

National Technology Day special issue

# Dream

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## SELF RELIANT INDIA THROUGH TECHNOLOGY

VIGYAN SAMACHAR

ENERGY

INFRASTRUCTURE

COMMUNICATION

IT REVOLUTION

SYSTEMS



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# CONTENTS



4

**Vigyan Samachar**



5

**SELF-Reliant India: Energy**



**SELF-Reliant India:  
Infrastructure**

11

19

**SELF-Reliant India:  
Communication**



26

**SELF-Reliant India:  
IT revolution**

31

**SELF-Reliant India:  
systems**



# Beyond self-reliance

**Pokhran is a village near Jaisalmer. On May 18th, 1974, it came into prominence when Pokhran-I happened. Twenty-four years later, on May 11th, 1998, Pokhran-II happened. Pokhran-I and II are two important dates in the history of India's technological prowess. These dates commemorate two successful nuclear tests. After the successful tests in 1998, former prime minister Shri Atal Bihari Vajpayee declared May 11th National Technology Day. Thus, the first National Technology Day was celebrated on May 11th, 1999. Since then, this day has been celebrated as National Technology Day. A number of programmes and initiatives all over the country will be organised throughout the country to celebrate this day.**

With more than 4000 graduate-level institutes of technology and a similar number of polytechnics, the nation requires a thrust into technological research & development. More and more research funding to develop new socially useful & productive technologies should be brought to the fore. For this, more and more collaboration with technologically advanced organisations should be emphasised to ensure that available resources can be aptly utilised. Our country, for that matter, still has a huge reserve of untapped resources. Whether human or natural resources, technology has a huge field open to be applied upon.

A number of recommendations from time to time have been proposed to ensure that our technology do more than what it has so far. For example, utilising available land patches in areas conducive to building a new and planned township with all smart facilities, augmenting the manufacturing sector to turning self-reliant in every domain and much more. The recent semiconductor crisis world over coerced us to become self-reliant in this domain. Similarly, regarding vaccines, we responded to the call positively and showed that, yes, India could do it!! But, this is a reactive approach. It's important that we step ahead of others. We must become the leader and further enhance our innovation. It's Amrit Kaal. This is the most favourable period for us to excel. This innovation requires a very different level of thinking and practically realizable execution. Technology forecasting at both levels, tactic and strategic, is required.

Before preparing any documents, using the available subject matter experience is important. Our academies and universities of engineering & technology have a huge pool of certified technocrats. It's, thus, time to further strengthen these academies by providing support in terms of enhancing public-private partnerships and overseas collaborations and establishing annual world-level recognitions to achieve a higher position in the global innovation index (GII). We have come a long way at the GI where we are in the top 50 today. However, we should stay inspired by Swami Vivekananda, who said, "Arise! Awake! And stop not till the goal is reached".

On the science communication popularisation & extension (SCoPE) end, we continue to add more and more Indian languages. Please join me in welcoming our newest addition—Bigyan Utkalika (SCoPE-in-Odia) and thanking a number of enthusiasts from the Odia-speaking scientists and BKIC, Bhubaneswar, who made this happen.

Summers have arrived, and not much to counter global warming is evident. Thus, prevention is the only bet. Please stay safe!



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## NEW DEVICE FOR EARLY DETECTION OF HEART DISEASE

Indian Institute of Technology Madras (IIT-Madras) researchers have developed a novel, non-invasive device to assess the health and age of blood vessels and thereby provide early screening for cardiovascular diseases.

Called ARTSENS, it is designed such that it can be used in routine medical examination by even non-experts, to assess and predict vascular health. It is powered by a proprietary non-imaging probe and an intelligent computing platform and is developed by the Healthcare Technology Innovation Centre (HTIC) at IIT Madras.

The device has been assessed on

more than 5,000 human subjects. The technology already has five utility patents in the U.S., European Union and India, 10 design patents and awaits awarding of 28 patents in various jurisdictions.

## RODENTS LIKELY TO BE ORIGIN OF THE OMICRON VARIANT

The Omicron variant of the SARS-CoV-2 virus may have originated from rodents, according to scientists. The scientists are investigating the means through which SARS-CoV-2

contracted so many mutations in the pandemic's second year and suggest that reverse zoonosis, circulation in rodent population and subsequent spread as a zoonosis probably led to the evolution and emergence of the Omicron VOC.

The researchers from Christian Medical College, Vellore, and other Indian institutes have proposed their theory in a paper published in the journal *Current Science* for the likely origin of the Omicron variant of SARS-CoV-2, the virus causing COVID-19. A previous study had suggested that the Omicron variant of the SARS-CoV-2 virus may have been transmitted from an animal species to humans.

## METAMATERIALS CAPABLE OF MAKING BUILDING FOUNDATIONS EARTHQUAKE RESISTANT

Researchers, from Indian Institute of Technology (IIT) Mandi, have proposed a 2D metamaterial-based foundation for protecting buildings against earthquakes. The research, detailed in the journal *Scientific Reports*, showed that a metamaterial foundation can help reduce damage to structures and offer protection to people living in earthquake-prone regions of the world.

The team used two-dimensional metamaterials. A metamaterial is created by assembling multiple elements made from composite materials like metals and plastics, usually arranged in repeating patterns that are smaller than the wavelengths of the phenomena they affect, such as earthquake vibrations or seismic waves.

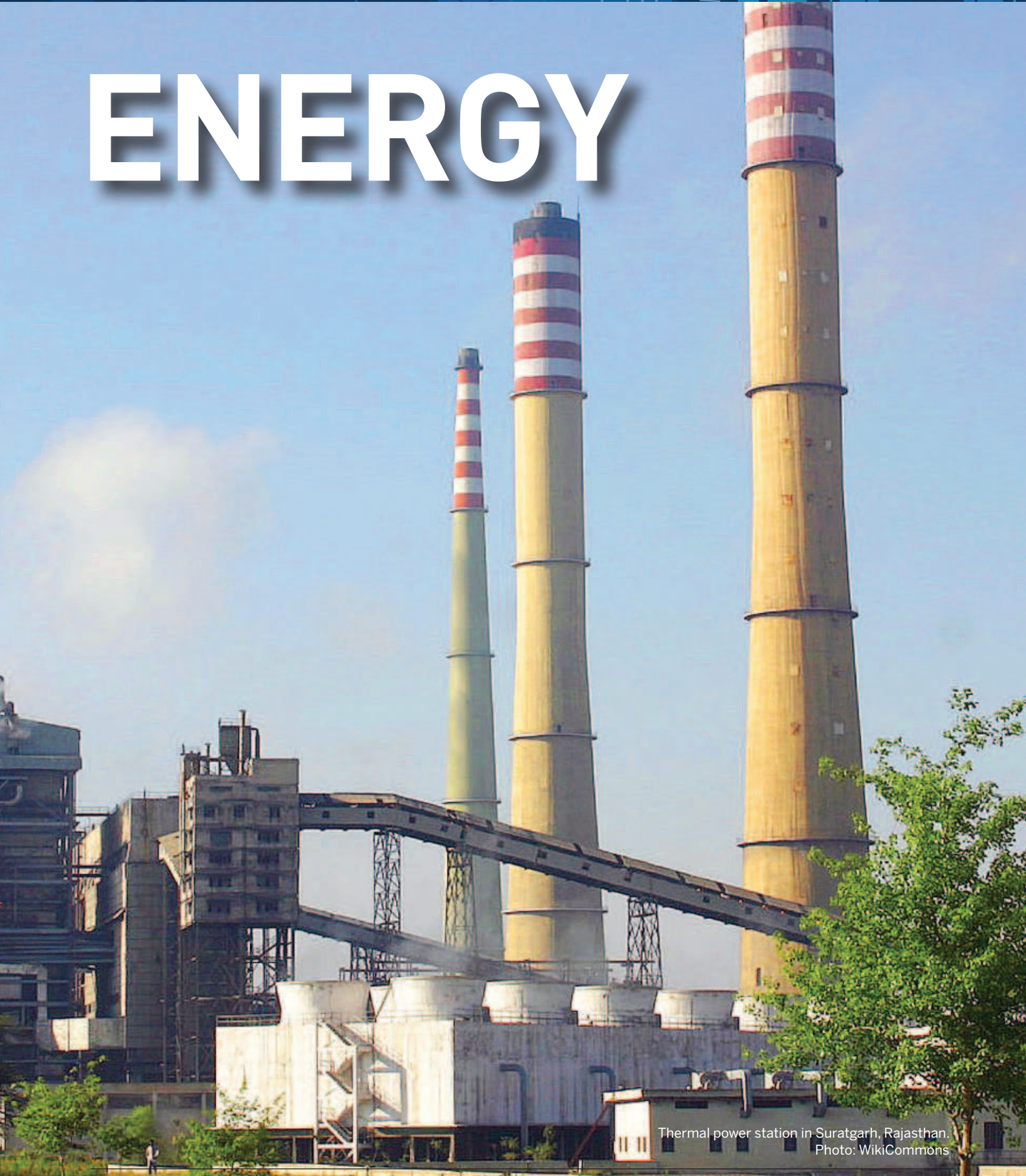
Seismic waves are elastic waves that transport energy through the Earth's layers. Unlike other types of physical waves, seismic waves have long wavelengths and low frequencies.



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# ENERGY



Thermal power station in Suratgarh, Rajasthan.  
Photo: WikiCommons

**E**nergy Sector plays vital role in the economic growth and human development of any country. One of the most commonly used forms of energy in the world is electrical energy. It can be easily converted into any other form of energy and can be efficiently transmitted over long distances. Electrical energy consumption is one of the most important indices for measuring the development of a nation. The energy sector of India is among the most diversified in the world. Sources of electrical power generation range from conventional sources and nuclear power to viable non-conventional sources. Electrical energy demand in the country has increased rapidly and is expected to rise further in the years to come. In order to meet the increasing demand for electrical energy in India, massive addition to the installed generating capacity has been taken up over the years since independence.

Indian energy sector focuses on tapping the available resources for generating electricity, transmitting it and utilizing it for economic development. Technology upgradation has been undertaken in all areas of transmission for increasing efficiency and improved economic operation in the course of last 75 years. UHVAC as well as HVDC systems have been built almost entirely with indigenously developed technologies and are in operation. To facilitate exchange of power and optimum utilisation of available electrical power generation facilities, the transmission system in India has evolved through fascinating engineering developments over the last seven decades, into a fully integrated national grid having one frequency.

Because of the successful implementation of UHV power transmission technology, electrical power generated from conventional as well as renewable sources is delivered to all parts of India on a large scale from a long distance to meet the demand for electrical energy and alleviate the strain on the local environment. India, being centrally placed in South Asian region, is spearheading mutual cooperation

amongst neighbouring countries and resource sharing in the region by power network interconnection through UHVAC/HVDC transmission lines.

India is presently the 3rd largest country for electrical power generation and is committed to meet or even surpass Conference of the Parties 21 (COP 21) commitments through renewable energy

in India. Innovative mechanisms in market pricing and revenue protection are opening up more opportunities for electrical power exchange between regions. Indian power sector is leveraging markets for transition towards a more transparent, efficient and cleaner power procurement strategy for better grid integration of renewable energy. The



Nagarjuna Sagar Dam. Photo: WikiCommons

adoption, energy efficiency measures and use of clean fuels. The ultra-supercritical (USC) technology has potential to solve two major bottlenecks of coal-based power plants, viz. less coal and lower CO<sub>2</sub> emission per megawatt generated. As major production of electrical energy in India is achieved through coal-based power plants, Indian power generating sector is continuously striving to design, manufacture and commission higher-efficiency and low polluting coal-fired power plants using USC technology. Large scale grid connected solar and wind plants are usually located in the far-flung areas, which require an expansion of grid connectivity. Consequently, significant development in the power transmission sector has been triggered by the expansion plans for renewable energy.

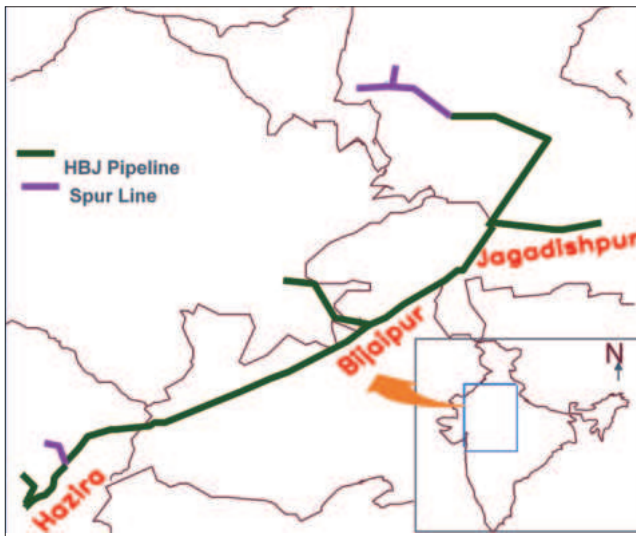
The electricity market is still evolving

paradigm shift in the Indian energy sector will increasingly influence and shape the global energy economy.

#### **INSTALLATION, COMMISSIONING & OPERATION OF HBJ GAS PIPELINE NETWORK**

HBJ (Hazira-Bijapur-Jagdishpur) is India's first cross state gas pipeline. The pipeline runs from Hazira, Gujarat through Vijapur, Madhya Pradesh to Jagdishpur, Uttar Pradesh. The project was started in 1986 after the incorporation of Gas Authority of India Limited (GAIL) to supply gas to the fertilizer plants located in the state of Uttar Pradesh. The first phase of the project consisting of non-branched 1,750-kilometre grid was commissioned in 1987.

Later the system was expanded with additional branches to supply gas for



HBJ Pipeline

industrial and domestic use in the states of Rajasthan, Haryana and National Capital Territory (NCT), which increased the total grid length to 3,474 km. In year 1998, newly established Indraprastha Gas Limited took control of the Delhi branch of the pipeline to set up a citywide gas grid. It has branches to Kota in Rajasthan, Shahajahanpur, Babrala and other places in Uttar Pradesh.

