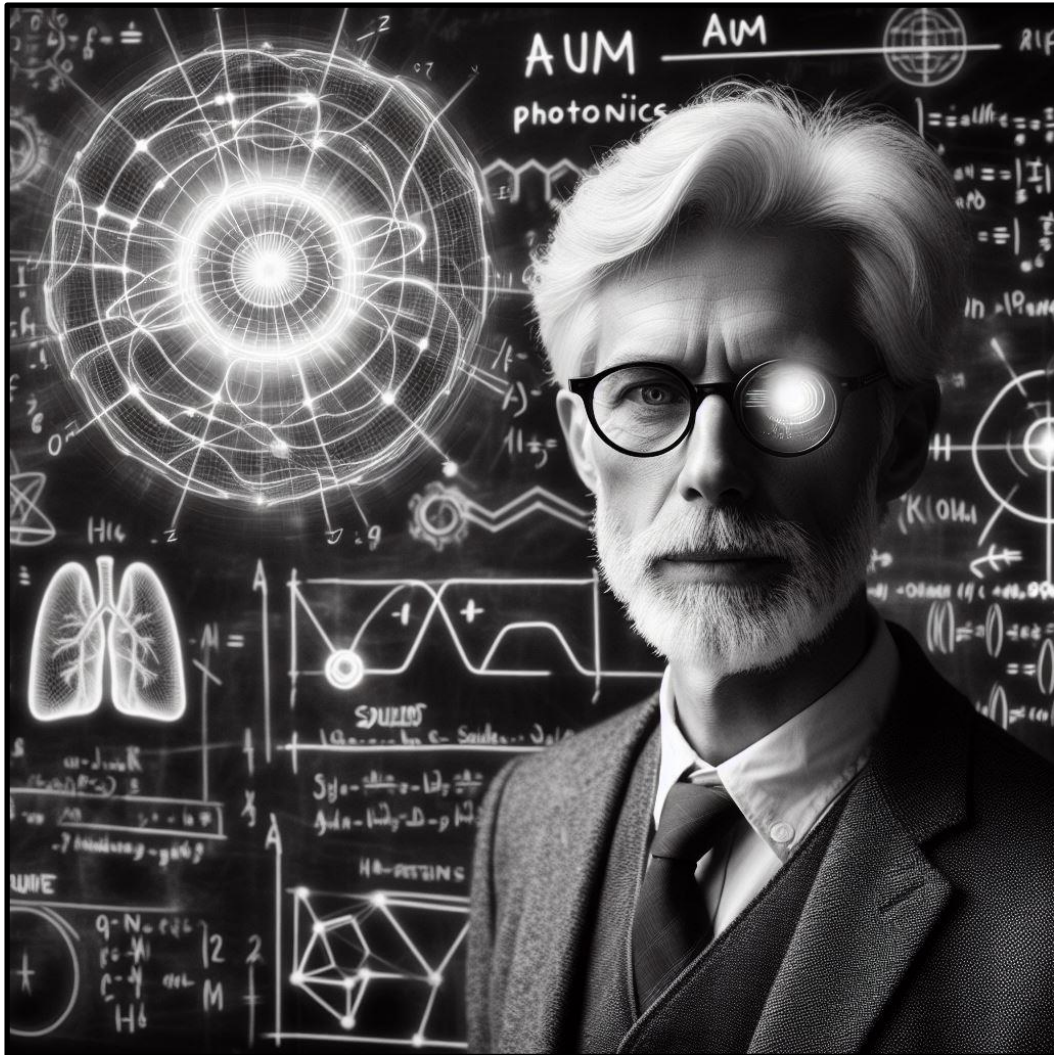


## Atma Nirbharta: Our Journey To Self-Reliance



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### **Impetus:** Self-Reliance in Science, Engineering, and Technology

Science and technology form the backbone of present-day knowledge societies. With their diverse applications encompassing all the domains of human endeavors, it is obvious that they drive societies' economies, lifestyles, and progress. Therefore, the knowledge gained by individuals and organizations worldwide must be shared and transferred to the whole world for the common good of societies.

While working as a Senior Scientist, Researcher and Program Director at the premier R&D organization of the country, the Defence Research and Development Organisation (DRDO), on several critical projects, collaborating with the best professionals in India and also in many friendly countries, Dr. Rao Tataavarti realized that Science, Technology and R&D agendas and the procurement of new systems and technologies to meet national requirements are not necessarily driven by the nation's needs and interests, but is a result of a complex maze of requirements, desires, ambitions, and interests of individuals and organizations with ample scope for influence peddling by national and international players to seduce and compromise the decision makers.

