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THE 'GENTLE GIANT'

RAMA GOVINDARAJAN

On a bus journey long ago, I fell into a chance conversation with the enthusiastic high school student sitting next to me. She confided her dreams in me: she dearly wished to be a pilot. If this didn't happen, she had a priority list she would go down until something worked out: become an academic researcher in aeronautical engineering, work as cabin crew, air-traffic controller, aeroplane mechanic, airport ground staff, travel agency employee. This was the craziest future plan I'd ever heard, so I told Roddam Narasimha about it. RN's face lit up in the most excited way and he literally screamed, "Where is she? Bring her to see me. Such people are precious!" He was disappointed that I had not got her contact details. When he was very young, he had been similarly enthralled with aircrafts and anything to do with them.

RN made immense contributions to science and to various national missions, and was a builder of institutions. Much has been written about these, so this tribute focusses instead on the unique person he was. He has left a big void in the science world and huge voids in the hearts of large numbers of students, colleagues and friends. He leaves behind his wife, Dr Neelima Narasimha, a doctor, and his daughter, Prof. Maithreyi Narasimha of TIFR.

How the boundary layer in a flow past a solid body (like an aircraft wing) transitions from laminar to turbulent is a crucial question that is not fully resolved. The picture (page 8) tells the story of a single-author paper RN wrote at the age of 24 (On the *Distribution of Intermittency in the Transition Region of a Boundary Layer*. Journal of the Aeronautical Sciences, 24, 711-712, 1957), which completely changed the way this process was understood. This is a top view of a flat plate over which wind blows at a speed U, creating a growing boundary layer. The words at the bottom are in his own hand.

Up to then it was believed that downstream of a particular location, which he here calls x_t, turbulent spots were born randomly in space, growing bigger in a self-similar manner by destabilising the neighbourhood as they got convected, until asymptotically taking the boundary layer to fully developed turbulence far downstream. RN realised that this was not consistent with experimental

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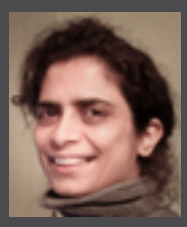
APPA, MY GENTLE GUIDE

MAITHREYI NARASIMHA



Roddam Narasimha, my father *(Appa)*, passed away aged 87 after a rough three months in and out of hospital. He had always seemed invincible in my eyes. There was so much more he wanted to do, and he had the passion, ambition, focus and energy to keep going. He worked 18-hour days from home during the early months of the pandemic, (nearly) finished work on two books (one on turbulence with his Caltech friends, Garry Brown and the Late Anatol Roshko, and the other, his translation of new verses from the Yoga Vāsiṣṭha)

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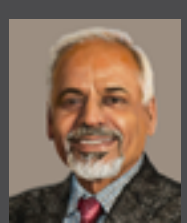
HOW RODDAM NARASIMHA APPEARED AS A SHINING STAR IN MY LIFE AND STAYED THAT WAY FOR MORE THAN HALF A CENTURY

K.R. SREENIVASAN



Preamble

Professor Roddam Narasimha (RN) wasn't well for a few weeks prior to his death on December 14, 2020. He was intellectually active except for those few weeks, during which he often fretted that he had neglected his work. I had deluded myself into thinking that he would return to normalcy, and that I would go back to seeking his suggestions and thoughts on any number of things,

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"THE NARASIMHA WE KNEW"

TRIBUTES FROM FRIENDS AND COLLEAGUES

EDITOR'S NOTE

Roddam Narasimha, the world renowned fluid dynamist and atmospheric scientist, passed away on 14 December 2020. We dedicate this special issue to his memory. His daughter, students, friends and colleagues remember Narasimha for his path-breaking research, mentorship, friendship and immense contribution to science building in India as well as his constant guidance to and deep involvement with ICTS-TIFR.

We include tributes from his students K. R. Sreenivasan and Rama Govindarajan, his daughter Maithreyi Narasimha and the founding director of ICTS-TIFR, Spenta Wadia. We also include reminiscences from Amit Apte, Leena Chandran-Wadia, P. P. Divakaran, Uriel Frisch and Roberto Benzi, Rajesh Gopakumar, K. Kasturirangan, Shekhar C. Mande, Joseph Matthew, Narayana Murthy, Itamar Procaccia, Govindan Rangarajan, C. N. R. Rao, J. Srinivasan and K. VijayRaghavan.

K. VIJAYRAGHAVAN

Deeply pained by the demise of noted aerospace scientist Prof. Roddam Narasimha who contributed immensely to space technology. His research in parallel processing, aerospace electronics, surface technologies, and computational fluid dynamics, leadership at National Aerospace Laboratories, and policy contributions to aerospace technology proved to be the stepping-stone to make India self-reliant in civil aviation. Indian science is indebted for his remarkable contributions to many of India's major scientific programs from issues of climate change, the design and development of civilian aircraft programs, and of the Light Combat Aircraft, Tejas. His passing away creates a void in the scientific community globally and in India.

K. VijayRaghavan is Principal Scientific Adviser to the Government of India

CNR RAO

I have known Prof. Narasimha for about seventy years. We went to the same school. I feel that he was the most outstanding accomplished Engineering scientist in India.

We shared the concerns and I miss him for any worthwhile cause.

CNR Rao is National Research Professor, Linus Pauling Research Professor and Honorary President at JNCASR, Bengaluru

ITAMAR PROCACCIA

My first great opportunity to familiarize myself with Indian Science at its highest level was in the year 2000 when I spent a month in Bangalore as a (thankful) recipient of the Raman Chair, (a Professorship instituted by the Indian Academy of Sciences in honour of its founder, C.V. Raman). During that month I met many wonderful colleagues who remained my friends for life, but two of them stood out: R. Radakrishnan and R. Narasimha.

Two very different personalities, Rad being overwhelmingly brilliant and Roddam rather coy in revealing his impressive scholarship. With Rad I had love at first sight, with Roddam I had a series of encounters that increased my admiration for him time after time. I have learned from Roddam things that I did not know about Indian mathematics and its cultural significance, opening my eyes to the relevance of the history of mathematical thinking. Due to Roddam's influence I explored the development of concepts like numbers, not only for their arithmetic significance, but also their role in language, in art and in architecture. But probably what left on me the greatest impression was how immersed Roddam was in early Indian culture, and how confident he was in the intellectual autonomy that this culture exhibited, prior to the British domination that tended to tarnish the confidence of Indian scholars in their own tradition.

With Roddam's exit from our lives we lose not only a wonderful scientist, but a great representative of the impressive intellectual contribution of India to the world at large.

Itamar Procaccia is The Barbara and Morris I. Levinson Professional Chair in Chemical Physics at the Weizmann Institute of Science, Israel

NARAYANA MURTHY

It was in the month of July 1967 that I joined my graduate studies in EE at IISc after passing out of NIE, Mysore. I spent just a month at IISc. Laster on, I moved over to do my graduate studies at IIT Kanpur. My one month stay at IISc was memorable due to two people who amazed me with their scholarship.

The first was Prof. Y V Venkatesh who taught us mathematical methods in EE. I have rarely come across another teacher who could make complex ideas simple to understand like Prof. Y V Venkatesh did. The second was Prof. Roddam Narasimha who taught me for just one lecture. Prof. Venkatesh could not take the class that day. He had requested Prof. Narasimha to stand in for him, and speak to us, the students, about any interesting mathematical idea that Prof. Narasimha thought appropriate.

Prof. Narasimha came to the class and asked us how many of us had been taught probability. Very strangely, most of the students coming from local engineering colleges like me had not been taught probability formally in their entire 5 years of engineering studies. So, he started his lecture defining probability as a mathematical measure of ignorance. He explained "ignorance" or "lack of information" with the example of the "problem of points" first enunciated in 1494 by the Italian monk, Luca Paccioli, then by the French mathematician, Antoine Gombaud, and posed by Gombaud to Blaise Pascal in 1654. Prof. Narsimha spoke about Pascal's correspondence with Pierre Fermat on this problem suggesting Pascal's solution, and Fermat's own solution to the problem. I hope my memory has not failed me and that I have not stated the problem incorrectly or used wrong names. The mistake, if any, is entirely mine.

Let me try and state how Prof. Narsimha described the problem. Two players A and B are playing a chance game like poker. It is agreed by both of them that the player who wins six games first would win the entire prize money. However, the game is terminated due to a reason beyond either of them when player A has won five games and player B has won three games. The question is how the prize money should be shared between A and B at this stage. I will leave you to work out the solution for yourself.

Prof. Narasimha made us, the students, discover, by our own effort (obviously, aided heavily by his guidance), the

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RODDAM NARASIMHA AND ICTS:

CLIMATE, DATA SCIENCE, JET ENGINES AND MORE

SPENTA R. WADIA

I first met Roddam Narasimha in 1998 during a meeting on nuclear disarmament at NIAS. However, I only got to know him in 2009 when ICTS organized a conference in Bangalore, 'Science without Boundaries' during its Foundation Stone Ceremony. He was very enthusiastic about the vision we had for ICTS. He was a regular visitor to the 'one corridor institute' when ICTS was temporarily located in the IISc campus.

During one of our walks in the IISc campus, he turned to me and asked, *"are you planning to set up a group on climate science, meteorology and data science in ICTS?"* I replied yes, provided we get a couple of excellent people to lead the activity. In February of 2011, Roddam along with other distinguished scientists and mathematicians, organized the program on, `Scientific Discovery Through Intensive Data Exploration'. This program (https://www.icts.res.in/program/datasci2011) brought together a host of disciplines and scientists dealing with 'big data'.

This was perhaps one of the most important of the early programs of ICTS. It also launched 'IndiaLight' a pilot project on big data connectivity for researchers in India, using GLORIAD, a fibreoptic big data network in the US, using a server gifted by the National Science Foundation of USA and free data connectivity for a year gifted by Tata Communications (https://www.icts.res.in/news/high-speed-international-connectivity-indian-scientists-and-researchers-india-connected-gloriad). Roddam was very involved in this project and was present during all our late evening discussion meetings. Other members of the 'IndiaLight' team were Amit Apte, Vijay Chandru, Ravi Nanjundiah and Leena Chandran-Wadia.

In a couple of years Roddam and other distinguished scientists organized a program on, 'Mathematical Perspectives on Clouds, Climate and Tropical Meteorology' (https://www.icts.res.in/discussion-meeting/CCTM2012). During this program on 22 January 2013, Andrew Majda delivered the ICTS Srinivasa Ramanujan Lectures. On the same day Roddam accepted to be on the International Advisory Board of ICTS, which he served actively till he passed away.

He strongly believed that while there is a lot of work in India in climate science, there is little done about the mathematical foundation of the tropical monsoon. A few years later ICTS created a group of mathematicians and physicists studying the Indian Monsoon using novel mathematical methods.

He was deeply interested in the history of mathematics, science and technology and especially comparing developments in India with those in other cultures. We were fortunate to have an insightful talk by him on this subject (https://www.icts.res.in/outreach/kaapi-with-kuriosity/great-triumphs-and-false-stories-brief-history-histories-indic-and).