HBJ Gas Pipeline also has the distinction of being the world's largest and the longest underground pipeline. It runs alongside 6 States (including NCT), 69 rivers, 300 roads and numerous railway crossings across India and supports several industries along the gas pipeline route. The pipeline network comprises the following significant features:

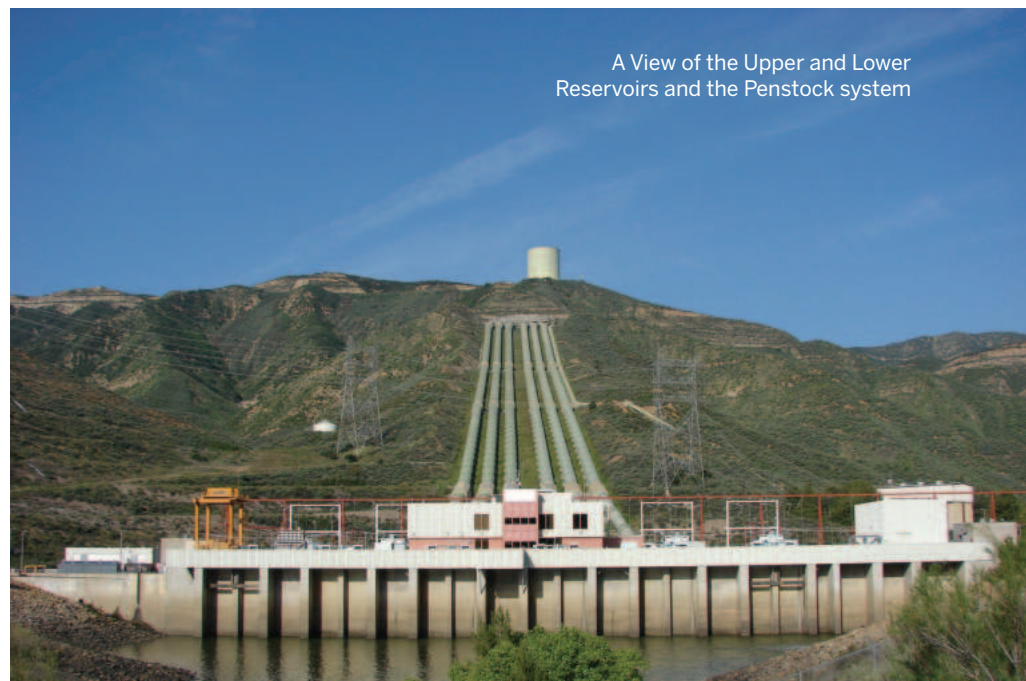
The installation of HBJ Gas Pipeline had been a major engineering challenge in terms of its sheer magnitude as well as a significant contribution to the energy and manufacturing sectors, as well as the overall economy of the country. It feeds to several fertilizer plants, indirectly contributing to the agriculture sector. It has made Piped Natural Gas (PNG) available to households for domestic use and Compressed Natural Gas (CNG) network available for automotive consumption. The use of PNG and CNG (cleanest amongst the fossil fuels) for cooking and as automotive fuel has had a huge impact in terms of improving the

quality of environment, particularly in metros and big cities where air pollution had been a major issue.

#### **PURULIA PUMPED STORAGE HYDEL PROJECT (PPSP)**

"Pumped Storage" is a novel concept in sustainable solutions to real-life problems. In a pumped storage project, the power is drawn from the Grid in the lean period to pump up the water to the upper reservoir and draw down the water to the lower reservoir when power is needed. It employs the use of reversible

turbine pumps and generator/motors and the same Penstocks/ pressure pipes, as well as conserving water, since the same water goes up and down. The main objective of PPSP is to meet the peak load demand of the system and utilize excess available power during off-peak time, hence flattening the load demand curve. The other key purpose is to strengthen peak-time power supply capacity by constructing pumped storage of a 900 MW (225 MW x 4 generating units) capacity with related transmission and substation facilities in Purulia District,



A View of the Upper and Lower Reservoirs and the Penstock system

State of West Bengal, in eastern India, thereby contributing to the economic development of the region.

Pumped storage Hydro is the World's largest energy storage system. It is the most effective as far as the Renewable Energy (RE) integration is concerned. Pumped Storage Technology is also the only long term technically proven, cost-effective, highly efficient and operationally flexible way of energy storage on a large scale and available at short notice.

### WORLD'S HIGHEST AC VOLTAGE TRANSMISSION LINE TEST STATION AT 1200 KV IN INDIA

At the turn of the century, India intended to make accelerated progress in introducing high voltage power corridors to evacuate bulk power from the existing and proposed Ultra Mega Power Projects. By the year 2005, India had a large 400 kV AC network and a 765 kV AC super grid was planned as an overlay. However, it was thought prudent to plan the next higher voltage level to support the 765 kV AC network and the  $\pm 500$  kV DC network. The next higher AC voltage option was 1200 kV. It was decided to involve transmission line designers and manufacturers in India to fine tune system design parameters through a hand-on experience before launching commercial projects.

UHV transmission at voltage level beyond 1000kV was tried in USA (AEP), Italy (CESI), Russia, Canada (HQI), Venezuela and Japan between 1970 and 1990. The challenges of 1200 kV system was 'reliability', which depended on the insulation coordination studies. Design of important hardware like transformer, circuit breaker, isolator, current transformer, capacitive voltage transformer, surge arrester and towers were influenced by corona inception voltage, frequency and intensity of lightning activity, wind velocity, altitude and seismic considerations, which are different for different countries.

This 1200 kV test transmission system made it possible for the first time to optimize parameters for Indian condition and gave an opportunity



1200kV AC test station at BINA

to Indian manufacturers to establish their credentials. The project at Bina in Madhya Pradesh was conceived in 2007; the test line was charged in Jan 2012 and the project was commissioned and dedicated to the Nation in Dec 2012. Stage II of the project at full power was commissioned in 2016.

Power Grid Corporation of India Ltd (PGCIL) coordinated the building of this Ultra HVAC testing station at world's highest ac voltage of 1200 kV.

The 1200 kV test station is a giant step towards 'Make in India', bridging the technology gap with advanced countries and invigorating the mindset of Indian Engineering community. This achievement has been discussed in several international fora like IEEE and CIGRE. Commercial proposals for connecting Wardha to Aurangabad and other UHV power corridors have now been launched.

### SOLAR & WIND ENERGY INTEGRATION TO INDIAN POWER GRID

India has made remarkable progress in recent years in bringing energy services to its citizens. In less than two decades, more than 900 million people have gained access to electricity and the energy demand of the country has more

than doubled over the same period. India has already crossed 210 GW of peak demand in June 2022. The Indian power sector has already achieved the coveted milestone of 100 GW of installed renewable energy capacity in August 2021 with a high pace of integration of wind and solar energy. Maximum energy from solar and wind farms in a day has reached 16% of the total energy generation and the installed capacity of solar and wind stands at 23% of the total capacity.

India has achieved 70-80% of indigenization of wind turbines and 44 different models of wind turbines are being manufactured in India. The solar sector has also achieved tremendous growth with domestic manufacturing capacity of around 2.5 GW for solar Photo Voltaic (PV) cells and 9-10 GW for solar PV modules, annually.

The short gestation period of renewable energy plants requires transmission to lead generation and corresponding upfront investments. Accordingly, a comprehensive scheme covering strengthening of power transmission systems at intra-state and interstate level has been evolved under Green Energy Corridor (GEC) for about 43 GW of renewables from 8 renewable energy rich states.

Ultra-Super Critical Thermal Power Plant at Khargone



### ULTRA-SUPER CRITICAL THERMAL POWER PLANT AT KHARGONE

The Ultra Super Critical Plant located at village Selda & Dalchi, Dist. Khargone, State of Madhya Pradesh, comprises two numbers 660 MW each coal based thermal power generation units, Khargone is the first thermal power plant in India using Ultra-Super Critical

technology. It has achieved an efficiency of 41.5%, which is 8% more than that of a conventional subcritical 500-MW unit and 3% more than supercritical units using similar coal, resulting in significant reduction of CO<sub>2</sub> emissions.

The completion of the project was a key step in the Government of India's program to develop an Advanced Ultra

Super Critical (AUSC) plant using indigenous technology. It marked a new evolution in India's quest for High-Efficiency Low-Emission (HELE) installations. The experience gained from building indigenously and operating the USC plant at Khargone is now extended to build and operate an 800MW coal-fired AUSC power plant using indigenous technology at Sipat in Chhattisgarh.

Fast Breeder Test Reactor (FBTR)



### INDIGENOUS DEVELOPMENT OF FAST REACTORS FOR SECOND STAGE OF NUCLEAR PROGRAMME

The importance of nuclear energy, as a sustainable energy resource for our country, was recognised at the very inception of our atomic energy programme in the 1950s. A three-stage nuclear power programme, based on a closed nuclear fuel cycle, was then chalked out. This was envisaged by linking the fuel cycle of Pressurized Heavy Water Reactors (PHWR) in the first stage, Fast Breeder Reactors (FBR) in the second stage and self-sustaining <sup>232</sup>Th–<sup>233</sup>U reactor systems in the

third stage for judicious utilization of India's moderate uranium and vast thorium reserves.

India is poised for rapid growth in nuclear power capacity which is essential for meeting the demand for clean energy with practically zero carbon footprint.

Indigenisation of the design and the complete nuclear fuel cycle has provided technological self-sufficiency in the strategically vital areas of high-tech manufacture and construction, along with the development of a huge pool of highly skilled human resources.

Nuclear power provides a reliable source of clean energy to meet the stable base load requirements and, in combination with renewable sources being increasingly deployed, it can meet the challenging national targets to combat climate change.



The Kaiga Atomic Power Station in Karnataka



External view of DHRUVA Nuclear Reactor

### **DHRUVA NUCLEAR RESEARCH REACTOR**

DHRUVA is a 100 MWth Research Reactor using natural uranium metal fuel and heavy water as both moderator and coolant which provides high neutron flux for advanced research in basic sciences and engineering. "Dhruva", a truly indigenous reactor, Construction of Dhruva was an important milestone towards development and implementation of indigenous nuclear

reactor technology in India. Dhruva is an example of a viable system, engineered within the limited means available.

Dhruva Reactor is an outstanding example of what Indian science, engineering and industry can achieve when compelled to rise to the occasion. Dhruva is a major source of radioisotopes being used in the production of radiopharmaceuticals for health care, water resource development and management using isotope hydrology,

nuclear agriculture and food processing, and in the industry for imaging, non-destructive testing and evaluation, etc. Refurbishment activities of Dhruva reactor are being planned to continue its operation till 2045.

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The content of the article is taken from the book "Landmark Achievements in Engineering and Technology in Independent India" published by Indian National Academy of Engineers through Vigyan Prasara

# SELF-RELIANT INDIA: INFRASTRUCTURE

NH-16 Vijayawada Guntur  
section at Mangalagiri.  
Photo: WikiCommons

The growth of economy of any country depends on the quantity and quality of its infrastructural and industrial facilities viz., buildings, highway and railway bridges, strategic structures, power plant structures, pipelines and pipeline networks, tunnels, waterways, dams, ports, harbours, transportation systems including metros, energy infrastructure, infrastructure facilities for urban and rural development and growth, transmission line towers, communication towers, campus development, etc. which are expected to serve for more than 100 years. The construction of these structures requires huge resources and investment, apart from deploying innovative designs and construction techniques.

Realising the above, when India attained independence in 1947, the development of infrastructure in various sectors got a big fillip and many projects were executed by teams of owners, designers, and construction agencies. However, the capabilities and capacities of the latter two were falling short, to a certain extent, as the homegrown agencies were still in an early stage of development. The saga of this capacity development over the last 75 years is best seen through the Landmark Projects, which have great visibility, novelty, uniqueness and are illustrative of the Nation's progressive march.

Keeping in line with the priorities as perceived by the national leaders and visionary engineers from time to time, the projects covered infrastructure in the areas of water resources, energy, transportation, defence requirements, power plant structures, energy, transmission and communication lines/towers, stadia, tunnels, pipelines, ports and harbours, transportation sectors, etc. The Landmark projects included in this compendium under the sector of "Infrastructure" represent examples of novel, iconic and exclusive structures/infrastructure created for society. There are some others, which could not be included because of paucity of space.

Many projects came up in the area of hydro and thermal power, besides the

development of nuclear power projects being a triumph of Indian science and engineering during the nuclear technology denial regime. The dams built for producing energy, also helped to meet the needs of irrigation, an iconic forerunner being the Krishna Raja Sagar (KRS) dam in Mysore, which was the brainchild of a great Indian engineer, Dr. M. Vishweshwaraiah. Another outstanding example in the context of irrigation schemes is the Kaleshwaram Lift Irrigation System (KLIS), currently the world's largest multi-stage lift irrigation project, whose farthest upstream influence is at the confluence of the Pranahita and Godavari rivers. The Pranahita River is itself a confluence of various smaller tributaries including the Wardha, Painganga, and Wainganga rivers which combine to form the seventh-largest drainage basin on the subcontinent, with an estimated annual discharge of more than 6,427,900 acre-feet (7,930 cubic hectometres) or 280 TMC. The project is designed to provide irrigation facilities for 16,40,000 acres in drought-prone areas in 7 districts in Telangana State, besides providing drinking.


Facilities were added for handling petroleum products in the coastal areas. A significant example was the Fourth Oil Berth at Butcher Island, Mumbai where the technology for prefabricating large diameter concrete caissons in a dry dock, towing them on high seas, and placing them in position in deep waters was demonstrated for the first time. The development of such marine project technologies also came to good use for the Indian Navy's Seabird project in Karwar which combined huge land and sea development for the construction of a very modern, multi-purpose naval base, despite encountering challenging soil formations. To consolidate the defence needs further and to ensure rapid access to border areas in the Himalayan regions, several tunnels were constructed overcoming stupendous terrain and climatic problems. Underground construction technologies also developed quite well for such projects and were put to good use for projects for strategic

storages, as for instance, the Cavern for storing liquid LPG 200 m below ground level in Vizag.