The problem of procurement of systems and technologies for the importing nations becomes exacerbated, especially for critical operational requirements. Technology, especially high-end critical technology, requires a very deep understanding of the capabilities, limitations, and effects of the operating environment where it is being deployed for achieving the desired objectives – suggesting a subtle aspect that technology can also be location-specific in effectiveness, which means that what (technology) works for one country in a particular region of the world may not work for others located in a different environment and climate.

### **The Protagonists: Tataavarti, Shekhar, CASTLE, and Shah**

Having an outstanding academic and research career built on the firm foundation of education and training in Science and Engineering at some of the best institutes in the world (Andhra University, IIT Madras, in India, and Dalhousie University in Canada), Dr. Rao Tataavarti joined the Defence Research and Development Organisation India, on invitation, where he had the opportunity to work for two decades on path-breaking but highly classified work related to Naval Surveillance.

Later, Dr. Rao Tatavarti opted for voluntary retirement from government service to free himself from the stifling constraints imposed by governmental rules, regulations, and structures. To pursue his vision for indigenous technology development, Tatavarti migrated to academia to become a Senior Professor, Dean of Academic Research, and Director of R&D, holding all positions concurrently at a premier private university in India. During his two-year stint at the helm of affairs of the largest private university, Dr. Tatavarti was able to redraw the contours of the research and development policies and practices of the university and was able to guide and steer the thousand-odd academic faculty along with thousand-odd research students towards new and innovative research activities in many interdisciplinary areas resulting in higher R&D outputs and patent productivity, catapulting the university into the top bracket in academic rankings.

After laying the foundations for good, basic, and applied research at the premier university, Prof. Tatavarti decided that it was time to move on to a smaller institution to demonstrate and prove his theory that to accomplish good research, one need not be required to be in big establishments with established R&D ambiance and facilities.

Rao Tatavarti, with over 35 years of R&D and Innovation in Aerospace Engineering, Biomedical Engineering, Bio-Technology, Fluid Dynamics, Photonics, Signal Processing, Image Processing, Satellite Image Processing, Ocean Engineering, and Technology, with more than two hundred peer-reviewed publications, and eight patents always believed that societal problems need to be highlighted, understood, and researched to herald innovation. He passionately nurtured and guided hundreds of youngsters from around the country in diverse fields to help him realize world-class photonic systems with diverse applications.

Being a Submariner and an Electrical Officer, Commodore Shridharan Shekhar served the Indian Navy in many responsible capacities, including a diplomatic assignment in Russia.

Having spent more than three decades in the nation's service as a Naval Officer and the Commanding Officer of the prestigious INS Valsura Electrical Technology School, Cmde Shekhar was a treasure trove of deep knowledge in many domains, especially in matters related to the Submarine arm of the Navy.

On realizing the dire need to establish an independent organization with appropriate structures and systems to attract the best, deploy them in complementary roles, and also deliberate on how India can soar above average to achieve excellence in various fields so that the country does not fall into the trap of imports of critical technologies, Tataavarti teamed up with the seasoned and outstanding veteran submariner, Cmde Shridharan Shekhar to start a non-profit think tank, CASTLE (Centre for Advancement of Science Technology, Law and Engineering) in October of 2010.

CASTLE had the unique distinction of pooling many like-minded individuals of the country who had the nation at heart in all their endeavors, had spent decades in the service of India, and retired from active service, having been pioneers and path-breakers in their respective fields. CASTLE, therefore, had the pooled wisdom of some of the best Academicians, Scientists, Administrators, Lawyers, Doctors, Diplomats, Ambassadors, Generals, Admirals, and Air Marshals of the Nation, along with some of the Indian-born foreign researchers and scientists who were colleagues of Prof. Tataavarti.

During this period, Commodore Shekar and Prof. Tataavarti were selected to concurrently shoulder responsibilities as Regional Directors of the National Maritime Foundation, a Think Tank of the Indian Navy, essentially heading the activities of the NMF regional centers in Chennai and Visakhapatnam.

