of an India-specific technology, designed and developed in and for the country.

It was in early 1980s, that Shri S. L. Shakdhar, the then Chief Election Commissioner of India paid a visit to ECIL to explore the possibility of obtaining an electronic solution to meet the needs of the Indian election process. The design team at ECIL developed an EVM to accommodate 4 candidates. The machine was designed to work on AC mains. ECIL than came out with a machine based on non-volatile counters that can accommodate 8 candidates with built in power pack employing commercially available battery cells. Over the period the EVM has gone through various design changes and has matured and put to extensive use in public domain since General Elections 2009 and performed to the expectations of the Election Commission. The EVM has successfully replaced the conventional ballot paper

method of voting and has revolutionized the election process in India. The EVMs were also manufactured and supplied to the neighboring counties Bhutan and Nepal.

Fig. 16: Major Products for IT & e-Governance Sector

4.6 International Discovery Science Programs

In the 1970s the company invested heavily in R&D for railway locomotive technologies, but had to discontinue the activity as users opted for the import route in preference to indigenous development. Power electronics activity was revived again when opportunities arose in international discovery science projects – LHC at CERN, FAIR in Germany, ITER in France and Fermilab in USA. ECIL along with design support from DAE units has been instumental in supply of systems to international science discovery programmes. These contributions are enumerated in the succeding paragraphs.

ECIL is among the institutions, which contributed to setting up the Large Hadron Collider (LHC) facility at CERN (European Organization for Nuclear Research) in Geneva, where the theory of the Nobel prize winning physicists Francois Englert and Peter Higgs was confirmed with the discovery of the Higgs particle. Under CERN-DAE Collaboration, ECIL supplied and commissioned at CERN breaker control modules (BCM), quench discharge local protection units (QDLPU) and quench heater power supplies (QHPS).

The successful and timely completion of the project at CERN established ECIL as an organisation capable of meeting international commitments and opened up opportunities to participate in upcoming major international projects such as ITER at France and FAIR at Germany.

4.7 Power Convertors for FAIR

The initial discussions on Indian participation in FAIR were started in 2009 steered by FAIR task force. The committee had members from BARC, VECC, RRCAT and FAIR, Germany. ECIL's participation was identified and Working Groups were formed in the areas of FPGA systems, power converters, SCADA systems etc. Bose Institute, Kolkata has been

designated as the Indian shareholder in the FAIR Company and the nodal Indian institute for management of FAIR programme from India. An Indo-FAIR Co-ordination Centre (IFCC) has been established by Bose Institute, Kolkata which has been authorised as the implementing body of the Indo-FAIR Programme.

ECIL signed bi-partite contract with Bose Institute, Kolkata in 2012 for the supply of ultra stable power converters to FAIR/GSI, Germany. The design organisations under DAE viz., VECC Kolkata, BARC Mumbai and RRCAT Indore provided technical support, design review and requisite guidance and ECIL undertook the manufacturing.

Power converters are used to power the normal and super conducting magnets that accelerate high energy particle beams. The power converters being designed and manufactured by ECIL comply with the European Standards. They range in power rating up to 360 kW.

4.8 High Voltage Power Supplies for ITER

International Thermonuclear Experimental Reactor (ITER) is a fusion based test reactor coming up at Cadarache, in the South of France. ITER aims to demonstrate nuclear fusion as a clean green source of energy. India's contribution to ITER includes delivery of various in-kind packages. The packages to be delivered involve first of its kind development of materials, technologies and quality to meet with the stringent nuclear safety norms of the French regulatory board and also ensure that the components work for the lifetime of ITER. As part of the programme ECIL, with design support from IPR, Ahmedabad has supplied high voltage power supplies.

Fig. 17: Products/systems for International Discovery Science Programs (Power Convertors and High Voltage Power Supply Modules)

4.9 Key Technogies/Products- the Trend setter

Over the year, ECIL pioneered the development of various complex electronics products and scored several **'firsts';** prominent among them are depicted in *Fig. 18*.

In line with the vision of founding fathers, the corporation has endeavored indigenous development of products/systems of national importance. The recent achievements in RF Seeker, PLC are significant technological products that have been realised in collaboration with DAE, DRDO units and qualify as true Atmanirbhar Products/Technologies and ECSCADA has been developed in-house by ECIL. A brief on these is enumerated below

4.10 RF Seeker

RF seekers are radars which help to guide a missile towards a fixed or manoeuvring target in terminal guidance phase of its flight. Once a target is acquired, an RF seeker locks on to the target and provides real time update of the target parameters such as range, look-angle and their rates.

