Science, Engineering, and Technology – Contributions

Prof. Rao Tatavarti possesses an outstanding academic and research career built on the firm foundation of education and training in Sciences and Engineering at some of the best institutes in the world. Tatavarti had his preliminary education from Andhra University, majoring in Physics in his undergraduate program and Physical Oceanography, Marine Sciences in his Master's program. Later he joined IIT Madras and secured a Master's in Ocean Engineering before moving to Canada to work on his Ph.D. After completing his doctoral research in Canada, Dr. Tatavarti joined the Defence Research and Development Organisation India, on invitation, where he had the opportunity to work on path-breaking but highly classified work related to Naval Surveillance. After a long stint at the Naval Physical & Oceanographic Laboratory in Kochi as a Senior Scientist and Program Director, Dr. Tatavarti opted for voluntary retirement when he was the Director Grade Scientist to move to academia as the Director (Research & Development) and a Senior Professor at VIT University, Vellore - a premier university in the country. From Vellore, Prof. Tatavarti moved to Visakhapatnam, where he initially served as Director of Gayatri Vidya Parishad institutions, Dean (Research and Consultancy), and Senior Professor at GVP College of Engineering; and is now a Distinguished Professor and Director.

Tatavarti had his first Masters's in Marine Sciences with Physical Oceanography as a specialization from Andhra University, where he secured the university's first rank. During his second Masters's in Ocean Engineering at the Indian Institute of Technology, Madras, Tatavarti worked on the problem of the nearshore sediment transport along the coast of Madras and its many implications to the nearshore shoreline dynamics, successfully identifying the alongshore and cross-shore components of sediment in motion during the various seasons of the year and for the first time, quantifying the effects of near-shore structures on the dynamics of shorelines (Tatavarti and Sundar, 1984 in the *Proc. Pacific Congress on Marine Technology;* Tatavarti, Sundar and Raju, 1985 in the *Proc. Intl. Conf. on Dock and Harbor Engineering;* Tatavarti, Sundar and Raju, 1987 in the *J. Institution of Engineers, India*). After completing his Masters's in Ocean Engineering, Tatavarti contributed to the prestigious national programs on renewable wave and tidal energy from the ocean as a Senior Project Officer at IIT Madras, wherein he was responsible for identifying and quantifying the energy potentials along the Indian coastline (Tatavarti and Sundar, 1982 in the *J. Energy*), which formed the guiding design criteria for extraction of renewable energy along the Indian coasts.

After securing two concurrent international scholarships and an invitation to work with two world-renowned senior professors, Anthony Bowen, and David Huntley, at Dalhousie University, Canada, Tatavarti moved to Dalhousie University for his doctoral work. As part of his doctoral work, Dr. Tatavarti's research in the area of wave hydrodynamics resulted in the development of analytical models and algorithms for quantifying the frequency-dependent wave reflections on natural beaches (and in laboratory wave flumes), which enabled the decomposition of waves into incoming and outgoing waves on a natural (or a laboratory) beach. This work provided insights into near-shore hydrodynamics of waves and the *first field evidence for the existence of long wave generation by time-varying breaker zone locations* (the breaking point) *in the surf zone*. The work directly applied to designing and constructing jetties and breakwaters in Coastal, Port, and Harbor Engineering (Tatavarti and Huntley, 1987 in the *Proc. Canadian Coastal Conference*; Tatavarti *et al.*, 1988, in the *Proc. ASCE Coastal Engineering Conference*; Tatavarti, 1989 in *Ph.D. Thesis,* Dalhousie University, Canada; Huntley, Simmons and Tatavarti, 1999 in *Jl. Port, Coastal, and Harbor Engineering*). While working on the various signal processing techniques on enormous data sets, Dr. Tatavarti demonstrated that the Eigen-value problem is a form of minimum least squared approximation and that the Complex Empirical Orthogonal Function Analyses are a better tool to extract additional insights from data (Tatavarti and Andrade, 1992 in *Jl. Ocean Engineering*). Dr. Tatavarti has also participated in many ocean exploration programs associated with the oil and natural gas industry in and outside India and has expert knowledge in exploration and exploitation techniques and technologies.

During his tenure with the Defence Research & Development Organisation (DRDO), Dr. Tatavarti pioneered non-acoustic naval surveillance technologies. He conceived, built, and headed the *Centre for Oceanics and Optronics* at Kochi's Naval Physical & Oceanographic Laboratory. He was also the Program Director of many major Defence and civilian programs, which had great significance to the Navy and the country's disaster management programs. Dr. Tatavarti has significantly contributed to ocean science, engineering, and technology through new algorithms, novel monitoring techniques, and innovative design and development of highly sensitive optoelectronic systems for studying the dynamics of stratified fluids. The optoelectronic systems developed by Dr. Tatavarti helped make significant inroads into understanding the free and forced

motions in stratified fluids. They opened new pathways in ocean and aerospace surveillance technologies and systems for Defence and civilian applications.