Under the aegis of CASTLE, Prof. Tataavarti and Cmde Shekhar journeyed together, addressing many issues with full vigor, traveled the world, and mostly made a mark with the powers to be in the country, as well as made a splash overseas.

Biren Mahendra Shah, based in Nashik, was an established direct tax law practitioner, a tax consultant, and a qualified lawyer at the 85-year-old reputed law firm P.G. Shah & Co. Ever interested in setting up enterprises; he has been a successful serial entrepreneur working with many corporations in India and Europe.

While deliberating on various national problems and wide-ranging issues under the aegis of CASTLE and NMF, Cmde. Shekar and Prof. Tatavarti, in consultations with Biren Mahendra Shah, realized the necessity of transforming *think tanks* into *do tanks*, which can innovate in design and develop critical technologies indigenously.

With over 30 years of experience in Business Development and Strategy, Financial Engineering, Marketing and Sales, Security Solutions, and Biocryptics, Biren Shah, who was adept at weaving strategic alliances, fostering meaningful networks, and cultivating long-lasting partnerships, proved an important asset, with an uncanny knack for articulating and strategizing the optimal business solutions with low OpEx and CapEx.

Biren Shah brainstormed with Prof. Tatavarti for over three months, convincing him to initiate the commercialization process of the photonic technologies developed by Tatavarti, and was responsible for shaping the business models of the proposed *do-tanks* and effective avenues for securing funds and investments from like-minded individuals without jeopardizing the original intents and objectives of self-reliance.

Most of the brainstorming was done virtually online with Prof. Tatavarti at the University of Georgia in the USA, where he was then a visiting professor, and Biren Shah at Nashik, India. Cmde. Shekhar, in the meantime, got involved in many other national commitments.

## **CASTLE to CATS: The Transformation**

The *think-tank* CASTLE, which deliberated on various national problems and issues, soon decided that it should pave the way for a *do-tank* that can demonstrate the design and development capabilities of some critical technologies for operational purposes with all the prevailing constraints and challenges. Hence, in the latter half of 2016, the decision was made to create a new group of companies under the CASTLE umbrella, called the CASTLE Advanced Technologies and Systems (CATS). The enormity of the challenges in executing the decision was serendipitously ameliorated by the clarion calls of the Prime Minister of India exhorting the citizens to establish *Start-ups and Make In India*.

To transform indigenous photonic solutions into smart systems by leveraging the advances in internet technologies, Dr. Tatavarti and Biren Shah convinced Anand Patel, the software and Information Technology wizard, to join the proposed *do tank*, the CATS group of companies.

Anand Manubhai Patel, with over 25 years of expertise in crafting and implementing robust enterprise architectures across diverse domains, has consistently delivered architectural solutions that redefine industries. His multifaceted skill set spanned various fields of Banking, Telecom, I.T. Service Management, IoT, IIoT, LegalTech, Reporting & Analytics (*Tableau, PowerBI, Snowflake, Data as a Service*), BigData, DevOps, MLOps, and AIOps.

Anand Patel was tasked to transform indigenous technological solutions developed by Prof. Tatavarti into cloud-based smart solutions by designing high-performance end-to-end enterprise cloud platform services, specifically creating solutions with his deep understanding of Big Data technologies and leveraging them to build systems capable of handling complex data processing tasks. Anand Patel's unwavering commitment to cutting-edge technologies powered innovation and was responsible for driving operational excellence.

Due to his many national commitments and advancing age, Cmde Shekar Shridharan decided not to shoulder additional responsibilities but to be a Mentor. Consequently, the CATS Group was founded in the latter half of 2016 by Tatavarti, Shah, and Patel with the Herculean task of indigenously designing and developing new technologies and systems with humble beginnings against many challenges.

### **Core Team of CATS**

**Tatavarti, Shah, and Patel** were soon joined by Dr. Sridevi Nadimpalli, Anuradha Shah, and Prof. P. Arulmozhivarman for shouldering specific responsibilities. Later, experienced medical professionals and entrepreneurs Dr. Vishwas Savkar and Dr. Vikrant Savkar joined the core team, followed by Premal Shroff, an accomplished businessman striving for society's common good.

**Sridevi Nadimpalli**, the accomplished researcher and professor of Chemistry and Environmental Sciences with over 30 years of experience, loved by her graduate and undergraduate students, became the core member responsible for understanding and elucidating the complex science at the atomic and molecular levels and helped address and solve many pressing and engineering and technological problems, at the cusp of micro and macro science.