Seeker is a complex high end technology equipment and only a few countries in the world have the capability to manufacture and supply seekers required for the missile programs. At present most of the seekers required for our missile programs are imported. However, with the support of BARC and DRDO, ECIL has developed Ka and X band RF seekers indigenously.

The development of X band seeker required for BrahMos started in 2010 with development order from DRDL and the same was delivered in 2016 after successful functional and qualification tests. Based on the initial success, DRDL entrusted ECIL with additional order for seekers. With success of flight trials, India is in the elite club of seeker manufacturing countries.

4.11 Indigenous Programmable Logic Controller (PLC)

ECIL has been a pioneer in the development of PLCs in the country. The first PLC was developed and launched in 1978 and successfully implemented in a large number of steel plants, cement and other process industries. There after the PROGICON series was launched in 1980. The PROGICON series PLC was installed in nuclear power plants of NPCIL in the areas of Emergency Transfer System (EMTR), Station PLC for safeguarding critical loads across plant, emergency airlock system for reactor building and heavy water vapour recovering systems. The MPROGICON series was launched in 2012 and was installed at IPRC, ISRO, BARC, IGCAR, RMP Mysore, UCIL, NFC and NPCIL. The development of advanced PLCs and Digital Distributed Control Systems (DDC) in respect of both hardware and software including MMI with design and development centered around very advanced processors found application in thermal power plants and NPP simulators.

With an aim to consolidate and address the requirements of DAE and other national critical infrastructures, ECIL, BARC & IGCAR came together to jointly design and develop a Safe and Secure PLC (NUCON1000 & 2000 Series). The NUCON (1000 & 2000) series PLC was launched on 18th May, 2022. The product incorporates safety and security features for applications in special applications and has already been deployed for applications in space and nuclear sector. Towards testing distributed control system, a test bed consisting

Fig. 18: ECIL's Firsts

of 32 node block and 9 node block NUCON-1000 PLCs interfaced with SCADA servers has been set up at ECIL. The performance evaluation of important parameters like cycle time, switchover time among redundant components, system response time etc. for large I&C applications can be undertaken and the test bed also facilitates application development, application change management, associated testing and validation before deployment of the application at plant site.

Fig. 19: Indigenous technological products

4.12 ECSCADA

A reliable, flexible and high-performance Supervisory Control & Data Acquisition (SCADA) software for industrial automation has been developed by ECIL. The software package has been developed in three different variants mainly Unix, Linux and Windows platforms. The ECSCADA has been in use in large number of installations across India. The Oil & Gas SCADA Systems supplied by ECIL to the Indian Oil & Gas Companies are excellent examples of indigenous efforts in high technology applications. ECSCADA was deployed in various sites for oil sector such as IOCL, BPCL, HPCL, CCKPL, HMEL projects. Further, Electrical ECSCADA software was supplied to steel sector such as DSP, BSP, RSP plants of SAIL. The package was supplied to a number of DAE units at various sites.

The journey of ECIL since inception is depicted pictorially in *Fig. 20 and 20a.*