Dr. Tatavarti's research on novel techniques for monitoring stratified fluid dynamics demonstrated that advances in optoelectronic technology could suitably be adopted for fluid dynamic studies. His monitoring techniques achieved higher sensitivity, thus demonstrating the efficacy of optoelectronics as a remote sensing tool for monitoring stratified fluid motions. The work thus established new pathways with far-reaching implications for both Defence and civilian applications (Tatavarti *et al.,* 1995 in *Current Science*; Tatavarti *et al.,* 2002 in *Proc. ICONS Conference*; NPOL-RR-08/2003 in *Research Report*). After successfully demonstrating the techniques under laboratory conditions, Dr. Tatavarti developed engineered optoelectronic systems for monitoring stratified fluids with very high sensitivity (Tatavarti*,* 2009 in *Proc. IEEE Conference on Sensors)*. During field trials in various oceans, Dr. Tatavarti further deployed the indigenously developed optoelectronic systems to demonstrate the feasibility of identifying natural and anthropogenic hydrodynamic signatures and fast-moving solitons in both upstream and downstream directions of moving bodies. The indigenous systems have multiple applications and have helped Tatavarti and the team file for national and international patents. As the Program Director and Chief Scientist, Dr. Tatavarti had efficiently designed and effectively deployed several naval and civilian platforms (ships, submarines, helicopters, and aircraft) during the 50+ missions he steered successfully.

Addressing the problem of detecting and discriminating spatial features, patterns, and objects from space-borne satellite images, Dr. Tatavarti developed a suite of image processing algorithms utilizing concepts from physics, hydrodynamics, pattern recognition, computer vision, and motion mechanics. Dr. Tatavarti and his team successfully tested the innovatively developed suite of algorithms for its utility in identifying spatial features and objects (ships and submarines) and their manifestations on the ocean surface. This work had significant implications for the Navy and therefore was documented in the form of classified research reports (NPOL-RR-10/2003, NPOL-RR-12/2003; NPOL-RR-47/2007) and publications (Tatavarti and Sivakumar, 2002 in Proc. *ICONS Conference*; Tatavarti, 2003 in Proc. *UDT Conference*). He was also instrumental in developing a decision-based algorithm for the efficient removal of salt and pepper noise from images (Nair, Revathy, and Tatavarti, 2008 in *Proc. IEEE CISP Conference*) and fuzzy-logic based automatic contrast enhancement method for images from satellites (Nair, Lakshmanan, Wilscy and Tatavarti, 2009 in *Signal Video and Image Processing Journal*) and an efficient noise detection algorithm for impulse noise removal in images (Nasimudeen, Nair and Tatavarti, 2010 in *Signal Video and Image Processing Journal*).

Simultaneously, in the R&D on the civilian domain, Dr. Tatavarti has contributed significantly to understanding the unique and complex fluid-mud (mud bank) phenomenon off the Kerala coast, utilizing indigenous sensors and conducting innovative field experiments. This work gave the first field evidence for the existence of strong edge waves, infragravity waves, far infragravity waves, wave reflections, alongshore and cross-shore currents and their interactions with the monsoonal dynamics, thus explaining the formation and sustenance of mud banks (Tatavarti *et al.,* 1996 in *Current Science*; Kumar, Narayana, and Tatavarti, 1998 in *Jl. Geol. Soc. India*; Tatavarti *et al.,* 1999 in *Current Science*; Narayana, Kumar and Tatavarti, 2001 in *Coastal and Estuarine Fine Sediment Processes*, Elsevier Publication; Tatavarti and Narayana, 2006 in *Jl. Coastal Research*).

Based on field studies immediately after the December 2004 tsunami, Dr. Tatavarti showed that the sediment deposits on the coast could serve as markers of paleo-tsunamis (Narayana, Tatavarti, Shinu, and Subeer, 2007 in *Marine Geology*). In 2008, working with the Department of Space, and the Ministry of Earth Sciences, Dr. Tatavarti developed an optoelectronic system for monitoring tsunamis in the ocean with very high sensitivity (3 to 4 orders of magnitude higher sensitivity than the conventional pressure transducers presently used).