**Anuradha Shah**, a well-respected teacher for young pre-degree students for over a decade, became an effective communicator with the pulse of society's identified problems.

**Arulmozhivarman Pachiyappan**, the respected and accomplished Senior Academician and Dean of Research with more than 25 years of experience in Physics and Optoelectronics at a prestigious private university, joined the CATS Group to bridge the R&D gaps between academia and the industry.

**Vishwas Savkar**, the renowned Orthopedic Physician and Surgeon, after establishing an orthopedic hospital and serving the people for over 30 years, developed a passion for creating new enterprises and developing technologies for societal good, together with his son **Vikrant Savkar**, a General Physician trained in India and the U.K., with 20 years of experience in steering and strategizing businesses to drive organizational growth, and **Premal Nitin Shroff**, the astute businessman with shared societal values and passion for entrepreneurship; helped fund and facilitate R&D on various problems which were fast transforming the Nation's Health and Economy.

The core team, with persons of diverse talents, vast expertise, and shared values and passions, quickly gelled to design and develop unique world-class technologies and systems for the good of society.

A galaxy of outstanding and distinguished individuals, **Cmde. S Shekhar**, **Ashok Bhanaut** (Senior Advisor to the MEST Leadership team, and Director of Meltwater Holding N.V., The Netherlands), **Dr. TGK Murthy** (former Outstanding Scientist and Program Director of ISRO), **Prof. P.S. Rao** (former Dean, IIT Madras), **Prof. Madhav Madhira** (former Dean, IIT Kanpur), **Dr. S. Kishore Kumar** (former Program Director and Senior Scientist, DRDO), **Dr. S. Gomathinayagam** (former Director General, NIWE, MNRE), **Prof. A.C. Narayana** (former Director UCESS, University of Hyderabad), and, **Prof. R.M. Pidaparti** (former Dean University of Georgia, USA), came on board as Mentors and Advisors to the CATS Group.

### **CATS: Core Competency, Vision, and Mission**

Having successfully conceptualized and completed several national defense programs on Non-Acoustic Technology development during his two-decade-long stint with the Defence Research and Development Organization, Ministry of Defence, Prof. Tatavarti quickly realized the vast and untapped potential of the photonics domain for diverse applications



and decided to exploit his knowledge and expertise of photonics as the core competency of CATS.

After deciding on the core competency, the core team agreed on the vision and mission statements for CATS. The vision for CATS was to develop world-class, cost-effective technologies and systems, and the mission was to become the benchmark for cutting-edge, adaptable, and affordable sensor technologies and systems.

### **SPHURTHI: Beliefs and Innovation**

After distilling the concepts of the many effective teaching-learning techniques, Prof. Tataavarti and colleagues experimented and designed a unique program called *SPHURTHI* (Societal Problems Highlighted Understood and Researched To Herald Innovation). In *SPHURTHI*, the mentor engages with the young mentees to motivate them, builds interest in the subjects, and imparts knowledge, comprehension, and specific applications in the context of the many fields of the sciences, engineering, and technologies, which form the backbone of the systems to be designed and developed.

Proving that people - *irrespective of their backgrounds and conditions*, can be effectively transformed into an efficient workforce, *even under challenging and exacting conditions* – Prof. Tataavarti transformed the workplace into a cerebral oasis where basic principles of science, engineering, and technology (*sometimes fossilized*) were removed from the cold storage, and fused life into them, resulting in a paradigm shift in terms of the definitions, perspectives, contours of science, engineering, and technology. Managing time properly, respecting time, working with people who are totally different, realizing the inherent beauty of discipline, accepting challenges, celebrating the successful completion of deadlines, sharing knowledge, patience, active listening, tolerance, and self-actualization were some of the things, taught and learned, at the workplace.

The innovative approaches practiced by Tataavarti and team wove science and sensibility into a beautiful tapestry, resulting in a wonderful metamorphosis where the young team members went from a '*Can I?*' attitude to an '*I Can !*' philosophy in solving pressing S&T problems. In short periods, the youngsters were no longer *aimless arrows* but *guided missiles*.

Pursuing the belief that - *the interplay of science with necessity ushers in new technology* and that *the interaction of science and technology is what helps bring about an understanding of the world, connecting with the world, thereby contributing to the transformation of the world*, Prof. Rao Tataavarti and his team assiduously coupled the relevant sciences with engineering, to design and develop *indigenous photonic technologies and systems*, to overcome many of the prevalent challenges using innovative principles.