Roddam Narasimha was one of independent India's most eminent engineer-scientist. My last communication with him was regarding the design and manufacture of Jet Engines in India, a proposal by the Bangalore Science and Technology Cluster (BeST). In an email dated 12 June 2020, Roddam said, *"... is right in saying that the Kaveri was a failure. But that is precisely why we have to do something new to reorganize our gas turbine program so that we can make our own (although it takes some effort and funding - as all such programs do). The LCA and ALH have shown how the airframes can be done in India, with carbon fibre composite technology."*

He was deeply involved in the design of airframes and the engines. We had many discussions on this topic over the years and especially in the past year, during which he narrated to me and Rajesh Gopakumar, the story of why India did not succeed in making a jet engine. It was not lack of technical capabilities but a lack of processes and professionalism coupled with human weaknesses that came in the way of realising this project. He had promised to give a talk on `Jet Engines', but that did not happen. It is my firm belief that India should embark upon the extremely complex multi-disciplinary aspirational engineering project to design and manufacture a jet engine. Roddam was in complete agreement; he saw hope in a fresh initiative.

He was very keen to participate in the BeST initiative especially in deliberations on the Jet Engine theme. On October 7th he wrote, *"... I could not come on the 25th Sep, because I was not completely discharged from the hospital and had to play some role in the Birthday Centenary Celebration of Satish Dhawan. I am glad that the GTRE man [Dr. Ramachandra] was enthusiastic about the project, and will have a chat with him sometime next week"*. I waited for him to recover.

Roddam passed away on 14 December 2020. I will greatly miss him for his friendship, encouragement and for the values we shared. He was so learned, so accomplished and yet so humble, always exploring mysterious Nature.

Spenta R. Wadia is Founding Director, Professor Emeritus and Infosys Homi Bhabha Chair Professor at ICTS-TIFR, Bengaluru.

Roddam Narasimha, with K.R. Sreenivasan and Obaid Siddiqi, at the conference 'Science Without Boundaries' *held on the occasion of the Foundation Stone Ceremony of ICTS in December 2009* (https://www.icts.res.in/event/science-without-boundaries).

BETWEEN THE SCIENCE

PARAMESWARAN AJITH, was awarded the inaugural TWAS-CAS Young Scientist Award for Frontier Science in the Physical Sciences. This award recognizes young scientists from developing countries.

ANIRBAN BASAK, received the 2020 NASI-Young Scientist Platinum Jubilee Award (for Mathematics) for his work on probability theory.

RIDDHIPRATIM BASU was awarded the 2020 INSA Medal for Young Scientists (Mathematics).

ABHISHEK DHAR was named a Fellow of the Indian National Science Academy (INSA).

The publication titled *Spatiotemporal Spread of Perturbations in a Driven Dissipative Duffing Chain: An Out-of-Time-Ordered Correlator Approach*, **ANUPAM KUNDU**, **MANAS KULKARNI** and **AMIT KUMAR CHATTERJEE**, was selected as the ***'Editors' Suggestion'*** in Physical Review E.

FRIENDS AND COLLEAGUES | *continued from Page 2 ...*

solutions used by Pascal and Fermat to this problem. We were mesmerised by his logic, his oration, his passion towards mathematics, his gentle nudging of us towards the solution, and his superb story-telling laced with mathematical equations. We were overawed that Prof. Narasimha had spent an entire hour introducing us to probability even mentioning the work of Thomas Bayes and Laplace who expressed mathematically that an initial belief can be improved by adding objective new information. All of this in just one hour of spellbound oration! That is Prof. Narasimha for you. I have no hesitation in saying that was the best lecture in my entire graduate studies.

I rekindled my relationship with Prof. Narasimha towards the end of eighties. I found him to be the same – curious, intellectually playful, logical, always willing for a debate, honest and courteous. He struck me that he had modelled himself after Richard Feynman. I never heard him speak much of himself. If any, he spoke about his team whether at IISc, NAL, and NIAS. He remained a quintessential fluid dynamics professor. I remember he and I were travelling to a function at NAL several years ago when our car started making some strange noise. The passion for fluid dynamics in Prof. Narasimha took over. He started referring to mathematical equations to explain the causes and solutions to the problem of car noise.

He was a patriot. His patriotism showed up in his actions to make our country look good in front of foreigners and to raise the confidence of the less fortunate Indians in the future of India. I feel honoured to have known him, interacted with him, and learnt from his wise words. His demise is a huge loss for India.

Narayana Murthy is founder of Infosys Limited, Bengaluru.

P.P. DIVAKARAN

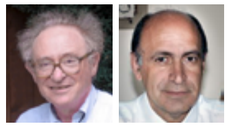
In the last phase of a remarkably productive life Roddam Narasimha took up a field in which he must always have had a lively interest: the philosophical underpinnings of India's intense engagement, throughout its history, with the life of the mind. The specific area he focussed on was astronomy and mathematics – the two went hand in hand in India. A succession of great minds, over millennia, had produced a body of work of the highest standard, as we know from the fine synoptic histories written by pioneering scholars like Bibhutibhushan Datta and Sarasvati Amma. But they had not, perhaps by temperament, paid much attention to the cultural and logical/philosophical backdrop against which this whole activity is to be seen. It then became Roddam's turn to take the first and hardest steps in bridging this gap. Anyone today trying to put in perspective the indigenous impulses behind India's mathematical journey and the way they differ from other cultures in this regard owes him an enormous debt.

As those who have known him would expect, Roddam was objective and meticulous in his approach to these ideologically tricky questions and buttressed his analytically argued positions with detailed textual references. The most significant outcome of this effort was the bringing to the attention of the scholarly world the extraordinary intellectual personality of Nilakantha (15th C. AD), the finest epistemologist (in the modern sense of the word) India has produced -- in addition to being an outstanding mathematician and astronomer. Nilakantha saw science as a finely balanced interplay of sensory observation, logical reasoning (including computation) and rigorous pedagogy: obviously a modern philosopher-savant before his time, far deeper in his thinking than say someone like Francis Bacon who, from the impact his analysis of Nilakantha's ideas has had on the history of Indian philosophy and epistemology, Roddam has also in the process made it possible for us to understand the great transformation brought to the study of mathematics and astronomy by the school founded by Madhava (of whom Nilakantha was a great-grand disciple).

I used to say that Roddam's broad interests, his open mind and the generosity with which he shared his insights made every encounter with him a stimulating experience. That has not changed except that the encounters are now virtual, with his thoughts as expressed in his writings.

P.P. Divakaran is former Professor of Physics at TIFR, Mumbai. In recent years, Divakaran's main interest has been in the study of the History of Indian Mathematics. He is the author of the book The Mathematics of India: Concepts, Methods, Connections.

URIEL FRISCH AND ROBERTO BENZI



Prof. Roddam Narasimha from the Jawaharlal Nehru Center for Advanced Scientific Research (Bangalore, India) passed away on December the 14th 2020. He was a world leader in fluid dynamics, with very wide international recognition (he was FRS, Member of the US National Academy of Sciences and of Engineering and of the Third World Academy of Sciences and - of course - of all academies within India).

The focus of his research had been fluid mechanics and atmospheric phenomena. In Fluid Dynamics, the three areas to which he has made lasting and important contributions are: transition between laminar and turbulent states, turbulent shear flows, and the shock structure.

In transition between laminar and turbulent states, Prof. Narasimha was able to show as early as in 1957 that intermittency occurs in localised bursts with self similar distribution, pioneering most of the current knowledge in the field. In his work on turbulent states (with Prabhu, Dhawan, Rao, Narayanan among others), Prof. Narasimha introduced many new and fundamental ideas on the relaxation time of turbulence and on the proper scaling of turbulent bursts in the boundary layers.

During the last 15—20 years, his main activity had been in the atmospheric sciences where he developed a model for the lifted-minimum effect: on calm, clear nights the temperature of the atmosphere attains it minimum slightly above the surface of the Earth (this is the Ramdas effect - it was discovered in the 1930s and it remained unexplained for 60 years). He also gave major contributions in the study of monsoon structures and dynamic (using, e.g. wavelets) and he was playing an important role in the space mission Megha-Tropiques on tropical cloud study, which was successfully deployed into orbit by a PSLV rocket in October 2011.

Last but not least, Prof. Narasimha has been an outstanding teacher, a world-class researcher, a dynamic leader, builder of institutions, and a person who has dispensed advice and wisdom to the highest circles, training new successful generation of scientists. Of course, his wisdom was known all over the world.

Uriel Frisch is Research Director Emeritus at CNRS, France and Roberto Benzi is Professor of Theoretical Physics, University of Roma "Tor Vergata"

JOSEPH MATTHEW

Prof. Narasimha appointed me at NAL, and told me of an emerging breakthrough in building a new parallel computer which had allowed the direct numerical simulation (DNS) of a turbulent flow.

He told me that there was an unsettled question of the process of mixing in turbulent shear flows. One of his former students, Amit Basu, who had also joined NAL, and I, proceeded to measure entrainment in a DNS and uncovered distinct roles for small and large scale processes. I think it was typical of him that he pointed out a direction for work that would be novel, with the promise of a satisfying end. There is a treasure at the end of the rainbow, and the path has delights.

I believe one of his greatest contributions has been the self-confidence given to a very large number of people of widely varying ability and preparation. As example, consider the light combat aircraft (LCA). If the objective had been to just build an LCA, it might have been achieved sooner. The aim seems to have been to master the many technologies of a modern combat aircraft – more like research projects in academia than in industry. So when the aircraft flew, so too the many technologies. So too, self-confidence and satisfaction in the many who worked to make it happen. When I watched (and heard) the LCA fly at the last Bangalore Air show, I could sense that it is world class. In his own career it started with his graduate student thesis in IISc, which has a result that was a starting point for gas turbine blade design even in the 90s – I heard of it at a seminar at NASA Lewis. His many students, and I use that term very broadly, would attest to the sense of achievement and satisfaction that Prof. Narasimha brought to their pursuits.

Of course, he had immense personal charm that drew us all to treasure the time we could spend with him.

Joseph Matthew is Professor and Head of Aerospace Engineering at the Indian Institute of Science, Bengaluru.

SHEKHAR C. MANDE

On 14th December 2020, India lost a renowned aerospace scientist who was known for his work in fluid mechanics, aerospace engineering and atmospheric sciences. I had the opportunity to meet him several times over the course of my career and I cherish my interactions. I miss his passion about aerospace and science in general. His vision and foresight for Indian aerospace sector led to many notable developments including the development of Light Combat Aircraft (LCA).

He ably led CSIR-National Aerospace Laboratories as Director from 1984-1993. He was instrumental in many new initiatives, including the lead role in the development of LCA, parallel computers, civilian aircraft and numerical modeling of the monsoon. He was not only a true academician but also an able administrator and led India's science policy too as a member of Space Commission, the Prime Minister's Science Advisory Council and the National Security Advisory Board.

In his own words, Prof. Narasimha's hobby was the attempt to understand the epistemology that drove classical Indic science during its most productive age, during the 1500 years or so from Caraka to Nilakantha. For an academician the true recognition comes from his students and associates and Prof Narasimha being chosen for the 2019 Nature Mentoring Awards speaks volumes of his mentorship abilities. India misses the highly accomplished scientist but his legacy lives on and I hope that his wish for jet engine program for India will be fulfilled in time to come.