From November 2008 to December 2010, Dr. Tatavarti worked as the Director of Research and a Senior Professor at VIT University, leading the R&D activities of the university, having 1100 faculty and 900 research students in his capacity as Director (R&D), and Member of the Board of Management and the Academic Council at VIT University. As Director of Research at one of the top Indian universities, Dr. Tatavarti developed algorithms for pragmatically quantifying the quality of research output from a university to enthuse and encourage the university researchers to excel further in their research endeavors (Tatavarti *et al*., 2010 in *Current Science*). VIT has conferred the Most Active Researcher Award on Prof. Tatavarti (2009, 2010).

Exploring the fertile domain of biomedical technologies, Prof. Tatavarti's image processing research - *for developing an automated diagnosis of diabetic retinopathy and glaucoma using Fundus and OCT images* – resulted in a benchmark publication garnering a large number of citations by the biomedical and biotechnological research fraternity (Arulmozhivarman, Das, Murthy and Tatavarti**,** 2012 in *J. Lipids in Health and Disease*).

Prof. Tatavarti's advanced work on non-acoustic technologies for the detection of surface and sub-surface platforms in the ocean, published by a high-powered committee of the Ministry of Defence, Government of India, attracted the attention of 1500+ academic and defense scientists/engineers/technologists/researchers from across 100 countries (*https://independent.academia.edu/RaoTatavarti/Analytics/activity/overview*; Toppaladoddi, Dixit, Tatavarti and Govindarajan, 2011 in *Physics of Fluids*; Tatavarti et al., 2013 in *IDST Journal*), including those in the highest echelons of Government of India.

Since December 2010, Dr. Tatavarti is working as the Director (Research & Consultancy) at Gayatri Engineering College, an autonomous institute affiliated currently to Jawaharlal Nehru Technological University, Kakinada, where he established state of the *art photonic research laboratory* and *an indigenous subsonic wind tunnel facility*. In 2010, Prof. Tatavarti also founded a non-profit think tank, *CASTLE*, which endeavors to inculcate the spirit of R&D amongst all and bring together researchers and various stakeholders to address societal problems.

Dr. Tatavarti's research interests are varied, and he has guided PhDs (5), Master's (43), and Bachelor's (38) students in various fields of Science and Engineering. In addition, he taught graduate-level courses in *oceanography/ocean engineering/signal and image processing/ fluid dynamics/optoelectronics/research methodology* for graduate students at IIT Madras, Cochin University of Science and Technology, VIT University, University of Hyderabad, GVP College of Engineering, Indian Maritime University, India; Dalhousie University, Canada and the University of Georgia, USA. As part of his professional career, Dr. Tatavarti headed projects from various governmental agencies with a total financial outlay of more than Rs.500 million and offered technical consultancy and advice to multiple industries and organizations. In recognition of Dr. Tatavarti's contributions, DRDO has conferred on him an *Award for Advances in Naval Technology (1997)*, a *Silicon Medal (2006)*, and *DRDO Laboratory Scientist of the Year Award (2007)*.

Employing novel pedagogical principles (Saripalle, Kumar, and Tatavarti, 2014 in *Journal of Innovation and Technology Management*), Prof. Tatavarti mentored, taught, and guided hundreds of science and engineering students of different disciplines at various institutes worldwide and successfully facilitated them in securing challenging, well-paid jobs in the industry, and or embark on research activities at other internationally reputed institutes. (Ref: http://*www.gvpsirc.in*). Prof. Tatavarti'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 (*http://www.cats-global.com/testimonial.htm*).

Addressing the problem of sea erosion at Visakhapatnam on the invitation of the Chief Minister of Andhra Pradesh in 2015, Dr. Tatavarti steered an inter-institutional team of researchers and students and conducted the *first and perhaps the only known field investigations and detailed scientific study of the nearshore zone (especially the surf zone) of Visakhapatnam* - with various state of the art instrumentation coupled with theoretical modeling and simulation studies. Based on the innovative studies and the engineering solution recommended to the Government, Prof. Tatavarti demonstrated how complex problems can be solved, even under challenging conditions and constraints, with local talent and resources (*Research Reports by Rao Tatavarti, 2015; on 'Wave, Current and Sediment Measurements in the Nearshore Zone for Suggesting Measures for Mitigation of Vizag Beach Erosion,' IENG/SE-V/AE-I, 12 Reports, pp.1300). https://www.thehindu.com/news/cities/Visakhapatnam/a-rewarding-experience/article6944195.ece; https://www.linkedin.com/pulse/saga-sea-erosion-visakhapatnam-prof-dr-rao-tatavarti).*

Pursuing the beliefs 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. Tatavarti 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. After undergoing rigorous testing and evaluations *as per standard international practices in the laboratory and the field*, Tatavarti demonstrated that the indigenously developed systems are not only more advantageous than any of the commercially available conventional systems in vogue, but also were more economical with superior sensitivities and accuracy. In brief, using innovative principles encompassing interdisciplinary fields of research, Prof Tatavarti had indigenously developed novel and highly sensitive photonic systems (*patents pending*) - *AUM, PRANEEDHI, SAMIRA, SARATHI, SAVDHAN, TARANI, VAYU, VIDUR, VEDA* - for a wide range of Defence and civilian applications, which are now ready for commercialization.