Several strides were also made in the area of transportation. The Airports in Metropolitan cities and tier-II cities are some of the best examples of re-use and re-conditioning of facilities using indigenous and innovative technologies. On the roads/highways front, the National Highway Authority of India spearheaded several highway projects including the outstanding Golden Quadrilateral (GQ) project of 5846km length passing through 13 states of India. Launched in 2001, it became operational in January 2012. GQ project included construction of new express highways, including renovation and extension of the existing highways to four or six lanes. The project was estimated to cost `600 billion but was one such project which was completed at about half of the estimated costs at `308.58 billion. Metro projects also developed in various urban centres and Kolkata and Delhi Metros pioneered this development with many different forms of viaducts and tunnels. Precast segmental construction of viaducts became very popular, after its initial demonstration in a project of Southern Railways at Aroor-Kumbalam in Kerala where precast segmental construction was used for the first time for railway projects. Indian bridge engineers also implemented several challenging projects. The very tall piers were slip-formed and the deck was constructed by innovative Incremental Push-launching technology.

Capitalising on the technology developed for the construction of tall structures, several skyscrapers, such as Palais Royale, Mumbai, were also built. Celebrating spiritual aspirations, as great examples of architectural aesthetics, the Baha'i Lotus Temple came up in New Delhi and an ultra-large statue of Lord Shiva came up in Nathdwara, near Udaipur.

The above are standing examples of development and deployment of several new and innovative construction practices and technologies introduced to meet the grand challenges effectively with



the creation of assets that are sustainable with reduced dependence on natural resources. Clearly, as civil engineers, one can observe beyond the development of new and innovative/novel technologies, that in creating these landmark assets, there are other grand challenges that need to be met to create assets that boast of long span bridges, largest stadia, tallest monuments, etc. These challenges are not of scaling but of deployment of innovative technologies be it planning, design, execution, construction, enabling works, procurement of natural resources, and the final finishes, as in none of cases normal rules, norms, practices, etc. would apply! Many of the nearly seemingly impossible outcomes could be achieved by synergistic involvement and efforts of several Indians who had a vision to make 'hypotheses' and "abstracts" materialize.

The Krishna Raja Sagara dam beside the Brindavan gardens in Karnataka. Photo: WikiCommons



Bird's Eye View of the Narendra Modi Stadium, World's Largest Cricket Stadium

**NARENDRA MODI STADIUM: THE LARGEST CRICKET STADIUM IN THE WORLD**

Narendra Modi Stadium, located in the Sardar Vallabhbhai Patel Sports Complex, in Ahmedabad is the largest cricket stadium in the world with a seating capacity of 1,32,000. The stadium was constructed in place of the old Motera stadium, for which the foundation stone was laid in January 2018. The expansion and renovation was completed in February 2020 and the stadium was opened to the public with the inauguration by the President of India.

India has been a hub of international cricket and the sport is immensely popular amongst people from all walks of life on a PAN India basis. Being a host to the best and the biggest cricket stadium with ultra-modern facilities supported by state-of-art technology is natural and befitting to the cricketing status of the nation. The stadium has the potential to be the preferred venue for the upcoming 2023 Cricket World Cup Final.

### TALLEST STATUE IN THE WORLD – THE STATUE OF UNITY

The iconic 182m tall statue of Sardar Vallabhbhai Patel is built, at Sadhu-Bet Island (3.5kms south of Sardar Sarovar Dam at Kevadia in Narmada district of Gujarat) on the Narmada River. The site is located between the Vindhyachal and Satpuda Ranges rising near the Narmada River, impounded by Garudeshwar, the Sardar Sarovar Dam, and the town of Kevadia.

The Statue of Unity is a fitting tribute to the Iron Man of India who played a vital role as the first Home Minister of the country in shaping up the geopolitical boundaries of independent India. The statue is a matter of pride for all citizens and the site is a source of attraction to global ecotourism.

An imposing view of the statue



### MAJESTIC UNDERGROUND TUNNELS

Underground structures assume a strategically important role in the overall space of infrastructure development for a nation. Out of various applications where underground structures are put to good use, storage and transportation are some of the key areas concerning strategic requirement as well as day-to-day needs of common population. Underground storage is deployed for supporting the energy infrastructure and creating a buffer stock of fossil fuels like LPG for energy security. On the other hand, tunnels are particularly critical to create an efficient surface transport infrastructure to provide rapid access to border areas in the Himalayan region for civil and defence requirements. At the same time, to build them is an equally daunting task while overcoming stupendous terrain and extreme climatic conditions.

Some typical examples are illustrated here to demonstrate the challenges of the task as well as the impact of their fructification in meeting the national requirements.

Atal Tunnel, on Manali-Leh Highway, Himachal Pradesh

The Patnitop Atal Tunnel, two-lane 9.02 km long, is currently the longest single tube highway tunnel in the world; at an altitude of 3000 m, and is equipped with electrical system, semi transverse ventilation system, emergency call box, turning cavern, egress tunnel at bottom, hydrant type firefighting system and access control system integrated with Tunnel Control System. This tunnel bypasses Rohtang Pass, which reduces the distance between Leh and Manali by 46 km and the journey time by 4 hours. Facilitating two-way traffic, it is designed to cater to up to 3,000 vehicles per day in any weather conditions at a maximum vehicular speed of 80 km per hour. The work on the tunnel was completed in August 2020.

### NOVEL & MAJOR DAMS OF INDIA

Dam is a structure built across a stream, a river, or an estuary to retain water. Dams are built to provide water for

human consumption, for irrigating arid and semiarid lands, or for use in industrial processes. They are used to increase the amount of water available for generating hydroelectric power, and, to reduce peak discharge of floodwater created by large storms. Thus, dams can be used to store water, control flooding, and generate electricity. Many types of dams were constructed across India post-independence as a follow up of the Krishna Raja Sagar (KRS) Dam. Each of the large number of such dams, envisioned, designed and constructed subsequently, during the post-independence period, stand out as landmark symbols of indigenous

engineering capabilities, comparable to the best anywhere in the world. The major dams in India have helped the inhabitants in a number of ways such as: i) providing adequate water for domestic, industry and irrigation purposes, ii) generating hydroelectric power and river navigation, iii) the reservoirs providing recreation areas for fishing and boating and iv) helping in the reduction of floods.

### **METRO TRANSPORTATION SYSTEM IN INDIA**

Worldwide, India is ranked second after China in regard to the pace in installing and expanding Metro Rail in its cities. The operational total length as on April 2021

has reached 720 km. Further, at present about 500 km is under construction or extension in various cities. The fast-paced implementation of Metro Rail in several mega cities and Tier-II cities has become a main constituent within the Governmental Transport and Traffic Policy for urban development.

Metro Rail in India, meeting the demand for Urban Mobility, is a success story for its fast-paced legislation, planning, financing, construction, and operation; and in the last 20 years has significantly improved Urban Mobility and changed the face of public transport in several Indian cities boosting socio-economic development.

### **POLAR RESEARCH INFRASTRUCTURE**

India has created “Polar Research Infrastructure” strategically in Antarctic and Arctic regions. The Ministry of Earth Sciences (MoES), Department of Space (DoS), Electronics Corporation of India Limited (ECIL) /Ministry of Electronics and Information Technology (MeitY) have steered the efforts related to design, development, erection and establishment of three stations at Antarctica and an Earth Station at Bharati.

India’s presence and its science investigations in the Arctic region helped it to become a member of Ny-Alesund Science Managers Committee, for enhanced cooperation and coordination for research at NyAlesund International Arctic Research and Monitoring Facility. India’s research at Arctic also helped it to gain permanent observer status in the Arctic council.



Bharati Antarctic Research Station. Photo: WikiCommons

High Level Viaduct over Panval Nadi.  
Photo: WikiCommons



### ICONIC BRIDGES OF INDIA – ARCHITECTURAL AND ENGINEERING MARVELS

A bridge is a structure made of metal or concrete that connects one end to another, be it roadways or railways. As basic as that might sound, construction of bridges overcoming challenges posed by the nature and geography is one of the biggest engineering achievements of human civilization. Bridges have helped changing the lives of people; they have provided people access to the outside world, made their life easier, and opened opportunities, both literally and metaphorically.

A large number of road, rail, and multi-modal bridges have been built in post-independence India across major rivers and seas in different parts of the country. Bridges have been constructed in places where it seemed impossible, over rivers, high altitude areas, and even mountains.

The first ever bridge in independent India was built in Prestressed Concrete for the Assam Rail Link in 1949. This was followed by the 3.2km long Sone Bridge at Dehri (1965) and Bassein Creek Bridge (the first long span continuous bridge, 1970). Since then, India has come a long way in building some of the best structures for flyovers, expressways and bridges. Some significant examples are presented here as being illustrative of national capabilities and achievement in the area.



Chenab Rail Bridge (World's Highest Altitude Railway Bridge)

Bogibeel Bridge. Photo: WikiCommons



Vande Bharat Express. Photo: WikiCommons



## TRAIN 18/VANDE BHARAT TRAIN

Technology in transportation / locomotive segment has undergone a sea change. A modern train set is one without any locomotives with two cabs at the ends and all the equipment for powering and hotel load mounted under the floor, leaving all the space on board for passenger amenities. Such a train was a long time coming in the Country. The first rolling stock which is truly Indian in origin from concept to design to engineering to manufacture to validation, has been achieved in the form of "Train 18/Vande Bharat Train" It has immense benefits on pan India stage due to great benefits like faster acceleration and deceleration, elimination of reversal, reduced travel time, lower energy consumption, better aesthetics, improved maintainability and export potential.

Challenge driven development work for "Train 18/Vande Bharat Train" was started at Integral Coach Factory (ICF), Chennai in 2016. The motivation was also that support industries in India had reached near world-standard in certain key areas. The need was to channelize the available resources and energy to bring out something noteworthy to fruition.

The Team-ICF decided that it would design and manufacture a train set for 180 km/h capability with modern features, the first, the best in India. The team was enthused but some of the team members had reservations in that they had not done anything at this scale ever and what if they failed. They were motivated to go ahead, develop the technology and

fabricate and manufacture based on the technology a product which was non-existent in the Country.

A matrix of the characteristics and requirements of a modern train was made, and it was found that these could be met, but for most of three areas, bogie design, exterior finish and interiors, where some hand holding was needed. It was decided to engage European Consultants, who had no stake in future supplies like ToT companies, to develop the relevant designs in total hands-on association with ICF engineers and with clear understanding that full IPR would rest with India.

A project of this magnitude takes 36 to 42 months from concept to actual turn out of the prototype but ICF had the challenge to complete the task within 21 months. The team was motivated to deliver the train before 21 months. As the train was to be developed and put on rails in the year 2018, it was called Train 18.

What followed was history in the making. Hard work and travails, a hitch here and a roadblock there. Problems galore but solution soon, with great synergy. All's well that ends well and come 27th October of 2018, the train was unveiled in a specially organised

ceremony and an electrically charged atmosphere never seen before in any railway factory. Train 18 had lived up to its name twice over, not only was it turned out in 2018 itself but the project took exactly 18 months from drawing board to prototype turn out. The proudest moment ever for ICF.

After the turn out the train was taken for extensive on-line testing for worthiness and safety and came a day in late November 2018 that it breached the 180 km/h speed in test with all parameters well within the safe limits and it was soon certified fit for commercial operations. It was commissioned in 2019.

The first train was launched as Vande Bharat express by the Hon'ble Prime Minister of India. The Train 18/Vande Bharat Train was deployed on Indian Railways services, Delhi-Varanasi and Delhi-Katra route. The trains are in service for nearly three years without any hitch, a feat not paralleled by even any imported rolling stock so far.

The content of the article is taken from the book "Landmark Achievements in Engineering and Technology in Independent India" published by Indian National Academy of Engineers through Vigyan Prasara

# SELF-RELIANT INDIA: COMMUNICATION

**T**oday, life without communication technology is impossible. Communication is all pervasive. Moreover, India has the world's second largest Telecom network with a subscriber base of 1.178 billion. At 765 million, India has the second largest Internet user base in the world. Communication technology is not just a multibillion-dollar industry, it is the backbone for all industries. Great strides in Information technology and

related services would not be possible without communication technology. During the pandemic we remained connected because of communication technologies. Many day-to-day activities continued and work from home was enabled because of communication technologies.

In this compendium we look at communication technology in its broadest sense: Communication technologies include mobile communication, Internet

technology, broadcast technologies, satellite communication, radar technologies, radio technologies, fibre-optic communication, and many other related technologies.

The impact of telecom is too wide, and few articles cannot do justice to it. The committee deliberated extensively and tried to come up with certain topics that they felt were significant to be included in this compendium. There are eight articles, that are believed to

**The Doordarshan tower, located at Rameswaram is unique in design being the tallest free-standing tower in RCC and Steel, with open foundation resting on rock.**

Tallest TV/Doordarshan Tower at Rameswaram.  
Photo: WikiCommons

reasonably capture the broad spectrum of communication technologies that have made a significant impact.

Selected articles deal with satellite communication, communication in electronic warfare, digital switches for telecom exchanges, Internet technologies, and radar technologies. One article on a very fundamental and recent contribution made by Indian researchers, often referred to as the merger of 5G and 5Gi has been included. This is profound because for the first time R and D work done in India on wireless communication has been incorporated as part of 5G standards by Third Generation Partnership Project (3GPP).

The purpose in the compendium has been to give a glimpse of the contribution that Indian communication researchers in academia, research labs and Indian telecommunication industry, have made in the last 75 years.

Presently, India's telecom sector is the third largest sector in terms of FDI inflows and contributes 8% to GDP. India has the second largest subscriber base of 1.18 billion in telephony and 750 million in Internet service. Major developments have occurred in telecom sector during the last 40 years.

The impact of telecom in India has been very dramatic. Today, besides 850 TV channels, India has 40 OTT platforms which have, by and large, taken over TV. Aggregated services (Ola, Zomato, Flipkart, etc.), financial services (UPI, Paytm, online banking), and many other services became viable because of Internet access. India's telecom network has played a big role in keeping many activities alive during the pandemic, making work from home and virtual education possible. Telecom will continue to play a significant role in all digital initiatives and missions to meet the challenges of and fulfil the opportunities of future.

