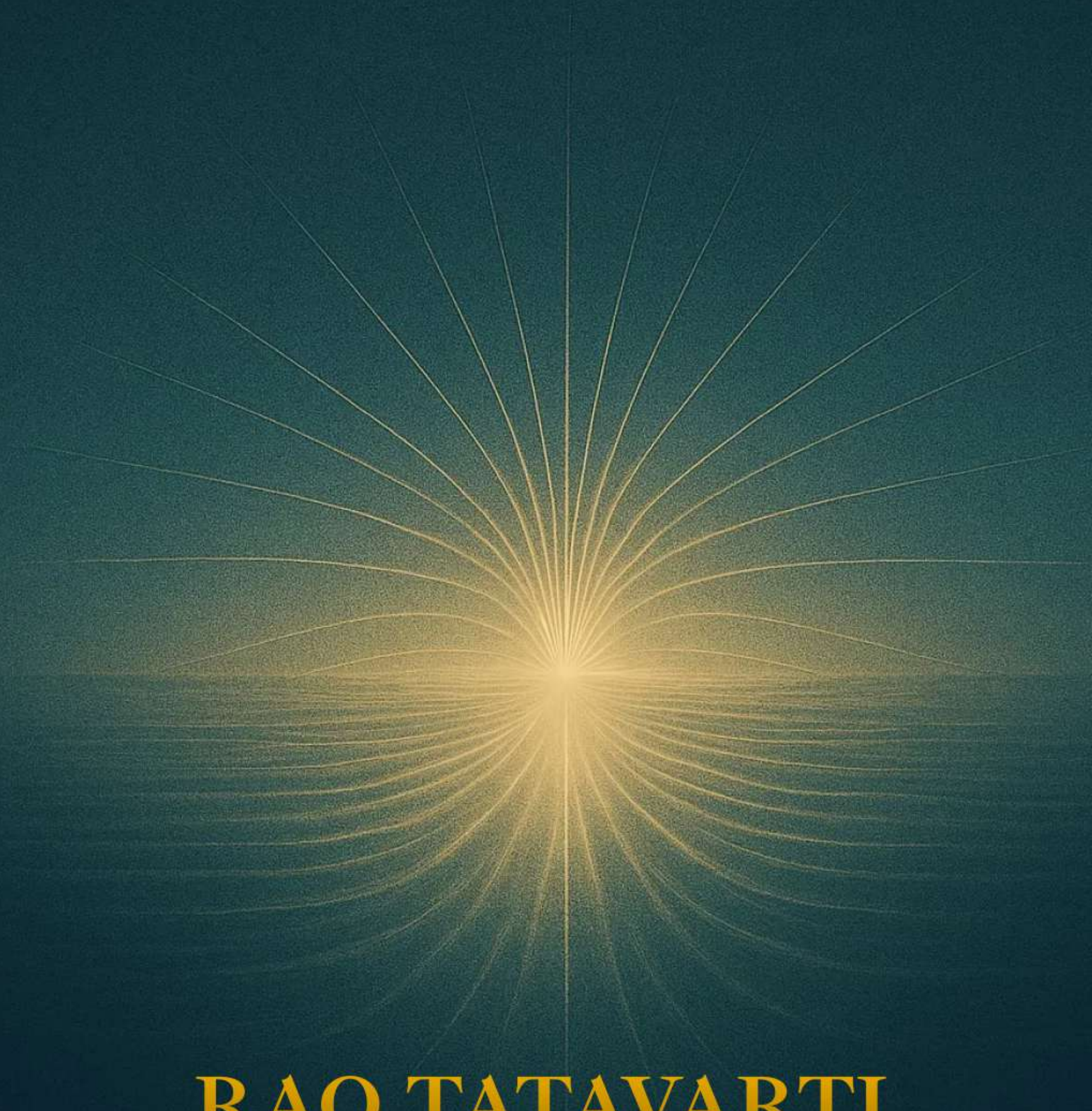
REFLECTIONS
FROM ECHOES TO INSIGHTS

Lessons Beyond Boundaries



RAO TATAVARTI

Reflections

From Echoes to Insights

Lessons Beyond Boundaries

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Foreword

There is a peculiar joy in engaging with Tatavarti's work—one that lies beyond critique or commendation.

Tatavarti's writing bears the calm authority of long contemplation, where intellect has learned to listen to silence, and knowledge has ripened into insight. In responding to it, I felt less the role of a reviewer and more that of a fellow traveler, pausing briefly along the same path to exchange reflections before the journey continues.

As I read Reflections: From Echoes to Insights, I felt less like I was reading a book and more like I was sitting across from the author—*listening*.

Listening to a lifetime of thought that has moved steadily between science and conscience, action and reflection, rigor and humanity.

This is not merely a scholarly work. It is a distillation of a life lived responsibly in knowledge. What makes it special is not just what he says, but how quietly certain truths emerge—without assertion, without excess, yet with lasting force.

Among the many ideas woven through these reflections, five stand out to me as contributions of the highest scholarly value—important not only to science and technology, but to society and generations yet to come.

1. *Science* That Never Lets Go of Conscience
One of the strongest threads running through Tatavarti's reflections is his unwavering belief that science must remain anchored to conscience. You do not treat ethics as an external constraint or philosophical luxury; you treat it as an intrinsic part of inquiry itself.

What stays with me is how naturally Tatavarti integrates responsibility into discovery—almost as if separating the two never occurred to him.

This matters deeply today. *For the scientific community*, it is a reminder that capability does not equal legitimacy. *For society*, it reassures that science can still be trusted as a humane endeavor. *For future generations*, it models a way of pursuing knowledge without losing moral clarity.

Tatavarti places himself firmly in the tradition of scientists who understood that progress without conscience is not progress at all.

The next one is,
2. Indigenous Technology and the Wisdom of Self-Reliance. Tatavarti's reflections on indigenous technology feel especially powerful because they come from lived experience, not abstraction. He explains with rare clarity why true technological strength cannot be imported wholesale—why it

must grow from local understanding, environmental realities, and institutional continuity.

Tatavarti's distinction between thinking and doing—between "*think tanks*" and "*do tanks*"—is sharp, practical, and timely.

This contribution is vital because it speaks to: Scientists and engineers striving for relevance, not imitation.

Policymakers seeking long-term resilience rather than short-term fixes.

Future generations who will inherit the consequences of today's dependency choices This is not ideology; it is systems intelligence shaped by responsibility.

3. *Building Institutions that outlive Individuals.* Very few people can speak credibly about institution

building—because very few have actually done it. His reflections reveal a deep understanding that institutions are not sustained by buildings, budgets, or branding, but by culture, leadership, and shared purpose.

Tatavarti quietly challenges the belief that excellence belongs only to elite or oversized institutions. Instead, he shows that clarity of vision and ethical leadership can create excellence anywhere.

This matters immensely:

- *For academia*, it offers hope and direction beyond rankings.
- *For administrators*, it reframes leadership as stewardship.
- *For society,* it spreads the possibility of meaningful research more equitably.

This is scholarship expressed through institutional life.

The 4th point to add is his teaching and mentorship as a moral act.

Tatavarti's thoughts on teaching, feel especially close to my heart. Tatavarti speaks of education not as instruction, but as resonance—something that happens when curiosity meets care.

He resists the reduction of learning to metrics and outputs, and instead affirms mentorship as a long-term ethical commitment.

Reading this, I felt that Tatavarti was not just describing education, but protecting it.
This is crucial because: Students learn to think, not just perform; Teachers rediscover meaning in their vocation; Knowledge continues as a living tradition, not a transaction.

Tatavarti reminds us that the true measure of a teacher is not what is delivered, but what endures.

Though I wrote volumes, let me conclude with one more.

5th. *Science in Conversation with Society* Throughout his reflections, science never hides behind walls. Tatavarti constantly brings it back into conversation with society—its needs, its fears, its misunderstandings, and its hopes too.

Tatavarti argues, gently but firmly, for humility in expertise and dialogue over authority. In doing so, he preserves science as a service to humanity, not an enclave apart from it.

This perspective is invaluable today: It strengthens public trust in scientific work. It informs wiser governance and policy. It keeps science aligned with human well-being.

In times shaped by rapid technological change, this is guidance we desperately need.

Taken together, these reflections reveal Tatavarti not just as a scientist or academician, but as a custodian of knowledge and conscience.

Reflections: From Echoes to Insights, does not attempt to provide final answers. Instead, it teaches something far more lasting—it teaches how to listen: to experience, to doubt, to responsibility, and to the future.

This is a work that will continue to speak quietly yet powerfully—to scientists, teachers, institutions, and thoughtful minds—long after the noise of the present moment fades.

For me, it reads as scholarship, guidance, and blessing—all at once.

N. Panangipalli
Sydney, Australia

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Prof. Dr. Rao Tatavarti

Acknowledgements

It is difficult to exactly point out who is responsible for this collection of disparate and seemingly random articles, written over many years, at different times, under diverse conditions of mind and the environment.

What unites them is not a chronology or uniformity, but the quiet enthusiasm for sharing my inner thoughts and the travails of life as a Scientist and Academician.

Each piece arose from a moment of reflection — sometimes in solitude, sometimes in dialogue, sometimes in the turbulence of institutional responsibilities.

Together, they form not a linear narrative but a mosaic of echoes, insights, and learnings, shaped by the shifting landscapes of science, conscience, and human experience.

Sincere thanks and gratitude to my wife Sridevi for allowing ample space and time for my thoughts, Biren Shah my friend, partner and believer who pushed me to collate and present my articles, my extended family of many mentors, colleagues, friends and students.

Preamble: Opening Note

Every life leaves behind echoes. Some are loud, carried by applause or recognition; others are quiet, whispered in the solitude of thought. My own journey as a scientist and academician has been shaped by both—the rumbling of discovery and the whisper of reflection, the resonance of institutions and the silence of memory.

Books are often born of design, carefully structured to follow a single theme or discipline. This volume, however, resists such boundaries. It is a collection of random articles—sometimes meditations, sometimes analyses, sometimes recollections—written over many years by a scientist and academician whose life has been shaped by curiosity, conscience, and the pursuit of knowledge.

This book is not a single story but a constellation of fragments. Each article is a star, written at different times, under different skies, and for different reasons. Some shine with the rigor of scientific inquiry, others glow with the warmth of teaching, and still others flicker with the contemplations of conscience. Together, they form a sky of experiences—diverse, scattered, yet bound by the invisible threads of curiosity and care.

The pages that follow are not arranged to tell a linear story. Rather, they echo the rhythm of a career lived across laboratories, classrooms, and institutions, where questions of science often intertwined with questions of society, ethics, and legacy. Each article stands as a fragment of experience: a reflection on discovery, a commentary on education, a remembrance of colleagues, or a philosophical musing on the responsibilities of knowledge.

Together, these fragments form a mosaic. They reveal the breadth of subjects that engaged the author—ranging from the technical rigor of scientific modeling to the broader concerns of institutional culture, from the exhilaration of research breakthroughs to the quiet lessons of teaching and mentorship. They are united not by topic but by voice: the voice of one who has sought, throughout his journey, to balance precision with reflection, and intellect with humanity.

Readers will find here not only the record of a professional life but also the resonance of a personal one. The articles hopefully invite the reader to consider how science and scholarship are never isolated pursuits; they are lived in dialogue with society, shaped by history, and enriched by the values we carry.

This collection of reflections is shared, therefore, not as a definitive treatise but as a companion for contemplation. It is a testament to the enduring curiosity of a scientist, the conscientious engagement of an academician, and the belief that knowledge, in all its diversity, is most meaningful when shared.

Science, for me, has never been only about equations or experiments. It has been about listening to the silence before a breakthrough, to the resonance of ideas exchanged with colleagues, to the renewal that comes when knowledge is passed on to students who will carry it further than I ever could.

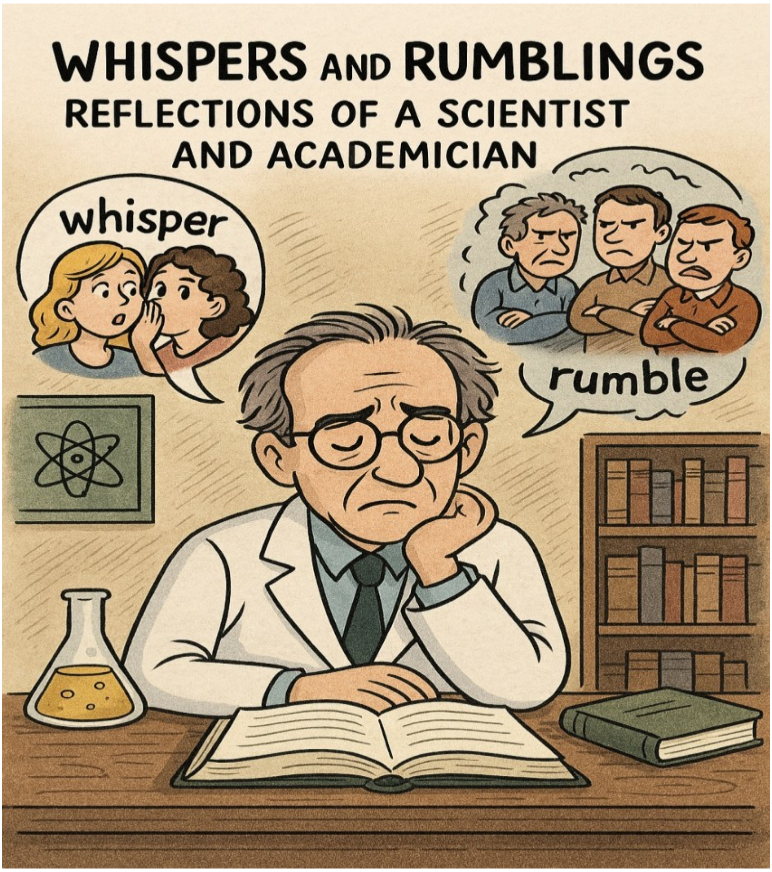
In these pages, you would find technical musings beside philosophical reflections, institutional memories beside personal recollections. Their diversity is not disorder but the rhythm of a life lived in inquiry.

If there is a theme that unites them, it is the search for meaning. For every silence holds a question, every resonance carries a response, and every renewal reminds us that knowledge is not an end but a beginning.

Again, this collection is offered not as a conclusion but as an overture—an invitation to listen, to reflect, and to find in these fragments the music of a life devoted to science, scholarship, and the enduring dialogue between knowledge and conscience, as "*In silence knowledge waits*, in resonance, it speaks; in renewal, it lives again."

Whispers and Rumblings

Reflections of a Scientist and Academician



Preface

Every journey of knowledge begins in silence. A child gazes at the stars, a student lingers over a question, a researcher pauses before an equation—and in that pause, a whisper is heard. It is faint, almost imperceptible, yet it carries the seed of inquiry. Whispers are the subtle voices of curiosity, conscience, and imagination. They do not demand attention; they invite them. They are the beginnings of science.

But whispers do not remain whispers. They grow into rumblings—the tremors of discovery, the debates of classrooms, the upheavals of institutions, the restless energy of societies grappling with change. Rumblings are the collective sound of knowledge in motion, the reverberations of ideas colliding with reality. They remind us that science is never solitary; it is always situated in a world of politics, ethics, and human consequence.

This article is born of both whispers and rumblings. It is not a technical manual, nor a mere memoir of experiments. It is a reflection on what it means to live as both scientist and academician: to inhabit the solitude of thought and the turbulence of institutions, to balance the purity of inquiry with the demands of responsibility. It is about the fragile equilibrium between silence and sound, between the inner voice that guides us and the external forces that challenge us.

As a scientist, I have learned that discovery is not only about precision but about patience. Equations and instruments reveal truths, but they are guided by something less tangible—the whisper of conscience, the murmur of doubt, the resonance of wonder. As an academician, I have witnessed how knowledge is shaped not only in laboratories but in classrooms, conferences, and policy debates. Here, the rumblings are louder: the pressures of funding, the politics of recognition, the shifting paradigms of disciplines, and the ceaseless demand to justify relevance.

The sections that follow are not arranged as a chronology of events, but as a meditation on themes that have defined my journey. They move between the personal and the institutional, the philosophical and the practical. They ask how science begins, how it grows, how it falters, and how it must be guided by conscience. They explore the responsibilities of teaching, the challenges of research, the turbulence of academic politics, and the ethical weight of knowledge in a world that often confuses progress with power.

This preface is, therefore, an invitation. It invites the reader to listen more deeply—to the whispers of curiosity that stir within us, and to the rumblings of society that demand accountability. It asks us to reflect on the nature of knowledge itself: not as a possession, but as a responsibility; not as a monument, but as a living dialogue between silence and sound.

In the end, *Whispers and Rumblings* is not only my story. It is a mirror held up to the larger story of science and academia, a story that belongs to all who seek, teach, question, and reflect. May these pages encourage you to hear the whispers more clearly, to face the rumblings more courageously, and to remember that the pursuit of knowledge is inseparable from the pursuit of conscience.

WHISPERS — The Inner Voice of Inquiry

Seeds of Curiosity

Every scientist begins not with a laboratory, but with a question. Mine began in silence—moments of wonder that seemed ordinary at the time, yet carried within them the weight of destiny. A child staring at the night sky does not know the names of stars, but feels their presence. A student watching the play of light on water does not yet know optics, but senses a mystery waiting to be unveiled. These are the seeds of curiosity: small, fragile, yet powerful enough to grow into a lifetime of inquiry.

Curiosity is not taught; it is awakened. It whispers in the mind when the world seems too vast to be explained by habit alone. It asks: *Why does the leaf fall this way? Why does the wind shift suddenly? Why does silence feel alive?* Such questions are not yet science, but they are its beginnings. They are the whispers that precede the rumblings of discovery.

In my own journey, these seeds were scattered across childhood experiences — books that opened windows to unseen worlds, teachers who asked more than they answered, and moments of solitude where imagination became experiment. I remember the thrill of dismantling a simple toy, not breaking it, but understanding its hidden order. I recall the quiet joy of watching shadows lengthen across the ground, realizing that time itself could be measured by light. These were not grand discoveries, but they were whispers that carried me forward.

Yet curiosity alone is not enough. It must be nurtured, protected, and given space to grow. Too often, institutions silence ‘whispers’ before they become voices. A child’s question dismissed as trivial, a student’s doubt ignored, a researcher’s unconventional idea ridiculed—these are the ways curiosity is stifled. To be a scientist is to resist that silencing, to preserve the fragile seed until it can withstand the rumblings of the world.

Looking back, I see that the seeds of curiosity were also seeds of conscience. They taught me that knowledge is not only about answers, but about responsibility. To ask a question is to accept the duty of listening, of seeking, of caring for the truth that emerges. The whisper of curiosity is inseparable from the whisper of conscience, and together they form the foundation of science.

This chapter, then, is not merely about beginnings. It is about the conditions that allow beginnings to flourish. It is about the silence in which whispers are heard, the patience with which they are nurtured, and the courage required to protect them. For without seeds of curiosity, there can be no rumblings of discovery. And without conscience, curiosity itself becomes hollow.

The Mentor’s Whisper

If curiosity is the seed of science, mentorship is the soil in which it grows. A whisper alone may fade, but when echoed by a guiding voice, it becomes a call to inquiry. Every scientist remembers not only the questions they asked, but the teachers, guides, and companions who gave those questions shape.

Mentorship is rarely loud. It does not announce itself with proclamations or commands. It is subtle—

a gesture of encouragement, a question posed at the right moment, a silence that allows thought to deepen. The mentor's whisper is not about providing answers, but about teaching how to live with questions. It is the art of nurturing without suffocating, of guiding without dictating.

In my own journey, mentors appeared in many forms. Some were formal teachers, whose lectures carried not only knowledge but conviction. Others were colleagues, whose quiet suggestions opened new paths of thought. Still others were books, voices from distant times, whispering across centuries. Each left an imprint, not by overwhelming me with certainty, but by reminding me that doubt is fertile, that patience is necessary, and that discovery is a dialogue between generations.

The mentor's whisper also carries responsibility. It reminds us that science is not only about what we know, but about how we pass that knowledge on. A careless word can extinguish curiosity; a thoughtful silence can ignite it. To mentor is to recognize that the future of science lies not only in discoveries, but in the minds we shape. It is to accept that our influence may outlast our experiments, echoing in the whispers of those who come after us.