Shekhar C. Mande is the Director General of the 'Council of Scientific and Industrial Research'.

K. KASTURIRANGAN

I came to know about Prof. Roddam Narasimha in the mid-seventies, as one of the illustrious students of Prof. Satish Dhawan at the Indian Institute of Science. Prof. Dhawan was then in the early phase of his stint as Chairman ISRO while continuing as Director of Indian Institute of Science. The familiarity was more from indirect inputs, such as Prof. Dhawan often referring to Prof. Narasimha's views, whenever there were internal discussions in ISRO on the design aspects of India's first satellite launch vehicle SLV-3.

For me, serious acquaintance with Prof. Narasimha really happened when he assumed the Chairmanship of the External Review Panel set up to review the causes for the failure of initial experimental test flights of the Augmented Satellite Launch Vehicle ASLV. I came to realise the extraordinary breadth and depth of Prof. Narasimha's knowledge in areas like fluid mechanics

Courtesy: SHEKHAR C. MANDE

At a workshop on Modeling in 1988; promoted cooperation among modeling groups leading to birth of Centre for Mathematical Modeling and Computer Simulation: C-MMACS

Courtesy: SHEKHAR C. MANDE

The Acoustic Test Facility completes 1000 blowdowns in 1992

K. KASTURIRANGAN

Narasimha and Kasturirangan at the Meeting of the Council of the Indian Academy of Sciences held at the RRI Farm at Kengeri on March 6, 2004, for which all the past-Presidents of the Academy were invited.

and aerodynamics as well as control, guidance and navigation, besides the overall systemic characteristic of the launch vehicle.

In 2001-2002, when I was the Chairman of ISRO, I was asked to Chair a National Committee to review the structure and functioning of the India Meteorological Department. I was fortunate to have Prof. Narasimha as a key Member in this Committee. Prof. Narasimha used his knowledge of air and fluid flow to look at the complexities associated with weather and climate change. We spent a lot of time looking at a number of issues related to both operational and research needs. Prof. Narasimha was passionate about the need to transform Indian weather services into something that was comparable to the best in the world. His experience as a practising researcher combined with his systemic understanding of local, regional and global weather systems brought in a breath of fresh air to the working of our Committee. These insights and the recommendations from them played a key role in the eventual creation of a new IMD under a new Ministry of Earth Sciences.

When I became the Chairman of ISRO, I had already a good assessment of how Prof. Narasimha was proving to be a valuable asset for ISRO's major reviews, both launch vehicles and satellites. He could easily develop exceptional insights into specific and complex technical and scientific issues, relating to the sub-systems, systems and mission of the various ISRO's rocket and satellite programs. On matters of policies and strategies, Prof. Narasimha's insights were very unique and deep, as I could see during different meetings of the Space Commission of which he was one of the key technical Member. I may also recall one significant role that Prof. Narasimha had played during my tenure as Chairman, ISRO, that of Chairing an all important scientific Committee set up to work out the modality of collaborative scientific research, as a part of a flagship space cooperative program between India and France designated as Megatropiques.

The Indian team led by Prof. Narasimha and his French counterparts came out with a comprehensive scientific program resulting in several seminal scientific outcomes, leading to a better understanding of the tropical weather systems.

His continuing association with NIAS during my period as its Director, revealed to me his extraordinary breadth of interests involving Indian philosophy, India's legacy in science and mathematics as well as his penchant to pursue deeply the meaning embedded in ancient Indian scriptures such as Upanishads and Vedas.

Most importantly, Prof. Narasimha was always available to me as a mentor, ever ready to explain lucidly the complex concepts whether it is related to launch vehicle design or to improve my ability to delve deeper into the intricacies of atmospheric sciences or serving as a sounding board on matters of national policy like education, mapping as well as interesting ideas about India realising medium size civilian aircrafts.

He was truly the tallest among the tall intellectual giants of this country in the recent times. I can keep writing many things about Prof. Narasimha, but words completely fail me when I have to express my personal feelings and to recognise the reality that he is no more with us. Even if I can inherit a small part of his scholarship and divinity, I would be a blessed human being on this planet.

K. Kasturirangan is Member, Governing Council of TIFR & of Atomic Energy Commission & Former Chairman, Indian Space Research Organisation.

GOVINDAN RANGARAJAN

Roddam Narasimha's association with IISc has stretched across decades. Fondly known as RN to the Institute community, he was an outstanding scientist whose presence on campus inspired many students and researchers.

As a young man studying for a Bachelor's degree in mechanical engineering, he happened to visit IISc's Department of Aerospace Engineering, and was drawn to the Spitfire aircraft displayed there – this sowed the seeds for what would grow to become a long and close relationship with the Institute.

In 1953, Narasimha joined IISc for a Master's degree in the Department of Aerospace Engineering, and had the opportunity of working under its Head, Oskar G Tietjens, and Satish Dhawan, a young and energetic fluid dynamicist who went on to become one of the builders of India's space programme. Dhawan remained a friend, mentor and colleague throughout Narasimha's career. It was he who influenced Narasimha's decision to pursue a PhD at Caltech, after which Narasimha returned to IISc to teach at and later head the Department of Aerospace Engineering.

At IISc, he made valuable contributions not just to aerospace research, but also to research on the monsoon, which led to the setting up of the Centre for Atmospheric and Oceanic Sciences. Narasimha was appointed the first Convenor of this Centre and continued at its helm until 1989.

Narasimha also had an illustrious career outside IISc, including a term as Director of the National Aerospace Laboratories. His contributions to the national aerospace programme have been acknowledged and appreciated by several scientists and dignitaries, including India's Prime Minister. Closer to home, he is remembered fondly by his students for his mentorship and guidance.

Govindan Rangarajan is the Director of the Indian Institute of Science, Bengaluru.

J. SRINIVASAN

Prof. Roddam Narasimha was a remarkable academician who worked on a variety of topics in his long and illustrious career. Some of the areas he contributed to were fluid mechanics, aerospace, atmospheric boundary layer, clouds, monsoon, parallel computing, technology policy and history of Indian science and technology.

Prof. Narasimha established the Centre for Atmospheric Sciences at IISc in 1982. In the first phase, the centre attracted faculty and students from Centre for theoretical studies, Aerospace, Mechanical, and Civil engineering departments. The faculty and students benefited by interactions with Prof. Narasimha because of his breadth of knowledge and the depth of his scholarship. The initial research at the centre was on the movement of large cloud systems based on new data from satellites. The existence of a temperature threshold for the formation of deep clouds was reported for the first time.

The centre was a pioneer in the laboratory study of clouds. This work enabled us to understand how the heat released by condensation of water vapor affects the structure of clouds. In the area of climate models, Prof. Narasimha encouraged the use of parallel computers to overcome the limited computing power we had in 1982. The hardware for parallel computing was developed at National Aerospace Laboratories while the software was developed at the Centre. Prof. Narasimha initiated the first field program to observe turbulent fluxes in the atmospheric boundary layer in India.

As a member of the Space commission, Prof. Narasimha convinced ISRO to launch a satellite devoted to the study of clouds. The payload for this satellite was developed jointly by Indian and French space agencies, the satellite named Megha-Tropiques (the name was inspired by Kalidasa's Meghadoot) was launched on 12th October 2011 from Sriharikota.

The most important contribution of Prof. Narasimha to intensify the research on monsoon was his role in the creation of Ministry of Earth Sciences. The creation of this Ministry has led to a larger funding for monsoon research and more integrated approach to understand the interaction between the ocean and the atmosphere in the tropics.

J. Srinivasan is distinguished scientist at Divecha Centre for Climate Change and Honorary Professor at the Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bengaluru.

RAJESH GOPAKUMAR

When a scientific community loses someone like Prof. Roddam Narasimha, it leaves an intellectual void that is difficult to fill. It is so rare to have someone who moved with facility and stellar success across the basic sciences and engineering all across the spectrum to technology and its realisations. And this is not to mention his able institutional leadership and stimulating forays into scientific historiography. It is an immense loss. We need to hearken back to the likes of Homi Bhabha or Vikram Sarabhai for appropriate comparisons. And indeed Roddam was a child of that pioneering generation of scientists and technologists fired by the post-independence glow of idealism and Nehruvian self-sufficiency in constructing a strong scientific and technological foundation for a young nation. And how well he and others succeeded in laying a secure base on which coming generations could further build.

Unfortunately, I only got to know Roddam personally after 2015 when I moved to ICTS. Though I, of course, knew of him and have had his (with Helaine Selin) Encyclopedia of Classical Indian Sciences on my shelf from the time it came out and which I used to regularly dip into.

It was a privilege these last five years to have him as a member of the ICTS International Advisory Board (IAB). He would never miss a meeting of the board and would come to the ICTS campus, even if it was late at night (to accommodate multiple time zones). I vividly recall the last meeting we had before the Covid lockdown moved things to a virtual mode, when Roddam, Spenta and I were on the campus much after the meeting had gotten over. Roddam was describing his experience with the development of indigenous jet engines and airplanes - I think back to that conversation and the wealth of experience that we have lost with his going away. He had also been extremely encouraging of the ICTS Monsoon Initiative emphasising how important it was to bring new perspectives to this critical topic. Even in our last (virtual) IAB meeting in August 2020, he was emphasising the importance of growing our computational infrastructure, raising resources for doing so and hiring faculty in this area. I will miss turning to him for counsel and encouragement. I only hope that at ICTS we can be true to his catholic spirit towards knowledge as we grow.

Rajesh Gopakumar is Director and Senior Professor of Physics at ICTS-TIFR, Bengaluru.

LEENA CHANDRAN WADIA

Like any graduate student on the IISc campus in the 1980s, I had Roddam pointed out to me in awed/ hushed tones by several people, but it was only in the last decade of his life that I had the good fortune of getting to know him a little, a privilege for which I will always be grateful.

An international networking effort I was involved in came together serendipitously with the ICTS event *'Scientific discovery through intensive data exploration'* organised by Roddam and several other scientists in February 2011. My effort was towards trying to take up the invitation of the world scientific and networking community to join them in collaboratively setting up Optical Lightpaths circling the globe for the movement of large quantities of data using dedicated wavelengths of light and setting up Open Lightpath Exchanges around the world. The US NSF had gifted some hardware and Tata Communications had donated the use of a 1 Gbps link connecting India to the rest of the world, free of cost for one year. Roddam immediately saw value in the project and helped actively to bring together several groups of scientists, potential users of a Lightpath network in India, and we put together a funding proposal.

Roddam took it upon himself to help us find funding and even accompanied us to Delhi to lend support to our pitch. We could have spared ourselves the trip however, because the funding agency had already made the decision not to fund us but were going through the motion of listening to our presentation. The referee was in clear conflict of interest, given that he was seeking funding for a project of his own. The sight of Roddam sitting absolutely still, staring at the review in stunned silence for several long minutes after the meeting, is an image that will stay with me forever. We did bring up the free International link at TIFR-CAM for a short period in June 2012, but without outward connectivity to the various research labs, it could not be used very much. Even so, some researchers who made the effort to travel to CAM were able to download Terabytes of data (from publicly available large databases in the US) within just a few days. Although the scientists lost an important opportunity, I gained a friend in Roddam given that we had spent many hours together during the nearly two years that we worked intensely on this project.