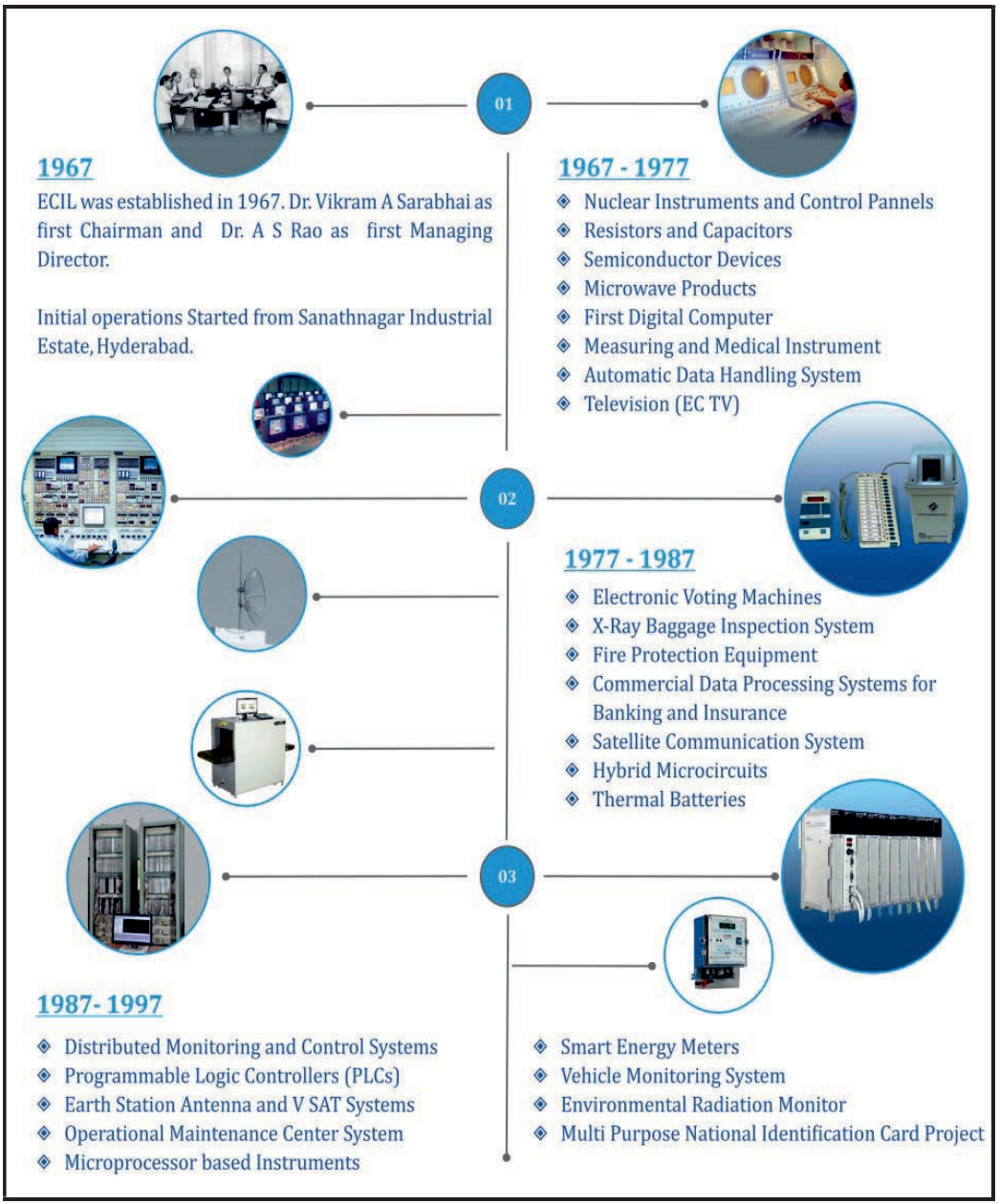

Fig. 20: Journey of ECIL in terms of Technologies/Products since inception

Fig. 20 a: Journey of ECIL in terms of Technologies/Products since inception

5. Way forward

Electronics systems are ubiquitous and the necessary basis for the economy and have far reaching implication in development of new technologies. ECIL, the electronic arm of the DAE over the past five plus decades, not only met the prime objective of becoming self-reliant and self-sufficient in the field of Control & Instrumentation for the Indian Nuclear Power Programme but has also emerged as an important national asset in the field of special electronics. The pioneering spirit displayed by the company with support of BARC and DAE units from its formative period has enabled it to realise several noteworthy products and systems needed in the domains of atomic energy, defence, space and security sectors in addition to few other fields of social or economic significance to the Country.

ECIL is poised to meet the technological challenges involved, given the internal strengths, focus and the springboard of developmental support from premier national R&D institutions of Atomic Energy, Defence and Space. The umbilical connections with BARC and the developmental linkages with other DAE Units like IGCAR, VECC and RRCAT have resulted in a strong technology base for catering to the requirements of the Atomic Energy Sector. Similarly, the development association with Defence Research and Development Organization (DRDO), Aeronautical Development Authority (ADA) etc. have enabled ECIL to enhance its product base and project execution capabilities in the defence Sector. The strong relationship forged with Indian Space Research Organization (ISRO) is paving the way for executing technologically complex projects of national relevance in the space sector.

Whilst the synergy with BARC and other DAE institutes continues to be strengthened, with the changing business dynamics, ECIL is constantly adopting and collaborating with industry and academic institutes to further 'Atmanirbhar Bharat' and Make in India Initiatives.

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