Yet mentorship is not without its rumblings. Institutions often reduce it to metrics — student counts, publications, and citations—forgetting that true mentorship cannot be measured in numbers. It is measured in the courage of a student who dares to ask, in the persistence of a researcher who refuses to give up, in the ethical compass of a scholar who chooses conscience over convenience. These are the rumblings that remind us that mentorship is not a transaction, but a trust.

Looking back, I see that the mentor’s whisper shaped not only my science, but my conscience. It taught me that to be a scientist is to be a custodian of curiosity, and to be an academician is to be a custodian of conscience. The whisper of a mentor is never fully ours; it is a gift we are obliged to pass on. And in passing it on, we become part of a lineage of whispers that sustain the rumblings of discovery.

Solitude and Silence

Science is often imagined as a collective enterprise—laboratories filled with instruments, conferences buzzing with debate, and institutions alive with activity. Yet beneath this noise lies a quieter truth: discovery begins in solitude. The whisper of curiosity is heard most clearly when the world is still, when silence allows thought to take shape without interruption.

Solitude is not isolation. It is a chosen space where the mind can wander freely, unbound by expectation. In solitude, doubt is not a weakness but a companion. It asks questions that others may dismiss, it lingers where others rush, it insists that truth cannot be hurried. Silence, too, is not emptiness. It is a medium in which ideas resonate, where the faint stirrings of imagination can be amplified into insight.

In my own journey, solitude was often the crucible of clarity. Long evenings spent with equations, quiet mornings reflecting on failed experiments, solitary walks where problems untangled themselves—these were not escapes from science, but their very essence. The rumblings of discovery are born in such silences, where thought is allowed to mature before it is tested against the world.

Yet solitude is fragile. Institutions rarely value silence; they reward productivity, visibility, and constant output. The scientist who pauses, who reflects, who listens inwardly, is often seen as unproductive. But without silence, science becomes noise—data without meaning, progress without conscience. To protect solitude is to protect the integrity of inquiry.

Silence also carries an ethical dimension. In silence, one hears not only the whisper of curiosity but the whisper of conscience. It asks: *Should this be pursued? What consequences will follow? Who will be affected?* These questions are easily drowned out by the rumblings of ambition and competition. Only in silence can they be heard clearly, reminding us that science is not only about what can be done, but about what should be done.

This section, then, is a meditation on the necessity of solitude and silence. They are not luxuries, but conditions of truth. They remind us that the loudest discoveries often begin as the quietest whispers, and that the rumblings of science must always be tempered by the silence of conscience. To be a scientist and academician is to learn not only how to speak, but how to listen—to the world, to others, and to oneself.

RUMBLINGS

The Laboratory as a World

The laboratory is more than a room filled with instruments; it is a world unto itself. Within its walls, whispers of curiosity transform into rumblings of discovery. Here, silence gives way to sound—the hum of machines, the clatter of glassware, the murmur of colleagues debating results. Yet beneath this noise lies something deeper: the laboratory is a theatre where ideas are tested against reality, where imagination confronts matter, and where truth reveals itself through struggle.

To step into a laboratory is to enter a space governed by both discipline and wonder. Discipline demands precision: measurements must be exact, procedures must be followed, results must be verified. Wonder, however, resists confinement. It asks questions that protocols cannot anticipate, it notices anomalies that data alone cannot explain, it insists that discovery is not only about control but about openness to the unexpected. The laboratory thrives on the tension between these two forces.

In my own experience, the laboratory was often a place of paradox. It was a site of failure as much as success. Experiments collapsed, instruments malfunctioned, results contradicted expectations. Yet these failures were not defeats; they were rumblings that shook assumptions, forcing me to listen more carefully to the whispers of doubt. Each failure carried within it the possibility of a deeper truth, reminding me that science advances not by certainty but by persistence.

The laboratory is also a community. Though solitude nurtures ideas, discovery requires collaboration.

Colleagues, assistants, and students, — all bring their own whispers, which together form a chorus of inquiry. The rumblings of debate, disagreement, and shared excitement are the lifeblood of science. No discovery is truly solitary; it is always shaped by the voices of others, by the lineage of knowledge that precedes us, and by the institutions that sustain us.

Yet the laboratory is not immune to external rumblings. Funding pressures, institutional politics, and societal expectations seep into its walls. The purity of inquiry is often tested by the demands of relevance, productivity, and recognition. To work in a laboratory is to balance two worlds: the inner world of curiosity and conscience, and the outer world of competition and accountability. The rumblings of discovery are inseparable from the rumblings of society.

Looking back, I see the laboratory as a mirror of science itself: *fragile yet resilient, disciplined yet* *imaginative, solitary yet communal*. It is a world where whispers become rumblings, where silence becomes sound, and where truth emerges not as a possession but as a dialogue. To enter a laboratory is to enter a world of possibility, but also a world of responsibility. For every experiment carries consequences, and every discovery echoes beyond its walls.

Academia and Its Earthquakes

If the laboratory is a world of discovery, academia is a continent of tremors. It is vast, layered, and restless. Within its halls, whispers of curiosity often collide with rumblings of ambition, politics, and recognition. To live as an academician is to inhabit a landscape where earthquakes are frequent—some subtle, some seismic, all reshaping the terrain of knowledge.

The first tremors are often personal. A young scholar enters academia with hope, carrying the whispers of curiosity nurtured in solitude. Yet soon, the ground shifts. Questions of funding, publication, and recognition begin to rumble beneath the surface. The purity of inquiry is tested by the demands of visibility. The scientist must learn not only how to discover, but how to survive.

Then come the institutional earthquakes. Academia is not only a place of learning; it is a system of power. Departments compete for resources, scholars vie for recognition, policies dictate priorities. These rumblings are louder than those of the laboratory, for they shake not only experiments but careers. A single decision—a grant awarded, a paper rejected, a position denied—can alter the trajectory of a life. To walk in academia is to walk on shifting ground.

Yet earthquakes are not only destructive; they are also generative. They unsettle complacency, forcing disciplines to evolve. They challenge assumptions, opening space for new paradigms. The rumblings of academia remind us that knowledge is not static; it is dynamic, shaped by conflict as much as by consensus. To endure its earthquakes is to accept that science is not only about truth, but about the structures that sustain—or suppress—it.

In my own journey, I have felt these tremors keenly. The exhilaration of recognition, the frustration of rejection, the turbulence of institutional politics — all were rumblings that tested not only my science but my conscience. They taught me that academia is not merely a place of discovery; it is a place of responsibility. To navigate its earthquakes is to balance ambition with integrity, competition with collaboration, progress with conscience.

Academia's earthquakes also echo beyond its walls. They shape the public perception of science, the policies that govern research, the futures of students who inherit its structures. Each tremor reminds us that the pursuit of knowledge is inseparable from the pursuit of justice. For if academia collapses into ambition alone, it loses its soul. Its rumblings must be tempered by whispers of conscience, lest the earthquakes destroy what they were meant to build.

Paradigm Shifts and Controversies

Science does not move in straight lines. It advances in leaps, ruptures, and revolutions. What begins as a whisper of doubt can grow into a rumbling that shakes the foundations of a discipline. These are the paradigm shifts—the moments when established truths collapse, when controversies erupt, and when the very meaning of knowledge is redefined.

Paradigm shifts are unsettling. They challenge authority, disrupt consensus, and force scholars to reconsider what they thought was secure. The

Copernican revolution displaced the Earth from the center of the cosmos. Darwin's theory of evolution unsettled centuries of theological certainty. Quantum mechanics fractured the classical vision of physics. Each of these shifts began as whispers—questions, anomalies, observations—that grew into rumblings powerful enough to reshape entire fields.

But paradigm shifts are not only intellectual; they are deeply human. They provoke resistance, controversy, and conflict. Institutions built on old paradigms resist change, scholars invested in established truths defend them, and societies struggle to absorb the implications. The rumblings of controversy are as much about power as they are about truth. To live through a paradigm shift is to witness not only the evolution of knowledge, but the turbulence of human response.

In my own journey, I have seen smaller but no less significant shifts—moments when a new method overturned accepted practice, when a fresh perspective unsettled consensus, when a student's question revealed a flaw in established reasoning. These were not revolutions on the scale of Copernicus or Darwin, but they carried the same essence: the whisper of doubt becoming the rumbling of change. Each controversy reminded me that science is not static; it is dynamic, restless, and alive.

Controversies also carry ethical weight. They force us to ask not only *what is true*, but *what is right*. Should a discovery be pursued if its consequences are dangerous? Should a paradigm be defended if it silences alternative voices? Should institutions cling to stability at the cost of progress? These questions are not answered by equations alone; they require conscience. The rumblings of controversy must be tempered by the whispers of responsibility.

Paradigm shifts remind us that science is not a monument, but a dialogue. It is built not on certainty, but on the willingness to question. Controversies remind us that truth is inseparable from courage—the courage to doubt, to resist, to change. To be a scientist and academician is to live in the tension between whispers and rumblings, between the quiet stirrings of doubt and the loud tremors of revolution. It is to accept that knowledge is never final, but always in motion.

Science in Society

Science does not exist in isolation. Though whispers begin in solitude and rumblings echo through laboratories and institutions, their consequences extend far beyond academic walls. Every discovery, every theory, every experiment eventually enters the wider world, shaping lives, policies, and futures. To be a scientist is therefore to recognize that society is both the stage and the audience of inquiry.

Society looks to science with expectation. It seeks cures for disease, solutions for climate change, technologies for progress, and explanations for mysteries. These expectations are rumblings that press upon the scientist, demanding relevance and urgency. Yet expectations can also distort. When society demands quick answers, science risks sacrificing depth for speed. When politics demands certainty, science risks silencing doubt. The challenge is to balance the whisper of conscience with the rumbling of public need.

Science in society is also a matter of trust. The public must believe that knowledge is pursued with integrity, that discoveries are shared with honesty, that risks are acknowledged with responsibility. Trust is fragile; it can be shaken by controversy, eroded by misinformation, or undermined by arrogance. To sustain trust, scientists must speak not only with precision but with humility, remembering that knowledge is not a possession but a service.

In my own journey, I have seen how discoveries ripple outward. A paper published in a journal may seem confined to specialists, yet its implications may shape industries, influence policies, or alter lives. A lecture delivered in a classroom may seem local, yet its echoes may guide students who later lead institutions. The rumblings of science are never contained; they reverberate through society in ways both visible and unseen.

But science in society is not only about impact; it is about responsibility. Should knowledge be pursued if it endangers humanity? Should discoveries be shared if they can be misused? Should progress be measured only in technological terms, or also in ethical ones? These are questions that society asks of science, and that science must ask of itself. The whispers of conscience must guide the rumblings of discovery, lest progress become peril without purpose.

Ultimately, science in society is a dialogue. It is not a monologue delivered by experts, but a conversation between seekers and citizens, between laboratories and communities, between whispers of curiosity and rumblings of need. To live as a scientist and academician is to accept that this dialogue is never finished. It must be renewed with each generation, each discovery, each challenge. For science without society is empty, and society without science is blind.

REFLECTIONS — Between Silence and Sound

Teaching as Resonance

If curiosity begins as a whisper and discovery grows into rumblings, teaching is the resonance that carries both forward. It is the echo of inquiry in the minds of students, the reverberation of knowledge across generations, the transformation of solitary reflection into shared understanding. To teach is not merely to transmit information; it is to awaken whispers in others and to prepare them for the rumblings they will face.

Teaching is often imagined as instruction, but in truth it is resonance. A lecture is not only words spoken; it is vibrations that stir thought. A question posed in class is not only a test of knowledge; it is an invitation to curiosity. A mentor's silence is not absence; it is space for a student's whisper to grow. In this way, teaching is less about control and more about rhythm—the rhythm of minds learning together, each echoing the other.

In my own journey, teaching was both challenge and joy. The challenge lay in recognizing that students do not inherit knowledge passively; they must be guided to discover it actively. The joy lay in seeing their eyes light up when a concept resonated, when a whisper of curiosity became their own. These moments reminded me that teaching is not about imposing truths, but about cultivating the conditions in which truths can be discovered.

Teaching also carries responsibility. The resonance of a teacher's words can shape not only intellect but conscience. A careless remark can silence curiosity; a thoughtful encouragement can ignite it. To teach is to recognize that every word, every gesture, every silence carries weight. It is to accept that the echoes of teaching may outlast the teacher, reverberating in the lives of students long after the classroom has faded.

Yet teaching is not immune to rumblings. Institutions often reduce it to metrics—grades, evaluations, outcomes—forgetting that true teaching cannot be measured in numbers. Its resonance is subtle, often invisible, revealed only in the courage of a student who dares to question, in the persistence of one who refuses to give up, in the ethical compass of one who chooses conscience over convenience. These are the echoes that matter, the resonance that sustains science and society alike.

Looking back, I see teaching as the bridge between whispers and rumblings. It carries the quiet stirrings of curiosity into the loud tremors of discovery, ensuring that knowledge is not lost but renewed. To teach is to become part of a lineage of resonance, a chain of echoes that sustains the dialogue of science across generations. It is to accept that our greatest legacy may not be the discoveries we make, but the whispers we awaken and the rumblings we prepare others to face.

Conscience in Science

Science is often celebrated for its power, —the power to explain, to predict, to transform. Yet beneath this power lies a quieter force: conscience. Without conscience, science risks becoming blind progress, knowledge without wisdom, discovery without responsibility. To be a scientist is not only to ask *what can be done*, but to ask *what should be done*. Conscience is the whisper that tempers the rumblings of ambition.

Conscience in science begins with awareness. Every experiment carries consequences, every discovery ripples outward, every theory reshapes understanding. The scientist must ask: *Who will be affected? What will be changed? What responsibilities follow?* These questions are not distractions from inquiry; they are its foundation. For knowledge without responsibility is incomplete, and progress without ethics is perilous.

In my own journey, conscience often spoke in silence. It whispered in moments of doubt, reminding me that not all questions should be pursued, not all answers should be applied, not all discoveries should be celebrated. It asked whether the pursuit of recognition was overshadowing the pursuit of truth, whether the demands of institutions were silencing the needs of society, whether ambition was eroding integrity. These whispers were not always comfortable, but they were necessary.

The rumblings of science often drown out conscience. Competition, funding, recognition—all press upon the scientist, demanding productivity and visibility. Yet conscience insists on patience, humility, and responsibility. It reminds us that the measure of science is not only in its discoveries, but in its consequences. A breakthrough that endangers humanity is not progress; a discovery that silences doubt is not truth. Conscience is the compass that ensures science serves life rather than threatens it.

Conscience also extends to teaching. The words of a teacher shape not only intellect but values. To teach science without conscience is to risk producing knowledge without responsibility. To teach with conscience is to remind students that every equation, every experiment, every theory carries ethical weight. It is to prepare them not only for discovery, but for responsibility.

Looking back, I see conscience as the thread that binds whispers and rumblings. It ensures that curiosity does not become recklessness, that discovery does not become destruction, that progress does not become peril. Conscience is the whisper that must never be silenced, the resonance that must always be heard. For science without conscience is noise, but science with conscience is harmony—an echo that sustains both knowledge and humanity.

Legacy and Continuity

Every whisper eventually quiets, and every rumbling eventually subsides. What remains is legacy—the echo of a life lived in pursuit of knowledge; the continuity of ideas passed from one generation to the next. Legacy is not measured in awards or titles, but in the resonance of influence: the questions we inspired, the consciences we awakened, the futures we helped shape.

For a scientist, legacy lies in discoveries that endure beyond the laboratory. A theory refined, a method established, a question posed—these are seeds that continue to grow long after the scientist has departed. For an academician, legacy lies in students who carry forward the whispers of curiosity and the rumblings of responsibility. Their voices become the continuity of teaching, ensuring that knowledge is not lost but renewed.

Legacy is also ethical. It asks not only *what we discovered*, but *how did we live as seekers of truth*. Did we protect the integrity of inquiry? Did we nurture curiosity rather than silence it? Did we temper ambition with conscience? These questions define continuity more than any publication or recognition. For science without ethics is noise, but science with conscience is harmony—and harmony is what endures.

In my own reflections, I see legacy not as a monument but as a dialogue. It is not about being remembered, but about ensuring that the whispers of curiosity and the rumblings of discovery continue to resonate. It is about leaving behind not only knowledge, but responsibility. Continuity is not repetition; it is renewal. Each generation must hear the whispers anew, must face the rumblings afresh, must carry forward the dialogue of science with courage and conscience.

Legacy, then, is not the end of whispers and rumblings, but their transformation. It is the assurance that silence will give rise to sound again, that curiosity will awaken once more, that conscience will continue to guide discovery. To live as a scientist and academician is to accept that our greatest gift is not what we achieve, but what we pass on—the resonance of inquiry, the rhythm of responsibility, the continuity of conscience.

Afterword

Listening Again

Whispers begin in silence, and rumblings fade into silence. The circle is complete. Yet silence is never empty; it is the space where new beginnings take shape. To listen again is to recognize that the pursuit of knowledge is not a journey with an end, but a rhythm that repeats—curiosity awakening, discovery unfolding, conscience guiding, legacy continuing.

As I reflect on my own path, I see that the whispers which first stirred my curiosity were not mine alone. They were echoes of generations before me—

teachers, mentors, thinkers—whose voices resonated in my mind. The rumblings I encountered in laboratories, institutions, and society were likewise not mine alone. They were part of a larger dialogue, a chorus of inquiry that continues across time. To listen again is to hear that dialogue anew, to recognize that science is not solitary but communal, not static but alive.

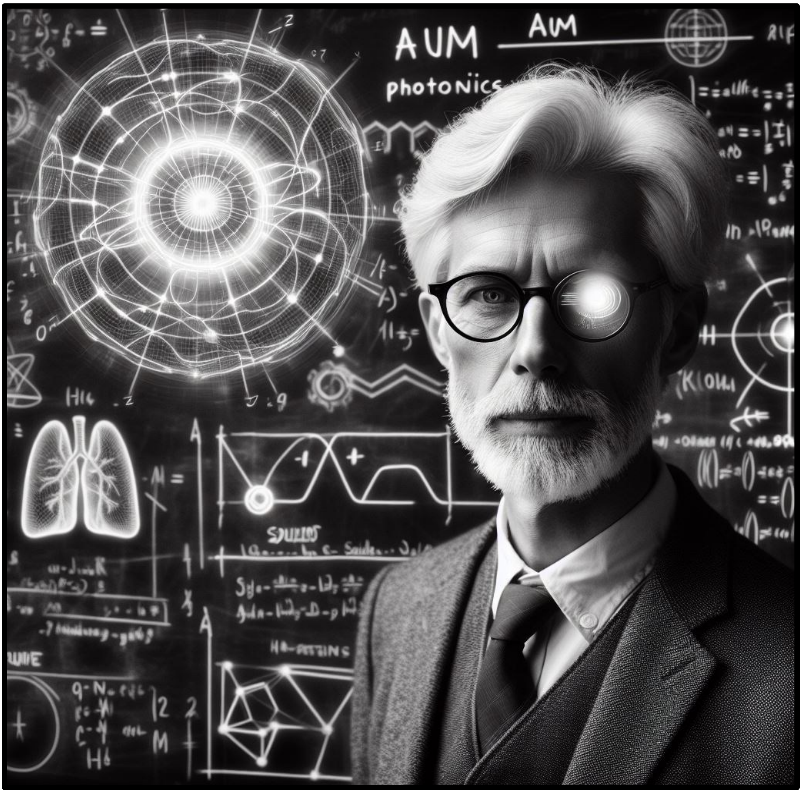
Listening again also means listening differently. With age, whispers sound softer but deeper; rumblings feel less chaotic but more consequential. The questions that once seemed urgent now reveal themselves as part of a larger rhythm. The discoveries that once felt final now appear as steps in an unfinished journey. Silence itself becomes more precious, not as absence but as presence—the presence of possibility, of conscience, of renewal.

This article has been a meditation on whispers and rumblings, from the whispers of curiosity to the rumblings of discovery and institutions, and finally to the reflections of conscience and legacy — on the balance between silence and sound, solitude and community, curiosity and responsibility. Yet it is not a conclusion. It is an invitation to listen again—to the whispers of curiosity that stir within us, to the rumblings of society that demand accountability, to the resonance of conscience that sustains both. For science is not only about knowing; it is about listening. And listening is never finished.