### **ELECTRONIC WARFARE SYSTEMS**

DRDO has developed a number of "Electronic Warfare Systems" indigenously. The R&D activities in the domain are well positioned and began in the year 2000. Indigenously developed

Electronic Warfare systems acting as a force multiplier with multi octave frequency coverage and enhanced EW Capability of Tri Services for Space, air, surface and sub-surface platforms.

### **Samyukta**

Samyukta is an indigenously developed integrated electronic warfare system. It is a hierarchical system with two distinct segments, Communication segment (Com) and Non-Communication segment (Non Com). The Communication and Non-Communication segments consist of a number of entities forming the basic building blocks to perform Electronic Support Measures (ESM) and Electronic Countermeasures (ECM) functions. The Communication segment of Samyukta is capable of searching, intercepting, monitoring, analysing, location fixing and jamming of hostile communication signals. The Non-Communication segment of Samyukta is capable of intercepting, identifying, tracking and jamming of hostile radar signals.

### **Sangraha**

Sangraha is a joint EW programme which encompasses five different types of indigenous EW systems consisting of KITE for helicopters, EAGLE and HOMI for aircrafts, PORPOISE for submarines and ELLORA for ships. The systems are being used for coastal and maritime EW surveillance and self-protection requirements.

### **Divya Drishti**

Divya Drishti is a ground based distributed, passive Communication Intelligence System for Interception, Monitoring, Direction Finding, Analysis and Recording of communication emitters in different frequency bands. The system is integrated through a secured communication network for voice and data fusion across the system. This integrated advanced Communication Intelligence gathering system consists of Static and Mobile Surveillance Stations spread across the Country. The system provides Real-Time Situational Awareness about adversary flying activities.

### **Varuna**

Varuna is an advanced ESM system for various classes of naval ships, operating in different RF bands with high Probability of Intercept (POI) and sensitivity along with accurate direction finding and parameter accuracy to intercept and report conventional as well as complex Radars.

### **Dolphin-II**

Dolphin-II is an ESM system for submarines, operating in wide bands. It is a compact system with Broad Band Receiver and integrated Radar Finger Printing System (RFPS). Production is in progress.

### **Dual Colour Missile Approach Warning System (DCMAWS) for Fighter Aircraft**

Dual Colour MAWS system operates in the mid IR band for identifying the approaching missiles of all generations. The spectral information of two colours is used to discriminate efficiently between sunlight reflections, background radiation and the radiation from the missile. DCMAWS is installed in a pod and flight evaluated successfully on a fighter aircraft.

### **Himraj**

Himraj Ground Based Mobile ELINT System (GBMES) operates in the wide frequency range covering both communication and Radar bands. The system is capable of interception, analysis and location fixing of radar signals and interception, monitoring of communication signals. GBMES comprises of one Control Station (CS) and three Receiving Stations (RxS) integrated in master slave concept to search, detection, monitor, record and process the hostile emissions as well as to find the location of the emitter fulfilling the strategic EW requirements of the Country.

### **Shakti**

Shakti is an integrated EW suite for capital ships, with ESM and ECM segments. The ESM segment has both broad band and narrow band reception capability in

order to meet the strategic and tactical requirements. The ECM segment is equipped with Multi Beam Jammer employing Digital RF Memory to support wide range of jamming techniques.

#### **Nayan**

Nayan is a ship-borne advanced COMINT system. It consists of Scan DF System with Monitoring and Analysis Receiver for detection, parameter estimation, signal analysis, demodulation and decoding. Commissioning of system has been commenced with production in place.

#### **Sanchay-II**

Sanchay-II is an Electronic Warfare Operational Support System (EWOSS) with high security level to provide operational support for the mission. It provides EW data management, Mission library generation and Post mission data analysis.

#### **Kautilya: Satellite Based ELINT System**

DRDO has designed and developed space based Electronic Intelligence (ELINT) system to gather intelligence from space about radars located on earth. Space ELINT system involves characterization and estimation of direction of arrival of radars and transmitters using Satellite as platform which provides ability to intercept data not accessible by ship/land/airborne systems. The development activity in Kautilya being the first space-based EW project for DRDO, it was a challenging task to understand the dynamics of space. The dedicated and committed efforts by Indian scientists led to successful integration, testing and evaluation of ELINT Payload with EMISAT satellite. The application software, for posts pertaining to ELINT Data Processing at Ground Control Station is developed indigenously.

The research and technological developments have resulted in total production orders worth `4,394 Crores till 2010 and `7,300 Crores during 2010-2022 from Indian Navy on Bharat Electronics (Prime Production Agency). It resulted in creation of a robust

indigenous industry base of more than 300 industry partners which includes SMEs and MSMEs.

#### **COMMUNICATION AND BROADCAST SATELLITE SYSTEM**

The Satellite Instructional Television Experiment (SITE) conducted, in the year 1975 helped India gain experience in the field of satellite broadcasting and led to creation of Indian National Satellite (INSAT) system. The Indian Space Research Organisation (ISRO) responsible for the development, has been leading the endeavour since then. The communication and broadcast satellites are deployed at different orbital slots in geo stationary orbit. The associated ground and user segment are installed across the Country.

The INSAT-1 series satellites were based on a unique three-in-one (broadcasting, telecommunication and meteorology) multi-function system designed to meet India's needs in a novel and innovative manner. With the experience gained from INSAT-1, ISRO indigenously designed and developed the second generation three axis stabilized INSAT-2 series of satellites, having higher capacity compared to the first generation INSATs.

The INSAT-3, INSAT-4 and GSAT series have embraced advanced technologies with enhanced power and coverage capabilities operating in a wide range frequencies UHF, S, C, Ext C, Ku, Ka and Q bands. ISRO has launched High Throughput Satellites providing multiple spot-beam coverage in Ku and Ka bands.

Some of the unique payloads carried on INSAT include Search and Rescue (SAR) payload, Data Relay Transponder (DRT), Very High-Resolution Radiometer (VHRR) for meteorological

imaging, and GPS Aided Geo Augmented Navigation (GAGAN) payload, to support specific applications. Today, India has a fleet of communication satellites that provide bent-pipe transponders and 25 Gbps High Throughput Satellite (HTS) capacity. The following info-graph summarises the evolution and growth of satellite communication in India.

Serving the geographic and demographic profile of India, the satellite communication plays an important role in reaching out to diversified regions of the Country. It helps to connect the hilly terrains, islands, inaccessible regions to providereliablemeansofcommunication. Satellite communication has evolved over the years in India and played a vital role in everyday life - receiving TV and radio programmes, providing essential communications, business and e-governance services.

Over the years, the use of satellite communication spanned into several applications like telecom and cellular backhaul, television broadcast, Direct



Insat-1B

**Satellite communication is used in several applications like telecom and cellular backhaul, television broadcast, Direct to Home television, news and event coverage, banking and ATMs and stock market network, etc.**

to Home television, news and event coverage, banking and ATMs, digital cinema transmission, stock market network, point of sale, linking oil rigs, maritime and on-the-move communications, etc. As per TRAI performance indicators report, more than 900 channels are beamed over India; there are about 103 million cable TV subscriber and 71 million active DTH subscribers; about 359 broadcasters, 1648 multi system operators and 1,40,000 cable operators; and 4 private DTH operators apart from the public sector broadcaster- Doordarshan. Further, 2.80 Lakh VSATs are in use catering to various communication services. The demand for satellite capacity is steadily increasing year after year.

Apart from commercial applications, several societal programmes were implemented with a focus to address specific problems of the society and the nation. Major societal programmes were:

- Jhabua Development Communication Programme (JDCP) - for tribal development;
- Training and Developmental Communication Channel (TDCC) and GRAMSAT - for rural development;
- Tele-medicine - for connecting Remote

Health Centres/Hospitals to Speciality Hospitals;

- Tele-education – for Curriculum, Supplementary and non-formal education;
- Village Resource Centre (VRC) – for advisories to villagers on Agriculture, Livelihood, Empowerment, etc.; and
- Disaster Management Support (DMS) Programme – Alert, mitigation, rescue and relief plan and implementation.

In addition, ISRO has implemented unique applications such as:

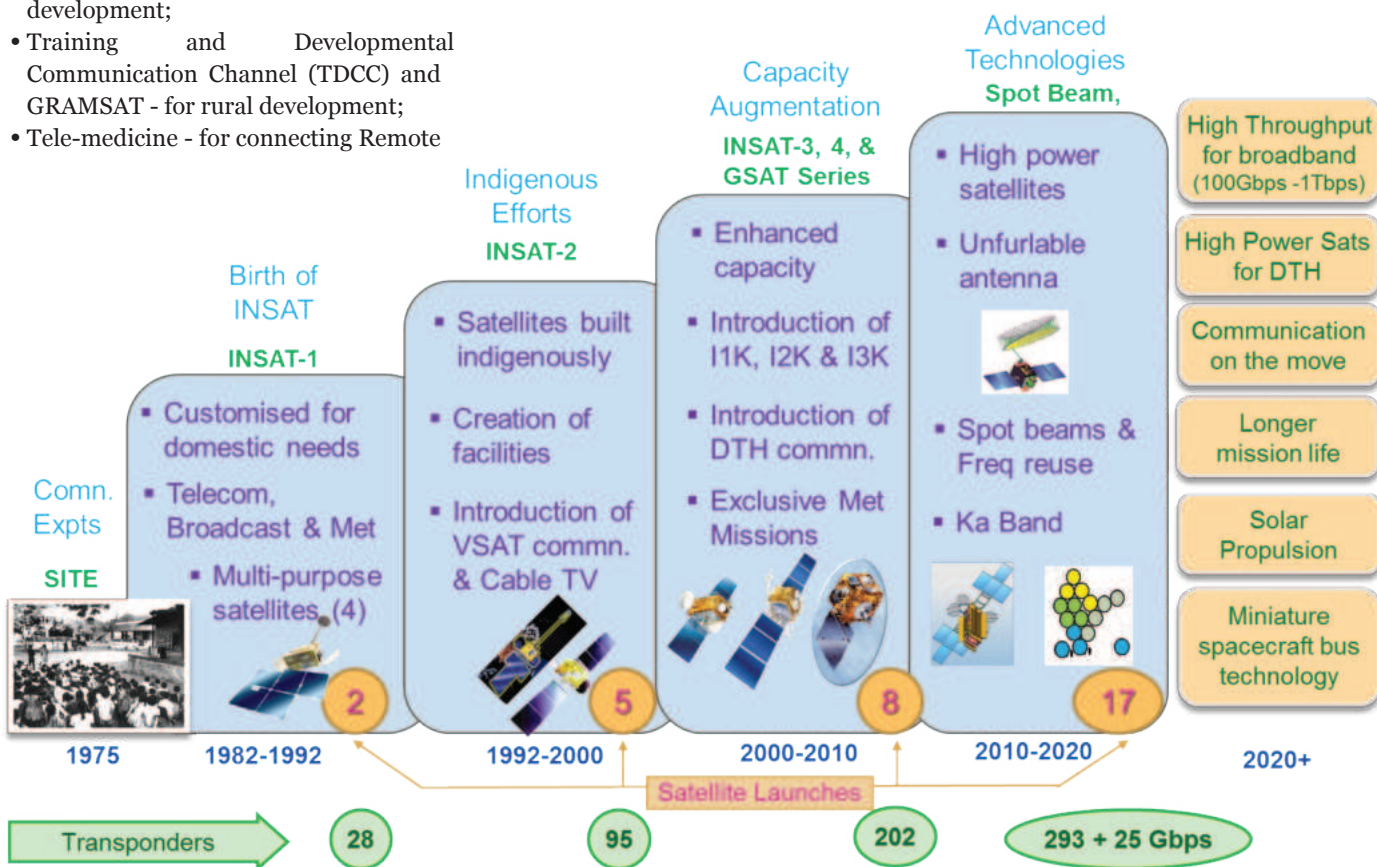
- Satellite Aided Search and Rescue: Search and Rescue (SAR) programme is implemented in collaboration with international agency COSPAS-SARSAT, for rescue of people at distress in ships, aircrafts on land through distress beacon;
- Distress Alert Transmitter (DAT): Indigenous customised solution for search and rescue of fishermen at sea;
- Data Relay Transponder (DRT): DRT supports variety of data collection and

sensor data monitoring applications related to weather, ocean, environment etc.;

- Mobile Satellite Services (MSS): MSS is an important component of satellite communication mainly meant for providing voice and data services using mobile and handheld terminals; and
- Real-time Train Information System (RTIS): Train tracking application for improving efficiency of operations and safety.

### RADARS

Defence Research and Development Organisation (DRDO) has developed several “Radars” indigenously. These radars strengthen the defence systems of the country by providing round the clock information of the threats in air, ground and sea. These radars are crucial to protect VAs and VPs of the Country. Several technologies embedded in these radars have been developed indigenously and could prove the potential and strength of



Evolution and growth of satellite communication in India



Aslesha Radar. Photo: DRDO



Bharani Radar. Photo: DRDO

indigenous sensor systems, mechanical systems, precision manufacturing amongst others.

#### **Battle Field Surveillance Radar – Short Range (BFSR-SR)**

BFSR-SR is a man portable, battery operated Surveillance Radar. BFSR-SR is a reliable sensor for day and night operations in all weather conditions. The radar is a simple, easy to use and user-friendly surveillance e-sensor. It can be installed and effectively put to use within few minutes. The radar is also a potential ground-based e-sensor for Border Security, Coast Guard and Police for surveillance of designated areas. The radar is a cost-effective perimeter surveillance sensor for airports, large industrial and other infrastructure.

#### **Swathi- Weapon Locating and Fire Control Radar**

Weapon Locating Radar (WLR) is an electronically scanned phased array radar. The radar automatically locates hostile artillery, mortars and rocket launchers and tracks friendly fire to locate the impact point of friendly artillery fire to issue necessary corrections. The radar is designed to detect projectiles with small cross section across the battle space horizon and has the capability to handle simultaneous fire from weapons deployed at multiple locations.