I learnt later that Roddam was no stranger to issues of ethics in the Indian science establishment, through some of the anecdotes he shared. His interests, knowledge and experience were so widespread. I listened in fascination to his description of efforts to teach science in Indian languages/ Kannada, communicating the excitement of science to ordinary citizens, his efforts to revive the fortunes of his alma mater UVCE (University Visvesvaraya College of Engineering) that remains an unfulfilled wish, his thoughts on several aspects of the national education policy and more. In his characteristic gentle and unobtrusive way, he helped me grow as a thinker in the policy space steering me towards taking ever more finely nuanced positions. The admiration and reverence I feel towards him will remain with me always.

Leena Chandran-Wadia is Senior Fellow at Observer Research Foundation, Mumbai and honorary member, ICTS Resource Development and Societal Engagement team.

AMIT APTE

Roddam Narasimha was already a legend by the time I met him first around 2007-8. What was remarkable to me even in the first meeting, and in every other meeting, was the affability and warmth of his personality, somewhat like an academic grandfather. He would welcome even a junior scientist like me with an infectious smile and a friendly handshake, and immediately start a discussion that would invariably reveal his clarity of thinking and his deep understanding of the earth sciences, the topic I discussed in most of the meetings. By the time the meeting ended, one would be left with no doubt why he was such a scientific and intellectual giant.

Over the years, I got to know more about his scientific work in fields ranging from fundamental research in fluid dynamics, to applied aerospace engineering, to theoretical and observational studies in atmospheric dynamics, and his writings about history and philosophy of science – an impressive and inspiring breadth and variety that is certainly rare in Indian academic community, where a large fraction of researchers are content with contributing to a narrow subfield. In each of these fields, he made deep and lasting contributions. Quite importantly to young researchers, he was always eager to discuss his ideas about new avenues to explore. This willingness to help and to share his profound knowledge inspired those around him to start new scientific explorations, knowing that RN would be behind them to guide and support whenever they faltered, an assurance that is now gone but one that continues to motivate all of us.

Amit Apte is a Professor at ICTS-TIFR, Bengaluru

GOVINDARAJAN | *continued from Page 1 ...*

findings. He proposed a 'concentrated breakdown' near x_t. Upon incorporating this into the model, the ensuing intermittency (fraction of time the flow is turbulent) was a universal function of the streamwise coordinate x when suitably scaled. It agreed very well with a host of experiments. A concentrated breakdown is also on sounder theoretical footing than random breakdown.

The fluid dynamics of clouds was in its infancy when Narasimha started working on it. If a rising cloud, effectively a wet plume, behaved like other plumes, it would dilute itself into annihilation. Narasimha showed, by an ingenious cloud-in-the-lab, by simulations and by scaling arguments, that heating due to condensation along its way is key to reducing entrainment, and indeed to the existence of a cloud. Narasimha and his student KR Sreenivasan in the seventies showed that turbulent flow can relaminarize, and showed that acceleration in the flow provided a mechanism. These are just a few examples showing that he set trends rather than followed them.

I had the privilege of being RN's PhD student in the Aerospace Department of the Indian Institute of Science as an external student. I was working then at the National Aerospace Labs where RN was Director. Later, I was his colleague in the Fluid Dynamics Unit, which he founded, in the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR). To me and to all his students, RN was a mentor par excellence. His style was to encourage us to define our own problems and research areas, which meant that he mentored students on a range of topics: nonlinear dynamics, mathematical aspects of fluid dynamics, aerospace, atmospheric sciences and the Indian monsoon. He would nudge us to turn our question into something bigger and better and force us to think about the big picture, and about the connections of our work to questions in other areas. And then allow us to sort it out. He thus raised our standards hugely, while appearing to only mentor from the sidelines. He was so busy in those days that I met him for an average of five minutes a few times a year, but was blown away by his insight every time. On boundary layer stability, I was trying to obtain first order corrections to the answer in a small parameter, epsilon. He saw that the

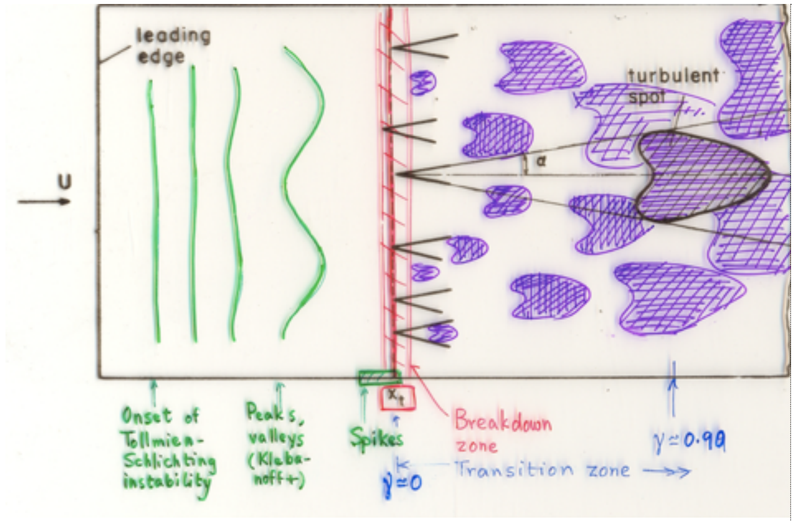


Fig. 1: The story of a single-author paper RN wrote at the age of 24 (On the Distribution of Intermittency in the Transition Region of a Boundary Layer. (Details on Page 1)

effects I was getting were much bigger than O(epsilon), and opined that I had a singular perturbation problem on my hands. Armed with this knowledge, I could derive the correct lowest-order equations for boundary-layer stability, and develop code to predict transition to turbulence over aircraft wings in a few seconds on a PC which were hitherto done on a large mainframe over days. Boeing Aerospace Co. acquired our code and found it useful.

Narasimha was distinguished by his attitude to the conduct of science. The word "rigour" is often used in connection to his approach. He practised rigour in all its forms in his experimental and theoretical work. His meticulous corrections of successive drafts, whether for a publication or merely for circulation within the group, could drive us up a wall, but we learned the value of clarity of expression. He listened carefully, alert to the possibility that the youngest student in the room could be the one who's right in an argument, and may be the one with the best idea. His ethical standards were exemplary and he was correct to a fault in giving credit, even in a conversation. He was happy to be contradicted, and believed in building a deep familiarity with the opposite point of view before criticizing it. His chance statement to me one day, that "We publish when we have something to say" is a principle that I try to follow.

As a postdoc in CalTech, I met visiting professors from many universities, and realised how high in everyone's estimation RN was. He was the go-to person when they faced science obstacles. He was always very generous with his ideas. There is a body of important literature, from different countries, which does not bear his name as author, but which has crucial input from him.

He was decades ahead of his time in many matters. At a time when Bengaluru and Delhi were connected by two Air-India flights a day, he realised that India was soon going to need a huge number of short-haul aircraft, and pushed for turboprops as a great solution. He started the Light Transport Aircraft programme at the National Aerospace Laboratories. He pushed for a Bengaluru-Mysuru bullet train and a fast highway, as a solution to many local problems. RN's inherent sense of democracy and fair-mindedness meant that he incorporated "diversity" naturally in his group, decades before it became a buzzword. He was completely gender-blind and blind to all other distinctions between people. He could therefore deal with people in science, in the government, in administration etc. in a positive and productive way. He made a deep impression on anyone who ever came into contact with him even briefly.

In the eighties and nineties Narasimha taught a famous fluid mechanics course for several hours every Sunday in IISc, which had no text book, no stipulated syllabus, no credits and no exams. A crowd would attend, and would benefit from his unique perspective and mastery over fluid mechanics. He fielded every question with utmost patience.

I would like to best remember him from the tea-table conversations at JNCASR. His original thoughts and detailed investigations, whether on Saki's writings, on Tipu Sultan's rockets, on the dynamics of societies which perceive themselves at risk and a whole host of other topics, were discussed over snacks and several cups of tea, and are testimonies of his brilliant mind, his penchant for reading, and his deep understanding of areas outside fluid mechanics.

One of RN's colleagues termed him a *"gentle giant"* and I hope the reader has understood why. □

Rama Govindarajan works in the field of fluid dynamics and is a Senior Professor at ICTS-TIFR. She is one of Roddam Narasimha's most distinguished students.

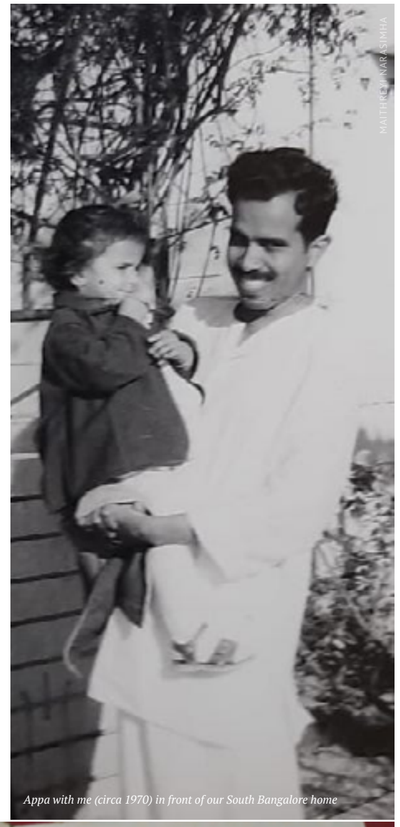
NARASIMHA | *continued from Page 1 ...*

that he admitted he would not have been able to finish had it not been for the lockdown, and had a few papers accepted. He had initiated a Covid project with three of his former students, aiming to analyse cough flows using the framework they had developed to analyse cloud flows. He had promised to write about the future of civil aviation and the aerospace industry in India. He arranged his surgeries (that had to be postponed because of the Covid19 lockdown) to fit between his commitments. He paid rich tributes to his guru, Prof. Satish Dhawan – whom he greatly admired and respected – on his birth centenary, and was full of regret that no one had yet written his biography. While in the intensive care unit on one of his hospitalisations, he kept looking at the clock like the white rabbit in Alice in Wonderland: 'it's getting late', he said, and kept asking to be allowed to go home. It became such an obsession that the duty doctor had the clock taken off the wall. In between, when it looked as if he was getting better, I lured him with the prospect of making a trip to Bombay to collect an award that had been conferred on him, if he ate better and got stronger. His enthusiasm for travelling on an airplane again was like that of a child who had never been on one before. 'Let's book tickets', he said. (Just over a year earlier, he had been disappointed - even a little jealous of the others who had - that he had not been offered a 'ride' on the 'Tejas', the indigenous Light Combat Aircraft that he had made a case for and had played a key role in designing forty years earlier). On an optimistic day in hospital during his final stay there, I would lead myself in to believing that he would wake up after he had rested enough and then say 'let's go, I have a lot of work to do'. I did not inherit his optimism. This time round, I think he also lost his.