As I close these reflections, I return to silence—not as an end, but as a beginning. Somewhere, a child is gazing at the stars, hearing a whisper of wonder. Somewhere, a student is questioning a teacher, feeling the rumbling of discovery. Somewhere, a scientist is pausing in solitude, listening to the whisper of conscience. These voices will continue, as they must. And so, the task is simple yet profound: to listen again.

January 4, 2026

Atma Nirbharta: Our Journey To Self-Reliance



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 endeavours, 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 Tatavarti 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: Tatavarti, 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 Tatavarti 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, Prof. 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.

With over three decades of R&D and Innovation in Aerospace Engineering, Biomedical Engineering, Biotechnology, Fluid Dynamics, Photonics, Signal Processing, Image Processing, Satellite Image Processing, Ocean Engineering, and Technology, and having more than two hundred peer-reviewed publications and eight patents, Prof. Tatavarti always believed that societal problems need to be highlighted, understood, and researched to herald innovation. He passionately taught, nurtured, and guided hundreds of youngsters worldwide 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, Prof. Tatavarti 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. Tatavarti.

During this period, Commodore Shekar and Prof. Tatavarti 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. Tatavarti and Cmde Shekhar journeyed together, addressing many issues with full vigour, travelled the world, and mostly made a mark with the powers to be in the country, as well as made a splash overseas.

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.

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 & Company. Ever interested in setting up enterprises; he has been a successful serial entrepreneur working with many corporations in India and Europe.

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, Prof. 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 spans various fields of Banking, Telecom, I.T. Service Management, IoT, IIoT, LegalTech, Reporting & Analytics (*Tableau, Power BI, Snowflake, Data as a Service*), Big Data, DevOps, ML Ops, 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.

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 Prof. 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

Prof. 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 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 Pachiappan, 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 orthopaedic physician and surgeon, after establishing an orthopaedic 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. Tatavarti 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. Tatavarti 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 Prof. Tatavarti 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 Tatavarti 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 Tatavarti 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. Tatavarti 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. Anand Patel's unwavering commitment to cutting-edge technologies powered innovation and was responsible for driving operational excellence.

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	***AUM*** **ॐ** **A**ir **U**nique – quality **m**onitoring	System for Environmental Monitoring
2	***PRANEEDHI*** **प्रणिधि** **P**hotonic **R**econnoitering of **A**coustic **N**oise for **E**ffective **E**aves **D**ropping and **H**ighlighting **I**ntelligence	System for Eavesdropping
3	***SAMIRA*** **समीरा** **S**eeing **A**ir in **M**otion: **I**nstrumentation for **R**emote-sensing **A**pplications	System for Wind Profiling

4	***SARATHI*** **सारथि** **S**earch **A**nd **R**escue **A**pparatus for **T**argeting **H**olistic **I**nformation	System for Search and Rescue in Disaster Management
5	***SAVDHAN*** **सावधान** **S**can, **A**nalyze, **V**alidate, **D**iscriminate, **H**ighlight, **A**ssess and **N**eutralize	System for Maritime Surveillance
6	***Dr. T*** **धन्वन्तरि (डॉ. टी)** *Dhanvantari's* **T**echnology	System for Exhaled Breath Analysis
7	***taraNI*** **तरणि** **T**echnology for **A**ir-data **R**eckoning for **A**erial **N**avigational **I**nformation	System for Air-data Monitoring onboard Aircraft.
8	***VAYU*** **वायु** **V**ariable **A**ir **Y**ielding **U**nit	Fully Instrumented Wind Tunnel Facility
9	***VEDA*** **वेदा** **V**ibrational **E**ffects – **D**etection **A**nalysis	System for Vehicle and Intrusion Monitoring
10	***VIDUR*** **विदुर** **V**ibration **I**ntelligence **D**ata **U**nravelling **R**emotely	System for Vibration and Condition Monitoring
11	***AJNA*** **आज्ञा** **A**erosol **J**udicating **N**avigational **A**pparatus	System for Microbial Surveillance in Air
12	***SWAASA*** **श्वासा** **S**ystem for **W**ellness **A**ssessment and **A**nalysis of **S**ampled **A**ir	System for Lung Functionality Assessment
13	***DronAcharya*** **द्रोणाचार्य**	Drone-based Integrated Photonic System for Diverse Applications

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 internationally accepted gold standards. After undergoing rigorous testing and evaluations, as per standard international practices in the laboratory and the field, Prof. Tatavarti 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 works on indigenously designed and developed systems were published in reputed, internationally acclaimed scientific and technical journals and as technical reports.

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

Proof 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. 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 [5].

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.

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 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.

Prof. Tatavarti's eloquent articulation on the need for indigenous defense technologies for India [6] made him a consultant and technical adviser to the then *Raksha Mantri*.

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 [7]. The indigenous systems are now ready for commercialization.

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.

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 [8].

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* [9].

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. Tatavarti to incubate CATS under their umbrella with attractive grant offers.

Atma Nirbharta: 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 performance, 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.*
- *Inspite of challenges, patience, and perseverance always pay rich dividends.*

January 2024

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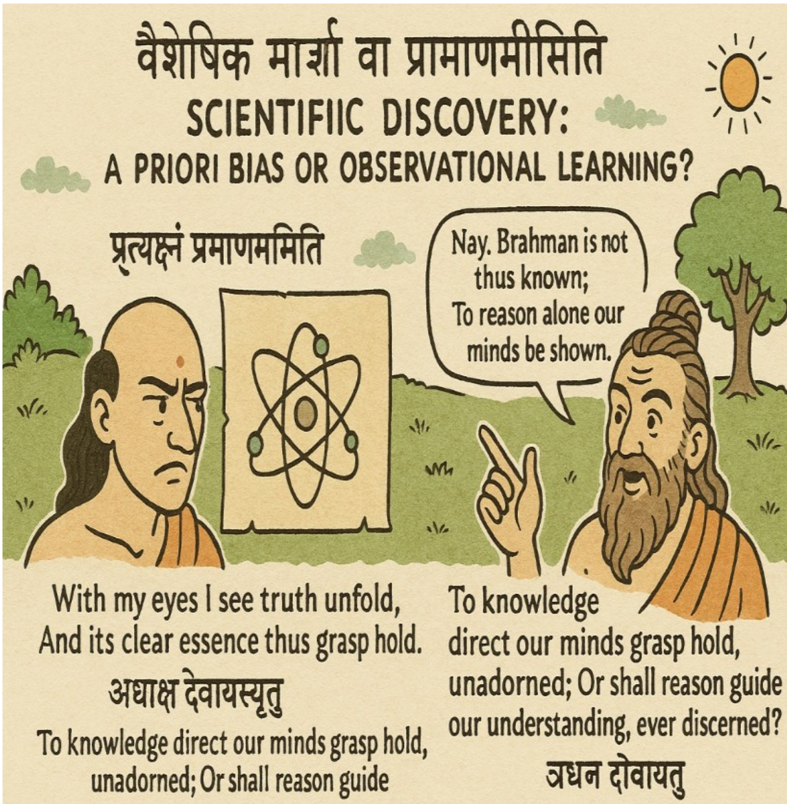
SCIENTIFIC DISCOVERY

a priori Bias *or* Observational Learning?



Preface

This article introduces the concept of Discovery by articulating the contemporary schools of thought that the general process can be the logical end manifestation of either an *a priori* bias or observational learning. The influence of prior knowledge on concept acquisition is discussed to bring out the unique process of Discovery or cognition by scientists and laypersons. Arguing that scientific Discovery is an evolutionary phenomenon, the patterns of scientific reasoning and the essential elements of scientific methods, namely, *a priori* bias (hypothesis generation) and observational learning (hypothesis evaluation - characterizations, predictions, and experiments), are highlighted. An overview of critical classics and recent scientific investigations shows how the prevalent culture, history, and environment have indubitably affected the outcome of the inquiry and resultant scientific discoveries. A historical overview of Indian scientific discoveries since the early civilizations is presented along with the puzzle: Why were th*ere no significant scientific discoveries from India since the 15th century, despite India spearheading the scientific revolution for fifteen long centuries?* Finally, it is argued that both *a priori bias* as well as *observational learning* are complementary and are required for affecting 'scientific discoveries' – as ingrained in our ancient Indian philosophies of *Sankhya* (Analysis), *Nyaya* (Logic), *Vaiseshika* (Atomism) and *Mimamsa* (Exegesis). The article concludes with the author advocating the necessity to reorient the path of scientific inquiry by capitalizing on the tenets of ancient Indian philosophies to achieve higher scientific stature in the world.

Science and Discovery

'Science' and 'discovery' are two popular words frequently used with connotations to *knowledge* and *learning*. The importance of science and Discovery in our everyday lives is well acknowledged and understood - as scientific discoveries bring about significant advances and technological breakthroughs, transforming the world we live in and our lives. However, if one were to define these frequently used popular words cogently and explain *how* scientific Discovery is brought about? Then, these questions indeed implore one to ponder and probe for meaningful answers. To simple minds, these are banal questions that do not brook much thought for an explanation, as the words probably bring to mind not science or Discovery *per se*, but the fruits of science and Discovery, the pervasive complex of technology that transform our lives.

Paradox of Scientific Discovery

Discovery forms the backbone of any scientific endeavor - heralding progress, ushering in insights, openingnew pathways, and uncovering the various mysteries of the world around us. But *how do discoveries occur? How are the discoveries brought about?* These are questions that border on paradox and mystique. Discovery is avery slippery concept, especially for a rational analysis. To produce a valuable observation, one has to have an idea of what to observe – *a preconception of what is possible*. As the name suggests, '*discovery*' has a connotation with something new. What is new is what you do not know *or* do not understand *or* expect to occur. Therefore, scientific Discovery deals with inconsistency. Thus, the patterns of scientific reasoning need to deal with several inconsistencies, unexpected results, or observations and therefore require '*incongruity resolution*'- an uncanny ability for resolving out-of-place or unexpected observations. Scientific advances come from uncovering a hitherto unseen aspect of things by not using new instruments but looking at objects from a different angle. The philosophers call this *teleological thinking* – thinking out of the box. Scientific Discovery, therefore, comes from testing theories by logically deducing hypotheses from them, using experiments and careful observation to test the hypotheses, and revising theoriesthat lead to incorrect predictions. Therefore, the answers to the simple questions, "What is science and discovery, and how are scientific discoveries brought about?" are ironically not so simple. If one were to introspect and delve deep into the thought processes serenely, the questions become rather complex, abstract, and mind-boggling, bordering on paradox for which there can be no simple answers. Therefore, the 'simple' questions would elicit complex answers.

The well-known 'Meno Paradox,' named after the protagonist in one of Plato's plays, sums up the complexity and confounding nature of the inquiry process in general, which should eventually lead to new discoveries.

"*Either you know what you are searching for or do not. If you know, you already have it; whence inquiry is pointless? And if you do not know, you would not recognize it even if you stumbled on it accidentally; hence, again, inquiry is impossible.*"

The paradox is fascinating from the point of view of scientific Discovery. *I*s it possible to understand the process of scientific Discovery? Is there any reasoned procedure or method that can be inferred from the present knowledge to acquire new knowledge? Or, are the method and novelty two incompatible horns of a 'Menoan' situation?

How Science Works?

In order to understand how scientific Discovery is brought about; itis imperative to get insights into *what science is*? And, *whether there is any established method for doing science*? Starting from Socrates, the idea has usually been to show that the Meno Paradox is paradox only seemingly – of course inquiry is possible, and we can learn something new. But what showsthe profundity of this question is the fact that there are various different kinds of solutions suggested to this paradox.

Scientific method, as envisagedby one of its early exponents, Isaac Newton - is fundamental to the investigation and acquisition of new knowledge based upon physical evidence. Scientists use observations, hypotheses, and logic to propose explanations for natural phenomena inthe form of theories - *hypothesis generation*. Predictions from these theories that can be reproducibly tested by experiment are the basis for developing new technology. The element of observation includes the elements of hypothesis development, prediction, and experimental testing. All these elements are typically necessary for observation and are categorized as *hypothesis evaluation*. Scientists use the scientific method to build a supportable, evidence-based understanding of our world. However, there is often disagreement in scientific communitiesover the various aspects of these understandings. In philosophical circles scientific methods have been the source of much controversy. Philosophers and historians of science have not only questioned the nature of scientific methods, but also its supposed efficacy. It is now generally agreed that scientific method is not a recipe; rather they involve intelligence, imagination, creativity and is constantly changing, *i.e.*, the scientificmethod is evolutionary in character.

Evolutionary Nature of Science

Science gains reality when it is viewed not as an abstraction, but as the concrete sum of work of scientists, past and present, living and dead. As Isaac Asimov pointed out, 'not a single element of science can exist in itself. Each scientific thought, observation and statement has been ground out of the industrious efforts of some person, and unless you know the person and the world in which the person lived and worked; the assumptions accepted as truths; the concepts considered untenable; you cannot fully understand that scientific statement or observation or thought'.

Science progresses on the basisof the innate use of knowledge gained by others to acquire new knowledge. This unique characteristic of '*standing on the shoulders of giants*' to acquire new knowledge is fundamental to the advance of science. The history of science teaches us that, since science originated as the product of men and not as a revelation, it may develop further as the continuing product of men. Once it isgrasped that scientific truth is limited and not absolute, scientific truth becomes capable of further refinement. Until that is understood, scientific research has no meaning. Moreover, of all the stereotypes that has plaguedscientists, the one that is most pernicious, is to portray the scientist as always right. It should always be borne in mind, that scientists share with all human beings the great and inalienable privilege of being completely wrong at times. Therefore, science itself can bewrong in this aspect or that. Ironically, itis this knowledge that scientist can be wrong, that ensures science from disasterand helps in scientific progress. When an individual theory collapses, it need not carry with it one's faith, hope and innocent joy. Once we learn to expect theories to collapse and be supplanted by more useful generalizations, the collapsing theory becomes not the grey remnant of a broken today, but the dawn of a new and brighter tomorrow.

Scientist and the Layman

Although the process of acquisition of knowledge by a scientist and a laypersonis more or less similar, the scientist's knowledge acquisition is based on a *structured process* which not only should appeal to the person but also to the scientific peers and community at large. However, for the layperson it is sufficient if it appeals to the personalself. That is, the scientist indulges in systemized learning and the layperson in personal learning. The systemized learning is based on an organized structure of facts and figures, which maymost likely introduce *a priori* bias in the scientist, and the outcome sometimes may result mostly in scientific rhetoric. While for the layperson, unbiased evaluation of evidence is part of the personal learning process, which is specific to each individual and therefore to each it would be the incontrovertible evidence – certain and appealing to the personal self to a much greater degree than any law of science.

Philosophy of Science

Philosophers from timeimmemorial were concerned about thescientific process and Discovery. In fact, till the 18th century 'scientists' were alluded to as natural philosophers. The term 'scientist' was a 19th century shift. Of the many philosophers who wondered how science works, the triowho made everlasting impressions by contributing immensely to the present day understanding of the scientific process and Discovery were Francis Bacon in 1870s, Karl Popper in 1930s and Thomas Kuhn in 1960s.

Francis Bacon believed thatscience progresses only when thescientist is a 'disinterested' observer. In short, the scientist should not have any *apriori* bias which may influence the scientific observations and results. In order not to have any *a priori* bias the scientists should neither be aware of what had already been established in science, nor should the scientist considerthe progresses made so far. The scientist should be a disinterested observer of nature, collecting observations with a mind cleansed of harmful preconceptions that might cause errors to creep into the scientific record. Once enough observations have been gathered, Bacon believed that patterns will emergefrom them, giving rise to truths about nature.

Karl Popper who put forth '*the logic of scientific discovery*' was deeply influenced by Einstein's theory of relativity which shattered the predominance of Newtonian physics. Karl Popper argued that the process of scientific inquiry should be logical and rational, emphasizing that, "*What we call scientific knowledge is onlyhypothetical and often not true, let alone certainly or probably true*". In contrast to Bacon, Popper believed that all science begins with a prejudice or perhaps more politely, a thesis or a hypothesis. Nobody can say where the theory comes from. Formulating thetheory is the creative part of science, andit cannot be analyzed within the realm ofphilosophy. However, once the theory is in hand, Popper tells us, it is the duty of the scientists to extract from it logicalbut unexpected predictions that, if they are shown by experiment not to be correct, will serve to render the theory invalid. In other words, a scientist needs to be extremely cautious and *skeptical* about the results. Thus, Bacon's disinterested observer of nature isreplaced by Popper's skeptical theorist.

Popperian philosophy dominated the scientific thinking from the thirties tothe sixties, until Thomas Kuhn, a physicist, philosophized about the structure of scientific revolutions. Kuhn argued that the process of scientific inquiry is heuristic, not rational, and therefore psychologically or sociologically biased. Kuhn believed that very often the successful scientist must simultaneously display the characteristics of the traditionalist and of the iconoclast. It is Kuhn who popularized the word *paradigm*, which has come to seem so inescapable. A *paradigm* for Kuhn is a sort of consensual world view within which scientists work. It comprises an agreed upon set of assumptions, methods, language, and everything else needed to do science. Within a given paradigm, scientists make steady, incrementalprogress, doing what Kuhn calls "normal science". Kuhn's relativistic vision of shifting paradigms advocated that science is similar to any other human activity like art or philosophy, only more specialized, perhaps. The idea that science proceeds by periods of normal activity punctuated by shattering breakthroughs that make scientists rethink the whole problem is an appealing one, especially to scientists themselves, who know from personal experience that it really happens that way.

Kuhn's modern relativistic vision of shifting paradigms triumphed over Popper's positivistic belief in science's revolutionary potential to falsify society's dogmas. Nevertheless, Kuhn's theory does suffer from a number of shortcomings as an explanation for how science works. One of them is that itcontains no measure of how big the change must be in order to count as a revolution or paradigm shift. Another difficulty is that even when a paradigm shift is truly profound, the paradigms it separates are not necessarily incommensurate. The 'new' sciences of quantum mechanics and relativity, for example, did indeed show that Newton'slaws of mechanics were not the all-encompassing fundamental laws ofnature. However, they did not show that they were wrong. Quite the contrary, they showed why Newton's laws were right: Newton's laws arose out of new laws that were even deeper and that covered a wider range of circumstances unimagined by Newton and his followers, that is, things as small as atoms, or nearly as fast as light, or as dense as black holes. In more familiar realms of experience, Newton's laws go on working just as well as they always did. Thus, there is no ambiguity at all about which paradigm is better. The newlaws of quantum mechanics and relativity subsume and enhance the olderNewtonian world.

None of the philosophies advocated by Bacon, Popper and Kuhn could give us a perfect description ofwhat science is or how it works; nevertheless, all three helped us gain a much deeper understanding of it all.

Scientific Discovery – *Apriori Bias or Observational Learning*

The central problem of scientific Discovery is to find scientific regularity in experimental observations.

In recent years, philosophers have started, more,to analyze the processes of Discovery rather than worry about the philosophy of science *per se*. In general, any technique may be employed, from wild guesses to careful explorations of mathematical models to discover possible scientific explanations. Historically, inspired guessing has been the predominate technique, but with the massive data sets being now available with the advances in technology, more disciplined ways of searching for underlying laws are being used. New conceptual models and tools have been developed which can be used for thispurpose, *e.g.,* the interrogative model of inquiry and new conceptualizations of inference. The background suppositionis that there is the area of *heuristics* that is not strictly rational but neither is totally blind, and it is possible to developconceptual and methodological (and even strictly logical) models for heuristic procedures. This supposition about heuristics would suggest that conceptual structures and a historical perspective should not be seen as opposites; rather "grammar" should embrace historicalperspective. Many other areas of research have taken the issue of Discovery much more seriously than philosophy. There are various models,*e.g.,* in education, in artificial intelligence, in cognitive sciences, and inbusiness sciences that have been proposed to capture *processes of Discovery*. In these areas it is felt that in order to genuinely understand modern "knowledge society," it is important to conceptualize dynamic processes of knowledge advancement and knowledge creation, and not just to analyze how already existing knowledge is justified or acquired. For example, learning, in genuine and deep sense, can be understood as analogous to processes of innovative inquiry. This means that learning is seen as a collaborative effort to advance knowledge and understand things more thoroughly, *i.e.,* to *discover* something new. The model of *progressive inquiry* is based on the idea that various conceptual means that have been developed in philosophy of science and in cognitive science can be used to model the “epistemological infrastructure" of learning. The contemporary school of thought is that the general process of scientific Discovery (or cognition) can be the logical end manifestation of '*scientific inquiry*' whose foundation is either in *Apriori bias* or *observational learning*.