#### **Ashwini – 4D Active Array Medium Range Surveillance Radar**

Ashwini - Low Level Transportable

Radar (LLTR) is a ground based rotating Active Phased Array 4D Radar for air space surveillance to detect and track air targets, under hostile EW operational environments. The radar operates either in staring or rotation mode. It has advanced technologies and has electronic scanning capability in both azimuth and elevation. The system is fully programmable through an efficient Man-Machine Interface from the Local Operator Work Station (OWS) and remotely from the Operator Work Station Unit in the operations shelter.

#### **Bharani-2D Low-Level Lightweight Radar**

Bharani-2D Low Level Light Weight Radar (2D LLLWR) is a light weight battery powered compact sensor. It provides 2D surveillance in mountainous terrain against hostile aerial targets like UAVs, RPVs, helicopters and fixed wing aircraft flying at low and medium altitudes. The radar can be transported into packages to facilitate quick relocation and installation in mountainous terrain. It will serve to provide early warning to

**Defence Research and Development Organisation (DRDO) has developed several “Radars” indigenously, that strengthen the defence systems of India by providing round the clock information of the threats in air, ground and sea.**



Revathi Radar. Photo: DRDO

air defence weapon systems employed to provide protection to vulnerable areas or vulnerable points.

The radar detects and tracks short-range air-to-ground threats with a high probability of detection. It can be operated in varied conditions including extreme climatic and geographical conditions and in battlefield situations.

#### **Aslesha-3D Low Level Light Weight Radar**

Aslesha-3D Low Level Light Weight Radar (3D LLLWR) is a multi-beam ground based 3D Surveillance Radar for deployment in diverse terrains like plains, deserts, mountain tops and high altitude regions. This radar detects and tracks heterogeneous air targets, including helicopters, fighters and UAVs at low and medium altitudes.

The radar is engineered in multiple packages to enable easy transportability in mountainous terrain by vehicles, group of men, or as an under slung carriage by a helicopter. It can be used in different roles like air space surveillance



3D TCR Radar. Photo: DRDO



AESA Radar. Photo: DRDO

in urban areas for VVIPs and large critical installations.

**3D Tactical Control Radar (3D TCR)**

3D Tactical Control Radar (3D TCR) is a stand-alone medium range all-weather 3D Surveillance Radar for detection and identification of aerial targets, transmission of pertinent data to Target Data Receiver (TDR). The Radar is capable of Track While Scan (TWS) of airborne targets.

**Revathi-3D Surveillance Radar**

Revathi-3D Surveillance Radar is a ship borne Radar. The radar has advanced technologies like digital receiver, programmable signal processor providing high resolution, accuracy, response and

The Rohini radar is an indigenously developed 3D medium range mobile surveillance radar of Indian Air Force. Developed by DRDO, it can detect and track aerial targets even under hostile EW operational environment. Photo: IAF

information availability. The radar has excellent ECCM features. The antenna of the radar is hydraulically stabilized. The radar incorporates interfaces with Ships Household Data (Gyro, Log, GPS etc) with Combat Management Systems (CMS) onboard.

**Arudhra - Medium Power Radar (MPR)**

Arudhra - Medium Power Radar (MPR) is a fully active, rotating, multifunction phased array radar. It is a ground based 4D surveillance radar for generation of true air picture, with accurate and precise measurement of aerial targets for air defence operation. The radar employs adaptive data rate, dynamic waveform selection and adaptation to environment. It can operate in rotation mode or staring mode with higher update rate. Radar can survive intense ECM environment and possible electromagnetic interference. MPR is fully programmable from the local operator work station (OWS) and

also remotely from Remote Operator Work Station Unit. The radar is remotely controlled.

**Atulya - Air Defence Fire Control Radar**

Atulya - Air Defence Fire Control Radar (ADFCR) in conjunction with Anti-Aircraft Guns forms a Ground Based Air Defence system whose main purpose is effective point defence against all air threats at short and very short ranges.

**3D Central Acquisition Radar (3D CAR) for SAM System**

3D Central Acquisition Radar (3D CAR) is a ground based mechanically scanning pulse Doppler radar for air space surveillance to detect and track air targets with reliability, even under hostile EW operational environment. The flexible architecture is a reliable and adaptable technology for multiple applications - early warning for air defence weapon system, air defence sensor at airbases.



Atulya- ADFCR Radar. Photo: DRDO



Battery Multi-Function Radar-BMFR.  
Photo: DRDO



Battery Surveillance Radar-BSR.  
Photo: DRDO



Quick Reaction Surface to Air  
Missile (QRSAM) Photo: DRDO

The radar, packaged on two vehicles, is easy to operate, transportable by air, rail and road, can be deployed and decamped in less time.

### Troop Level Radar (TLR) and Troop Control Center (TCC)

Troop Level Radar (TLR), a multi-function electronically scanned phased array radar, is the primary sensor at the troop level for air defence weapon system. The TLR has the capability to perform extensive search, track multiple targets and missiles, and to command and guide own multiple missiles concurrently. The Radar system is mounted on two HMV namely Troop Level Radar (TLR) and Troop Control Center (TCC), to provide sensor support for all air defence operations. The radar has built-in UHF communication component providing voice and data communication with squadron control center when deployed in a group. Also, Integrated Radio Line Modern (IRLM) provides data communication to the launchers.

### Flight Level Radar (FLR) and Flight Control Center (FCC)

Flight Level Radar (FLR), a multi-function electronically scanned phased array radar, is the primary sensor at the flight level for air defence weapon system. The FLR has the capability to perform extensive search, track multiple targets and missiles, and to command and guide multiple missiles concurrently. The radar has built-in communication component providing voice and data communication with squadron control center when deployed in a group. Also, Integrated Radio Line Modern (IRLM) provides data communication to the launchers.

### Radars for Quick Reaction Surface to Air Missile (QRSAM)

Quick Reaction Surface to Air Missile (QRSAM) Radar consists of Battery Surveillance Radar (BSR) and Battery Multi-Function Radar (BMFR). Each radar has been configured with four Active Arrays. The BSR and BMFR use state-of-the-art active phased array technology combined with advanced signal processing and data processing algorithms to detect and track fixed wing aircrafts including UAVs as well as rotary wing aircrafts including hovering helicopters in intense EW environment.

The BSR and BMFR use advanced platform motion compensation and electronic stabilization algorithms along with high accuracy motion sensors. Both radars are mounted on 8x8 High Mobility Vehicles and are capable of operating on the move in plains, deserts and semi-deserts.

### Active Electronically Scanned Array Radar (AESAR)

AESAR is a multimode, solid-state active phased array fire control radar with scalable architecture that can be adapted for various types of fighter class of aircraft. It is a fully electronically scanned agile beam radar which uses Transmit / Receive module (TRM) technology. The radar has state of the art features including wide band RF front end, ultra-low side lobe antenna, frequency and waveform agility, multiple SLC channels for jammer suppression, Low Probability of Intercept and Non-Co-operative Target Recognition. It is capable of tracking multiple targets with high accuracy suitable for missile firing with interleaved Air-to-Air, Air-to-Ground and Air-to-Sea modes for all terrain operation.

### Ground Penetrating Radar (GPR)

GPR System is used in detection of Anti-Tank Mines, Anti-Personnel Landmines

(metallic and non-metallic) and Improvised Explosive Devices (IED) in a variety of Indian soils such as Sand, Red, Laterite, and Black Cotton. Handheld GPR system is extremely useful for Army and Para-military forces respectively in jungle area where very narrow path ways exist. Vehicle Mounted GPR is mainly used for scanning and detecting buried objects on roads and tracks that are used by patrolling parties of Para-military forces and services.

### Through Wall Imaging Radar (TWIR)

TWIR is a sensor used for detection and location of static and moving targets, especially human beings behind walls. The radar can image in real time the scenario behind wall, identify the number of people and their location behind walls, study their activity patterns and thus help in identifying a hostage scenario behind the wall. The different types of wall include concrete, reinforced concrete, brick, cement, wood, stone etc. Imaging the scenario behind wall, tracking the path of the moving targets and presenting fine Doppler information like heart beat and breathing of a person are the important functions of this radar.

The deployment of radars has enhanced the surveillance capability of Indian Armed Forces. The Country has achieved self-sufficiency in the field of Radars. This has resulted in substantial savings to exchequer. The technology and manufacturing capability and capacity created in the domain is the true example of Make in India.

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# SELF-RELIANT INDIA: IT REVOLUTION

Information Technology (IT), a term coined in 1958, is defined as the technology involving the development, maintenance, and use of computer systems, software, and networks for the processing and distribution of data. It is a young field from an engineering perspective. The term “software engineering” was coined in the mid-40s, about the time India was born.

Indian investment in computing machinery started in 1955 when the first machines were being set up in ISI and TIFR. Through the sixties commercial establishments (ESSO, Tatas) and government organisations (LIC, RBI) began investing computing. Computers from American, British and Russian companies arrived at Indian academia. However, there was resistance from labour unions. There were also debates on whether computers should be indigenously made or simply imported. Computing was not scaling the way it was in USA, where large commercial installations such as the airline reservation system were operational by the mid- sixties.

Yet, today IT is a highly visible, scaled, and impactful success story across multiple dimensions in India. It has public services programs impacting practically all Indians.

This success has been possible because of

- Early experiments and continuing investments in hardware engineering, especially in academia and the public sector
- Education and training of engineers
- Continual growth in software engineering models, tools and paradigms that has made creation of software solutions, services and their

export possible

- The rise of software products and upward movement in the value chain, and a growth in the entrepreneurial ecosystem

## CDAC FOUNDED IN 1988, BUILT INDIA'S FIRST SUPER COMPUTER PARAM

In the 80s the public sector unit “Semiconductor Complex Ltd (SCL)” came up, providing chips for a variety of uses especially in space tech and defence. In the early 2000s the Department of Information Technology encouraged investments in semi-conductor fabrication industry.

In 2014, SHAKTI, an open-source initiative by the Reconfigurable Intelligent Systems Engineering (RISE) group at Indian Institute of Technology Madras to develop the first indigenous Indian industrial-grade processor was launched.

## ELECTRONIC VOTING MACHINES (EVMS)

It is a matter of pride that India should adopt EVMs and that the IT industry should contribute to the key democratic process of the country.

The M3 EVM with the voter verifiable paper audit trail is an engineering success story: its hardware, software, performance and deployment design exhibit ingenuity. It comes after 6 years of evolution and two generations of technology changes.

## PMJDY

Financial inclusion (FI) programs are not new to India. However, the Pradhan Mantri Jan Dhan Yojana took it to another level. Launched in the year 2014, it has covered 44.91 crore beneficiaries,

55% of them women, by 2022. About 98% of the unbanked now have bank accounts. It enabled Direct Benefit Transfer (DBT) for 391 government schemes (such as gas subsidies, PM Kisan and Educational Scholarships to notified segments of society etc) spread over 54 ministries, distributing ₹6.3 Lakh Crore in 2021-22.

What is of interest from an engineering perspective is the government’s keenness in creating a robust digital infrastructure with the “India Stack”. This digital core provided identification, interoperable payments, data sharing through consent, leading to presence-less, cashless, paperless transactions. Self-service and assisted banking, vernacular language ATMs, robust network of POS Machines and Banking Correspondents (BCs) enhanced rural reach; digital KYC, video KYC, digital authentication, 24x7 payment gateways helped remote operations.

Jan Dhan-Aadhar-Mobile (JAM) has inspired innovation from large players and young fintech start-ups in the payment space. Tata Consultancy Services, for instance, has built an India Digital Interaction Platform Services Bus, that enables many business solutions; the company catered to 70% of the FI initiatives of public sector banks. Components of the India stack are not conceptually new; together, with interoperability, they offer great synergy. FI India for the year 2020-21 stood at 53.1%, ahead of the average for South-East Asia (46.4%).

With the proliferation of simple mobile phones, it was possible to extend services to rural Indian farmers who were number literate. Agriculture consulting and information services began to gain ground. Other societal solutions built at the intersection of computing and other



An Aadhaar Registration centre. Photo: uidai.gov.in

engineering disciplines continued to be explored: low cost water filters, disaster management, coastal surveillance and tsunami warning, city planning, and recently, services during the COVID crisis. Currently sustainability and Green IT are in greater focus.

The future looks bright for Indian software engineers as new types of computing are being explored, strengthened by stronger networks emerging (5G, 6G) to drive beneficial transformations.

## AADHAAR

An Indian used many documents - driving license, ration card, bank passbook etc - to prove identity in the pre-Aadhaar days. However, fake documents and duplicate identities made fraud commonplace. There was no single system that was nationally accepted providing a verified identity document/number that all residents had, and service providers could trust.

The Unique Identification Authority of India (UIDAI) was established (2009) to empower residents of India with a unique identity and a digital platform to authenticate it anytime, anywhere.

### The Engineering Challenge

UIDAI had to create infrastructure

that scaled to identify the entire Indian population (1.4 billion). It was a project that demanded unique process design and engineering skill: it had to offer a smooth user experience for a demographically diverse user base; remain secure; preserve privacy while enabling the right amount of data to be shared to be of high utility value; support billions of transactions per second; and be available 24\*7.

As a first step, Aadhaar clearly defined the information it would collect. It acts on three core principles of Minimal information, Optimal ignorance and Federated database. In its whole lifecycle an Aadhaar database contains only that much information as an Indian gives at the time of enrolment or updation. It records the name, address, gender, date of birth, photograph and core biometrics (10 fingerprints and 2 iris scans) of the residents. It also stores the mobile number and email address if one chooses to give. The triumph of Aadhaar is that, without being invasive, it acts as a tool of transformation, empowerment and development.

### The Technology Architecture

Entire technology architecture behind Aadhaar is based on principles of openness, linear scalability, strong

security, and most importantly vendor neutrality. The Aadhaar technology backbone is built using the following principles:

**Open Architecture** – It uses open standards to ensure interoperability and build vendor neutrality; a platform approach with open APIs to allow the ecosystem to build; and an identity system designed to work with any device, any form factor, and any network.

**Design for Scale** – The Aadhaar system continues to grow as the resident population expands. Since every new enrolment requires biometric de-duplication across the entire system, the system must handle hundreds of millions of transactions across billions of records doing hundreds of trillions of biometric matches every day! In addition, all online services such as Aadhaar authentication, e-KYC service, and update service must work with high availability. Network and data centre load balancing and multi-location distributed architecture for horizontal scale are critical to such massive scalability.