Of the hundreds of students who benefitted from the program, a few interested youngsters with humble backgrounds were encouraged to join the CATS Group in designing and developing indigenous technologies and systems. Prof Tataavarti successfully created a small but dedicated and highly motivated team of youngsters, a state-of-the-art Photonics Research Laboratory, and a sub-sonic wind tunnel facility with frugal funding. The sincerity, hard work, and dedication of these young Indians from across the country and different parts of the world were responsible for developing CATS technologies and systems of world standards.

### **CATS: Indigenous Smart Photonic Systems**

Innovatively utilizing principles encompassing interdisciplinary fields of research, Prof. Tataavarti and his team indigenously developed many novel and highly sensitive photonic systems (*some patents granted and some pending*) for a wide range of Defence and Civilian applications.

In a short period, CASTLE Advanced Technologies and Systems Group developed photonic and smart technologies and systems, aiming to provide innovative solutions for various domains such as aerospace, healthcare, green buildings, and surveillance. A conscious effort was made to name all the indigenously developed photonic systems with appropriate *Sanskrit* terms, to not only drive the message of the Prime Minister that the time has come to boost the nation's efforts and economy through self-reliance but also to showcase to the world that Indian products have world-class quality.

1	<b>AUM</b> <b>ॐ</b> Air Unique – quality monitoring	System for Environmental Monitoring
2	<b>PRANEEDHI</b> <b>प्रणिधि</b> Photonic Reconnoitering of Acoustic Noise for Effective Eaves Dropping and Highlighting Intelligence	System for Eavesdropping
3	<b>SAMIRA</b> <b>समिरा</b> Seeing Air in Motion: Instrumentation for Remote- sensing Applications	System for Wind Profiling
4	<b>SARATHI</b> <b>सारधि</b> Search And Rescue Apparatus for Targeting Holistic Information	System for Search and Rescue in Disaster Management
5	<b>SAVDHAN</b> <b>सावधान</b> Scan, Analyze, Validate, Discriminate, Highlight, Assess and Neutralize	System for Maritime Surveillance
6	<b>Dr. T</b> <b>धन्वन्तरि (डॉ. टी)</b> <i>Dhanvantari's</i> Technology	System for Exhaled Breath Analysis
7	<b>taraNI</b> <b>तरणि</b> Technology for Air-data Reckoning for Aerial Navigational Information	System for Air-data Monitoring onboard Aircraft.
8	<b>VAYU</b> <b>वायु</b> Variable Air Yielding Unit	Fully Instrumented Wind Tunnel Facility
9	<b>VEDA</b> <b>वेदा</b> Vibrational Effects – Detection Analysis	System for Vehicle and Intrusion Monitoring
10	<b>VIDUR</b> <b>विदुर</b> Vibration Intelligence Data Unravelling Remotely	System for Vibration and Condition Monitoring
11	<b>AJNA</b> <b>आज्ञा</b> Aerosol Judicating Navigational Apparatus	System for Microbial Surveillance in Air
12	<b>SWAASA</b> <b>श्वासा</b> System for Wellness Assessment and Analysis of Sampled Air	System for Lung Functionality Assessment
13	<b>DronAcharya</b> <b>द्रोणाचार्य</b>	Drone-based Integrated Photonic System

		for Diverse Applications
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The systems designed with the COTS philosophy involving several state-of-the-art technologies are modular, portable, and occupy optimal space with low power requirements. Except for a couple, over 95% of all components in the systems were indigenous.

The monitored data from these systems are pushed through wireless sensor networks onto cloud-based platforms and servers, facilitating big data analytics for the real-time posting of digestible comprehensive information and predictive analytics to any user worldwide for operational purposes.

All the photonic systems resulted from innovative applications of the principles of laser backscattering, statistical mechanics, optoelectronics, artificial intelligence, machine/deep learning, and the Internet of Things. The systems facilitate real-time remote monitoring with high precision, sensitivity, and accuracy.

All photonic systems were calibrated with gold standards. After undergoing rigorous testing and evaluations, as per standard international practices in the laboratory and the field, Prof. Tataavarti and his team demonstrated that the indigenously developed systems are more advantageous than any commercially available conventional systems in vogue and are more economical with superior sensitivities and accuracies. After rigorous peer reviews, the work on indigenously designed and developed systems was published in reputed, internationally acclaimed scientific and technical journals and as technical reports.