Theory Laden Observations – *Apriori Bias*

The interrogative approach to inquiry is one important way of explaining how research process can be based on bee-like activities – like the bee feeding on nectar it gathers, digesting it, and so transmuting it into the purest honey. Menoan horns are avoided when it is noticed that we can know things in some sense, and at the same time, not know them in another sense; so knowledge comes from a combination of knowledge and ignorance. However, the interrogative approach emphasizes that prior information and background knowledge impose constraints on and at the same time, anticipate admissibleanswers.

Observation Laden Theories - *Observational Learning*

It is also true that observationscan yield clues for theories; theories are often searched for in order to explain observational phenomena. However, one should emphasize that '*seeing*' is always'*seeing as*'. We see things through gestalts or patterns. The challenge for scientific inquiry is to reason from surprising data to an explanation. But are we not in a vicious circle? Observations are supposed to be theory laden and theories are observation laden. This is the essential tension in scientific Discovery, but not a contradiction or an empty circle. The various other tensions in scientific Discovery often result in dichotomies, *i.e.,* to the idea that one hasto chose between, for example, Discovery and justification or between product and process. But these tensions also give an opportunity to understand the dynamic process of inquiry.

Dynamics of Scientific Inquiry

Many claims and requirements that seem to be controversial are often connected to the idea of scientific inquiry. There are lots of examples: scientific discoveries are often described as sudden moments of insight, but on theother hand, they can be seen as a resultof hard work and "perspiration". Or; creativity can be seen as a result of a "*divergent thinking*" and playfulness, which can break constraints and boundaries, set by old ways of thinking. But, on the other hand, creativity can be seen to be based on "*convergent thinking*" where it is important to know those constraints, which older theoriesand paradigms require.

Discoveries are almost by definition something unique, but often,in the history of science, similar discoveries are made at the same time. It can also be claimed that in order to find something new, it is important to be ableto assess various possibilities impartiallyand critically, but on the other hand, it seems that discoverers often highly emotionally defend their favorite ideas even without much evidence. Innovativeness seems also to require that things are seen from many perspectives, but on the other hand, it is important to have a firm ground which does not change continually. The acts of creation seem to be often individual achievements where previous barriers of thought are transcended. But, on the other hand, it seems that they are the result of social interaction where the individual achievements are almostinevitable results of those resources that culture offers.

It could be argued that creativity and Discovery by their nature are concepts that border on paradox. In Discovery you almost have to *try* to have your cake and eat it too! Various models and characterizations of Discovery are instructive because they often try to avoid dichotomies by emphasizing the dynamic way of thinking. In discoveries it is *not* the case that one should choose between insights and hard work, or between tradition and innovation, or between individual and community, or between logic and emotion. In productive models of Discovery, there are both of these.

Various models of learning and knowledge advancement, which emphasize the aspect of knowledge creation, also border on paradoxes. The models of innovative knowledge communities nowadays often are based on the idea that knowledge creation is very fundamentally a collaborative and social process. But at the same time, they emphasize individual initiative in processes of inquiry and learning. Individualistic actions are embedded in social interaction, and both of these aspects must be taken into account. The models are also based on the idea that knowledge should be seen more broadly than just as propositional or conceptual knowledge.

Influence of Culture, Environment and History on Scientific Discoveries

Looking at the history of science, one would observe many instances when the prevalent culture, history and environment have indubitably affected the outcome of scientific investigations and resultant scientific discoveries. This is to be expected as the process of inquiry is fundamentally dependent on the 'prepared' mind of the inquirer. Although philosophically it is possible to have a Baconian disinterested nature, in practice the inquirer's mind would be befuddled with biases from the environment one is surrounded with and the prevalent scientific culture. Pertinent examples of how biases stonewalled the acceptance of scientific observations are many – a classic example being the proof for the existence of Gravitational Lens Effect because this was against Newtonian Physics. Arthur Eddington, in 1919, eventually proved the existence of gravitational lens effect by his observations during a solar eclipse, inspite of the prevalent biases existing due to the stature of Newtonian physics. Eddington's Discovery had significant impact in denting the permanency of Newtonian Gravitation in the world of understanding physics, and ushering in the importance of Einstein's general relativity concepts. Similarly, a more contemporary example (late 1980s) is the proof for the existence of Black Holes. The prevalent biases about the infallibility of Einsteinian physics influenced eminent scientists like ArthurEddington from doggedly resisting thetheory propounded by Subramanian Chandrasekhar on the existence of BlackHoles in the cosmos. Nevertheless, Chandra was proved right eventually and was awarded the Nobel Prize for his outstanding contributions to theunderstanding of Black Holes.

Joseph Needham's Poser

Some of the most outstanding scientific discoveries in various disciplines like Mathematics, Astronomy, Physics, Chemistry, and Botany during the last few centuries are credited to people like Pythagoras, Copernicus, Galileo, Newton, Einstein, Dalton, Heisenberg and Linnaeus. This has led the British researcher Joseph Needham to wonder why China and India (*although having a long history and culture of science, and being in the forefront of scientific revolutions for fifteen long centuries)* have not contributed anything significant after the 15th century in various fields of science and Discovery. Needham's poser evoked much debate and discussion which resulted in propounding a number of reasons for *our* (Indian) apparent failure to contribute significantly to modern dayscience and Discovery. Of the many reasons suggested, the fact that we are weak in observation with a closed educational system brought about by Macaulay, and that we do have a culture of contentment from a philosophical perspective are probably, *what I feel,* are the most important reasons for our collective failures.

Interestingly, Narasimha (2005), had argued that axiomatism and computational positivism – *the two different mathematical cultures of the occidental and the oriental respectively* – may be the important reasons for Indians not contributing to science after 15th century, while the westerners benefited by marrying their model making skills with the ingenuity of Indian mathematics and progressing appreciably in science. Roddam Narasimha's argument seems very convincing if we look at the following quotes from some of the outstanding scientists of our times.

"The ingenious method ofexpressing every possible number using a set of ten symbols (each symbol havinga place value and an absolute value) emerged in India. The idea seems so simple nowadays that its significance and profound importance is no longer appreciated. Its simplicity lies in the wayit facilitated

calculation and placed arithmetic foremost amongst usefulinventions." - **La Place,** on the Indian Numeral System.

"We owe a lot to Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made." - **Albert Einstein,** on the Indian Numeral System.

"If I were asked under what sky the human mind has most fully developed some of its choicest gifts, has most deeply pondered on the greatest problems of life, and has found solutions, I should point out to India." **Max Mueller,** on the Ancient Indian Science.

"After the conversations about Indian philosophy, some of the ideas of Quantum Mechanics that had seemed so crazy suddenly made much more sense." **Heisenberg** on Atomic Physics.

Although many of the possiblereasons discussed by Narasimha and others may seemingly be appropriate in the present day context, on serious contemplation one could also argue that our inability to perform well in the field of science, *perhaps,* stems from the fact that there has been a phenomenal changein the path of our scientific inquiry andin the way we do science; significantly influenced and transformed with the changes brought about in the language, environment and society, as a result of the invasions by the Moghuls and theEuropeans, starting from the 15th century. Interestingly, this argument can be substantiated by looking at what Lord Macaulay had to say in the British Parliament on February 2, 1835 (Bharathiya Bouddhik Sampada, 2006).

"I have traveled across the length and breadth of India, and I have not seen one person who is a beggar, who is a thief. Such wealth I have seen inthis country, such high moral values, people of such caliber, that I do not think we would ever conquer this country, unless we break the very backbone of

this nation, which is her spiritual and cultural heritage, and,therefore, I propose that we replace her old and ancient education system, herculture, for if the Indians think that all that is foreign and English is good and greater than their own, they will lose their self-esteem, their native self-culture and they will become what we want them, a truly dominated nation."- **LordMacaulay.**

Ancient Discoveries of India

Some of the amazing discoveries which have come from ancient India in various scientific fields are highlightedin the following section to emphasize the point that perhaps the *then* existing path of scientific inquiry, uninfluenced by the foreign invasions *and the resulting transmutation of the Indian psyche and thought process*, may have been responsible for the various discoveriesbrought about.

Psychology & Cosmology:

Kapil (3000 BC) had postulated in *Sankhya Philosophy* the secret levels of psyche, including mind, ego and intellect and how they relate to Soul or Atman – well before Sigmund Freud's time. Kapil's view of cosmos was that essential nature (*prakruti)* comes from the eternal (*purusha*) to develop all creation.

Aviation & Medicine (Ayurveda):

Bharadwaj (800 BC), recognized as the father of ayurveda and developer of aviation technology presented a treatise titled *Yantra Sarvasva*, in which astonishing discoveries in aviation and space sciences and flying machines were presented well before Leonardo Da Vinci's time.

Athreya (8 BC) had published a treatise called *Charaka Samhita,* which is a compilation of all aspects of ayurvedic medicine including diagnoses, cures, anatomy, embryology, pharmacology and blood circulation.

Chemistry and Metallurgy:

The atomic theory of Kanad (600 BC) talks about atomic motion and chemical reactions. Kanad postulatedthat every object in creation is made of atoms that in turn connect with eachother to form molecules nearly 2500 years before John Dalton's time. Nagarjuna was credited for bringing out *Rasa Ratnakara*, a treatiseon chemistry and how to develop alchemical metals for medicinal purposes. Ancient India was also famous for gold jewelry (3000 BC), brass and bronze (1300 BC), non-corroding ironpillar in Delhi believed to be 1200 years old; well before their entry into western world.

Astronomy and Mathematics:

Aryabhatta (476 BC) discovered the motions of planets and time of eclipses nearly 1000 years before Copernicus. In the treatise, *Shulaba Sutra*

(600 BC), the topics of zero, pi, geometry and trigonometry werepresented well before Euclid and Pythagoras of the Greek era. In the book titled, *Surya Siddantha* (400 circa), Bhaskar Acharya spoke about the law of gravity nearly 1200 years before Newton did. The decimal system, *i.e.*, decimalscale to base 10, was invented in India without which no counting can exist.

Medicine and Surgery:

Sushrutha (600 BC) was acknowledged as the father of surgeryand developer of surgical instruments and processes. His treatise, *Sushruta Samhita,* was considered as the encyclopedia for surgical techniques andinstruments.

Scientific Notation and Grammar:

Pannini (500 circa) was credited for his publication *Astaadhyayi,* which was a comprehensive and scientific theory of phonetics, phonology and morphology - a precursor to computer languages

1400 years before John Backus's Normal Form in 1959. Astronomy, Botany and Animal Science: Varaha Mihra (500 circa) was credited with his treatises,*Pancha Siddhanta, Bruhad Samhita,Bruhad Jataka*, which describe geography, constellation science, botany and zoology in great detail.

Indian Philosophy and Scientific Inquiry

The Indian philosophy or way of thinking is a dynamic phenomenon punctuated by the Vedic period (1500BC – 600 BC), the Epic period (600 BC - 200 AD), and the Sutra period (From 200 AD). The sutra period was governed by six philosophical systems *which inmy view* basically propounded the process of scientific inquiry. The six philosophical systems being *Nyaya*(Logic), Vaiseshika (Atomism), *Sankhya*(Analysis), *Yoga*(Method), *Purva Mimamsa* (Exegesis) and U*ttara Mimamsa* or *Vedanta.*

The amazing discoveries of ancient India were perhaps brought about by the time tested efficacy of the process of scientific inquiry ingrained in our six ancient Indian philosophicalsystems. It is argued that this processand path of scientific inquiry in Indiawas transformed and subsequently lost to the modern-day scientist in India after the Indian invasions starting from 15th century. The argument, in a way, resonates with Thomas Kuhn's philosophy that the process of scientific inquiry is psychologically and sociologically biased. The suggestion being that, there was a significant change in the path and process ofscientific inquiry in India after the Mughal and European invasions of India. As a result our (Indian) scientific achievements and stature have come down, not at all commensurate with our numbers and intellect. Therefore, it is strongly felt that it is time we shed our '*colonial*' way of thinking and revert back to the scientific processes and inquiry as ingrained in our ancient Indian philosophy to regain our lost stature in the world of science and Discovery.

Afterword

The paradoxical nature of scientific Discovery and the importance of the process of scientific inquiry were stressed; summarizing that scientific Discovery can be brought about by botha *priori* bias as well as observational learning as was ingrained in our ancient Indian philosophical systems. It isadvocated that we reorient our path of scientific inquiry by following the tenets of the six Indian philosophical systems of *Nyaya* (Logic), Vaiseshika (Atomism), *Sankhya* (Analysis), *Yoga* (Method), *Purva Mimamsa* (Exegesis) and U*ttara Mimamsa* or *Vedanta* in order to regain our lost scientific stature in the world and perhaps effect great new scientific discoveries.

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Need For Indigenous Defence Technologies

Prime Minister Narender Modi's recent exhortation to the scientific and R&D fraternity at the Indian Science Congress—to Dream, Imagine and Explore, with an assurance to recognise and remove excessive controls is certainly a step in the right direction for attaining self-reliance for India’s Defence Sector.

Armed Forces of any country in the world generally demand state of art technologies which are very complex and are multidisciplinary in nature. Indian Armed Forces being no exception, continuously demand state of art technologies from the national institutes in general, and the Defence Research and Development Organisation (DRDO) in particular; in order to maintain the envisaged high levels of Defence preparedness in an ever changing and complex world scenario.

DRDO with its 50 plus laboratories spread across the country primarily caters to Armed Forces’ qualitative requirements which are projected by Armed Forces. However, in most cases the urgent requirement of state of art technologies by the Armed Forces, is not balanced by the long gestation time required for developing a new technology by DRDO; thereby creating a significant gap between the demand from Armed Forces and the supply by DRDO. This purportedly resulted in a significant number of Defence technologies being imported, with India enjoying the dubious distinction of importing more than 70 per cent of systems and technologies pertaining to the Defence Sector. Staggering budgets of approximately Rs 95,000 crore for Defence imports during 2014-2015 coupled with sufficient number of high-profile players seriously wanting India to remain bogged down within the pernicious cycle of imports are serious indicators for all to sit up and think about alternatives.

It is well known that technology wins wars. However, recent global experience has also demonstrated that technology loses wars, if inappropriately used. The problem with technology (especially high end critical technology) is that it requires a very deep understanding of the capabilities, limitations and the effects of the operational 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 other country located in a different environment and climate.

Time and again, Indian stakeholders have debated hard and fast, the necessity for imports by the Armed Forces and the ability of Indian R&D organisations to meet the evolving demands of Indian Armed Forces in the stipulated time frames. The debates have resulted in a number of analyses and insights into the problems, while stressing the importance of self-reliance in critical technologies. Several analyses and insights were provided by high profile wise men and women often posing the simple question whether Indians in India can design and develop technologies which can cater to the growing demands of the Armed Forces in the time frames required, thus engendering intricate and sometimes impractical solutions. If one were to serenely introspect and delve deep into the thought processes, the simple questions become rather complex, abstract and mind boggling, bordering on paradox for which there can only be complex answers. It pays to rationalise the question per se, by counter questioning, what and who are responsible for sprucing up the requirements of the Armed Forces?

Obviously, the responsible persons base their actions and reasoning on the basis of their respective backgrounds and their acquired knowledge (from literature, books, journals, intelligence and prevailing information, which I call as a priori bias, and also based on personal observations and learning, which I call as observational learning). Suffice to say that, optimising the process of requirements generation is by no means an easy or trivial task for the Armed Forces.

Requirements generation process starts with validated assumptions on strategic requirements arising from threat perceptions and national policies to contain them (combined effects of a prior bias and observational learning). Arguing that any knowledge based on a combination of both a prior bias and observational learnings is affected by the prevalent culture, history and environment, it would perhaps become clearer that the common temptation to ‘technological solutionism’–the belief that technology can benignly and efficiently solve all our Defence problems—is at best a hope, and at worst causes unnecessary dependence on others in the critical domain of national security and therefore defeats the very tenet of self-reliance which is a primary requirement in the Defence Sector.

The average Indian following the developments in the Defence Sector stands justifiably puzzled and somewhat sceptical of capability acquisition in progress. For the average citizen the national security perception remains a conundrum with a serious disconnect between appearance and reality.

Commercial common sense also suggests that a country which is exporting Defence technologies, would not necessarily give the state of art but rather the outdated systems due to security and commercial reasons. This can indeed result in the country falling into a pernicious cauldron of dependence on foreign powers to cater to the critical Defence needs. Excessive and continued dependence on Defence imports is usually fraught with additional security and political dangers.

Self-reliance has been a mantra for India's policy makers since India's Independence. Since Independence our rulers have sufficiently emphasised on scientific temper and enquiry, necessary for self-reliance, without really forming and developing an ecosystem for self-reliance and innovation. Despite the desire to be self-reliant, the fact remains that India is dependent on others for critical technology in Defence.

Lack of creativity and innovation coupled with a lackadaisical work culture and zero accountability within the Defence establishment are certain roadblocks against high aspirations. Moreover, whatever innovation the Defence R&D and industry boasts of is mostly confined to reverse engineering, implying the unveiling of technology behind an imported item, and using it.

The need for the country, therefore, is to follow the path of self-reliance by encouraging innovation, removing perceived bottlenecks and controls, allocating sufficient funding and additionally insisting on accountability from the R&D fraternity.

Ample examples of Indian researchers successfully developing indigenous technologies by thinking out of the box, in a control free environment with frugal funding demonstrate the plausibility of self-reliance in time frames shorter than commonly believed.

January 2015

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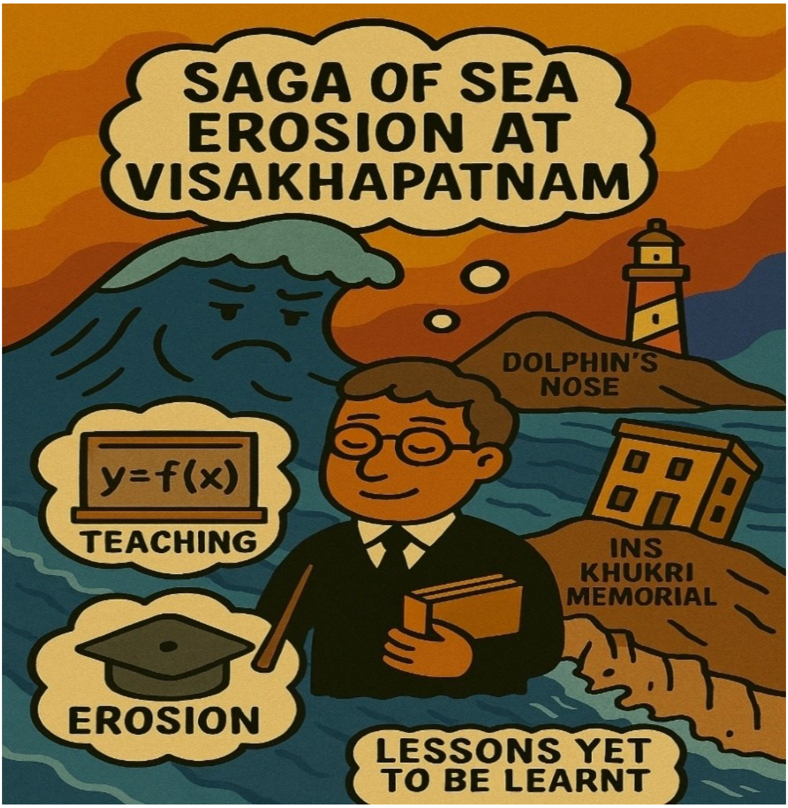
Saga of Sea Erosion at Visakhapatnam:
Lessons yet to be learnt



Visakhapatnam - a strategically important and fast developing city on the southeast coast of India, in the state of Andhra Pradesh; with a huge potential for becoming an economic and commercial hub of South Asia and also of becoming a strategic pivot in the geo-political strategy of maritime nations – *is also known for its beautiful beaches*.

The beautiful natural beaches jutting the Bay of Bengal off Visakhapatnam - have been experiencing episodic erosion since the last 25 years. The problem however, has aggravated during the last 3 to 4 years due to an increasing number of avoidable factors and decisions (*or rather, a lack of them*) by local, regional as well as central administrators and political leaders of the country.

The sea erosion problem has rightfully attracted the attention and *ire* of the public at large, various levels of administration, academicians, scientists, engineers, politicians and many other stake holders - ably aided by a concerned Media, both Print and TV.