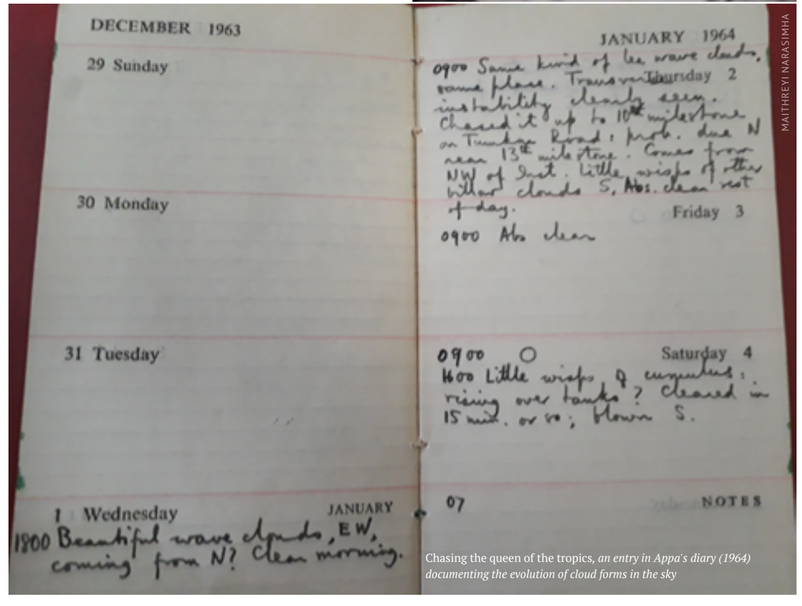
Appa will always remain my favorite person, my gentle guide. He was the standard against which I measured other fellow humans. In all these years, no one I have known has come close.

Appa grew up in a fairly large joint family with his parents and siblings and his father's brother's family (with whom Appa remained very close) in south Bangalore. After a year spent in Glasgow when I was just over two years old, we moved to Bungalow 11 on the campus of the Indian Institute of Science (IISc, the place I call home). My first memories are almost certainly reconstructions from photographs and audio recordings of our conversations that Appa made when we were in Glasgow. Years later, it amused me to hear myself say in a strong Glaswegian accent, *'I am a wee Scottish lass'*, and when we were both in England in the early 90s, we revisited old haunts in Glasgow. During my school years, Appa made me feel comfortable being different even though it often got me in trouble, or brought down the number of marks I scored. *'You don't say Bala Miss, you say Miss Bala'*, I would go back to school and say. He made it a point to correct me when he saw I got something wrong, and to gently explain why it was wrong. When school closed for summer, he designed holiday homework to keep us (me and my sister Aditi Simha, who sadly passed away two years ago) busy. Every morning, we would go eagerly with our books - old 'Senate Papers' of the Indian Institute of Science, thick, matte, light green sheets that were cyclostyled on one side and were ideally suited for painting - and he would write down for us a list of activities for the day. This would typically include making observations on the trees and plants on campus, as for example describing how the 'propeller seeds' of the Mahogany tree (that line Mahogany Marg behind the Faculty Hall at IISc) fall, or counting the number of spirals that make up the bracts of a pine cone we had collected on a holiday in Kashmir, or watching the unpredictably graceful plumes emanating from lit incense sticks. It would be followed, when he returned home from work in the evening, with an explanation for why they fall the way they do or why those numbers are interesting, and making us aware that there are many things that we don't fully understand. He introduced us to Sanskrit: we would read and write down verses from the Bhagavad Gita (Mahadev Desai's *'The Gita according to Gandhi'* was a favourite) and would learn the meanings of words, how they must be parsed, and also how sentences are constructed. Appa was recently surprised (when we were looking at the new verses from the Yoga Vāsiṣṭha that he had just translated) that I still remembered: he had forgotten that he had taught us. He encouraged us to paint what we saw around us – the trees (mine), the birds (Aditi's) and elegant buildings became our passions. Years later, we had our versions of the Faculty Hall at IISc, our house on S. Hill Ave in Pasadena, and the Round Church in Cambridge. He taught us to consult books when we needed to find answers and we built a huge collection over the years, a substantial part of which I still have. From his trips abroad, he brought back kits that allowed us to build things (like the burglar alarm we put together in our room at home to warn us that someone was coming in), and we became proud owners of a Timex Sinclair ZX Spectrum in the very early days of home computers. We travelled with him on his sabbatical visits to Caltech and Cambridge. He had himself wanted to travel the world (and did a fair share of it after his student days at Caltech: he did not think then that he might have an opportunity to do it again), and wanted to introduce us to new worlds and cultures and make us aware of the differences. Appa also took us along on his curiosity driven adventures, as for example, to find the mango groves in Srirangapatna where Tipu Sultan's superior rockets had fallen and claimed its first British victims, the subject of his millennium essay for Nature (1999) more than a decade later. It was only much later that I realized that what seemed like a lot of fun and very different from what we learnt in school was his gentle way of inculcating in us a sense of wonder, curiosity and inquisitiveness about the things we see and hear around us and showing us how to interrogate, interpret and understand them. He also instilled in us fearlessness in exploring the unknown. This has given my life meaning (and also provided a means of livelihood!) and for that, I will remain forever grateful.

Appa firmly believed that each of us has to find our way in the world and to enjoy the journey. He introduced me to Hermann Hesse's Siddhartha when I was in my late teens (and Hesse's other works became a topic of discussion between me and Aditi over the years). Without being forced, I organically made the decision of making 'doing science' my profession - I really did not find anything more interesting or worthwhile - and found myself paying a lot of attention to how Appa did things. Appa loved to work more than anything else. He worked on a lot of things and did not squander any time. Any suggestion from me that he was working too hard would be met with the clarification that he was not always doing hard work. I realized that what he called 'soft work' was just hard work that he was not paid to do. All his insightful work on the history and philosophy of science, and his interest in understanding Indian philosophy through reading Sanskrit literature (which sparked my interest in history and philosophy) fell into this category. These were his solo pursuits and were as scholarly as his works on fluid dynamics. Appa was a true polymath. He did everything he did with an unparalleled seriousness, and delved very deep. He took his time but made it matter. It saddens me now to see how little scholarship is valued in today's impatient world where flashy snippets rule the pages. He also liked to work on complex problems, and we often debated over dinner which was messier, biology or fluid mechanics, especially after my interest veered towards understanding tissue dynamics and mechanics, and he got interested in the kinds of problems I was looking at. He spent time picking the right word, often consulting the dictionary (Monier-William's Sanskrit dictionary was a favourite, the only work I have heard him refer to as scholarly), and edited drafts over and


MAITHREYI NARASIMHA

Appa with me (circa 1970) in front of our South Bangalore home



MAITHREYI NARASIMHA

Chasing the queen of the tropics, *an entry in Appa's diary (1964) documenting the evolution of cloud forms in the sky*

over again. The end result was beautiful, often magical. He loved to talk to almost anyone who would listen to him and ask him questions - school children, brothers, cousins, nephews, nieces, students, colleagues, his driver - and some of his colleagues made it a Saturday ritual (supplemented with visits on his birthday, and on Ugadi and Vijayadashami to receive bevu bella and shami patrak) that he looked forward to. He readily accepted invitations to speak- he spent a lot of time preparing even for the smallest of occasions - and when he spoke, his passion was infectious. Suddenly, people began to see clouds in a different light (as my late colleague, Prof. Veronica Rodrigues who heard him speak about the 'queen of the tropics' confessed to me)! When I once suggested he should learn to say 'no' more often and reduce his commitments, he explained to me his philosophy: he felt his mission was accomplished even if one person in an audience got something out of what he had said. He loved his students, and talking to them about all the things that interested him (often while they had lunch and tea, and more recently on the phone or by email) was, I think, his favorite pastime. He was very proud of their achievements and aspirations and could not stop singing their praises when he received the Nature mentorship award this time last year. He was very moved that they had nominated him for it. They adored and respected him in return (he was fondly called Meshtru, the Kannada word for teacher) and many became and remain his best friends. They were deeply concerned about his health, and some told me recently that Appa was like a father to them. Many, despite the difference in age, also became some of my early friends. Appa also felt deeply indebted to all the people who helped him with instrumentation, administration, drawings and manuscripts, some for all these years. He treated them as partners and held them in very high regard.

Appa led and directed institutes, missions and programs, far many more than I was aware of until a few weeks ago. I never once heard him talk about empowered committees or protocols. We never discussed the politics of doing science but spent a lot of hours over the years lamenting about the direction that 'scientific pursuit' was taking: it's conversion from a passionate hobby and profession to a cut-throat business, the emphasis on quantity, the lack of appreciation for scientific creativity and deep scholarship, or for tackling tough problems of fundamental importance. In recent years he expressed concern, tinged with a sense of guilt and sadness, that he may not have prepared us for survival in today's world. I assured him that I enjoyed doing what I enjoyed, and that I was comfortable with being different.

I feel privileged to be his daughter and fortunate that the pandemic allowed me to spend quality time with him after a gap of almost thirty years. But there was so much more I wanted to ask and know. □

Maithreyi Narasimha is Professor of Biology at the Tata Institute of Fundamental Research, Mumbai.

Appa receiving the Nature mentoring award in 2019

PROGRAMS

All programs were held online

Dualities in Topology and Algebra
1–13 February 2021 ✦ *Organisers* – Samik Basu, Anita Naolekar and Rekha Santhanam

Nonperturbative and Numerical Approaches to Quantum Gravity, String Theory and Holography
18–22 January 2021 ✦ *Organisers* – David Berenstein, Simon Catterall, Masanori Hanada, Anosh Joseph, Jun Nishimura, David Schaich and Toby Wiseman

Advances in Applied Probability II
4–8 January 2021 ✦ *Organisers* – Vivek S Borkar, Sandeep Juneja, Kavita Ramanan, Devavrat Shah and Piyush Srivastava

Statistical Biological Physics: From Single Molecule to Cell
7–18 December 2020 ✦ *Organisers* – Debashish Chowdhury, Ambarish Kunwar and Prabal K Maiti

Turbulence: Problems at the Interface of Mathematics and Physics
7–18 December 2020 ✦ *Organisers* – Uriel Frisch, Konstantin Khanin and Rahul Pandit

Winter School on Quantitative Systems Biology: Quantitative Approaches in Ecosystem Ecology
30 November–18 December 2020 ✦ *Organizers* – Antonio Celani, Jacopo Grilli, Simon Levin and Matteo Marsili

Recent Developments Around p-Adic Modular Forms
30 November–4 December 2020 ✦ *Organizers* – Debargha Banerjee and Denis Benois

Less Travelled Path of Dark Matter: Axions and Primordial Black Holes
9–13 November 2020 ✦ *Organizers* – Subinoy Das, Koushik Dutta, Raghavan Rangarajan and Vikram Rentala

Physics of the Early Universe - An Online Precursor31 August–3 September 2020 ✦ *Organizers* – Robert Brandenberger, Jerome Martin, Subodh Patil and L Sriramkumar

Knots Through Web
24–28 August 2020 ✦ *Organizers* – Rama Mishra, Madeti Prabhakar and Mahender Singh