Therefore, the USP of the CATS photonic systems has become real-time, remote, sensitive, and accurate monitoring, and they are much more economical than other conventional systems.

## Proofs of Concepts (PoCs): Field Trials / Demonstrations

VEDA and VIDUR, having applications in real-time remote Vibration and Condition Monitoring, in addition to structural health monitoring, have attracted the attention of the Ministry of Railways and the Ministry of Road Transport and Highways, Government of India due to their potential applications to both the Ministries of Government of India.

Consequently, technology demonstrations and field evaluation trials for VEDA and VIDUR systems were successfully carried out - for the *Ministry of Railways* on the KK Line (Kothavalasa-Kirandul Line under the Waltair Division of East Coast Railway of the Ministry of Railways, which passes through three southern states through complex terrains coupled with problems of track removal/obstruction by insurgents), and for the Ministry of Road Transport and Highways on the NHAI Road Bridge on NH16 (*a bridge identified to be under distress by MORTH, GOI*), Visakhapatnam.

The technology demonstration for the Ministry of Railways was conducted in the presence of the Divisional Railway Manager, Waltair Division, East Coast Railway, and the details were presented to the Cabinet Minister of Indian Railways and at the International Technical Seminar of the Institution of Permanent Way Engineers (India). Against the background of the complexities in real-time monitoring of permanent ways, bridges, and structures, the novel, innovative photonic systems were demonstrated to be capable of monitoring real-time vibrations and can be deployed on the train and on track for real-time effective monitoring.

Prof. Tatavarti and the team completed the technology demonstrations of VEDA and VIDUR at Visakhapatnam, on a live road bridge in the presence of the Director General and Special Secretary of MORTH (Ministry of Road Transport and Highways), Govt. of India [1].

The systems are compact, portable, and can be easily deployed at any location for real-time vibration and condition monitoring in a non-intrusive fashion, even in inaccessible areas, and can remotely track vibrations and conditions of structures simultaneously in the time and frequency domains. Technologies for integrating various spatially separated systems using fundamental Internet of Things communication concepts are also in place for quick deployment.

Questioning the conventional wisdom of air pollution monitoring at a single location, which involves measurements by a suite of sensors having different technologies from different manufacturers - integrated and housed in a rather bulky shipping container, which not only poses significant challenges in data acquisition and assimilation but also involves significantly high costs to arrive at digestible information for researchers, policymakers as well as the common public; Prof. Tatavarti and team designed and developed a compact photonic system capable of remote real-time monitoring of various air pollutants in situ - either at a particular location or across a spatial domain of interest. The photonic system was designed and developed using COTS (commercially off the shelf) technologies, making it significantly cheaper for broader deployment, in sync with the WHO's roadmap and solving the accompanying problems and challenges associated with the monitoring of air pollution at a single location with the disparate sensors of varying sensitivities, accuracies, and temporal responses.

The uniqueness and novelty of the novel photonic system, AUM, lay in its ability to innovatively apply the concepts of laser backscattering, artificial intelligence, and machine (deep) learning to identify, classify, and quantify various air pollutants simultaneously from a single laser backscattering measurement. The photonic system was extensively evaluated in the laboratory and the field.

Field inter-comparisons and evaluation exercises of AUM with the imported conventional systems for Continuous Ambient Air Quality Monitoring Stations (CAAQMS) were

performed over an 18-month duration by collocating AUM with CAAQMS in Karnataka, Maharashtra, West Bengal, and New Delhi. The intercomparison results were good, yielding air quality estimates with high sensitivity and accuracy at high sampling frequencies. This was duly recognized by the Prime Minister of India [2], the Minister of Science & Technology and Health, the Government of India, and the Department of Science & Technology of India [3, 4].

Prof. Tataavarti's penchant for taking up work on complex and challenging scientific problems, coupled with his out-of-the-box thinking, reaped rich dividends in the form of the development of novel photonic technologies to solve pernicious problems related to fast-moving fighter aircraft (*for the Ministry of Defence, Government of India*); and for accurate and cost-effective resource assessment for setting up wind power plants (*for Ministry of New and Renewable Energy, Government of India*). The path-breaking technologies received appreciation and accolades from the Government of India [5].