Against the back drop of Prime Minister's praiseworthy exhortation to the World in general, and India in particular; that India's economic progress can and should be linked to Indian innovations and indigenization (*Make in India*) - innumerable discussions, deliberations and meetings of various stakeholders resulted in many novices as well as experts in various fields - airing their views about sea erosion, in private and public, generally creating more confusion and chaos to the common public, as well as decision makers and political leaders.

As is commonly observed and accepted in India, the decision makers and political leaders formed various working groups and committees (sitting and standing, *sic!*) to look into the problem. During the course of time, national organizations like CWPRS (Central Water and Power Research Station) in Pune, under the Central Ministry of Water Resources, River Development and Ganga

Rejuvenation; NIOT (National Institute of Ocean Technology) in Chennai, under the Ministry of Earth Sciences; NIO (National Institute of Oceanography) headquartered in Goa with a Regional Centre in Visakhapatnam, under the umbrella of CSIR (Council of Scientific and Industrial Research) coming under the Ministry of Science and Technology; NRSC (National Remote Sensing Centre) a premier space research agency under the Department of Space which directly comes under Prime Minister; premier academic institutes of the nation - like IIT Madras; local organizations like Andhra University, Visakhapatnam Port Trust, Central Fisheries Institutes, Dredging Corporation of India, Gangavaram Port, Vizag Sea Port represented by many of their experts, coupled with many international experts, consultants and *players* of India, The Netherlands, USA, Australia and Europe have had either expressed views and opinions, or, participated in various deliberations with concerned administrators and decision makers.

During an initiative taken by the Honourable Member of Parliament of Visakhapatnam, to discuss with all local experts regarding the sea erosion, Prof. Rao Tatavarti (of Gayatri Vidya Parishad and CASTLE), strongly advocated that the complex problem of sea erosion is site specific, and hence so is the solution. Therefore, it was articulated that one cannot resort to solutions which worked elsewhere, *until a systematic study of all the scientifically known parameters which affect erosion are considered in right earnest, at that specific site*.

Prof. Tatavarti further stated in the meeting that his inter-institutional team comprising of researchers and students from Gayatri Vidya Parishad College of Engineering and GVP – SIRC (Gayatri Vidya Parishad Scientific and Industrial Research Centre); Centre for Earth and Space Sciences, University of Hyderabad; and the Indian Maritime University at Visakhapatnam; would be happy to *voluntarily* take up a study of the various conditions at the specific site using all expertise and sophisticated state of art instrumentation available at his team's disposal; if appropriate logistic support is forthcoming from concerned departments.

The problem of sea erosion was consequently discussed in the legislature of Andhra Pradesh by the Chief Minister, as well as in the Parliament by the Minister of State for Science, Technology and Earth Sciences and discussions were held with many National and International experts.

Based on inputs from local administrators, a standing committee with Chairman VPT as the convener and many representatives from many of the above-mentioned organizations was created by the Government of Andhra Pradesh, but somehow the names of GVP and University of Hyderabad representatives who voluntarily and proactively came forward to conduct studies were omitted for unknown reasons.

Later, under apparent instructions from the Chief Minister's office the convener co-opted Prof. Rao Tatavarti (GVP) and Prof AC Narayana (University of Hyderabad) in the standing committee as both of them have vast experience in coastal and ocean engineering projects, having worked together for many decades at different places in and outside India.

Notwithstanding the hurdles from different quarters, Prof Rao Tatavarti of Gayatri Vidya Parishad voluntarily 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 art instrumentation coupled with theoretical modelling and simulation studies. Visakhapatnam Port Trust with its dynamic Chairman provided financial support to take care of the logistics for this major field study.

The entire task from the design to development and successful implementation was completed in a record time (even as per international standards and practices) of four weeks; *with locally available human resources* (*undergraduate students and fishermen trained ab initio, and suitably motivated)*, innovative designs and out of the box thinking; with support from MECON, a local firm which facilitated the logistic support in the form of catamarans for deployment of instrumentation.

The deployment of state of art instrumentation at three spatially separated locations, enabled real time site specific data of cross-shore, alongshore and vertical structures of all the different parameters of waves, currents, tides, sediments, bathymetry, geomorphology, *etc.* pertaining to the nearshore zone (*encompassing the complex surf* *zone and the location of the specific problem of erosion*). The study demonstrated to the public in general, and the scientific and engineering fraternity in particular, how complex problems can be solved even under challenging conditions and constraints, by locals - *when many national and international stalwarts were suggesting that it is next to impossible to deploy instrumentation in the nearshore surf zone*.

After successful completion of the site specific studies, Prof. Tatavarti and team submitted detailed technical reports (*12 reports running to more than 1300 pages of technical and scientific details*) with a summary of analyses of very large data sets comprising more than 15 million observational data. Based on the site-specific studies, the team suggested recommendations for tackling the problem of sea erosion at Visakhapatnam.

The sum and substance of their extensive in-situ studies combined with state of art numerical modelling was that, given the complexity of the nearshore hydrodynamics and sediment dynamics, *construction of any man made structure in the sea would prove to be, not only detrimental to the coast of Visakhapatnam, but also would be prohibitively expensive to the exchequer; and therefore suggested that a shore parallel hybrid rubble mound revetment at the landward edge of the beach can serve as a cost effective protective wall from sea erosion, without jeopardizing the aesthetics of the existing beach.*

The team further suggested that appropriate vegetation on the revetment would also help in enhancing the aesthetics, as well as the beach - over a period of time. The recommended solution was projected to approximately cost, *not exceeding* Rs. 1*crore* per kilometre stretch of coast. The team suggested that the proposed structure can be realized *with locally available human as well as material resources*, at a fraction of the cost compared to the annual sand bypassing costs generally known to be budgeted by VPT, and offered to give a detailed engineering design of the same, if desired by the authorities.

Subsequently, Prof. Tatavarti and Prof. Narayana made a detailed presentation to the Chairman, VPT; District Collector, Visakhapatnam and the Commissioner of Greater Visakhapatnam Municipal Corporation, GVMC. The administrators felt that a decision should be taken after listening to what other National institutes like NIO, NIOT, ISRO and Ministry of Earth Sciences recommend after their studies (*which were not even started by that time, given the peculiar procedures and idiosyncrasies of work culture - associated with governmental organizations)*.

Later, NIO deployed a single wave rider buoy (from *Data Well*, Netherlands) capable of measuring waves at deep water locations at a water depth greater than 10m*, (whose location is kilometres away from the beach of interest, and therefore by no stretch of imagination a site specific study*) to monitor wave heights for a period of time.

Incidentally, the Datawell directional wave rider buoy deployed by NIO is known to be capable of monitoring waves in the frequency range of 0.05Hz and 0.5 Hz only, due to constraints in the fundamental physics of wave sensing mechanisms. This means that far-infragravity waves and motions (wave motions with very low frequency, <0.05Hz) which were generally known and accepted *(by scientific fraternity across the world)* to dominate nearshore dynamics, *and also observed to be at times, dominating the nearshore dynamics off Visakhapatnam by the GVP team* - could not be monitored by the wave buoy.

After some time NIOT apparently conducted a numerical study based on bathymetry surveys conducted off the deeper waters of Visakhapatnam (*as regular boats cannot easily venture into surf zone*) and reached conclusions regarding the preventive measures for Visakhapatnam beach erosion, based on whatever archived data available with Ministry of Earth Sciences.

NIOT with active collaboration from NIO and Andhra University made recommendations to the Government of Andhra Pradesh that *a submerged structure should be built parallel to coast* in water depths of 3 to 5m with special structural units called *tetrapods*.

NIOT and others also recommended that *geo-synthetic tubes should be additionally placed for protection of the beach*, primarily arguing that these measures worked elsewhere in the world and some international experts can vouch for *their* efficacy.

The projected cost for the solution was approximately pegged at INR 100 crores.

Even teams representing World Bank came forward to look at sea erosion at Visakhapatnam and offered loans (*of course, to be repaid with premier interest rates*) for resolving the problem by advocating long term engineering solutions to be suggested and implemented by, *you guessed it*, International Agencies *in sync* with World Bank practices and procedures.

Administrators, politicians and even some in the scientific fraternity were thrilled that the local problem had garnered international attention. Many of the decision makers of the state as well as many interested parties outside the country, were visibly excited, apparently at the opportunity of working on a complex problem with significant commercial spin offs.

The Government of Andhra Pradesh, in its wisdom immediately agreed *in principle* to the NIOT recommendations and asked an international agency DELTARES based in The Netherlands to vet the NIOT recommendations and give their views.

Naturally, there was a general amnesia regarding possible irritants and banalities like *Make in India,* and other such related exhortations by well-meaning people.

Presumably, there was a collective yet firm belief, that complex issues and problems created by Indians with either vested interests or appalling levels of inefficiencies and ignorance *(like the sea erosion problem of Visakhapatnam whose roots lie in indiscriminate developmental activities, aided by the complex vagaries of the ocean)* cannot be solved with local expertise and resources.

It seems ridiculous, that we still have to deal with decision makers who strongly believe that Indians are incapable of finding long lasting solutions to complex engineering problems of India. This attitude, *nay conviction*, is clearly an insult to the Indian capabilities and intelligence, in a day and age when India showed the world that it could send a complex technological system *Mangalyaan*, built in India by Indians, at an incredibly low cost that astonished the entire world.

The saga of sea erosion took an interesting turn, when the team from DELTARES refused to appreciate the wisdom in going *for submerged structures and geo-synthetic tubes* in the nearshore zone and indicated that they would like to conduct their own site specific study to arrive at optimal solution, *of course after receiving a request and substantial funds by the concerned authorities*. The DELTARES views have thus pushed the entire saga of sea erosion at Visakhapatnam, back to square one.

Three years after the sea erosion problem caught the attention of decision makers, we are again at a time (January/February) when the sea is expected to taunt the locals by making its now customary annual jaunt shoreward onto the Visakhapatnam coast.

The confounding irony, typical of decision makers in India - *three years on, and the decision makers are nowhere yet to take a decision.* The long winded yet unsolved saga of the sea erosion at Visakhapatnam, should therefore serve as an eye opener to the decision makers of the country, who would *hopefully* be accosted by the following lessons:

- *What's good for goose may not always be good for gander*. Effective solutions in USA, Europe or Australia may not be effective in India.

- *The difference between possible and impossible, lies in the determination*. Nearshore field experiments in the surf zone, hitherto claimed to be very difficult, if not impossible were successfully completed by a small team with local resources, under challenging constraints.

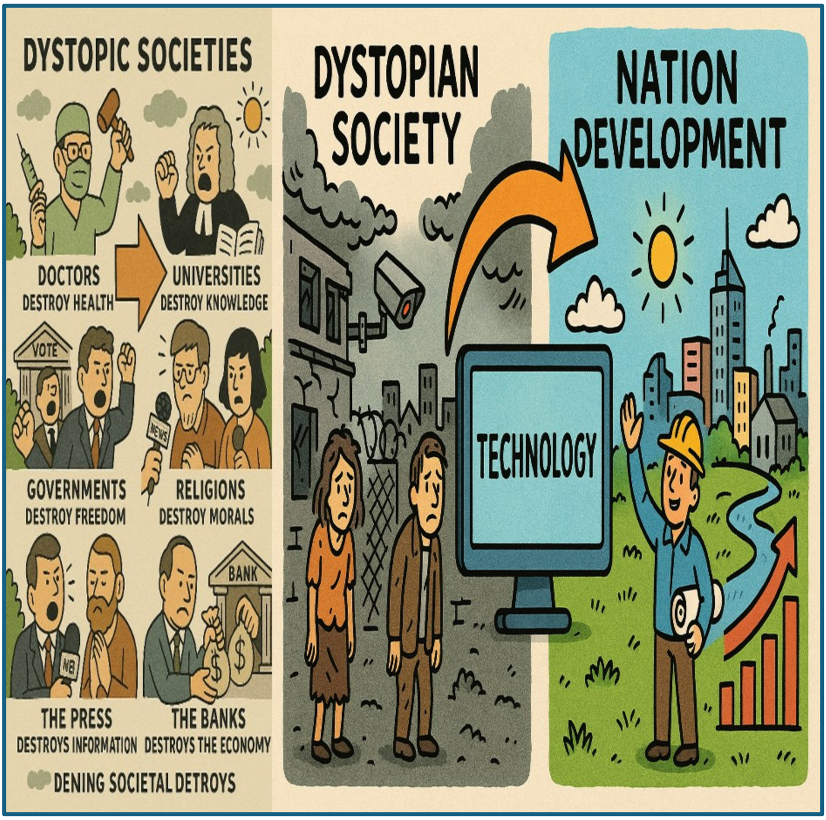
- *Knowledge and ability to solve complex engineering problems are neither proprietary nor the prerogative of National/International institutes*. History and legacies cannot solve present problems; a lot depends on the people who are working on the problems. Ideas propounded by small dedicated and motivated teams can help in Nation building.

- *It pays to not only listen to our own people with good intentions, but also have the wisdom and ability to differentiate good* *intentions and vested interests.* Cost effective and simple solutions *can also be* the optimal solutions for complex problems.

On a concluding note, it would certainly be an interesting turn of events for decision makers, if the sea decides to show its prowess during the International Fleet Review at Visakhapatnam; when the Indian Navy, Raksha Mantri of India, Prime Minister of India, and of course, the Commander-in-Chief of the Armed Forces of India would like to showcase the nation's capabilities to the many distinguished international visitors.

January 31, 2016

Pivot For National Development



Dystopic Societies

Christopher Lynn Hedges, the Pulitzer Prize-winning American journalist, and a former Princeton

University professor, often questioned the structures of present-day societies by insisting that we now live in nations where doctors destroy health, lawyers destroy Justice, universities destroy knowledge, governments destroy freedom, religions destroy morals, the press destroys information, and the banks destroy the economy.

As ominous and outlandish as they sound, Hedges' words seem to ring closer to reality, especially in our country in the context of the recent happenings cutting across many vital facets that constitute the fundamental structures of society - like education, medicine, media, politics, religion and now even judiciary.

Declining Societal Mores

In the name of democracy and social inequity aversion, new societal inequities are being imposed on the helpless and unsuspecting public by vested interests, resulting in additional troubles and vitiating the social environment for peaceful co-existence, which is the foundation for a civil society. In the democratic set-up of the day, we are now increasingly facing situations where people in small numbers and fringe groups are holding entire communities and sometimes even the nation to ransom, clamouring more and more for their presumed rights with outright abandonment of their duties as citizens, and the decency and decorum expected by human beings of a civilized society.

As a result, pettiness in social behavior, intolerance to others, and a wanton display of selfishness with total disregard for fellow citizen's space and fundamental rights are on the rise today.

Petty considerations fuelled by ego-centric motives, peppered with an increasingly brazen display of growing intolerance, boorish behaviour by individuals constantly stepping onto the rights and liberties of other citizens, and mindless hooliganism by fringe groups are engendering societal turmoil and affecting our daily lives, the quality of life of citizens and additionally becoming an unnecessary hurdle for economic growth and prosperity of the nation.

Increasing Litigations – Stultifying Effect on National Progress

People's contentious attitude naturally pushes society at large to indulge in disputes and litigations. The more than 3.5 million pending court cases (as per recent reports attributed to the Law Commission) in India starkly testify to the present sociological upheaval in our changing world.

The alarmingly growing percentage of aspiring and litigant population, coupled with the massive number of pending cases, is thrusting an additional burden on the nation and stultifying whatever little economic growth the country tries to achieve in these trying times.

For a developing country with an alarming rate of rising population and reeling under the throes of rampant allegations of deceit, deferment, dishonesty, and sometimes outright corruption in the dispensation of Justice, the adage' *Justice delayed is Justice denied'* attains a more ominous hue with far-reaching repercussions threatening to push the nation into an uncivil society where might may become the right.

Adding to this pernicious situation, today's print and electronic media are full of stories alluding to the squabbles and altercations even in the highest echelons of the judiciary, thus painting a rather grim picture for the country's ordinary citizens.

Needless to say, the recent news of the bickering judges and the wranglings for power and pelf emanating from the hallowed portals of even the Indian parliament portends a painfully bleak future for a nation that is at the cusp of a unique demographic dividend and dreaming to encash it for its future growth and prosperity.

Science, Engineering, and Technology in Nation-Building

For a long time, the public and economists believed that land, labor, and capital were the key drivers of an economy, with intellectual pursuits and scientific knowledge having no role in nation-building.

However, scientific and technological revolutions underpinning economic advances, improvements in health systems, and the overall lifestyles of people worldwide have entirely overturned the earlier beliefs and brought awe and respect to science, engineering, and technology. Scientific and technological advances in biotechnology, computers, electronics, telecommunications, photonics, and transportation have ushered in far-reaching changes in our society and helped create a better quality of life for people.

The role of science and technology for socio-economic development is now well established. Progress in science, engineering, and technology are critical drivers for national development. It is now believed that scientific knowledge is more essential for the wealth creation of a nation than land or capital. The mushrooming growth of the IT industry over the last decade and its positive impact on the Indian economy is a case in point.

Scientific Solutions for Societal Problems

Be that as it may, however essential science and technology are considered, the myriad complexities of societal structures dictate that a sufficient driver for effective implementation is the public discourse, narrative, and consensus to use the essential science and technology tools for national growth and development.

For a nation like India, where more and more engineers are being churned out every year, it certainly pays rich dividends if we can effectively use the young engineers to solve some of the significant problems that threaten to tear the fabric of our civil society.

One such problem is the pending judicial cases because of (*a*) the domino effect on society at large and its indirect role in its stifling effect on national growth and (*b*) the multi-pronged difficulties posed to humans to administer Justice in traditional ways. Therefore, it pays to look for scientific and technological solutions to this societal problem of delays in the delivery of Justice to citizens.

Artificial Intelligence, Machine Learning, and Deep Learning for Delivery of Justice

Today, the common public is more conversant with the internet, virtual reality, and robotics fields and the many fascinating pathways for progress they promise. Recent science and technology developments have ushered new areas like artificial intelligence (AI), machine learning (ML), and deep learning (DL) into the realm of public knowledge.

Simply put, Artificial Intelligence (AI) involves machines that perform tasks characteristic of human intelligence - like planning, object recognition, sound recognition, understanding language, learning, and problem-solving. While Machine Learning (ML) is a way of achieving Artificial Intelligence, Deep Learning, although different from Machine Learning, can naively be stated to be one of the many approaches to Machine Learning primarily inspired by the structure and functioning of the human brain, wherein vast amounts of data are processed and analyzed to arrive at intelligent solutions.

The common public would be pleasantly surprised to realize that Deep Learning is now responsible for conversation-carrying *chatbots*, Amazon Alexa, Microsoft Cortana, Facebook, Instagram, and more in our daily computer interactions. On social media, algorithms based on Deep Learning churn out content and page suggestions. Deep learning is even helping companies customize their advertising to individual tastes.

Against this backdrop of huge advances made in AI, ML, and DL, we can look forward to solving the pending judgment problem by *allowing* and *training* machines to arrive at the best decisions objectively by resorting to Deep Learning technologies. This may significantly result in (*i*) eliminating bias so commonly alleged in the justice delivery system and

(ii) phenomenal multiplication of the speed of the justice delivery, so much so that in a couple of years, the problem of pending judicial cases would cease to exist. Therefore, using appropriate AI, ML, and DL tools may eliminate and adjust societal imbalances so that national progress is unimpaired.

In some countries, basic AI-driven systems already help courts in garnering background literature, reference judgments to allude to the final dispensation of Justice, and assess various risks posed by defendants - from the likelihood that he or she will skip bail to the possibility that a potential parolee will re-offend.

As these tools become more sophisticated, they have the uncanny potential to not only deliver Justice with a high degree of fairness but also to alleviate the massive congestion facing our state and federal justice systems.

Of course, such developments are not without controversy as there certainly would be issues and concerns regarding privacy and accountability, which deserve serious consideration and, in some cases, may warrant new laws and regulations.

However, to solve national problems, the issues and concerns emanating from implementing new tools, techniques, and technologies shouldn't deter developing and implementing trained intelligent systems with enormous potential to produce better outcomes for society.

In conclusion, although science and technology may not be the panacea for all the evils of our society, they certainly could serve as a pivot for national development.