**Data Security** – Security and privacy of data within the Aadhaar system have been foundational. UIDAI has taken several measures to ensure security of resident data from the time it is captured all the way to how it is stored within CIDR. Usage of 2048-bit PKI encryption and tamper detection using HMAC ensures no one can decrypt and misuse the data, even if they are in possession of enrolment packet. Resident data and raw biometrics are always kept encrypted even within UIDAI data centres. In addition, entire Business Intelligence (BI) sub-system anonymizes all Personal Identifier Information (PII) to ensure resident personal data is protected across all system components.

Aadhaar software currently runs across two of the data centres, within India, managed by UIDAI and can handle 1 million enrolments a day. The authentication service is built to handle 100 million authentications a day across both the data centres at sub-second response time. Central to the Aadhaar system is its biometric sub-

## AADHAAR IS DEEPLY EMBEDDED IN RESIDENTS' LIVES

**1.32 billion**  
Aadhaar Generated

**11 billion**  
eKYC Done

**230 million\***  
(80%) residents linked Aadhaar with cooking gas connection for LPG subsidy

**730 million\***  
bank accounts are linked with Aadhaar & 9.38 billion\* transactions via AePS



**66.51 billion**  
Authentication Done

**700 million\***  
(89%) residents have linked Aadhaar with ration card to avail ration

**90%**  
of farmers (~9.6 crore\*) have given Aadhaar for their fertilizer subsidy

system that performs de-duplication and authentication in an accurate way.

### Data Security and Privacy

Some of Aadhaar's strong data privacy and security features:

- The Aadhaar number is a random number with no built-in intelligence or profiling information
- The system follows "optimal ignorance" to provide identity related functions (and nothing else).
- Aadhaar authentication responds only with yes/no answer
- The Aadhaar e-KYC service allows resident to authorize UIDAI to share electronic version of their Aadhaar letter.
- Service providers collecting Aadhaar are not permitted to share Aadhaar details

### Aadhaar – Usage in Direct Benefit Transfer

When linked with a bank account, Aadhaar becomes the 'financial address' of an individual which helps to accomplish the country's goal of financial inclusion. It is sufficient to transfer any payment to an individual's bank account, through Aadhaar Payment Bridge (APB), thus eliminating the need to give other details. This facilitated door-step banking services and helped mitigate the hardships faced during the pandemic (view PMJDY).

Aadhaar, a core entity in the "India Stack" has forever changed the digital landscape of the country. It has not only brought empowerment to the poor and marginalized by providing them anytime-anywhere verifiable identity but also easy access to their entitlements.

### TRANSFORMATION OF INDIA'S FINANCIAL MARKETS

Economic liberalization of India aimed at making the economy more market oriented and expanding the role of private and foreign investment. In 1991, it set in motion a series of well-planned reforms. Capital markets provide financial resources required for long-term sustainable growth and hence development of viable capital markets was an important element in the macro-financial policy for India.

In 1990 India's capital markets were far behind in terms of technology. Stock exchanges were localized to major cities; paper share certificates and regulatory control gaps, perceived to be a cause for financial irregularities, led to significant market crisis in 1992. This eroded both market capitalization and investor confidence. The government recognized the need to overhaul the financial systems. What followed was a decade of technology transformation of India's capital markets that laid the foundations for what is now projected to be a \$5 trillion market capitalization by 2024.

### THE FIRST STEP - COMPUTERISATION OF STOCK EXCHANGES

National Stock Exchange of India (NSE) established in 1992 redefined how stock exchanges worked in India. Trading was completely online, real-time with transparency of demand and supply and pricing of shares visible to all market participants from every corner of India. NSE Trading System launched in 1993 was a proprietary in-memory application offering high throughput implemented on mainframe Stratus Computers that provided full hardware-fault tolerance. They could scale to handle about 2 million trades with more than 15,000 concurrent users. Brokers could place orders using the National Exchange for Automated Trading (NEAT) system, an automated screen-based application. Trades were executed at an average rate of 3,500 trades/minute and peak rate of 6,000 trades/minute with less than 2 seconds response. A significant highlight was connectivity in all corners of India using 3000 VSATs and leased lines spread across 400 cities. NSE also implemented the Nationwide Clearing and Settlement System of physical shares where its unique algorithm ensured highly optimized movement of physical shares to designated clearing houses for settlement.

In 1995 India's oldest stock exchange BSE-Bombay Stock Exchange launched BSE On-Line Trading System (BOLT).

BOLT was implemented on the Tandem Fault Tolerant System. The

\*As on March 2021

high performance Tandem systems were accessed by BSE's trading members through a nationwide network spanning 360 cities and 7,000 workstations. They used on-campus LAN in Mumbai and leased lines and VSATs for upcountry members.

The exchanges expanded rapidly through 1990s to 2000s offering services in equity, derivatives, debt, commodities and currency derivatives segments.

In terms of global positioning BSE today occupies 9th rank with USD 3.96 Trillion market capitalization and NSE is at 10th rank with USD 3.77 Trillion market capitalization.

### Dematerialization – The Most Material Reform

While stock exchanges transformed, substantial problems persisted with paper-based settlement of securities. The promulgation of the Depositories Ordinance in 1995 paved the way for the establishment of National Securities Depository Limited (NSDL), India's first depository in 1996.

Securities were now held in depository accounts in Dematerialized digital format similar to funds in bank accounts. Transfer of ownership of securities was done through account transfers doing away with the hassles associated with paperwork, all executed rapidly on the demat registry of shares. NSDL's technology infrastructure was on an IBM mainframe with the core depository application adapted from Swiss SEGA Intersect architecture.

Central Depository Services Limited (CDSL) - India's second depository founded in 1999 implemented the CDAS platform - a 3-tier architecture that had Oracle database, Tuxedo middleware for scalability and thick client developed in Visual Basic for end users.

Both depositories implemented a business architecture consisting of Depository Participants (DP) who were responsible for investor accounts and for managing all transactions including dematerialization and transfer of traded securities. By 1999 over 1500 cities in India and over 50 cities abroad had DP presence.

With the depositories and DP network in place, SEBI pushed the mandate of compulsory dematerialization of shares starting in 1999. Compulsory demat propelled the growth of demat account holders.

More importantly compulsory dematerialization enabled the Indian securities market to implement T+2 settlement matching global standards by April 2003 – a rapid progressive milestone achieved from T+5 settlement in 2002. This coupled with risk-mitigated paper-less electronic settlement via demat holdings substantially raised the stature of the Indian capital markets as technologically advanced and progressively aligned with developed world markets.

The system development work on all the platforms has been collaboratively executed by Tata Consultancy Services (TCS), erstwhile CMC Ltd, key academia from leading Indian technology institutions and dedicated professionals working across the key market institutions.

Today the platforms are resiliently executing benchmark volumes on commodity hardware and software evolved in the past two decades by Indian engineering ingenuity.

With the strong technology foundations laid down in engineering the key capital market platforms in 1990s, India today is confidently poised to touch the \$5 Trillion market capitalization by 2024.

### UNIFIED PAYMENT INTERFACE (UPI)

On the back of the success of Aadhaar, the



Source: npci.org.in

'Digital India' initiative was announced in 2014, under which many successful systems like eSign, Digilocker, etc were launched leveraging the JAM (JanDhan, Aadhaar, Mobile) trinity at a billion people scale. The Unified Payment Interface (UPI), launched in April 2016, as part of India Stack, became one of the globally celebrated payment innovations doing a staggering 4.5 billion transactions a month in Dec 2021 making India the global leader in digital payments.

India's investment into its resilient payment infrastructure was tested to its fullest post the demonetization period and during the COVID years. The Aadhaar based Direct benefits Transfer and UPI payment infrastructure truly was a blessing, making it possible for subsidies to be sent to millions of people

Source: npci.org.in



and enabling people to transact easily without physical money. In the coming years, UPI is expected to further scale within India, work across the border, and provide interoperability with digital currencies, bringing both inclusion and innovation to a billion people.

### DIGITAL CONTENT FOR HIGHER EDUCATION IN TECHNOLOGY

The National Mission for Education through ICT (NMEICT) was launched in 2009 under the 11th five-year plan with the ambitious vision of “catering to the learning needs of India”. This essay gives a glimpse of pioneering initiatives in this field.

#### NPTEL

Post liberalization, hundreds of engineering colleges opened all over India. However, the quality of teachers and the syllabus adopted was uneven. On a suggestion from some IITs, after workshops to brainstorm, the Ministry (MHRD) flagged off the National Programme on Technology Enhanced Learning (NPTEL) in 2000.

A National Committee and subsidiary units were set up. A process was developed to select, create, and review courses from six engineering disciplines. Two formats were recommended: web-based animation with concept-rich online text and graphics for courses, and fully recorded video lectures. Courses would contain adequate material, problems and assignments that could be covered in 40-45 hours, a typical 3-credit Semester Course. By 2006 a web portal was created with a web server located in IIT Madras. A highly successful eLearning platform and other software to create graphics, equations and animation were recommended. Content was stored in CDs and DVDs and was streamed through the portal. Within a year, 1,60,000 users registered, and more than 5,80,000 visits were recorded. Mirror sites were created in other IITs and IISc and integrated. Later YouTube provided an exclusive channel for NPTEL. Since 2014 NPTEL has conducted proctored examinations and awarded certificates to successful candidates through the

institute that conducted the course. In 2019 NPTEL showed an impact way beyond the expectations of the team that mooted NPTEL with MHRD in 1999. It has been internationally recognized as a phenomenal success, largely owing to the planning, infrastructure building and technology adoption.

**SWAYAM:** Following the success of NPTEL, the Ministry of Education (MoE) launched India’s national MOOC portal - SWAYAM - in 2017, following the same model of open online learning and in-person exam-based certification. SWAYAM was indigenously built and hosted on public cloud and can support lakhs of simultaneous users, offering a wide variety of teaching/learning tools.

National Digital Library of India (NDLI), developed by IIT Kharagpur, offers a single-point integrated search for browsing educational content from India and the world. Initiated in 2014, it is built on a unique open source platform architecture, that offers 24 x 7 access to educational resources for all learners, at all levels, and in all disciplines. It currently has 85+ million content elements covering text, audio, video, data, simulation, question banks, etc. It uses indigenously developed semi-automated technology for content ingestion, is SDG 4 compliant and has interfaces in ten Indian languages. NDLI is among the largest resources for educational content in the world and has been a life-line during the pandemic.

**DIKSHA,** launched in September 2017, is a ‘one nation; one digital platform’ under the PM eVidya programme for schools in India. DIKSHA, as a national digital infrastructure designed for India’s scale, is accessed in many languages and across curricula. The platform is being leveraged and developed for school education, foundational learning programs, teacher capacity development programs, content crowd-sourcing program (VidyaDaan) and to support inclusive learning for underserved and differently abled communities of learners and teachers. DIKSHA’s technology architecture provides for a

variety of content types such as student and teacher explanation videos; practice content; assessments; sample question papers; AR/VR/interactive content for immersive experience, lesson plans and micro-courses. It is perhaps the largest daily accessed educational portal in the world.

**Virtual Labs:** The Virtual Labs consortium has 11 institutes and is led by IIT Delhi. Virtual labs (started in 2010) are any-place, any-pace, any-time, any-type labs. Students/ teachers can avail the various tools for learning, such as web-resources, video-lectures, animated demonstrations and self-evaluation.

**Spoken Tutorials:** Spoken Tutorial is a 10-minute-long audio-video tutorial created for self-learning of IT topics using open source software. It comes with the associated study material, such as code files, outline, and prerequisites. Spoken Tutorials are dubbed into all our 22 languages. It is usable offline.

**FOSSEE:** Free and OpenSource Software for Education (FOSSEE) promotes opensource software in academia. The FOSSEE team trains students and teachers, makes them contribute useful content, curates them, and releases them as open source to the public.

**e-Yantra:** e-Yantra is a project that trains students in the domain of robotics and embedded systems through project-based learning. e-Yantra helps establish robotics labs in colleges. It conducts highly successful robotics competitions.

Today digital content is created by many organizations and disseminated based on a variety of business models. However, the software and hardware engineers at IITs and IISc were the pioneers, setting up initiatives such as NPTEL at the turn of the century.

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The content of the article is taken from the book “Landmark Achievements in Engineering and Technology in Independent India” published by Indian National Academy of Engineers through Vigyan Prasar

# SELF-RELIANT INDIA: SYSTEMS

## UNDERWATER WEAPONS AND COUNTERMEASURES

Defence Research and Development Organisation (DRDO) has developed successfully a number of Underwater Weapons and Countermeasures 2010 onwards. These have been deployed for strategic use systematically.

### Heavy Weight Torpedo Varunastra

Varunastra is a ship launched, heavy weight, electrically-propelled, anti-submarine torpedo, capable of targeting quiet submarines, both in deep and shallow waters in an intense countermeasures environment. It can be fired from all ASW ships capable of firing heavy weight torpedoes. The torpedo is powered by an electric propulsion system. Varunastra has features comparable to contemporary torpedoes world over, such as speed, range, and depth of operation.

### Advanced Light Weight Torpedo (ALWT)

Advanced Light Weight Torpedo (ALWT) is an electrically propelled self-homing torpedo and can be launched from ship and rotary wing aircraft. It has both active and passive modes of operations, and all digital control and guidance systems. ALWT is an anti-submarine weapon with variable speeds of operation and high endurance. The Torpedo can attack submarines in shallow and deep waters.

### Anti-Torpedo Defence System (ATDS) Maareech

“Maareech” is an Anti-Torpedo Defence System (ATDS) for surface ships. It is capable of providing reliable defence mechanism against a possible torpedo attack by vintage as well as modern torpedoes. The system has both

torpedo detection and countermeasure capability. The Maareech system is used to detect, classify and offer countermeasures against an impending torpedo attack. The system consists of several components for: detection of torpedo signatures; decoying of torpedoes; signal processing; display and recording of sonar information, etc. The Maareech systems are in use at the frontline warships of Indian Navy ships.