Compact Stars and QCD 2020
17–21 August 2020 ✦ *Organisers* – Manjari Bagchi, Sarmistha Banik, Sudip Bhattacharyya, Prashanth Jaikumar, V. Ravindran and Sayantan Sharma

DISCUSSION MEETINGS

All Discussion Meetings were held online

Multi-Scale Analysis: Thematic Lectures and Meeting (MATHLEC-2021)
15-19 February 2021 ✦ *Organisers* – Patrizia Donato, Antonio Gaudiello, Editha Jose, A.K. Nandakumaran and Daniel Onofrei

Thirsting for Theoretical Biology
11-22 January 2021 ✦ *Organizers* – Vaishnavi Ananthanarayanan, Vijaykumar Krishnamurthy and Vidyanand Nanjundiah

Extreme Nonequilibrium QCD
5-9 October 2020 ✦ *Organizers* – Ayan Mukhopadhyay and Sayantan Sharma

OUTREACH

Kaapi With Kuriosity has been temporarily renamed. All talks are held online

KURIOSITY DURING QUARANTINE

Symmetries of Nature and Nature of Symmetries
24 January 2021 ✦ *Speaker:* Rohini M. Godbole *(Indian Institute of Science, Bengaluru)*

Kolam: A Western Perspective
13 December 2020 ✦ **Speaker** — Claudia Silva *(Photographer & Videographer)* and Oscar Garcia-Prada *(Institute of Mathematical Sciences, Madrid)*

Can forests in India influence rainfall?
22 November 2020 ✦ *Speaker* — Jagadish Krishnaswamy *(Ashoka Trust for Research in Ecology and the Environment, Bengaluru)*

Cosmic Whisper from Binary Black Holes
18 October 2020 ✦ *Speaker* — Archana Pai *(Indian Institute of Technology, Bombay)*

Agents of Change: The Role of Catalysts in the Modern World
26 September 2020 ✦ *Speaker* — Shobhana Narasimhan *(Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru)*

A Life of Resonance with Quantum Matter: P.W. Anderson
23 August 2020 ✦ *Speaker* — Ganapathy Baskaran *(The Institute of Mathematical Sciences, Chennai, IIT Madras,* and *Perimeter Institute for Theoretical Physics, Waterloo, Canada)*

VIGYAN ADDA

Vigyan Adda is a forum through which academics from ICTS and other similar institutes and universities can explain their scientific work to broader audiences, or engage with the public on scientific and mathematical topics of interest. These talks are aimed at people with a background in science, undergraduate students would get to know about current scientific developments in a lucid way.

Black Holes and the Reversibility of Time
22 December 2020 ✦ *Speaker* — Suvrat Raju *(ICTS-TIFR, Bengaluru)*

RAMANUJAN YATRA LECTURE

ICTS-TIFR was one of the organisers of the special lecture 'Gems of Ramanujan and Their Lasting Impact on Mathematics' by Manjul Bhargava (Princeton University, USA) on 22 December 2020. This event was held in collaboration with Vigyan Prasar to celebrate National Mathematics Day. The event was also part of the Ramanujan Yatra program.

SREENIVASAN | *continued from Page 1 ...*

big and small. That was not to be [1].

I remember someone exclaim once, "What use are flowers when one can no longer see, feel or smell them?" Thankfully, RN did get many metaphorical flowers when he was alive; and those flowers will keep coming, for such was his admirable personality. I myself have written two articles on him since December 14, one with Professor G.S. Bhat [2], and have the honor of having agreed to write a few more in due course, devoted largely to his scientific work. Here, I will record a few personal memories to reflect mostly on his research group in the 1970's. I had known RN for some 52 years, and was his student formally for a few of them. The technical material I learnt long ago from him is now buried under increasing layers of other material and ideas, but what he taught me by example on the kernel of a science career — about balancing internal enjoyment with external approbation, and appraising one's obligation to one's country or institution with one's personal achievement — has always stayed with me. Thus I never stopped being his student. There is no way to express all the thoughts that flood my memory — no matter how many pages I write; for me, he was and will always remain exemplary and nothing I say, here or elsewhere, should be construed to mean differently. If he had certain foibles, which he did, he transcended them by the essence of his humanity that elevated him to a higher stratum.

Most of what I say here is my personal experience; so I will insert myself often but make no apologies because of the pleasure I find in recalling our association: he was an integral part of my consciousness for very long. But I will try to move self-adulation to end notes to reduce their offense; but you will get a better glimpse of RN (very partial though it will be) if you don't skip them. Also know that RN's style changed somewhat with time — no one is the same between 35 and 85 — but he remained steadfast and effortless in personal dignity and grace.

How RN entered my life

I heard of RN for the first time in 1968 as a final year engineering student in University Visvesvaraya College of Engineering (also RN's alma mater). Professor N. Rudraiah, then teaching us a course on PDEs, tried to entice me to work with him for my Ph.D. [3]. I told him my desire to join the Indian Institute of Science (IISc), and he rhetorically asked, "Who is there in IISc?" and continued to answer it himself, "Of course, there is Narasimhan in aeronautics". He thought that RN's name ended with an n (and I knew no better then).

I did submit my application to study aeronautics at IISc [4] and, as a 'safety school' (though that phrase had not yet entered my vocabulary), I applied to IIT Kanpur (IIT-K) as well. Unlike IISc, where I was admitted with no interview, IIT-K asked me for a visit and interview. Professor V. Vasanta Ram, who moved to Germany a few years later (and remains an excellent friend), asked me a few questions in the interview on boundary layers. Undergraduate education of those days included little on boundary layers, but even my minimal knowledge and how I approached his questions were enough to impress him. He immediately invited me to join IIT-K. In a longer discussion in his office when I revealed my intentions, he said he had no quarrel if I chose IISc, by adding: "There is Narasimha in aeronautics, and he is VERY good". His emphasis on the word VERY was strong and wistful and made a far greater impression on me.

RN with the technical staff who ran the high speed lab

By the time I ended up at IISc a few months later, I had heard more of this famous man, educated at Caltech and regarded as a genius. At some point during the orientation week when different faculty members introduced us to different aspects of the department, in comes a young man in short sleeved shirt with bold checks [5], opening the door by leaning on it with extra energy and a forward-leaning angle, who went on to speak technical things without a single informal word. That was RN. He was all business (and hadn't turned up at the earlier informal faculty introduction session). He spoke about the area-rule for transonic airplanes that the cross sectional area along the airplane axis should vary smoothly for low wave drag. I later learnt that he was consulting for HF-24 at that time, and there were discussions about it in that context. But I cannot forget the bright twinkle in his eyes or some of his mannerisms [6]. Over time, I took 3.33 courses with him [7] and learnt a lot. I had already seen some good teachers in action by then, but no one who was also a world-class researcher measured up to the quality and clarity of his teaching.

My research apprenticeship with RN

I decided to ask RN to be my research supervisor for the final semester project. My approach was hesitant because a few encounters had revealed my inadequacies to him [8]. As luck would have it, he had just finished grading the turbulence final exam when I went to his office. He expressed disappointment with the general performance but declared that I had done much better. That was how, I believe, he readily agreed to my overture. Thus began my research apprenticeship with RN; as I already said, it never ended.

To my dismay, however, measurements and theory in my ME thesis did not agree with each other [9], but RN must have seen some merit in it and gave it a good grade. Overall, I ended up doing well as a Masters student, so most professors advised me to go abroad; I did indeed write for applications from Caltech and MIT, but was sufficiently enamored by RN by then. It wasn't obvious, however, that he would accept me as a Ph.D. student [10]. When I did ask, he said that S.M. Deshpande had just been appointed a lecturer and needed students, so why don't the two of them supervise my thesis together? I already had excellent interactions with Deshpande, who had taught us kinetic theory of gases; since I had developed a keen interest in the subject, I said yes, though, to my regret, I ended up doing nothing with him.

Before I say more, let me describe a bit about RN and his research group, and the general intellectual ambience at the time. He was not yet the national figure that he later became but his reputation as a scientist was in full bloom. He had gathered around him [11] a number of bright people (A. Prabhu, S.M. Deshpande, S. Vasanth, K. Narahari Rao, M.R. Anantasayanam, K. Yegnanarayan, P.R. Viswanath, G. Srinivasan, P.V. Subba Raju, among others), each pursuing a different research problem; others like H.S. Mukunda and N. Ramani were close by. I took courses in statistical physics, functional analysis, measure theory, and control theory (though none was required), and had gotten to know some of those professors. Professor M.A. Badri Narayanan (Badri) treated me as an equal. RN had put on my thesis committee Professor N. Kumar from Physics, who had just arrived on the Campus. Kumar was convinced that the turbulence researchers were not taking advantage of the progress made in critical phenomena, though I never heard about renormalization methods from him (Ken Wilson's Nobel Prize was still some eight years away). But his questions have been on my mind ever since. Altogether, the atmosphere in IISc at the time was hugely stimulating; essentially anything I wanted to know, there was always someone who knew it better. (Not everyone felt that way, however).

Until he moved to the IISc campus, probably around 1973, RN would arrive at work around 9:30 AM. He drove his two wheeler, a Lambretta, from his home in Jayanagar, and the trip would take him almost an hour (especially because he would never cut corners in driving); he would work until about 7 or 8 PM in his office. Except for one or two short breaks, he spent no time on gossip and politics. He would eat lunch, brought from home, alone in his office, entertaining himself with Physics Today or some such magazine [12].

RN's style of supervision was not to intervene too much. He left the student (all male at the time) to pursue research at his own pace. There were no formal group meetings at which each student was required to present his progress but he was available for discussions during tea time, around 3 PM each day, in the High Speed Lab, during which there would be many free discussions. (I myself went there only occasionally partly because I have no use for coffee or tea and partly because that mid-afternoon hour broke up my concentration). Especially if Badri prevailed on him, RN might go to the cafeteria for a cup of coffee around 5:30 again, and the conversation there would be free-wheeling. Otherwise, he might perfunctorily ask, "How are things?" and move on; he mostly got involved when something interesting and concrete had emerged.

RN never pressed anyone to hurry but I suspect that he kept score in his head. If he felt a student was capable, he drew him into various projects besides the main line of work. He drew me several times into such projects — collecting existing data on the effects of free stream turbulence on the transition Reynolds number, specific aspects of the thesis work of Prabhu and Narahari Rao, shock structure problems [13], etc. The rich experience I had in working with him on sonic booms produced ten or so reports for the Department of Science and Technology [14]. He allowed me to do anything I wanted — experiment, theory or numerical work. At the end of some four or five years, I felt ready to tackle any problem; while that may have been to some degree a false supposition on my part, that confidence was unquestionably the result of my interactions with RN [15].

My own progress in the first two years was quite rapid. Ironically, much of that occurred when RN was away on a year-long sabbatical at Glasgow around 1972. I would write him a monthly hand-written letter during this period, detailing the progress, with graphs and equations, and he would promptly write back in his meticulous handwriting. It was in this way that we drafted a long paper for the Journal of Fluid Mechanics (JFM). When it was nearly ready, however, I discovered to my horror an error I had made, which literally shook me up. The error made little difference to the asymptotic state with which the paper was mostly concerned, but had a huge impact on how that state was approached. I corrected the error, redrew the figures, and wrote my next letter with full-scale self-recrimination. RN wrote a kind and consoling letter. The draft of that letter, which was inadvertently tucked away in one of his books that I later borrowed, was much more personal and spoke about the time he had made an error himself. (I never asked what it was.) When I read that draft, I was pleased that he felt close enough to me to think of writing that way, and also somewhat peeved that he cut out those personal remarks in the version that he did mail; the draft version would have relieved my anxieties enormously.