January 29, 2017

Surmounting digital world challenges in the march towards utopia

Preface

Tremendous advances in the digital technologies have not only ushered in many facilities resulting in better lifestyles and health, to the people around the world, but also, have brought in associated challenges detrimental to the society at large. This article discusses the recent advances in science and technology in general, cognitive sciences in particular - to highlight the persuasive power of the narrative on the human psyche. Further, showcasing how the power of narrative is being used by governments and big corporations for surveillance, intelligence gathering and business purposes, the article highlights the narrative power of the Indian philosophies and fables, from time immemorial - in building and framing our Indian psyche and ethos, and in realizing a better society. Keeping in mind the unique opportunity the nation enjoys today, in terms of the demographic dividend, the article suggests and argues that we should harness the demographic dividend by utilizing the technological advances for inculcating moral and ethical values propounded in our Indian philosophies and fables. Using the above arguments, the article concludes that necessary mechanisms *can and should* be built to realize a better, and perhaps, a utopian society tomorrow.

Life in the Digital World

Not very long ago, the commonly held belief was that land, labor, and capital were the key drivers of an economy - with intellectual pursuits and scientific knowledge having no role in improving human lives and nation building.

Today, tremendous advances in digital technologies, especially in the fields of Photonics, Biomedical Technology, Information and Communications Technologies (ICT), have enabled people across the world to:

- enjoy better and faster means of communication and can stay connected even with people far away in remote places thousands of miles away. In fact, can stay connected even with astronauts in the outer space, or with divers in the deepest trenches of the oceans.

- travel to far flung places anywhere in the world, including outer space and the deepest ocean, by means of sophisticated and faster modes of transportation.
- lead more luxurious lifestyles.
- access and utilize better health care and medical facilities.
- stay connected with the world over, by just clicking on their digital devices.
- live longer with increased life spans.
- access wide ranging information on any subject, past or present, instantaneously.
- visualize and listen to happenings anywhere in the world in real time, sitting in living rooms.
- order for almost anything, from anywhere in the world and get them delivered to chosen locations with remarkable speeds.
- teach and learn any art or subject online.

Challenges for Digital Utopia

Not surprisingly, the recent technological revolutions underpinning human advances, improvements in health systems and the overall lifestyles of people across the world have now completely overturned the earlier beliefs. So much so, that today, digital technologies are unquestionably accepted as the harbingers for better and healthier lives, secure and prosperous nations.

This paradigm shift in the public perception often misleads the layman to believe that the advances in science and technology pertaining to the digital world are the stepping stones on the path to utopia - an ideal society in which laws, government, and social conditions, are solely operating for the benefit and well-being of all its citizens[1]. Technological utopianism is often associated with discourses presenting technologies as agents of social and cultural change [2-3].

The logic of *digital* utopianism often imagines that the digital technologies can be the panacea for all the problems of the society, and that they are the means for attaining eternal peace, happiness, and prosperity, as the technological utopianism naively views only the positive impacts of technology.

Digital utopian critics, therefore, rightfully claim that techno-utopianism's identification of social progress with scientific progress, is a form of positivism and scientism, and often point out that technological utopia is misguided optimism, as science, technology and society cannot be seen as independent, as should be construed as interdependent, and that the philosophical reflections on scientific activity and technological doing are essential in understanding the effects on a society[4].

Against this backdrop, this article attempts to carry forward the utopian exuberance of the digital world vision, by projecting it on a perceived model of socio-technological innovation that hopefully can translate into a more pragmatic reality in the march towards digital utopia.

Impact of Digital Transformation on the Digital Generation

Digital Transformation is the adoption of digital technology to transform manual processes with digital processes or replacing older digital technology with newer digital technology. Digital solutions generally enable efficiency via automation. Today, as we live in an interconnected world, empowered by invisible networks of instant communications and various modes of transportation, facilitating communications and movements with incredible precision and speeds;

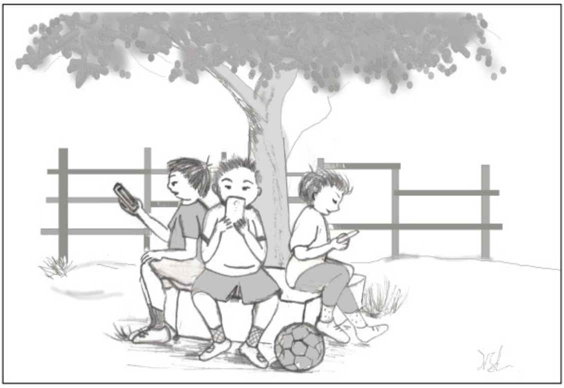
digital transformation has affected our lives in all the fields covering education, economy, business and commerce, defense, communications, transportation, health, and medicine. Digital transformations have had significant impacts on the common public.

Digital transformations have immensely affected young people’s lives in more significant ways. The young, specifically the digital generation - a generation of people born in the digital era that has grown up with access to digital information and the abilities to navigate the new communication technologies - have had a tremendous impact of information and communication technology on their ideology, organization, mobilization, and their societal structures which underpin their way of living[5-6].

For young people, today social media serves as an avenue for civic participation. It affects their norms, values, attitudes, and behaviours regarding democracy, power, politics, policymaking, social and political participation, both online and offline, and the organisation of economic, social, and private life

Science, Technology, and Society

Today, we all are more conversant with field of Information and Communication Technologies (ICT) comprising of internet, virtual reality and robotics and the many fascinating pathways for progress which they promise. Recent developments have



Children in the playground - Sketch by Dr N. Sridevi

ushered in new fields like Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) into the realm of public knowledge and our everyday lives.

In simple words, Artificial Intelligence (AI) involves machines that perform tasks, characteristics of human intelligence - like planning, object recognition, sound recognition, understanding language, learning and finally problem solving, while Machine Learning (ML) is a way of achieving Artificial Intelligence. Deep Learning, although different from Machine Learning can simply be stated to be one of the many approaches to Machine Learning primarily inspired by the structure and functioning of the human brain, wherein huge amounts of data are processed and analyzed to arrive at intelligent solutions using what are called predictive analytics.

It is against this backdrop of huge advances made in AI, ML and DL that we look forward for solving the many of the pressing societal problems by *allowing* and *training* machines to arrive at the best judgements objectively by resorting to Deep Learning technologies. This may significantly result in (i) the elimination of bias so common in conventional designs by engineers, and (ii) phenomenal multiplication of the speed of delivery of desired outcomes. It is hoped by many scientists and researchers that using appropriate AI, ML and DL tools may result in eliminating and adjusting the associated imbalances in the society, so that national progress is unimpaired.

Smart algorithms, Natural Language Processing (NLP), Machine learning, and Big Data technologies are used to create analytics and insights. NLP is designed to be inherently language agnostic, or genomic with text mining. In simple terms NLP can be construed as an area of artificial intelligence research that attempts to reproduce the human interpretation of language. With the advent of the World Wide Web, XML, and the World Wide Web

Consortium's (W3C) Resource Description Framework (RDF), the realization of a fully communicating artificial intelligence, earlier considered a science fiction fantasy, is fast becoming a pervasive reality [7].

People often wonder how their personal computer, phone or tablet has the uncanny ability to show case information suiting his or her tastes and perceived behavior. They would be surprised to realize that Deep Learning is now responsible for conversation-carrying *chatbots*, Amazon Alexa, Facebook, Google Assistant, Instagram, Microsoft Cortana, Twitter, You Tube and more in our daily interactions with computers. It is imperative to realize that on social media and across search engines like Google, Bing, Chrome, Microsoft Edge, *etc.*, the algorithms based on Deep Learning are the ones that *churn out content and suggestions based on perceived individual preferences, biases, and tastes*.

Few people are aware of the significant developments in the fields of Linguistic Genomics and Deep Learning, which makes it possible to learn about, not only the *content and preferences* of people using internet, but also, make accurate inferences regarding the *intent* of the users. This kind of information is now routinely being used by various governments, corporations, and intelligence agencies and for surveillance and intelligence gatherings. Not surprisingly, it is Deep Learning and Linguistic Genomics that is now helping companies and corporations customize their advertising to individual tastes.

It is of paramount importance, therefore, to understand that however essential science and technology are considered; the assumption that the tools of science and technology would always be deployed with altruistic intentions in a society, is at best *naïve,* and at worst, extremely perilous. One need not dig deep into the checkered history of humankind, to realize that unbridled ego, self-centered ideas and ambitions, greed for wealth, power, and pelf, have caused immeasurable and widespread devastation in our world.

Prudent pragmatism therefore suggests that the myriad complexities of societal structures demand that the public discourse, narrative, and consensus as essential ingredients to ensure responsible deployment of tools of science and technology in a society.

The Power of Narrative

The human brain is considered the most complex, sophisticated, and powerful information-processing device known. Today the breakthroughs in Brain and Cognitive Sciences reveal that it is the n*arrative* which can be persuasive and powerful. A narrative can entertain, inform, and persuade — *but most importantly, it can forge deep, meaningful, and lasting connection* [8]. Most of us realize that when we listen to a narrative, whatever our age, we get vicariously transported to another time and space. Most of us have also experienced that depending on the narrative that we read, watch, or listen to, our palms start to sweat, eyes blink fast, and heart flutters or skips a beat. A growing body of brain science and cognitive psychology brought additional insights, into what is behind these experiences, and it was discovered - based on functional MRI scans – that many different areas of the brain light up when someone is listening to a narrative. *Lo and behold*, now all the professions have a compelling interest in how the brain works. Educators, curriculum designers, engineers, scientists, judges, public health and safety officials, architects and graphic designers, and especially big business, mega corporations, and governments - all want to know more about how the brain processes information. Brain research and its resulting applications have now become an integral part of how corporations and organizations function and succeed. It is against this backdrop of the power of narrative and the feasibility of deploying the same for narrow minded and self-centred motives, that sufficient checks and balances need to be put in place in the digital world [9-10].

Power of Narrative Enshrined in Indian Philosophy

Digressing from the present narrative on the recent advances in Brain and Cognitive Sciences brought about by research conducted primarily in western world, if one were to indulge in *divergent thinking* and *ponder,* it would be pleasantly surprising to note that that the importance of the power of narrative was well recognized by the venerable sages of India, from time immemorial. Indian ancestors had the wisdom to guide, disseminate and help people imbibe the great virtues, ethics, and morals. Indian psyche and culture are eternally punctuated and peppered with the philosophy garnered from the Vedic period (1500 BC – 600 BC), the Epic period

(600BC–200AD), and the Sutra period (from 200AD). The Vedas, Upanishads and the eighteen Puranas in Sanskrit and in the Indo-Aryan languages, are perhaps the oldest recorded language of the world. The four Vedas comprise the Rig, Sama, Yajur, and the Atharva Vedas and are considered the oldest extant literature. The Vedas collectively refer to a corpus of ancient Indo-Aryan religious literature that is considered by adherents of Hinduism to be revealed knowledge.

The two famous works that are synonymous to epic literature of India, are Ramayana and Mahabharata. These two classical epics of India are written in ancient Sanskrit and present the most common ideals of human civilization and where the value of truth, the importance of self-sacrifice, *etc.*, that make good human beings are explained in much detail. The Indian epics are full of moral teachings and sacred discourses that are relevant eternally for a utopian society.

Although the world is aware of the role the great epics (*Ramayana* and *Mahabharata), the Upanishads and the Puranas* play in guiding our everyday lives to lead a righteous, moral, and meaningful life with good values, a lesser number of people are aware of the role played by *Panchatantra* and so many other fables, play in helping Indians lead a good and meaningful life.

To the uninformed, *Panchatantra*, is perhaps one of the oldest collections of Indian Fables still surviving. *Panchatantra* (`*Five Treatises'*), is an ancient Indian collection of interrelated animal fables in Sanskrit verse and prose, written by the great Hindu Scholar Pandit Vishnu Sharma, around 200 BC [11-13], and is considered as *NitiShastra* - an essence of maxims on proper conduct. The book is written in the form of simple stories and each story has a moral and philosophical theme which has stood the test of time in modern age of atomic fear and madness, and therefore, guides us to attain success in life by understanding human nature.

Demographic Dividend and the Digital World

A 2019 United Nations report [14] on young population of the world, points out that about 16% of the global population (*i.e.,* 1.2 billion people) are youth, aged 15 to 24 years. India's youth comprise more than 50% of its population (*i.e.,* 695 million) forming the unique and often bandied about demographic dividend, which is hoped to leapfrog our nation to greater heights of development [15]. Juxtaposing these statistics with UNICEF's State of World's Children report [16] elucidates that one in three digital technology users is younger than 18 years, and 71% of 15–24-year-olds are online, making them the most connected age group worldwide. Out of this young population, almost 75% are known to be deeply associated with the digital world, spending most of their wakeful hours in the digital world. It is therefore not surprising, that digital technologies have profoundly changed the youth, children, as well as the infants of today. Digital information and communication technologies like the Internet, World Wide Web, and the means to access it, such as computers, iPads, iPhones, tablets, and smartphones, along with social media platforms and messaging apps, have become inseparable and integral to the lives of infants, children, and the adolescents around the world [17].

A common experience most of us are subjected to these days is that people (more often the youth) are more withdrawn, indifferent, and at times insolent. Even family members and friends sitting next to each other, are generally seen twiddling their thumbs engrossed in their smart phones. Studies have shown that there are clear problems and issues linked to becoming digital slaves and failing to develop adequate social networking by transforming into self-centred individuals having undesirable traits:

- lack of emotional connection
- propensity to be hurtful
- decreased face-to-face communication skills
- inauthentic expression of feelings
- diminished understanding and thoughtfulness
- disinterested and disconnected face-to-face interactions
- laziness
- skewed self-image
- reduced family closeness
- constant distractions

For the digital generation, therefore, the digital world has left an indelible mark and significantly transformed their daily lives, education and learning, the way they make and maintain friendships, how they spend their leisure time, and their engagement with wider society. The undesirable traits which are often reflected in youth of today, have a pernicious influence on the society at large as the youth of today comprise an overwhelming majority of the Indian population.

Solution to overcome challenges – March towards Utopia

For a nation like India, where youth are clearly projected to be the demographic dividend for nation's development, it certainly pays rich dividends - if we can effectively persuade the young to develop core values and abilities to solve the problems threatening to tear the fabric of an ideal civil society.

Recent studies have demonstrated on how the young people of today can become caring family members, innovative workers, ethical leaders, and engaged citizens in an increasingly complex society, by inculcating the core moral and ethical values and abilities of *adaptability*, *creativity, curiosity, compassion (empathy), enthusiasm, integrity, positivity, resilience, resourcefulness, self-awareness, and sociability*. Interestingly, these are the very core values, morals and ethos that are taught by the great Indian Vedas, Epics, Puranas, and Fables like the Panchatantra.

Studies have shown on how families, schools, and communities can play critical roles in raising and educating tomorrow's citizens by nurturing, imbibing, and inculcating the core values and ethos needed by youth to navigate their lives in meaningful ways in their chosen endeavours to become good, caring human beings and engaged citizens of the community [18].

Against this backdrop it is argued that utilizing the advances in digital technologies and employing the power of the narrative, systematic mechanisms *can and should* be built to nurture, imbibe, and inculcate the moral values and ethos ,into the sensitive minds of the youth, *as reflected in the Indian philosophies and fables*.

The idea to manipulate the content for the young consumer to help constantly reify the moral and ethical constructs of the youth, may be contradictory to the common beliefs[19]. But it is argued that, however contrarian it may sound, it is nevertheless worth pursuing, as irrefutable evidence exists on how ideas - *originally thought to be unrealistic, unreachable and a utopian fantasy* - can become a reality in our lifetime (Bregman, in Utopia for Realists[20]). In fact, we do have a very good example of how the digital world can be reified to imbibe the age old ethical

and cultural values encapsulated in our age-old *Upanishads*, if one were to view the 2012 Tele serial *Upanishad Ganga*, created and conceptualized by Swami Tejomayananda of Chinmaya Mission with a vision to take the message of *Upanishads* to the masses[21].

On a concluding note, despite the challenges brought about by digital technologies of today, it is imperative that we safeguard, nurture, and goad the younger generations through the digital technologies themselves to become good human beings by inculcating the core moral values and ethos as enshrined in our Indian philosophies and fables. This a necessity for enabling tomorrow's dream of a utopian society.

August 26, 2021.

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Tsunamis, Kelvin Waves, and Life

Musings of an Ocean Research Scientist

Traveling in a chauffeur-driven luxury car during the early hours of October 1, 2009, from Vellore to Chennai in India, I took the first gulp of the freshly brewed cappuccino; and casually opened the neatly folded early morning newspaper to find the headlines screaming about the deadly tsunami in *the Southern Pacific Ocean, which hit the tiny nations of Samoa and Tonga the previous day.*

Reading about Samoa and Tonga rekindled old memories of an incident from a few years ago, which was still vivid in my memory.;

Full of excitement and enthusiasm, my good friend Dr. BM and I were deeply engrossed in a scientific discussion with our beloved senior, friend, and philosopher Dr. GK - regarding some of his recent research work on ocean dynamics in the equatorial oceans.

After analyzing the oceanic currents data collected during the recently concluded scientific cruise in the Equatorial Ocean south of the Bay of Bengal, GK hypothesized that his observations strongly indicated the existence of Kelvin Waves and that they are propagating westward.

Taken aback by the hypothesis of westward propagating Kelvin Waves in the North Equatorial Ocean, BM and I launched into a long-winded scientific presentation expressed with sophisticated theoretical derivations peppered with sufficiently strong emotions - elucidating the origin, propagation, and non-dispersive characteristics of Kelvin Waves in the Northern Hemisphere.

BM and I valiantly argued with GK and concluded that Kelvin Waves in the Northern Hemisphere could only propagate eastward and were gloating with satisfaction for our well-rounded scientific argument. As we were about to pat on each other's backs and offer well-deserved congratulations for a convincing scientific expostulation – we discovered to our abject dismay, that our scholarly (*we thought!*) argument could not move our beloved GK, even an inch -nay, 0.0254metres (*for the benefit of SI unit puritans*).

With a condescending smile, GK nodded his head (*alas! We thought in agreement with our argument*) and declared that whatever he proposed was right and we were wrong.

Collective wisdom garnered from countless interactions of colleagues, individually and collectively with GK, always concluded that it's practically impossible to convince GK, let alone win an argument once he decides on something.

As GK was doggedly pursuing and reiterating whatever he thought was right, albeit with a very pleasant, smiling, and erudite face – we had no other option but to give up our valiant efforts.

Instead of tearing our hair (*not that BM was having much even then*), we diverted our attention towards the World Physical Map displayed prominently on the wall in Room 615 of our workplace at the Naval Research Laboratory of DRDO in Kochi.

Our other good friend (Dr. SK), who was well experienced with GK, and who had, by then, waged several battles and lost each one of them, was bemused and smiled condescendingly at both of us for joining his Club - BALM (Battered and Lost Members) - for which he was the undisputed President.

Never to admit our 'defeat,' BM and I coyly smiled at him and, on the spur of that moment, decided that we should go and live in a place far-far away from all the madding crowds, where no man can lose an argument, anytime, whatsoever; however wrong one could be.

We immediately decided that such a place could only be a faraway island, full of natural resources and native tribes, who would nod their heads in agreement to whatever was said, not argumentative, and most importantly, who we thought could be bossed around by us (obviously a very foolish, and an utterly wrong thought).

At random, I zeroed in on Samoa, and BM chose Tonga, both small South Pacific islands occupying tiny dots on the World Map.

On discovering tiny islands where we could go, boss around, and rule, our moods instantly buoyed up. Having found the elixir of happiness, we unilaterally declared ourselves the rulers of Samoa and Tonga. We felt on top of the world for pulling out this bloodless virtual coup that provided instant elation.

The next day, BM, who was ever vigilant to pull a fast one on me, discovered to my utmost horror, that half of Samoa was already occupied by the USA, who cleverly convinced the world to refer to it as American Samoa.

It was a shattering blow to me to discover that 'my' newfound country's extents were only half what had been expected. In addition, I had to deal with the pernicious problem of having the most powerful neighbor who could easily trounce me. BM had a wonderful day that day and slept very contentedly.

To my delight, the next day's papers declared that the Olympic Bronze medal for boxing went to a person from Tonga.

So happily, I chided BM that if the country has people capable of winning an Olympic medal, they should naturally be much more competent than us, who have not won even one Olympic Medal by then. My profound argument was that BM could not rule Tonga, as the people there are much more competent than us (thus, by logic, BM).

Flabbergasted, BM had to concede to the logic of my argument and was depressed and sad.