On a request from Hindustan Aeronautics Limited (HAL), an Indian state-owned aerospace and defense company in 2020, Prof. Tataavarti demonstrated the technology of the photonic system VIDUR, for detection and localization of damage on one of two identical specimens provided by HAL, the specimens specially fabricated to represent complex Aircraft structural assembly - with the damage camouflaged under the layers of one of the specimens. The successful technology demonstration laid the foundation for collaboration with HAL in aircraft maintenance and repair.

In 2023, proof of concept demonstrations were conducted at the Jindal Steel Works (JSW), India's leading steel manufacturer. The CATS Group demonstrated the efficacy of AUM and VIDUR photonic systems for real-time gas leak detection and pipeline integrity management applications.

## Worldwide Collaborations and Accolades

CATS technological developments have attracted the interests and attention of the international scientific and engineering fraternity, which resulted in his collaborations and MoUs with *Ecole Polytechnique Federale de Lausanne (EPFL)*, a research institute and university in Lausanne, Switzerland, and M/S SenseFly, SA (Parrot Group), Switzerland.

The Indian Defence PSU HAL, Nashik, and the Air Force Station BRD11 (Base Repair Depot 11) Ojhar, Nashik, have requested Dr. Tatavarti to share his indigenous technology for the Structural Health Integrity Assessment of the Indian Fighter aircraft.

Judging the importance and potential of CATS technologies, the multinational consortium of AIRBUS had selected CATS Global from among 140+ start-up firms across seven countries to accelerate the commercialization process [6]. The indigenous systems are now ready for commercialization.

The premier Industry body of Indian Industry, the *India Electronics and Semiconductor Association (IESA)*, honored CATS Global with the *Most Promising Aviation & Defence Start-up of the Year Award (2019)* - after adjudging it to have demonstrated its innovation, technical and marketing excellence, customer acceptance/market success/a true leadership offering by a start-up in Aviation and Defence [7].

In recognition of his multifaceted achievements, *Aviation Update*, India's premier aviation monthly magazine, featured Prof Tatavarti on its cover page with a caption titled, *Up, Close and Personal with the savant Prof Dr. Rao Tatavarti* [8].

Prof. Tatavarti's eloquent articulation on the need for indigenous defense technologies for India [9] made him a consultant and technical adviser to the then *Raksha Mantri*.



In 2017, Prof. Tataavarti was elected Fellow of the Andhra Pradesh Akademi of Sciences for his multifaceted pioneering and path-breaking works across many disciplines of Science and Engineering.

In 2022, the CATS technologies were judged as one of the Top 100 Indian Innovations by the Indian Innovator Association [10]. The Department of Science and Technology (DST) Government of India showcased the AUM Photonic System as one of India's major achievements of 2022 in Science and Technology [11].

In 2023, the CATS products were judged as the Top Product at the ELECRAMA Expo in New Delhi [12]. The Andhra Pradesh Innovation Society (APIS) in Visakhapatnam and IIT Madras Foundation, Chennai, invited Prof. Tataavarti to incubate CATS under their umbrella with attractive grant offers.

### **Atma Nirbharata: Lessons Learnt**

We began our journey by addressing some pressing social problems, embarking on developing indigenous scientific and technological solutions for the societal good against the backdrop of established international technologies and players with vested interests dictating terms and standards involving very high costs. The many challenges were compounded by the global COVID-19 pandemic.

The two-year COVID-19 pandemic disruption taught us new ways to re-align, focus, and support the team members to reach our goals despite the complete lockdown periods. As we complete seven years of our journey, we have reached the cusp of commercialization of the indigenously developed products with a multi-million USD valuation.

The journey toward self-reliance, driven by challenging conditions and constraints, taught us the following lessons.

- 
- *Knowledge and ability to solve complex technological problems are neither proprietary nor the prerogative of developed countries / big organizations.*
  - *The difference between possible and impossible outcomes lies in the team's determination.*
  - *Technological performances, especially for operational purposes, can be strongly governed by site-specific temporally varying environmental conditions. Therefore, technologies imported from other parts of the world may not always suit our requirements. What is good for the goose may not always be good for the gander.*
  - *It pays to listen to our people with good intentions and have the wisdom and ability to differentiate between good and vested interests.*
  - *In spite of challenges, patience, and perseverance always pay rich dividends.*
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