The paper was submitted soon after. When he came back from the sabbatical, RN asked me to write up my thesis, but I refused because I had received too much help from him in writing that paper, and wished to do something on my own. I argued that I had done nothing important and my results were quite obvious [16]. In a relatively long conversation that ensued, RN taught me how to recognize the value of my own work, how many original ideas often appear obvious in hindsight, etc. I have cherished that tutorial all these years — for it has served me well.

Then RN told me his story, which he later recorded in his interview for Bhavana [17]. Here it is, edited for brevity. "At Caltech, I did the problem on jet noise and actually worked with a visitor from MIT, Professor Erik Mollo-Christensen... We finished that work and published it in JFM...I was quite surprised when Liepmann [RN's thesis advisor] said, "You know, if you want to get your degree, you can write your thesis on it. And then stay here as a postdoc." But I said, "Well, I think that I need to do some more and I need to learn something more." And at that time, he was beginning to work on low-density gas dynamics and had set up a research program in rarefied gas dynamics, and I said I would like to work on that subject. I offered to make an attempt toward the free-molecule end of the continuum." This is the subject on which RN ended up writing a few single-author papers as a student and ultimately his Ph.D. thesis.

Distant interactions

Prabhu was in Sydney working with Professor Robert Antonia around 1973-74 and had recommended me as his replacement as he was returning to IISc. I thus received an unsolicited offer from Sydney and went there as a postdoc, though my thesis had not yet been approved formally, and though going abroad was a low priority trajectory for me. RN visited me in Sydney and I visited him in Adelaide. The formality between us was eroding, especially after RN discovered that Bob and others had formed a good opinion of me in those few months [18]. At that point, he advised me to go to the US for some time. His essential point was that one develops complete confidence only when one interacts with the very best people outside one's zone of comfort; it doesn't serve one well whether one underestimates oneself or revels in inflated ego (not his exact words).

So I went to Johns Hopkins University which at the time had probably the best collection of contemporary greats in mechanics. There used to be many seminar visitors as well. As RN had implied, nothing gave me greater confidence than my interactions at Hopkins. I have recorded elsewhere why my efforts to return to India didn't materialize at that time [19]; I joined Yale instead and stayed there for almost 22 years.

RN was soon appointed as the Director of the National Aerospace Laboratory (NAL). New initiatives and other matters of national importance kept him very busy. It was difficult to maintain a sustained scientific interaction from a distance, but we did talk enough about fluid dynamics that we even managed to write a paper together [20]. RN tried to get me to return to Bangalore twice, once very seriously, but circumstances would not permit it. (I bantered on both occasions by quoting a remark of Klaus Gersten that I was his fluid dynamics heir in Bangalore, wherever I lived).

Our contact before his NAL years was mostly through airmail. During his NAL days, he would rapidly shoot off a fax, sometimes following it up with a detailed letter as time permitted. After he adopted email, our correspondence became more frequent and the diversity of topics increased. His last serious email (September 24) was about our joint nomination of a colleague for an honor. He was gracious to his last working day.

RN's impeccable scientific reputation

Let me comment on the impeccable scientific reputation that RN cultivated and sustained diligently. I will relate two instances, both told to me by RN himself, and add a third.

As a student at Caltech, RN once attended a scientific talk at a meeting in Berkeley, related to his recent paper. The speaker, a distinguished professor from MIT, unaware that RN was present in the talk, began by telling the audience, to RN's horror, that RN's work was wrong. Devastated (as he said in [17]), he drove back to Caltech and related this to Liepmann, who asked him to discuss it with two experts in the department. Both experts certified RN's work, whereupon he convinced the speaker about errors in his calculations, resulting in the latter withdrawing his paper. From then on, RN could do no wrong at Caltech!

After his return to Bangalore, RN submitted a paper to JFM. George Batchelor was the editor. During the refereeing process, George discovered another paper submitted on a similar topic by a different author, X, also to JFM. So George sent RN a rejection letter with a somewhat unfriendly comment on the overlap of material with X's. What had transpired was that RN's JFM paper was built on an unpublished report that he had earlier written and circulated. RN took George's letter seriously, and carefully documented his priority. To his credit, George inquired into it and found that it was accurate: X apparently agreed that he indeed learnt about the problem first through RN's unpublished report, found the problem interesting and made progress on his own, assuming that RN had no interest in developing it further. He withdrew the paper, and RN's got published. It was clear that George was very impressed with RN after

this, and remained a fan all his life.

I will cite another instance. A difficult paper was once submitted to JFM. Its author was well-known but new to the field so the paper was unorthodox. George asked Don Coles at Caltech to serve as a referee. Don said that he couldn't do it but listed three alternatives, with RN at the top of the list; the other two were from Harvard and Stanford. And Don added that, while any of those three could competently review the paper, his personal confidence in their opinions would go down by an order of magnitude each time one went down the list of three! (Don told me this story himself.) One cannot beat the impact of such informal opinions that prevailed about RN at powerful places such as Cambridge and Caltech. By the way, RN had a hearty laugh when I related Don's remark to him (and even agreed that it may have been right).

Within IISc, RN's reputation was spectacular. It helped that Satish Dhawan, with whom he had worked before going to Caltech, thought the world of RN but he had independently built his reputation — e.g., in the Electrical Communication Engineering department when he worked on nonlinear strings [21], at NAL where he consulted [22], etc. He was conscious of the high reputation he enjoyed; his desire to sustain it only reinforced his inherent tendency to be careful about what he said and how he said it. Rarely did his work become controversial but on the few occasions it did, he reacted with uncharacteristic vehemence, spending enormous amounts of energy and effort on it. He generally believed that once an interesting result is published, people will not allow the author the freedom to further develop it at his own pace.

He felt this pressure more because of his "Indian address". He himself did not suffer much in being able to publish his papers wherever he targeted them, but it was clear to him that not all his work was cited as often as the quality and quantity deserved. Part of the reason is that he deliberately avoided publishing in fashionable areas; in part, he was a proud individualist with a particular sense of how papers should be written, which made it difficult for him to be part of a group other than his own. And there could be no Lifschitz to his Landau.

Until he took on heavy-duty administration, RN would write and rewrite his papers, often going back and forth on the same word. He later became more easy flowing with his writings, and the charm that required greater effort at one time came to him with more naturally. If he earlier felt that he shouldn't publish more than a certain number of papers in a year, he relinquished that policy later. I am not at all saying that he lowered his standards, but came to depend a bit more on his intuition for the subject, allowing a greater role for his creativity to flourish [23]. He loved the art of writing well, enjoyed seeing his papers published (as he had told me himself), and cherished the many honors that came his way – for none of which he craved. One can ask: how did he manage to do so much in his life? He worked hard, no doubt, but the real answer is that he was simply gifted – by divine grace, if one chooses to look for a spiritual answer.

Closing remarks

I began with the statement that RN was amazingly productive and intellectually active until a few weeks before his death. It is an honest statement, but in truth he was exactly not the same since his younger daughter, Dr. Aditi Simha, passed away about two years ago. The agony that it caused the family was immense. A little before Aditi's death, RN had agreed to write a letter of reference for me but, of course, he did not. When I saw him not long after, he apologized for dropping it. He knew that I didn't expect it under the circumstances but was answering to a higher calling of responsibility.

In all the years I knew him, RN was impatient with me only a few times. Once in the draft of a joint paper, I had cast a mildly benign doubt on an earlier result of his. He cut it out and sternly rebuked that I should write separately if I felt that way about it, but should not implicate him. Needless to say, I dropped the sentence and did not develop that theme, either. RN often used me as a sounding board on his draft reports and papers. It was marginally beneficial to him, more so to me because it taught me how to write well. One time, I presumed too much and inserted a "correction" everywhere in his draft document. He said, *"I don't know which dictionary you use, but my dictionary says I am right."* I was mortified because he was indeed right and I hadn't checked it before making those entries! Once I was upset with him because I felt that he was not doing enough to hold his group together at IISc (this was after I had left Bangalore); and another time when he uncharacteristically put himself down on a certain personal matter. Who the heck did I think I was to tell him ANYTHING, however well meant? When I later brought up these events, mainly for cathartic reasons of my own, he remarked with characteristic magnanimity that he didn't remember them. I believed him; I believed him on everything. □

Endnotes

[1] His last email was dated September 24. I continued to write periodically almost until he died. When possible, my mails were kindly read out to him by his daughter, Professor Maithreyi Narasimha, who would relay RN's response—which could just be a smile. The last concrete letter he wrote was on September 19 and is reproduced here:

"Dear Sreenivasan,

Thanks for your email. Did you hear Kasturirangan's talk? He has read your Bhavana article (excellent, by the way), and quoted your reference to that well-known sloka from the Yaksha-Prasna, very appropriate for the occasion!

Best wishes, RN."

[2] K.R. Sreenivasan and G.S. Bhat, *"Roddam Narasimha (1933)-(2020)"*, Curr. Sci. 119, 2027-28 (2020); K.R. Sreenivasan, Frontline: India's National Magazine, January 15, 2021. For a more complete account of RN's life and work until 2014, see G.S. Bhat and K.R. Sreenivasan, *"Living Legends in Indian Science: Roddam Narasimha"*, Curr. Sci. 107, 297-305 (2014).

[3] Professor Rudraiah, with whom I remained on affectionate terms until his death, told me that he was impressed because I was the only one in his class who attempted to solve by an approximate method a nonlinear differential equation he posed as a test. My attempt was the first step in Picard's iterative method, about which I knew nothing then; he went on to teach it the next day, making a reference to my incomplete attempt.

[4] Unlike RN, who had loftier reasons for choosing aeronautics, as he himself described elsewhere, my only reason was the angst I felt for the design philosophy in other engineering disciplines, as I had understood it, where a factor of safety was always necessary and the prevalence of coefficients of ignorance was overwhelmingly common. I have begun to appreciate their need better over time but as an idealist young student who assumed that most things were capable of being calculated exactly (I don't know whence this idea had emerged), I knew that aeronautics by necessity was ahead of other disciplines; that aerodynamics, in particular, was closer to physics and mathematics, which I had loved as a student.

[5] RN almost never wore jacket and tie during those years. He had at least one suit stitched before he went to Caltech but was influenced in his sartorial style by his Caltech colleagues. Before going abroad in early 1975, I applied for a bank loan and mentioned the loan amount to RN in passing. "Why so much," he asked. I said, X for my airfare (which to Sydney wasn't all that much) and Y for two suits. He said, "NO, NO, do not make that mistake. You won't use those suits there, and, in any case, the style will be different,"—perhaps the only time he intervened in my personal decisions. So I eliminated Y and almost halved my bank loan. RN kindly guaranteed that loan, which I repaid within a month or two, to his delight at my promptness.