Keeping up with the traditions of the rulers to remain unfazed by the myriad problems of everyday governance, BM and I decided to move forward and leave our fights to focus on being rulers who must deal with ever-evolving international and national issues, not necessarily tackling them, but conveniently pushing them to the dungeons of lost memories, for reminiscing on a later day.

I called up my friend BM living in Kochi, and after exchanging pleasantries over the phone, reminisced about our old days at the Naval Research Laboratory and mutually exchanged condolences - as 'his' country, Tonga, lost six people. 'My' country, Samoa, lost 120 people in the tragedy caused by the tsunami.

As a parting thought, I sternly declared that I would sack the Samoan PM - who was holidaying in Hawaii when the tragedy struck.

This article was penned on the spur of the moment, in a lighter vein, after reading the news about the tsunamis which hit Samoa and Tonga on September 30, 2009.

The article only intends to share random thoughts on the prosaic tapestry, the irony, and the complexity of our lives - with profound respect and commiserations to the tsunami-affected nations, their leaders, and their people.

October 1, 2009.

On Being a Professor

"*When the heart speaks, the mind finds it indecent to object.*"
- Milan Kundera, in **The Unbearable Lightness of Being**, 1984

Acquaintances and strangers, upon realizing my title as a professor, often question what subject(s) I lecture on.

The query, albeit simple, unfailingly launches my thought process into overdrive.

In almost all academic institutes (schools, colleges, and universities) worldwide, the teaching tasks include preparing lessons according to agreed curricula, giving lectures, and assessing pupil progress, often leading to a presumptuous perception in society that a good teacher lectures well and a good student devours the information and regurgitates the same during examinations.

Traditional teaching methods generally presume the teacher is the only source of information in the classroom. Formal education indeed focused on *teaching*, not *learning*, by incorrectly assuming that for every ounce of instruction, there is an ounce of learning by those who are taught.

Therefore, the prevalent belief is that teaching involves standing on a podium and lecturing to students. These notions are the genesis for the presumptive intelligence gathered by society, leading to questions on what subjects professors lecture on, equating a professor to one who *lectures*.

By and large, the notion of a professor teaching their pupils through lectures is prevalent worldwide, resulting in the presumptive intelligence that *professors can and should impart knowledge only through lecturing*. However, recent research findings surprisingly reveal that what we learn before, during, and after attending lectures is understood without being taught to us formally.

Advances in cognitive psychology now suggest that context and expectations influence people's perceptions and interpretations by introducing a *contextual bias* that affects decision-making. Therefore, the question that acquaintances and strangers confront me with, although primarily an attempt to start a conversation, triggers divergent thinking and deep introspection, nudging me to ponder and question the role of a professor *in toto*.

Against the backdrop of the insights gained, to my mind, the query reveals the questioner's presumptive intelligence that a professor should teach students through lecturing. Indeed, this is a condescending connotation for the students, as the teaching-learning process is a two-way street where the student and the teacher benefit.

The prevalent notion (of who a professor is), having origins of either a benign nature or due to the presumptive intelligence, had wreaked havoc with the entire teaching–learning' process *per se*, with teachers unwittingly presuming that the primary method through which learning can happen is through lecturing in classes. The learners often believe that the knowledge is acquired primarily by attending the lectures.

Therefore, the simple answer as to who a professor or a teacher *is* would undoubtedly fit the commonly held perception that a teacher is the one who helps people to '*learn*.' But how a teacher should 'teach' and how a learner 'learn' are more complex to answer in simple terms.

The complexity of pedagogy and learning has been addressed by many. Teachers use many techniques to help learning take place. Still, the questions of the best methods for the knowledge dissemination and acquisition processes remain unresolved, and therefore, it would suffice to say that many variables determine the desired outcomes. It is essential to realize that simple notions can lead to egregious perceptions.

Many researchers tried to understand the teaching and learning process to determine the best teaching method(s). Carl Wieman, the 2001 Nobel Laureate in Physics, who has shifted his research to science education to provide more effective instruction at Stanford University, passionately argues that there's a solid body of research to show that if you only lecture to students, they don't learn nearly as much as if you'd used other ways to teach that get them far more mentally engaged — practicing, thinking like scientists. After experimenting with many unconventional teaching methods, Wieman underscores that much more work is needed to understand what sorts of engagement work best, how to learn challenging ideas, and how best to enhance the interaction of professors and students, particularly with new technologies.

With the launch of the World Wide Web, the Internet, and the associated advances in digital technologies, we now see that youngsters and learners of all ages have become much more prudent and practical in realizing that large amounts of data and information on everything are available with a swipe on their smartphones.

Not surprisingly, Russel Herman, the Editor-in-Chief of the *Journal of Effective Teaching*, in one of his seminal 2011 editorials titled," *What makes an excellent professor*?", also stresses that a professor must provide opportunities for students to see the world through their chosen disciplines, in addition to quality teaching; as students chose some of the professors as their role models by observing the qualities like - the ability to conduct quality research, the passion for a greater understanding of the subject, and the importance of developing a lasting intellectual curiosity.

I believe that challenging and nudging students to do what's hard encourages them to practice grit and tenacity as they develop new ways of thinking. So, instead of only lecturing to students, I believe that professors should facilitate learners with information on the nonlinear paths of knowledge acquisition and how many of the learned people overcame obstacles in their quest to acquire knowledge. This approach would enable students to discover their resiliency and explore the mark they can leave on the world.

The actual ability of a good teacher lies in influencing original thinking, facilitating learners to ask more questions and thus construct their understanding of concepts. Therefore, my teaching methods always encourage learners to *think* and reach conclusions based on their knowledge so that they *learn* new things.

Although seemingly contradictory, on deeper introspection, one would therefore agree with the general quote attributed to either Xunzi (Xun Kuang), a Confucian philosopher, or Benjamin Franklin (depending on whether one is an Asian or a Caucasian), - "*Tell me, I forget; Teach Me, I may remember; Involve me, and I learn*."

For many worldwide, it would be surprising to realize that the thought processes related to the abstruse questions on *teaching-learning* have much older origins and are not the marks of contemporary pedagogy.

Most Indians and other people familiar with the *Upanishads* realize that teaching-learning is a two-way street, as enshrined in the *Shanti Mantra* of the *Krishna Yajur Veda Upanishads*. In the *Chandogya Upanishad*, through the enchanting stories of Satyakama and Shvethakethu, one realizes the complexity, depth, and breadth of many effective *teaching-learning* methods.

Indeed, irrespective of the roles played and techniques adopted by professors, each one makes a significant and positive contribution to transforming the individuals they interact with and is instrumental in changing them by influencing the process with which they learn and act or behave.

Returning from my peregrinations of divergent thinking brought about by the banal question of what subjects I lecture on, my humble response would be, "*After distilling the concepts of the many effective teaching-learning techniques, we experimented and designed a unique program called SPHURTHI* (Societal Problems Highlighted Understood and Researched To Herald Innovation)*. In SPHURTHI, the teacher engages with the students to motivate them, builds interest in the subjects, and imparts knowledge, comprehension, and specific applications in the educational context in many fields of the sciences, engineering, and technologies, aiming to shape individuals' character and prepare them for their future as human beings and their desired work based on several other factors*".

It is always amusing to note the bewildered and lost look on the questioner's face after my long-winded and abstruse reply to such a simple question, mostly posed as a conversation starter.

On a serious note, it is always immensely gratifying to reflect on the scores of students who have successfully passed through the portals of our program *SPHURTHI* and are now occupying elevated positions in academia, industry, and other enterprises globally, standing testimony to the efficacy of our teaching-learning process.

July 6, 2023.

Vegetarianism: Mitigating Air Pollution, Climate Change, Pandemics, and Human Diseases

"Life is really simple, but we insist on making it complicated"
– Confucious

Air Pollution and The Need for Effective Monitoring

WHO (World Health Organization) data show that almost all the global population (99%) breathes air that exceeds the WHO guideline limits and contains high levels of pollutants, with low and middle-income countries suffering from the highest exposures [1].

Higher levels of air pollution are a pernicious global problem affecting not only densely populated countries like India and China but also countries with sparse populations, as well as regions like the Arctic and Antarctica where no population exists.

Air quality is closely related to the earth's climate and ecosystems globally. Whatever the reasons for the present levels and the sources of pollution, global pollution levels are highly dynamic and are associated with atmospheric and oceanic dynamics.

The resulting climate change, with a feedback loop, is now accepted and understood.

One needs to monitor the pollution levels in the spatio-temporal dimensions to adopt remedial measures to mitigate pollution effectively. Therefore, air quality monitoring involves systematically collecting physical, chemical, biological, and related data on ambient air quality, pollution sources, meteorological parameters, and other factors that influence or are controlled by ambient air quality.

The many complexities and challenges posed by ambient air quality monitoring prompted the World Health Organization (WHO) to suggest a road map for all nations for 2020 – to arrive at a consensus for effective air quality monitoring by all stakeholders.

Domino Effect of Pollution on Climate Change, Global Health, and Economy

Air pollution may result in massive impacts, causing different effects on human health, the environment (*e.g.,* ecosystem damage), and the economy of nations worldwide [2,3,4].

The Lancet Commission on Pollution and Health reported that Pollution was responsible for 9 million premature deaths in 2022 [4], making it the World's most significant environmental risk factor for disease and premature death. Nine million deaths annually correspond to the alarming number of one in six deaths worldwide.

Even the WHO 2023 [5] report states that worldwide ambient air pollution accounts for 43 % of deaths and diseases from chronic obstructive pulmonary disease, 25 % of deaths and diseases from ischemic heart disease, 24 % of deaths from stroke, 17% of deaths and diseases from acute lower respiratory infection, 29% of deaths and diseases from lung cancer.

Antibiotic resistance is another growing global issue, causing millions of yearly deaths [6]. Particulate matter (*PM*) has diverse elements of antibiotic resistance that increase its spread after inhalation. The misuse and overuse of antibiotics are the main drivers of antibiotic resistance. The rapid spread of antibiotic-resistant bacteria and antibiotic-resistance genes across global regions and sectors (e.g., human beings, animals, and environments) is vital for antibiotic resistance transmission and prevalence [7, 8, 9].

Although a thorough understanding of the contribution of $PM_{2.5}$ to global antibiotic resistance is poor, the emerging research underlines the linkages between global estimates of antibiotic resistance and the burden of premature deaths attributable to antibiotic resistance resulting from $PM_{2.5}$ pollution.

Recent research at Harvard University [10] suggested that even a *1μg/m³* level of $PM_{2.5}$ could lead to a 15% increase in fatality rates due to infections. The study demonstrated and underlined the urgent necessity and paramount importance of *effective* ambient air quality monitoring, as air quality, *or rather the lack of it,* directly affects the nation's health, economy, and security. It is imperative, therefore, to protect the air we breathe by taking actions to ensure its best possible quality. The widespread inequities between developed and developing countries naturally demand accurate and cost-effective monitoring to ensure good air quality worldwide.

Quantifying the economic impact of air pollution, the Centre for Research on Energy and Clean Air (CREA) [11] made a conservative estimate of *USD 2.9 trillion*, or *3.3% of global GDP* in 2018, as the global economic burden caused by air pollution from fossil fuels.

For these reasons, national and international regulations typically require accurate air quality monitoring to assess the general population's environmental exposure systematically and accurately to multiple ecological contaminants.

Many of the drivers of air pollution are also sources of greenhouse gas emissions. Therefore, policies to reduce greenhouse gases offer a win-win strategy for climate and health, lowering the disease burden of air pollution and mitigating near- and long-term climate change. Framing and implementation of the right policies for air pollution mitigation necessitate accurate ambient air quality monitoring.

Complexities of Ambient Air Quality Monitoring

As we approach the end of 2023, the multifaceted and multidimensional problems related to effective ambient air quality monitoring remain herculean and extremely expensive - for wider deployment to gather realistic spatio-temporal information related to ambient air quality, to draw up effective plans to curb or mitigate the air pollution.

The process of selecting sensors and systems for effective ambient air quality monitoring has become quite complex under the garb of standards and certifications, which were ambiguous, outdated, unscientific, or outright erroneous, given the advances made in our scientific understanding. The complexities in effectively monitoring ambient air quality led to confusing practices in the siting of systems, and the empirical approaches followed by different stakeholders in arriving at averaging times related to measurement methods have resulted in ambiguous definitions of air quality, making it prohibitively expensive and unscientific. Today, the confusion is worse confounded by the advent of new entrants into the field advocating low-cost sensors with lesser accuracies for niche applications.

Novel Photonic System AUM for Ambient Air Quality Monitoring

Against this backdrop, after highlighting the impetus, complexities, and challenges posed by ambient air quality monitoring, our team has designed and developed a novel state-of-the-art photonic system *AUM* (Air Unique-quality Monitoring) for ambient air quality monitoring with higher accuracies and overarching capabilities for diverse applications [12, 13]. We have also designed and developed a unique calibration facility for the photonic system *AUM,* which ensures that after a one-time calibration under ISO/IEC 17025-2000 and ISO 17034 International Standards, the ruggedized system can be deployed for field usage anywhere in the World, even under extreme weather conditions. Numerous field trials of inter-comparisons of the novel photonic system *AUM*, collocated with conventional reference monitoring stations of ambient air quality, convincingly demonstrated that AUM is far superior in sensing characteristics. In addition, *AUM* is highly economical compared to the traditional reference stations, thus making it ideal for large-scale deployment to effectively monitor the hitherto eluded spatio-temporal variations of ambient air quality.

Shrouded with scientific temperament and curiosity and the desire to make scientific and technological advances in solving a pressing social problem, little did we realize that the apathy and indifference from decision-makers would deter the acceptance of novel and advanced technology.

UN Agenda 2030 of Sustainable Developmental Goals – Sham?

Realizing the domino effects of air pollution, the United Nations has set actionable policies (Sustainable Development Goals - SDGs) to reduce air pollution [14]. Under Agenda 2030, the UNGA resolution set specific targets, with measurable indicators for each SDG, to achieve most SDG targets by 2030.

However, according to the European Commission's in-house Emissions Database for Global Atmospheric Research (EDGAR) [15], the Green House Gas (CHG) emissions continued to rise, reaching 53.8 $Gt\ CO_{2\,\mathrm{eq}}$ by 2022. In 2022, most GHG emissions comprised fossil CO_2, accounting for 71.6% of total emissions, while CH_4 contributed 21% to the total, N_2O 4.8%, and *F-gases* 2.6%.

A scientific assessment of the political impacts of the SDGs in 2022 found that the SDGs have only *had limited transformative political impact* thus far [14]. The only effect seen was the publication of ambiguous policies of local and global institutions. The result has mainly been discursive, affecting the way actors understand and communicate about sustainable development, with more profound normative and institutional impact from legislative action to changing resource allocation being nonexistent, prompting the question of the efficacy of the UN and its resolutions.

Mitigation of Pollution and Climate Change – Is there a Will?

The fact of the matter is that in 2022, China, the United States, India, the EU27, Russia, and Brazil were the six World's largest GHG emitters, accounting for 50.1% of global population, 61.2% of global Gross Domestic Product, 63.4% of global fossil fuel consumption and 61.6% of global GHG emissions [16].

Most countries worldwide are still preparing plans to implement actions to tackle climate change. The European Union has an ambitious target set to reduce its net domestic greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels and to become climate neutral (*net zero greenhouse gas emissions*) by 2050.

At the global level, all G20 countries, covering about 75% of global GHG emissions, have decided to fix a target date in which they will become net-zero emitters. The USA, Canada, Brazil, Australia, and the European Union have pledged to reach climate neutrality by 2050, China and Saudi Arabia by 2060, while India targets net zero emissions by 2070 [16].

But the reality is that we are fast reaching the Climate tipping point of $1.5^{\mathrm{o}}C$ rise in global warming (brought about by GHG emissions worldwide), which is a cause for grave scientific, policy, and public concern. *Therefore, the moot question remains whether the governments and politicians, with their ever-changing priorities, are concerned about climate change or only interested in mouthing platitudes for their survival.*

Practical Solutions for Societal Problems – *Citizen-driven or Government-driven?*

History is interestingly replete with numerous examples when societies have immensely benefitted from bottom-up movements reaching tipping points after passionate triggers conceived by individuals. Grand visions cannot be realized without self-organizing from the ground up. The broadest-based and most prolonged enduring transformational movements grow from the grassroots up.

Ordinary citizens have the potential to discover new solutions to wicked problems. Indeed, one is also reminded of the powerful words of the great Telugu poet *Sri Sri* (Srirangam Srinivasa Rao) [17], *who remonstrated the common public not to deceive themselves in believing that someone would come and solve their problems and, therefore, sleep over their difficulties, by forgetting the truth*.

ఎవరో వస్తారని,
ఏదో చేస్తారని,
ఎదురుచూసి మోసపోకుమా,
నిజము మరచి, నిదురపోకుమా - శ్రీ శ్రీ

Climate change, extreme poverty, pandemics, health inequalities, and natural disasters are examples of where citizens can hold the key to driving solutions for a better world. Recent studies have shown the crucial role Citizen Science plays in finding solutions to wicked problems. For example, Air Quality Citizen Science uses low-cost sensors deployed by citizen scientists to generate spatially and temporally resolved air quality data that complement satellite observations.

Can we, the citizens, think of *a solution* to solve the pernicious problems of pollution and climate change instead of depending on Governments, bureaucrats, and politicians to find answers? *A simple solution that we can implement without* *forgoing our modern-day amenities and developmental lifestyles.*

Complex Problems and Simple Solutions

Solving real-world complex problems demands that we break free from a reductionist paradigm and develop a more holistic and systematic understanding of the World's complexity. Therefore, instead of improving the ability to measure, predict, and control the processes, the focus should shift towards adopting insights gained elsewhere.

In Science, we have seen that introducing insights from Chaos Theory and Nonlinear Mathematics into Systems Science sparked the development of Complexity Theory. This Science recognizes and celebrates the creativity of nature [18, 19, 20].

While looking for solutions, faced with two competing hypotheses, we will likely choose the most complex one. As a result, when we need to solve a problem, we ignore simple solutions and instead favor complex ones. Complexity bias is a logical fallacy that gives undue credence to complex concepts. To understand complexity bias, we must first define three key associated terms: complexity, simplicity, and chaos. Chaos theory is an interdisciplinary area of scientific study, and a branch of mathematics focused on the underlying patterns and deterministic laws of dynamical systems that are highly sensitive to initial conditions and were once thought to have completely random states of disorder and irregularities.

Scientifically, the advent of Chaos Theory made us realize that *i)* initial local conditions significantly affect the system's complexities globally, and *ii)* complex problems can have simple solutions. A metaphor for this behavior is that a butterfly flapping its wings in South America can cause a severe cyclone associated with widespread destruction in North America.

That's counter-intuitive because it opens the door to a new way of seeing the World, acknowledging that complex dynamic systems are sensitive to initial conditions and have emergent properties.

We must, therefore, learn to brood over the complicated systems on which the quality of our lives depends, from microbial ecosystems to the biosphere, because we can strongly influence them, although we cannot control them.

Therefore, we must realize that the triad of pollution, climate change, and biodiversity loss are critical global environmental issues of our time, which are intricately linked, and solutions to any will benefit others.

Animal Farming, Anti-Microbial Resistance, Climate Change, Diseases and Health

The nexus of animal farming, antimicrobial resistance, climate change, and biodiversity conservation represents one of the most pressing and least understood threats to a sustainable future and can, therefore, become the cynosure for convergence while searching for solutions [21, 22].

Reports of evidence of antibiotics in livestock and poultry feed, antibiotic residues in powdered milk products, and milk from various dairies [7-9] are on the rise. A September 2023 report in *Our World in Data* [23] quotes the Food and Agricultural Organization (2021) statistics to answer *how many animals get slaughtered daily*. The stark statistics are mind-numbing – 0.9 million cows, 1.4 million goats, 1.7 million sheep, 3.8 million pigs, 11.8 million ducks, 202 million chickens, and hundreds of millions of fish.

The 2021-2022 Annual Report of New York University's Centre for Environmental and Animal Protection [24] cries out that to fulfill growing meat demands, humans now manage, slaughter, and consume billions of terrestrial and trillions of aquatic animals yearly. As a result, animal agriculture is now the second largest contributor to human-made greenhouse gas emissions, contributing significantly to global climate change, exceedances of biogeochemical flows, biodiversity and wild animal loss, land, energy, and water consumption, and ecosystem destabilization. Despite the enormous amount of animal agriculture, global food and nutrition insecurity is still a constant issue, as this sector primarily serves the industrialized World and wealthier population segments.