Two of the indigenous photonic systems - 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 in December 2016 - 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 in February 2017 - 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 Ministry of Railways 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 2017 of the Institution of Permanent Way Engineers (India) in January 2017. Against the background of the complexities in real-time monitoring of permanent ways, bridges, and structures, the novel, innovative photonic systems (*patents pending)* - designed and developed by Prof. Tatavarti - were demonstrated to be capable of monitoring real-time vibrations and can be deployed on the train, as well as on track; for real-time effective monitoring.

Prof. Tatavarti completed the technology demonstrations of VEDA and VIDUR in February 2017 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. 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. *(http://www.thehindu.com/news/cities/Visakhapatnam/now-get-updated-on-health-ofstructures/article17328904. ece).*

In 2017, Prof. Tatavarti started a high-end Technology Start-Up Company, CATS Global, which endeavored to push indigenous technologies and systems worldwide (Ref: *http://www.cats-global.com*). 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 (*https://www.airbus-bizlab.com/news/airbus-bizlab-bengaluru-starts-third-season-with-six-finalist-start-ups/view)*.

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; Tatavarti (2018) 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, lies 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 and was found to be good, yielding air quality estimates at very high sampling frequencies with high sensitivity and accuracy. This was duly recognized by the Minister of Science & Technology and Health, Government of India and the Department of Science & Technology of the Government of India. *(https://www.google.com/url?sa=t&source=web&rct=j&url=https://mobile.twitter.com/drharshvardhan/status/1293748811647442944&ved=2ahUKEwjNiZvZhZzrAhUJbn0KHTJ_CMQ4ChAWMAB6BAgIEAE&usg=AOvVaw0QmFmiEtrz1N44No4iFlHX; https://www.google.com/url?sa=t&source=web&rct=j&url=https://dst.gov.in/indigenous-air-unique-quality-monitoring-aum-photonic-system-developed-real-time-remote-monitoring&ved=2ahUKEwiBwPSMiZ_rAhV3_XMBHROrCMwQFjABegQIAhAB&usg=AOvVaw23H8DU9u1lnelned3xOfG).*

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 (*https://www.youtube.com/watch?v=GEIIC346O4E*).

On a request from Hindustan Aeronautics Limited (HAL), an Indian state-owned aerospace and defense company in 2020, Prof Tatavarti 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.

Prof. Tatavarti's 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.

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' (https://www.magzter.com/IN/AVIATION-UPDATE/Aviation-Update/Business/410116; https://www.magzter.com/article/Flying-Aviation/Aviation-Update/INTERVIEW*; *Aviation Update*, Feb. 2020, Vol 6, Issue 5, *http://www.avaiationmagazine.in*).

Prof. Tatavarti's brief yet eloquent articulation on the need for indigenous Defence technologies for India (Tatavarti, 2015 in *Organizer* and *Panchajanya*) resulted in him becoming a consultant and technical adviser to the then *Raksha Mantri*. Having varied research interests, Dr. Tatavarti has 200+ Scientific and Technical contributions to his credit (*169 Research Publications in Peer Reviewed Journals / Conference Proceedings / Classified Research Reports, 2 Monographs, 4 Book Chapters, 12 Indigenous Systems, and 8 Patents - Indian Patent No.1469/DEL/2007, US Patent No. US2010/0321698/A1, European Patent No. EP 2160577 (A2), International Patent filed in African Countries – PCT No. 1469/IN2008/000444, Indian Patent – IPO No. 1819/DEL/2008, Indian Patent No.2567/CHE/2010, Indian Patent No.3597/CHE/2010, US Provisional Patent No. 62/863,013/2019*). In 2017, Prof. Tatavarti 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.

Prof. Rao Tatavarti is currently having an *h-index* of 19 and an *i10 index* of 24, with more than 1000+ *citations* (Ref: *https://scholar.google.co.in/citations?user=soE7Q9MAAAAJ&hl=en*); is an active researcher and a keynote speaker at many reputed institutes and scientific and technical gatherings worldwide, in addition to being a reviewer and editor of peer-reviewed journals.

Prof. Tatavarti travels worldwide and actively collaborates in multi-disciplinary research and academic activities with his peers at many internationally reputed institutes.