[6] Bright eyed he always remained. RN's mannerisms in those days appeared a bit unusual to many of us. The decibel level of his speech would fade towards the end of his sentences, he would lean forward resting on his fists over the lectern when he wished to emphasize a point, etc. His accent was not typical Indian then (could have been blended with some California version) but it became more Indian with time.

[7] Three of them were on Gas Dynamics, Turbulence and Advanced Fluid Mechanics; the 0.33 part was on the kinematic of fluid dynamics.

[8] In one class I pedantically insisted that he should have used Fourier Integrals instead of Fourier Series. He was slightly miffed but, true to his character, reviewed conditions for both in the next class, occasionally directing disarming smiles at me. Another time, I annoyed him by pretending to know more about spherical harmonics than I did. A third time, I went for a discussion on bulk viscosity (and showed off my newly acquired knowledge of tensors and symmetry principles), and he demonstrated in a flash how stupid my question was—yes, there are some stupid questions—and almost pushed me out of his office. Looking back, I think he put up with me because I also made occasional sense.

[9] The problem that he suggested could be either experimental or theoretical—but he gave no guidance on how to proceed on either aspect. I remember my embarrassment when I made a conceptual blunder the first time I discussed my theoretical progress. I rapidly corrected and persisted, but began to wonder if I was cut out for theory. On the experimental part (which I voluntarily decided to include as well, with RN's approbation), V. Ramjee (later a Professor of Aeronautics at IIT Madras), then a Ph.D. student of Professor M.A. Badri Narayanan, showed me how to make and operate hotwires; but it was clear that I was a benign nuisance to him, instead of being a resource, causing diffidence in my experimental proficiency, as well.

[10] In those years, RN had enough number of excellent students and didn't need another; I was just fortunate that he acceded to my request. He was also very conscious of his time and made known his preference to work on his own during morning hours. And he worked diligently. Almost no student went up to his office to see him but would wait for the coffee/tea hour. Since I didn't participate much in that ritual, I would unceremoniously barge in to his office whenever necessary; I am grateful that he never displayed any annoyance. My belief is that he didn't keep to his morning-hours rule as rigorously in his later life.

[11] I recently learnt that the older members of this group were put together by Dhawan just before RN joined IISc in 1962. RN recalled that it was the best thing that Dhawan did for him.

[12] During those years RN did some light reading; I had seen him with Perry Mason, Sherlock Holmes, etc. Once I lent him my copy of a thick book on modern poetry in Kannada, which he returned some weeks later, with a few comments that showed familiarity with at least parts of it. He later preferred to read philosophical works focused on analytical aspects (less on spiritual goals) and historical accounts. I remember two brief discussions with him on East Asian history, none on philosophy. RN was present at a conversation with Prabhu many years later, but chose not to participate except by benignly smiling at us both.

[13] GS had, for some two years, been working on the structure of strong shocks (which was to be the extension of RN's work on the structure of weak shocks, published some years earlier in JFM). GS was stuck somewhere but no one had determined where. I volunteered to look at his work and immediately found a trivial error, and reworked a good part of it quickly. I think that it established my research credibility; in fact, my friends thought I was well into my thesis already, especially after GS left for the US for his Ph.D. (alas, he is no more). But I had also been working on relaminarization as a side project to the Ph.D. thesis of K. Narahari Rao. I showed RN some preliminary results and the progress thereafter was sufficiently promising that we together made a de facto decision to give up the shock problem. Years later, RN and P. Das completed the problem ("A spectral solution of the Boltzmann equation for the infinitely strong shock," Philos. Trans. R. Soc. London, Ser. A 330, 217, 1990). Once I tactlessly reminded RN of my early involvement in the problem and caused him needless embarrassment because he had forgotten about it.

[14] Around 1973, the Department of Science and Technology asked RN if he would agree to assess the effects of supersonic flights over India. He took it on only after confirming with me that I would assist him (for zero money, of course!). I wrote up a long report. RN read it and suggested that it would be better if we broke it up into smaller reports, and so we produced about a dozen of them (which formed the basis for banning supersonic flights over India). In the meantime, unbeknownst to me, he had asked Pergamon Press about possible interest in publishing our work as a book, and showed me the enthusiastic response received. So I was put to the task of reassembling the reports into a cohesive single book. But my effort did not satisfy RN's sense of perfection, who promised a revision. I went to Sydney in the meantime, and the revision never came through.

[15] I write this note for young readers whose research career is ahead of them. By the time I completed my engineering degree, I was brimming with confidence mostly because there was no exam until then in which I hadn't excelled. Facing a person as bright and deep and articulate as RN had a perceptibly intimidating effect on me, and it was only after doing a few things on my own that my confidence began to be restored. H. Blasius (known for the Blasius Boundary Layer on a flat plate and the Blasius Theorem for calculating forces on a two-dimensional body) gave up research by stating that both his good ideas came from his famous advisor, L. Prandtl. Luckily, I didn't fall into the Blasius trap. It is important to associate with the very best people but, at the same time, beware of the need to give your very best!

[16] RN seemed to know the answers to every question I posed, partly because he was very good at thinking on his feet; partly also because he had been thinking about relaminarization for some years already, though in the different context of Badri's experiments. Badri wrote his Ph.D. thesis as Satish Dhawan's student but received most help from RN. Incidentally, when the external reports on Badri's thesis did not arrive even after a year, a brief investigation revealed that the airplane that carried Homi Bhabha and had disintegrated over the Alps also carried Badri's thesis as well. More copies were made and dispatched promptly.

[17] Bhavana interview: https://bhavana.org.in/roddam-narasimha-part2/. Part 1 of this interview is also worth reading.

[18] RN was delighted whenever anyone spoke well of his students, but was reluctant to have to be the only one to say good words about them. The reluctance was not because he was stingy in praise, but he thought that his students were extensions of himself in some way, and praising their virtues was a bit like praising himself—which he almost never did. When he found others were speaking well of his students, he would reinforce those views with no reservations. As a new department chairman at Yale, I came across a folder left inadvertently on my desk by my predecessor; it contained the entire set of confidential recommendation letters written for my tenure. I was touched by the graciousness and effectiveness of RN's letter. (I must admit to reading all the letters before sending them to the Provost's office for safekeep.)

[19] Please see *"In Praise of Serendipity"*, http://users.ictp.it/~krs/speeches_pdf/IISc_essay_sreenivasan.pdf

[20] R. Narasimha and K.R. Sreenivasan, "Flat plate drag reduction by turbulence manipulation", Sadhana 12, 15-30 (1988)

[21] R. Narasimha, "Non-linear vibration of an elastic string", J. Sound Vib. 8, 134-146 (1968)

[22] About two years into his associate professorship, RN was promoted as a senior professor, bypassing most others with more seniority. To his considerable discomfort, this put him at odds with a number of his colleagues. RN went to Director Dhawan to ask why that promotion was necessary, since he didn't seek it. Dhawan's diplomatic response was: "Well, Valluri argued for it so strongly for it that all the others on the committee fell in line with it." S.R. Valluri was then the Director of NAL.

[23] Once I asked Sir Sam Edwards, who pioneered several topics in complex fluids, as to how he knows that his starting points were correct. He said, "Well, a little angel whispers in your ears." S. Chandrasekhar said at one time that he had no use for such angels, but made his equations speak to him. RN had his use for the angels, but was also guided by his equations and data. That philosophy served him very well.

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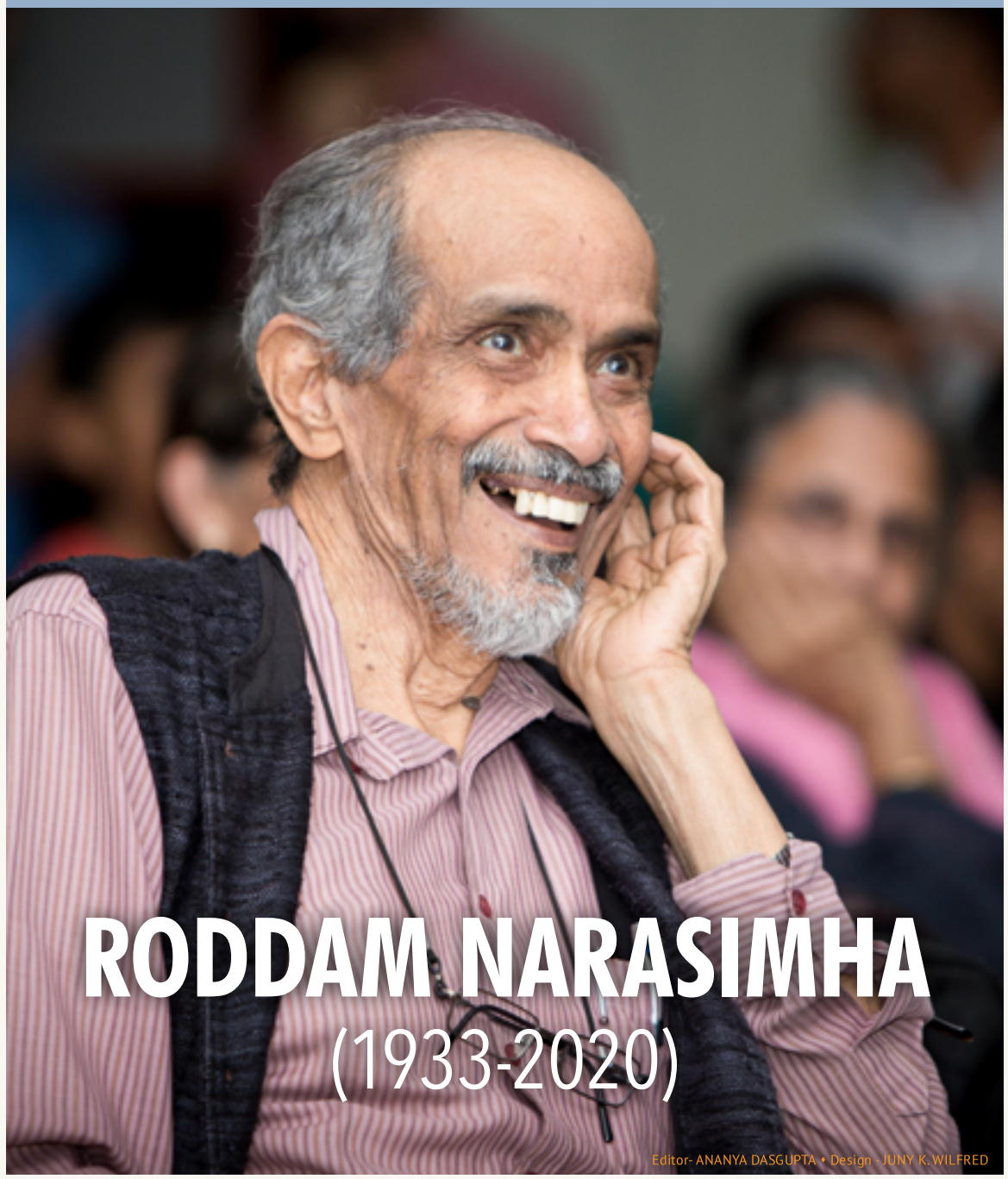

RODDAM NARASIMHA
(1933-2020)

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