From the perspective of animal suffering, not only are the absolute numbers of animals killed, but also the suffering they endure while being raised in dismal conditions would be intensely gut revolting to most persons.

According to the USA's Centers for Disease Control and Prevention, the generally common dismal conditions practiced worldwide in the animal industry are the primary cause of zoonotic diseases or those that spread from animals to humans, which account for roughly 60 percent of all known infectious diseases and 75 percent of new and emerging ones [24]. Although the exact origins of the COVID-19 pandemic remain murky, the news that the coronavirus might have first jumped into humans at a live animal market in Wuhan, China, is still fresh in our collective memory.

Vegetarianism – Panacea for Global Pollution and Climate Change?

The World now produces more than three times the meat and more than double the milk as it did 50 years ago, thus establishing adverse effects on the environment, including the destruction of native ecosystems for supporting livestock grazing and increased cultivation of animal feedstocks. Livestock and its supply chain also contribute to greenhouse gas emissions, such as carbon dioxide, methane, and nitrous oxide. Livestock farming accounts for 50% of methane and 60% of nitrous oxide emissions, which respectively have 25 and 298 times the global warming potential of carbon dioxide on a mass basis [25, 26].

Additionally, most nitrogen pollution in wastewater is due to animal-based protein sources and inefficient agricultural practices, which lead to acid rain and toxic algal blooms that cause dead zones of aquatic life [22, 27].

Air pollutants like methane and black carbon are potent Short-Lived Climate Pollutants (SLCPs) contributing to climate change and ill health. Although SLCPs persist in the atmosphere for short lifetimes, their global warming potential is often much more significant than carbon dioxide (CO_2).

Black carbon, a component of fine particulate matter, is one of the most significant contributors to global warming after CO_2. Black carbon warms the earth's atmosphere by absorbing sunlight, accelerating snow and ice melting. Methane, another SLCP, is a potent greenhouse gas 84 times more powerful than CO_2 and a precursor to the air pollutant ozone. Ozone and black carbon affect weather processes and decrease agricultural yields, thus threatening food security [28].

Meat production, therefore, has several significant negative impacts on the environment, wildlife, and human health.

Hence, moving towards Vegetarianism and a meatless future, reducing human consumption of *animal protein, coupled with effective screening for antibiotic residues in milk and other food products, is one of the most effective things we can and should do personally for both environmental and human health and animal welfare.* Moreover, an emerging body of research indicates that diets higher in plant proteins—pulses, legumes, and coarse grains—could offset losses in animal protein by providing nutritionally dense foodstuffs, thereby contributing to food security and protein needs while providing several environmental co-benefits.

Personal Dietary Choice: The Bridge Between Personal and Planetary Health

A growing number of research studies have established that vegetarians have lower risks of heart disease, diabetes, and cancer compared to non-vegetarians. Based on data from 12 surveys, a systematic scientific study assessed the nutritional quality of vegetarian diets and found higher healthy quality levels among vegetarians than omnivores, establishing the bridge between personal and planetary health [29, 30].

According to the Academy of Nutrition and Dietetics, vegetarian diets are nutritionally adequate for all stages of life if they are well-planned. However, some precautions to minimize the risk of nutritional deficiencies are warranted. Vegetarianism has gained more visibility in recent years. Understanding the effects of adopting a vegetarian diet beyond its nutritional aspects is essential. Studies have also indicated that a vegetarian diet could have positive outcomes, such as better physical health, positive feelings related to adopting a morally correct attitude, an increased sense of belonging, and lower environmental impact.

Benefits of Vegetarianism

Numerous scientific studies showcased the significant benefits of reducing meat consumption and becoming vegetarians [29, 31]:

Less land use for agriculture and more biodiversity: The use of land for agriculture is the primary driver of biodiversity loss. Today, almost half of the World's ice- and desert-free land is used for agriculture, most of which is used by livestock. The total global land use for meat and dairy production is 37 million square kilometers, an area as large as the entirety of the Americas.

Studies have shown that if we do not eat meat, it would be possible to reduce agricultural land from 4 to 1 billion *hectares*. Therefore, a change towards less meat consumption would have enormous benefits for animals worldwide as wilderness could regrow to provide habitats for wildlife.

__Benefits for the World's Climate__: Reducing global meat consumption would also help to address climate change – it would reduce direct emissions from burping cows and nitrous oxide from manure and reduce emissions from deforestation and land use change.

__Less antibiotic resistance__: Reducing the World's meat consumption would decrease the use of antibiotics in livestock farming, a practice that contributes to the rise of antibiotic-resistant bacteria. This reduction could preserve the efficacy of existing antibiotics and people's health worldwide.

__Lower risk of pandemics__: Many infectious diseases originate in other animals. The high-density conditions in many meat production facilities create ideal environments for the mutation and spread of pathogens. Reducing global meat consumption would reduce the risk of zoonotic diseases and the chances of another pandemic.

Less animal suffering: Less meat consumption would mean less harm to animals.

Panacea Hidden in Plain Sight: Vegetarianism

Facing a plethora of complex problems of increasing levels of pollution, climate change, rising incidences of diseases, deteriorating human health, and growing burdens on national economies, and standing on the cusp of the rapidly closing window for humanity's climate action, we must realize that all the problems are inextricably intertwined.

Against the backdrop of the prevailing unbridled practices in animal farming, non-compliance of the agriculture industry (especially overuse of antibiotics in dairy and animal farming, chemicals and pesticides in agriculture), ineffective regulatory bodies, and in different global leadership, *perhaps* individuals practicing Vegetarianism coupled with strict control of the use of chemicals and pesticides in agriculture, maybe the panacea hidden in plain sight for the issues related to pollution, climate change, antimicrobial resistance, and global health and economies.

Our collective personal actions and choice of switching over to a vegetarian diet can have positive effects. While individual efforts may seem small, they can swing the needle in the right direction. Perhaps the personal choices of integrating into the complex nature of systems with humility would be the necessary *initial condition* to ensure a positive and sustainable world.

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A Slice of Academic Life

The Plot

As is their wont, the two academicians and senior professors nestled into their comfortable chairs on a pleasant wintry day with cups of insipid coffee from the college cafeteria to engage with each other and deliberate on some of their recent abstruse ideas.

Although from different academic, cultural, and professional backgrounds, the two have an excellent rapport, a rare trait in academicians, with their shared love for compelling, rational, and logical critiques on matters of mutual interest — while analyzing, comprehending, and appreciating each other's views, culled and decanted over a century of their cumulative experiences.

The Muse

The topic for the day was the abstractness of *reading* and *writing*, the two typical, essential, and intricately intertwined human pursuits. What is fascinating is that the covert inherent abstractness, intriguingly, gushes out in torrents into plain sight upon serene reflection.

All living organisms communicate to share information using some form of signaling involving varying forms, methods, and complexities, with communications taking place using sensory organs of sight, sound, and touch.

Scientifically and philosophically, *reading* and *writing* are the essential tools for communication driven by science and technology and, therefore, evolve with time and location.

Time and again, we realize that *reading* and *writing* have varied connotations dictated by the societies we live in and deal with, driven by the sciences and technologies adopted by communities and local and global cultures.

It is essential to realize that *reading* and *writing*, in the traditional sense, are not the only way to gain knowledge or entertainment. Many other forms of media, such as movies, TV shows, podcasts, and video games, can provide similar benefits.

Without restricting to the general meanings of *reading* and *writing*, *i.e.,* without implied assumptions about specific modes and mediums, if one were to probe the methodology of how people communicate, the conventional horizons for *reading* and *writing* quickly broaden and expand to the usage of any, or all, of the sensory organs of sound, sight, and touch for communications.

Discussions regarding the efficacy of spoken vis-à-vis written communication are often peppered with arguments for the primacy of the written word as the pre-eminent mode of communication, duly countered by an advocacy of the unique power of the spoken language to ignite the listener's imagination, often leading into veritable long-winded debates. Nevertheless, one cannot deny that *reading* and *writing,* associated with the medium of text, are effective modes of communication in varied languages, if not the only ones.

Conventional wisdom has already established that *reading makes a full man, conversation a ready man, writing an exact man, and practice a perfect man*. However, evolving societies with their paradigm technological shifts dictate and drive the metaphorical processes of *Reading* and *Writing* into esoteric and unexpected realms.

Therefore, the seemingly banal everyday actions of reading and writing transform into inter-connected, esoteric, puzzling, and complex human pursuits necessitated by social, psychological, philosophical, and physical factors, compelling the probing mind to contemplate and confabulate.

The Modern-Day Conundrum

Contemporary societies face the peculiar problem of a significantly high decline in the readership of the innumerable tomes of written matter (prose and poetry, in numerous languages, in the form of technical documents, in varied shades and genres of literature), with most people not being able to read more than short texts, primarily with the advent of burgeoning digital technologies of the day. This fact, therefore, begs the question of whether the vast majority of the writers' works lie untouched in the annals of oblivion, laden with dust.

The declining ability of society in general, and the younger generations (*Gen Z* and the *Millenials)* in particular, to read and write detailed notes and documents and the pernicious usage of communication abbreviations fostered by digital technologies have ushered in a unique situation where generational and socio-cultural differences make comprehension difficult.

The backdrop of literacy statistics, the asymmetric ratio of readers to writers (with more readers than writers), intrigues the probing mind to ponder the readers' relative role and importance vis-à-vis the writers. Not surprisingly, the subject of readers and writers can, at best, be confounding as it depends on context.

The Torrent of Questions

Why do people *read*? What goes on in the mind of the reader? What does a reader look for while reading? Does the reader benefit from reading? Is the reader interested in reflecting, learning, understanding, comprehending, and gaining knowledge? Or do they only look for pleasure and titillation?

Do readers get affected by reading? Do they get influenced and transformed into different thinking individuals based on their reading? Are readers essential spokes in the complex wheel of society and life in general?

Why do people *write*? Does the writer benefit from writing? Does the writer have the reader in mind while writing? What goes on in the mind of the writer? To share, connect, correspond, communicate, teach, feel good, exhibit, document, or just pour out the thoughts for the benefit of eternity? Do writers get their due credit in contemporary society? Or do they attain greatness after their lifetime? If so, what drives the writers to pour their thoughts out for posterity? What incentives do writers derive from the readers, in addition to aggrandizement, fame, and glory? Do writers want to push their ideas into the readers' mindscape or share their thoughts after serious research, reflection, and contemplation, owning shared responsibilities for societal development and forming the hub of the complex wheel of society and life in general?

Can societies flourish without writers and their writings? Can communities exist without readers reading the writings? Can we imagine a scenario where the writers and readers do not benefit from each other? What happens if writers vanish? These are intriguing questions to ponder.

The Writers vs the Readers

Writers are essential to society as they create literature that reflects, criticizes, and enriches the human experience. Literature influences readers' values, beliefs, and attitudes and inspires them to think creatively and imaginatively.

Writing is critical because it creates content, expresses ideas, shares knowledge, and stimulates thought. Writers can influence, educate, entertain, and inspire others through their words.

Some possible consequences of losing writers are (*i*) a decline in the diversity and quality of literary works, as fewer voices and perspectives would be represented, (*ii*) a loss of historical and cultural memory, as literature preserves and transmits the stories and experiences of different times and places, (*iii*) a reduction in readers' critical and analytical skills, as literature challenges and stimulates the mind to question and explore various issues and themes, (*iv*) a decrease in the empathy and compassion of people, as literature exposes them to the feelings and thoughts of others and helps them understand different points of view, and (*v*) a lack of innovation and creativity, as literature sparks the imagination and encourages the expression of new ideas and possibilities. Therefore, writers play a vital role in shaping and enriching society, and their disappearance would negatively impact humanity's cultural, intellectual, and emotional development of humanity.

Reading is essential to human life and has been a source of knowledge, entertainment, and inspiration for centuries, as it is a unique experience that offers many benefits, such as improving cognitive function, reducing stress, and increasing empathy.

Readers can always broaden their perspectives, gain new knowledge, and be inspired by what they read. If people stopped reading books, it could lead to a rapid decline in literacy rates and a ripple effect on education, employment, and the economy. It could also lead to a loss of history, cultural heritage, and traditions, as books are often used to preserve and pass on knowledge from one generation to the next. Readers, therefore, are equally important.

By and large, the number of readers in any society is substantially higher than that of writers; the onus of sustaining the fragile balance by incentivizing writers effectively rests on the community at large. As readers consume the content writers create, engage with it, and often provide feedback, they make themselves an integral part of the complex activity of communication.

The Sum and Substance

Vedas, Upanishads, World folk epics, and all other literature orally transferred and transmuted over the millennia always remind us that there are many different ways to share and gain knowledge.

The reader-writer relationship is prosaically symbiotic in nature. Writers need readers to engage with their work, and readers require writers to provide content. Both roles are crucial in the realm of literature and communication. So, one may argue that neither is more important than the other, and they both hold significant positions in communication and learning.

If all readers vanished, it would significantly impact the world. If the number of writers were to disappear, society would lose a valuable cultural expression, education, and entertainment source. Hence, the plausible scenarios of vanishing readers and disappearing writers should vigorously shake the societal stupor to immediate awakening.

On reflection, the rhetorical questions regarding the everyday mundane banalities of *reading* and *writing* quickly transform into deeply philosophical inquiries with myriad complexities.

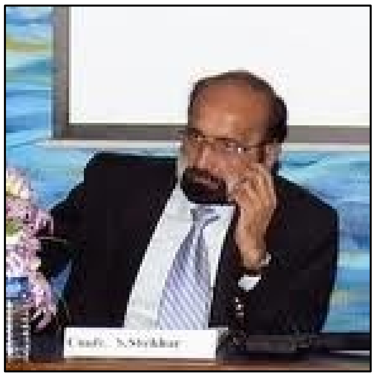
The End

Having regaled each other with abstract musings and consumed their cups of coffee without actually savouring the taste, the two academicians parted ways to follow their other daily academic pursuits.

December 28, 2023

Run Deep, Run Silent

In Memory of Commodore Shridharan Shekhar (1943-2019)



Commodore Shekhar passed away on October 22, 2019, at 1030hrs in Chennai, after a cardiac arrest. The shocking news of the untimely death of Cmde. Shridharan Shekhar, a friend, philosopher, and guide to many, brought profound sorrow to all of us who had known him for many years.

Cmde. Shekhar was a highly intelligent, vibrant, cheerful human being who made friends across all sections of society; and was deeply respected for his wisdom, and his strong sense of ethics, by one and all.

Having an uncanny flair for languages (Indian, as well as foreign - *especially Russian*), Cmde. Shekhar was well-read, and possessed great oratory and organisational skills, which he used graciously to work for the common noble causes.

Therefore, it was not surprising that Cmde Shekhar led a cheerful and vibrant life, full of contagious energy and had been a trail blazer in many facets of his life.

Cmde Shekhar’s friends and contacts ran across different cross-sections of society - academia, defence personnel, diplomats, industrialists, and religious scholars. Being a gregarious, fun loving but deeply committed individual Cmde Shekhar not only successfully networked with his contacts, but also consciously nurtured networking between his many contacts for the greater good of society.

His penchant for coining appropriate acronyms to his many projects, often led to lively discussions and fruitful solutions to many problems.

Cmde Shekhar was among the initial few to join hands with Ambassador Smita Purushottam in effectively contributing to the cause of the High-Tech Defence Innovators Forum, DIIA and SITARA. He later was instrumental in setting up AIDAT along with his namesake. In December 2018, Cmde Shekhar accepted to become the Chairman and Managing Director of TUNGA (Technological Upgradation of Naval, Ground and Air) Services Pvt Ltd, an SME started to cater to the supply of spares, manufacturing, and technology requirements in the defence domain.

His scholarly writing skills slowly surfaced into the public domain, when he released his first book last year, after a lot of coaxing from some of us to pen down his thoughts in the form of a book, '*Get onto the TRAMWAY*' -the first of his intended 3-part Life Trilogy.

Being a Submariner and an Electrical Officer, Cmde Shekhar served the Indian Navy in many responsible capacities, including a diplomatic assignment in Russia. Having spent three decades in the service of the nation as a Naval Officer, Cmde Shekhar was a treasure trove of deep knowledge in many domains and especially in matters related to the Submarine arm of the Navy.

His most recent contribution to the Nation (when he was suddenly called by the National Security Advisor Shri Ajith Doval, who was his course mate at NDC*)* was in effectively tackling a pernicious issue (of flared up egos and divergent views of two important arms of the nation's defence), which almost threatened to shelve an important program concerning Indian defence/naval surveillance.

Thanks to his sagacity, power of persuasion and his unfailing commitment to support indigenisation - the nation now has a new platform for ocean surveillance.
Never one to brag about his contributions, Cmde Shekhar worked with dedication and sincerity towards building a strong nation and society, and therefore it was not surprising that his motto in life was *Run Deep, Run Silent*.

A thorough gentleman, Cmde Shekhar always treated everybody with respect and dignity. I had been blessed to enjoy his friendship and camaraderie and benefitted immensely from his thoughts which he graciously shared.

I have had the distinct privilege and honour of experiencing Cmde. Shekhar's long-lasting friendship for more than two decades - initially when I was part of DRDO, later when I moved to the academia to finally, when we both teamed up to serve the cause of indigenisation under challenging conditions.

Our initial acquaintance slowly blossomed from the days when both of us were with Ministry of Defence and evolved into a long-lasting friendship while we traversed our different paths in life – with Cmde. Shekhar transforming himself from a highly respected Senior Naval Officer to a Veteran, and I, from a Senior DRDO Scientist and Program Director to a Senior Professor and Director at the academia.

It was during the Summer and Fall of 2009, after many brainstorming sessions, Cmde Shekhar and I conceived CASTLE (Centre for Advancement of Science Technology, Law, and Engineering), which we eventually started as a non-profit society based in Visakhapatnam in October 2010.

Under the aegis of CASTLE, we journeyed together addressing many issues with full vigour (thanks mostly to Cmde. Shekhar's ebullience, unending energy, and penchant for making a difference), travelled the world and mostly made a mark with the powers to be in the country, as well as made a splash overseas.

Our association grew stronger when we were concurrent Regional Directors (at Chennai and Visakhapatnam respectively) of the National Maritime Foundation, NMF – *a think tank of the Indian Navy*.

In 2015, when we finally realized that the photonic technologies which I had developed over the years were ready for commercialization, we founded a high-end technology start up - CATS - CASTLE Advanced Technologies and Systems, along with another dear mutual friend Biren Shah. Now, when we are on the verge of making a mark in the world with our indigenous systems and technologies, we are shattered by his untimely death.

Despite his immense knowledge and seniority, Cmde. Shekhar always joyfully used to address me as *Dr T*, which I most humbly cherish.

My wife and I, fondly remember and cherish Cmde. Shekhar’s long, yet focussed interactions; interlaced with his usual cheer, humour, and bonhomie.

Cmde Shekhar left behind his wife of many decades, Mrs. Malathi Shekhar; his two sons and their families and thousands of his friends.

On behalf of CASTLE and CATS, and of the many groups of like-minded individuals who crossed Cmde Shekhar’s many and varied paths in his life journey, our deepest condolences to Mrs. Malathi Shekhar and the rest of Shekhar family.

His passing away has left a great void in all our lives. May his soul rest in peace. *Om Shanti*.

Postscript: Concluding Note

As these pages draw to a close, I am reminded that reflections are never final, nor confined. They ripple outward, carried by echoes of memory, sharpened by insights of experience, and renewed through the learnings we pass on. What began as scattered thoughts across time and circumstance has become, in its gathering, a testament to continuity — the enduring dialogue between science and conscience, between the individual and the institution, between silence and renewal. If these words reach beyond boundaries, it is because knowledge itself knows no borders. May these reflections inspire others to listen to the echoes of their own journeys, to seek insights with humility, and to carry forward the legacy of learning into futures yet unseen.

"Knowledge is not a possession, but a passage—from silence into resonance, from one mind into many."

Reflections

From Echoes to Insights

Lessons Beyond Boundaries

Prof. Dr. Rao Tatavarti

Reflections: From Echoes to Insights is more than a memoir — it is a meditation on science, conscience, and legacy.

Prof. Tatavarti invites readers on a journey where silence becomes a teacher, echoes become reminders, and insights emerge as guiding lights. This book speaks to scholars, educators, and seekers alike, offering wisdom that transcends disciplines and generations.

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