### Processor Based Ground Mine (PBGGM)

The PBGM is a bottom sea mine capable of detecting and destroying surface and sub-surface targets based on the Acoustic/Magnetic/Pressure influence anomaly in littoral and blue waters. The salient features of PBGM are: deployability from surface ships in depth; pre-set moored depth sea mine against surface targets; sensors – flexural acoustic hydrophone, flux gate, magnetometer; and composite construction to evade mine hunting of SONAR.

### Processor Based Moored Mine (PBMM)

The PBMM is the Sea Mine for Blue Seas capable of detecting and destroying Surface/Sub-surface by the Acoustic/Pressure influence anomaly generated by targets passing in proximity. The salient features of PBMM are: deployability from ships and submarines; fibre glass body to evade mine hunting SONAR; safety for electrical power, explosive & torpedo tube; and sensors – hydrophone, flux gate, magnetometer, depth sensor.

### Processor Based Exercise Mine (PBEM)

The Processor Based Exercise Mine (PBEM) is a sea bottom exercise mine

with capabilities identical to that of the combat sea mine PBEM in detecting the target ships and submarines by means of the acoustic/magnetic/pressure influences. The salient features of PBEM are: deployability from surface ships, torpedo tubes & mine saddles of submarines; detection of target by acoustic, magnetic, pressure influence, data recording and storage; and recovery system – HE bolt, flasher, smoke marker and Plunger.

The indigenous developments of torpedoes and torpedo defence systems have placed India in the club of few elite Countries having similar capabilities in naval systems and technologies. The technologies were developed indigenously and proved the potential and strength of indigenous underwater systems.

## MAIN BATTLE TANK - ARJUN MARK 1 & 1A AND ADVANCED TOWED ARTILLERY GUN SYSTEM

The Main Battle Tank (MBT) Arjun Mk-1 is Made in India and Made for India. The MBT Arjun is a family of MBTs developed by the Indian Defence Research and Development Organisation (DRDO) to provide India with an indigenous MBT design, development and production capabilities to have an indigenous MBT towards National self-reliance in Armoured Fighting Vehicle.

MBT Arjun Mk-1 manifests the latest battle tank technologies that make it a distinct front-runner amongst the array of contemporary Main Battle Tanks (MBTs) of modern armies world over. MBT Arjun Mk-1 offers the troops a state-of-the-art tank with superior firepower, high mobility, excellent protection and accommodates four men Crew. Encouraged by its excellent

## The Main Battle Tank (MBT) Arjun Mk-1 is Made in India and Made for India and is developed by the Defence Research and Development Organisation (DRDO).



MBT Arjun Mk-1A in live demo at Def Expo 2018. Photo: DRDO

performance at the highly challenging operational conditions in harsh Indian desert environment, MBT Arjun Mk-1 has been named as “Desert Ferrari” by tank experts in the world. The primary variant is the MBT Arjun Mk-1 followed by the MBT Arjun Mk-1A.

The developments are unique in terms of technology and characteristics. With the expertise gained by DRDO during the development of MBT Arjun Mk-1, the MBT Arjun Mk-1A was designed, developed and fielded for trials within a record time. After extensive field trials the MBT Arjun Mk-1A has been recommended for induction into service. MBT Arjun Mk-1A manifests the latest battle tank technologies that make it, a distinct front-runner amongst the array of contemporary Main Battle Tanks of modern armies of the world.

MBT Arjun is one of contemporary best MBTs available elsewhere in the world. It is indigenously designed, developed and has supremacy over the opponents in tank-to-tank battle scenario in Indian subcontinent terrains. The indigenously designed and developed Advanced MBT Arjun Mk-1 and MBT Arjun Mk-1A were tested in Indian terrains and climatic

conditions. The MBT Arjun has export potential to friendly countries. It will boost India’s defence sector.

### Advanced Towed Artillery Gun System – ATGAS

Advanced Towed Artillery Gun System (ATGAS) is an indigenously developed large calibre gun system with the capability to program and fire long range guided munitions to achieve precision and deep strike. It is the world’s longest-range gun in this category. It is developed by the: Defence Research and Development Organization (DRDO) and is under advanced stage of trials. The gun consists of a barrel, breech mechanism, muzzle brake and recoil mechanism to fire 155 mm calibre ammunition. It has an all-electric drive to ensure reliability and minimum maintenance over a long period of time. It has advanced features like high mobility, quick deployability, auxiliary power mode, advanced communication system, automatic command and control system with night capability in direct-fire mode.

The gun is two tons lighter than guns in the same category and is designed to provide better accuracy and range and is

capable of firing five successive rounds in short duration. It is compatible with C3I systems for technical fire control, fire planning, deployment management and operational logistics management.

Prior to ATAGS’s India was dependent on the imported gun systems like Bofors. Also, there is considerable dependence on the imports for spare parts and maintenance in addition to the base system import. The development of ATAGS has the capability to significantly improve the existing gun capability of the Country. The ATAGS is configured with an all-electric drive that will ensure maintenance free and reliable operation over longer periods of time. ATAGS will enable the Country with long range artillery guns with indigenous production capability.

### GIANT METREWAVE RADIO TELESCOPE (GMRT)

Set up in the 1990s and operational since 2001, GMRT is one of the largest and most sensitive low frequency (110-1460 MHz) radio astronomy observatory in the world located about 80 km north of Pune at Khodad. GMRT consists of 30 fully steerable parabolic dishes of 45m diameter each spread over distances of upto 25 km. The antenna configuration and range of radio frequencies of the GMRT are optimised to produce high quality, good resolution images of astrophysical objects at metre and centimetre wavelengths, to probe several outstanding astrophysics problems. The National Centre for Radio Astrophysics (NCRA) a centre of the Tata Institute of Fundamental Research (TIFR) has set up and runs the GMRT.

The radio waves from celestial source arriving at each of the 30 antennas are received using feed antennas at the focus of the dish, working at 5 distinct frequency bands centred at 150, 235, 325, 610 and 1420 MHz, followed by high gain, ultra-low noise amplifiers for each band. The signals from the selected band are then translated to intermediate frequencies using highly stable oscillators at each antenna that are locked in phase to a common observatory reference signal and are transmitted over optical



Hon'ble PM handing over the MBT Arjun Mk-1A to Gen MM Naravane COAS in the presence of Dr. G. Satheesh Reddy, erstwhile Secretary DD R&D and Chairman DRDO on 14 Feb 2021. Photo: MoD

fibre to the receiver room in the central building. Here the optical signals are converted back to electrical, mixed down to baseband signals with maximum bandwidth of 32 MHz, and then digitised by high speed analog to digital converters. A digital back-end processor carries out the signal processing steps to implement a spectral correlator for all the 435 pairwise combinations of the 30 antennas, and a beam former that can combine the signals from any selected set of antennas. The integrated data products from these are recorded on disks for off-line processing by astronomers to generate the images with a resolution corresponding to a 25 km size antenna, as well as time series data (with resolutions down to microseconds), that are used for the scientific investigations of specific objects and phenomena.

Operational as an international facility for over twenty years, the GMRT has produced many front-line results and discoveries in a diverse range of topics, greatly enhancing understanding of the Universe. Used by astronomers from all over the world (about 35 Countries to date), there are more than 40 papers published in international journals every year that are based on data from the GMRT. The design and building of the GMRT and its subsequent upgrade have pioneered new techniques in antenna design, RF electronics, use of optical fibers, and signal processing, and also significantly boosted the level of interest

and participation in the country in astronomy in particular and science and technology in general.

A unique feature of the structural design of the antennas was the deployment of high strength stainless steel wire ropes to replace, where possible, the conventionally used steel members. This enabled a reduction in the design wind loads, and consequent economy in structural design as well as the steering equipment.

The GMRT was one of the first in a series of new radio observatories that heralded the renaissance of low-frequency radio astronomy from 1990 onwards. Shortly after its commissioning, new facilities such as LOFAR, MWA, LWA were conceived around the world, and started becoming operational towards the end of the first decade of this century.

In basic sciences, the GMRT is one of the most challenging and highly successful experimental programme undertaken by Indian scientists and engineers. It is a completely "Made-in-India" facility which has pioneered new techniques in antenna design, RF electronics, use of optical fibers, and signal processing. The design of the array is exclusive and provides an optimal combination for

excellent imaging capabilities. The design of the antennas using the SMART concept, is also highly novel.

GMRT was the first radio astronomy facility to pioneer the use of optical fibers for signal transport. It continues to enjoy an exclusive position on the global stage as the most sensitive radio astronomy facility at metre wavelengths.

GMRT has become only the third Indian scientific facility to be awarded the Institute of Electrical and Electronics Engineers (IEEE) milestone status (honoring significant technical achievement and excellence for the benefit of humanity carried out anywhere in the world) for its novel engineering, advanced technology and scientific contributions made in the field of radio astronomy.

#### GROUND BASED MULTIWAVELENGTH OBSERVATORIES

India has developed and built several "Ground Based Multiwavelength Observatories". These could be classified into four categories, namely, Radio Observatories, Infra-red/Visible Observatories, Solar Observatories and Gamma Ray Astronomy. Each one of these under its umbrella has several observatories.

#### Radio Observatories

Ooty radio telescope (1970) is 530-metre-long and 30 metre tall. It is the world's longest radio telescope and works at a frequency of 326.5 MHz. The observatory



Hon'ble Prime Minister of India Shri Narendra Modi rode on MBT Arjun Mk-1 in 2020. Photo: MoD

is mainly used to study Sun and Solar system objects, radio galaxies, quasars, supernovae, pulsars and interstellar matter.

Gauribidanur Radio Observatory (1976) is a radio array consisting of 1000 dipoles arranged in a T configuration, 1.4 km long East-West arm and 0.5 km South arm. It obtains two dimensional images of the outer solar corona in frequency band of 40 – 150 MHz. The observatory is used for studying radio emission from Sun, galaxies and pulsars.

e-CALLISTO Solar Radio Spectrograph (2006) is a movable radio observatory capable of real time monitoring of solar origin of space weather, study of magnetic and plasma processes during solar flares and Coronal Mass Ejections (CME) and also used for outreach activities and education.

Gadanki Ionospheric Radar Interferometer (GIRI) consists of a 30 MHz radar system for ionospheric, meteor and space weather research.

Shaped Antenna measurement of the background Radio Spectrum (SARAS) is a deployable radio antenna designed for wideband measurements of background spectra to study the spectral signatures of Epoch of Re-ionization in the cosmic radio background.

### Infra-red/Visible Observatories

1.04 m Sampurnanand telescope (1972) is RC reflector with a Cassegrain focus and a field of view around 45 arcmin. The telescope mainly used for scientific programs such as, study of star-clusters, young star forming regions, AGN, brown dwarves, GRBs and observation of variable stars and astero-seismology.

Vainu Bappu Observatory (1972) is a 1-meter telescope similar to Sampurnanand telescope, Naini Tal and a 2.34 meter aperture, f/3.25 Vainu Bappu telescope (VBT, 1986). The VBT is mated with a CCD spectrograph which got converted into a spectro-polarimeter and a high resolution (70,000-1,00,000) Echelle spectrograph.

Mt Abu 1.2 m telescope (1986) has a back-end instrument, the PRL optical fiber-fed high resolution cross-dispersed echelle spectrograph (PARAS) capable of

velocity precision better than 2 m/s.

Himalayan Chandra Telescope (2003) is a 2m telescope, setup at an altitude of 4,500 m at Mt Saraswati, Hanle in Ladakh for all season observation possibilities. It is open for international astronomers through call of proposals.

Girawali Observatory (2006) is an optical observatory setup specifically for training and observational proposals from Indian Universities.

Devasthal Fast Optical Telescope (2010) is a 1.3 m Cassegrain telescope suitable for optical follow-up of transient events, deep imaging of star clusters, search and study of variable stars, exoplanets. The main objective is monitoring of transients like GRBs, Super novae explosions.

Devasthal Optical Telescope (2016) is a national facility of 3.6 m Ritchey-Chretien telescope. It is currently the largest reflecting telescope in Asia and the first in India to adopt active optics system with a wave front sensor and pneumatic actuators to compensate the distortions in the shape of the 4.3 tonne mirror.

### Solar Observatories

ARIES 15 cm Solar telescope (1961) is a 15 cm Coude solar telescope with Halph filter. It can observe the solar corona during eclipses. It observes regularly the solar eruptive events. Jaipur Solar observatory (1976) is a 50 cm aperture multi-application Solar Telescope (MAST). It is part of Global Oscillatory Network Group (GONG) for continuous monitoring of solar oscillations.

Kodaikanal Observatory (1895) has a 15 cm English mounted Heliostatic refractor, a 46 cm Foucault siderostat, and 38 cm f/90 achromat solar tunnel telescope.

### Gamma Ray Astronomy

Gamma Ray Astronomy PeV Energies (1955-2000) is designed to study cosmic rays with an array of air shower detectors and a large area muon detector.

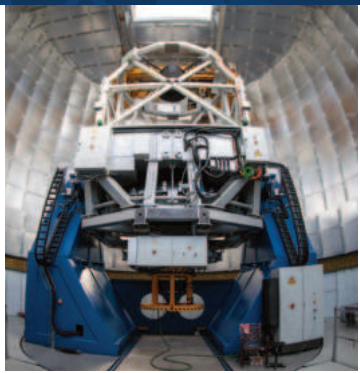
High Altitude Gamma Ray (HAGAR) Telescope is a constellation of seven telescopes, each with 7 mirrors to a total area of 31 m<sup>2</sup>. It is an atmospheric

Cerenkov experiment to work between 10-250 GeV. Historically India has heritage of observing the sky with various instruments and in different time scales. The Country could pursue various studies through “Ground Based Multiwavelength Observatories” and significant conclusions were arrived at. These include: Evershed effect was first detected at Kodaikanal observatory; SARAS-3 refuted the claim of detection of radio wave signal from cosmic dawn; Observations from 104 cm Sampurnananda telescope is the first photo-electric observations of stars from Indian soil. It helped in detection of rings around Uranus with occultation technique and independent discovery of ring around Neptune; Kavalur telescope discovered thin outer ring around Saturn. It also reported discovery of a new minor planet in 1988. This is the first such discovery from India in the 20th century. Kavalur telescope also found evidence of trace of atmosphere on Jupiter’s largest satellite Ganymede; the 1.2 m Mt Abu telescope with PARAS has produced many interesting results including discovery of an inflated hot Jupiter; and the first ever lunar occultation event were made on February 1970 by Ooty Radio Telescope.

### SATELLITE-BASED NAVIGATION

Ability to provide positioning, navigation and timing services based on Satellite Navigation technology provides enormous benefit to nation’s economy. GAGAN (GPS Aided Geo Augmented Navigation) has been put into operation since 2015 by Indian Space Research Organization (ISRO), together with Airports Authority of India (AAI). ISRO has designed and implemented NavIC (Navigation with Indian Constellation) and is providing services since 2018 which places India among the six nations in the world with a capability to provide independent satellite-based navigation services to its citizens.

GAGAN (GPS Aided Geo Augmented Navigation) is a Satellite-Based Augmentation System (SBAS) for enhanced accuracy, availability and integrity of the navigation services to



Devasthal Optical Telescope



Mt Abu 1.2 m telescope



Vainu Bappu Observatory

support Safety of Life operations over the Indian Flight Information Region (FIR), with expansion capability to neighbouring FIRs. The GAGAN is inter-operable with other international systems like US-WAAS, European-EGNOS, and Japanese MSAS and provides seamless air navigation across regional boundaries, to support en-route and precision approach navigation.

#### GAGAN Infrastructure Consists of:

- **Space Segment** encompasses bent pipe navigation payloads on Geo Stationary Satellites GSAT-8, GSAT-10 and GSAT-15, providing in-orbit redundancy.
- **Ground Segment** consists of Reference Stations at 15 locations pan India, Master Control Centre, Indian Uplink Stations, Data Communication Sub-systems, with redundancies. A new region-specific Ionospheric model developed by ISRO enables APV 1.0 precision approach navigation over the Indian region.
- **User Segment** includes all aviation users such as aircrafts and helicopters equipped with SBAS receivers and FMS. All non-aviation users with SBAS capability in their receivers.

NAVIC (NAVigation with Indian Constellation) is an independent satellite-based navigation system to provide positioning, navigation, timing services. It is designed to provide uninterrupted navigation service to the users in the region covering India and an area extending up to 1500 km from its geo-political boundary with a position accuracy better than 20 m ( $2\sigma$ ). NAVIC provides two types of navigation services: Standard Positioning Service (SPS) for

civilian users and Restricted Services (RS) for authorized users.

#### The NavIC infrastructure has three segments:

- **Space Segment** consists of a constellation of satellites broadcasting navigation signals - three satellites in Geo Synchronous orbits and four in Inclined Geo-synchronous orbits.
- **Ground Segment** includes precise timing systems, ranging stations, navigation software, communication networks and spacecraft telemetry, tracking and command networks with adequate redundancies to ensure faultless performance.
- **User Segment** consisting of the various types of user devices in civilian and strategic domains, with the capability to receive and process signal in L5 and S-bands.

Some of the important applications of NAVIC and GAGAN include:

- **Civilian Applications:** Personal navigation for travelers, Railways, Maritime Applications, Vehicle tracking, Automated vehicle navigation, Search and Rescue, etc. NAVIC and GAGAN have been mandated as standard requirements for tracking applications for public and commercial vehicles by Ministry of Road Transport and Highways;
- **Surveying Mapping and GIS:** surveys and production of maps, Geodesy, etc. Large Cadastral mapping applications in Forestry in number of states are moving to GAGAN based solutions;
- **Maritime:** Ship and fishing vessel navigations, ocean studies, position information of potential fishing zones;

- **Railways:** Indian Railways using GAGAN and NAVIC for real time train tracking, collision avoidance, wagon tracking and asset management applications;
- **Strategic Applications:** Tracking of vehicles, airborne vehicles, landing etc.; and
- **Messaging:** Alert messages and Disaster warnings to fishermen at Sea.

The space-based augmentation system GAGAN improves the positioning service with integrity for safety-of-life applications like civil aviation. Directorate General of Civil Aviation (DGCA) has certified GAGAN for en-route operations (RNP 0.1) and precision approach services (APV 1). GAGAN helps airlines to save time and money by efficient and optimized air traffic management. GAGAN has messaging service supporting broadcast of disaster alerts.

The indigenous and independent navigation system NavIC addresses various applications of day-to-day life in civilian domain and strategic requirements of India ensuring self-reliance. Information regarding potential fishing zones and alerts regarding high waves, cyclones etc. are broadcast via NavIC messaging service.

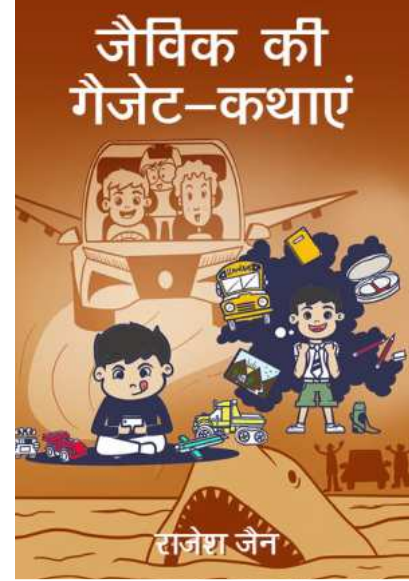
Home-grown industries, start-ups have been developing end-to-end systems for navigation and timing applications contributing to the vision of *Aatmanirbhar Bharat*.

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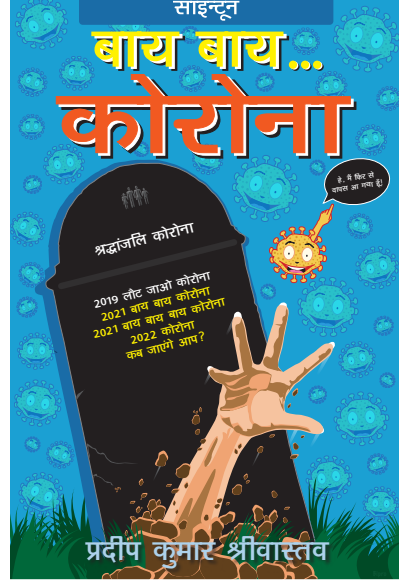
The content of the article is taken from the book "Landmark Achievements in Engineering and Technology in Independent India" published by Indian National Academy of Engineers through Vigyan Prasar



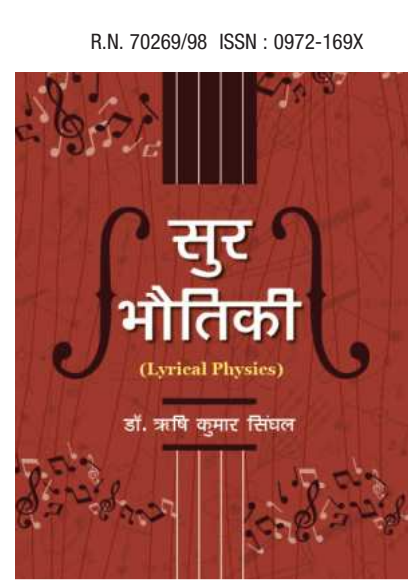
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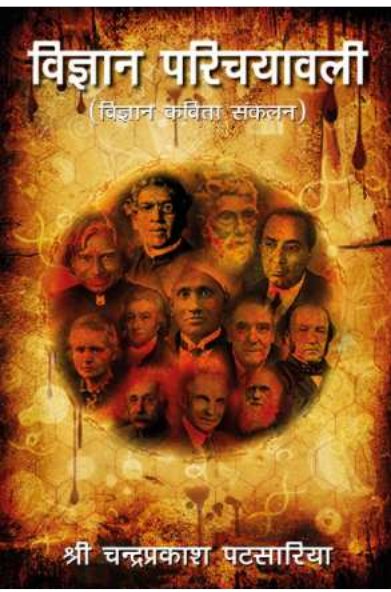
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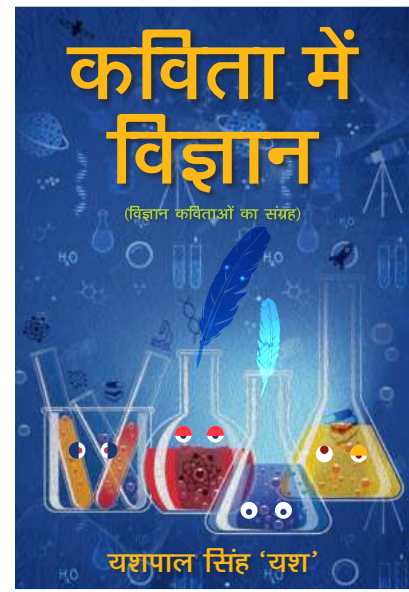
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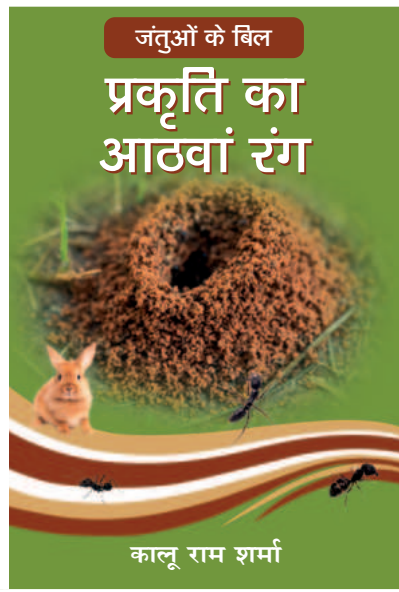
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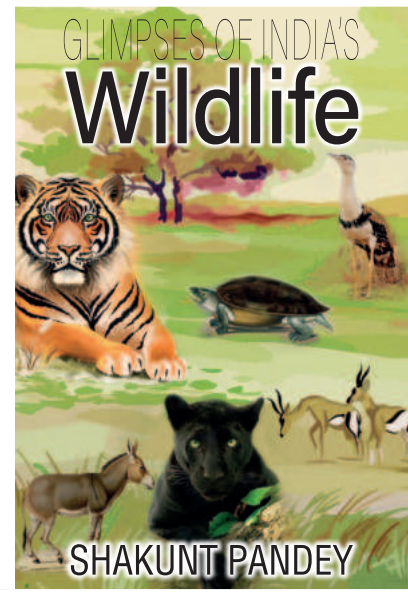
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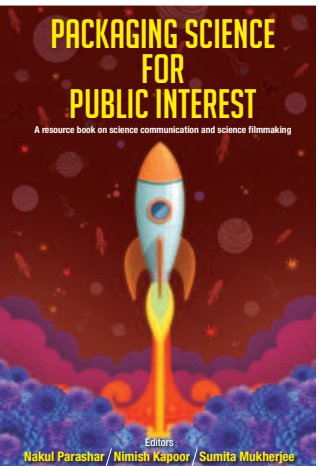
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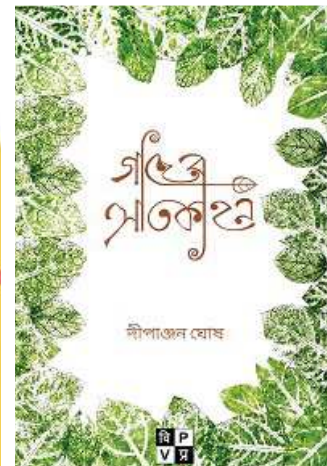
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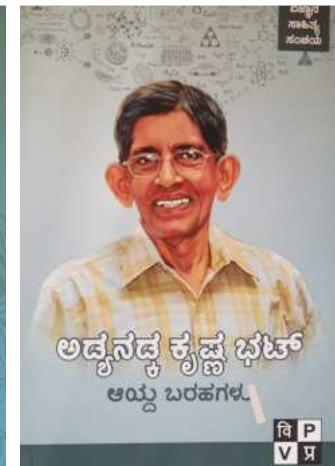
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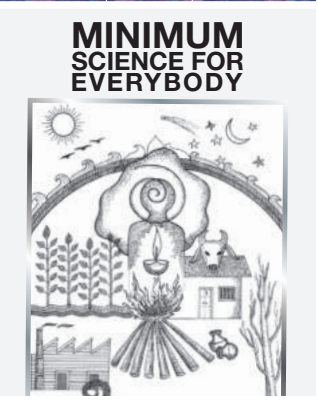
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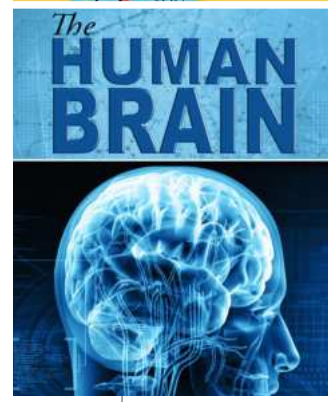
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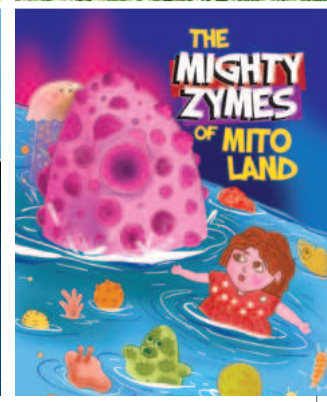
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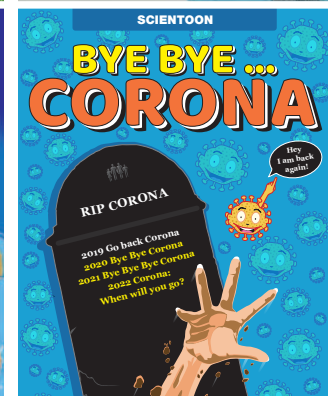
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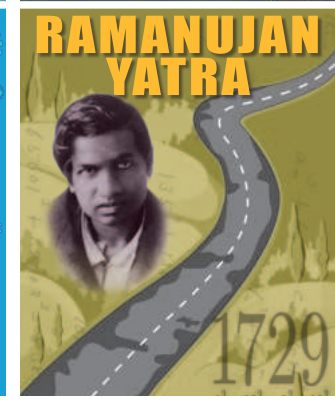
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