C R Rao, Sc.D. (Cantab), F.R.S
Padma Vibhushan Awardee

Significant contributions

C R Rao is among the world leaders in statistical science over the last six decades. His research, scholarship and professional services have had a profound influence on theory and applications of statistics. **Technical terms such as**, ***Cramer-Rao inequality, Rao-Blackwellization, Rao's Score Test, Fisher-Rao and RaoTheorems, Rao distance, orthogonal arrays (described by Forbes Magazine as "new manthra" for industries),Analysis of Dispersion (MANOVA) and Canonical Variate analysis and G-inverse of matrices*** **appear in all standard books on statistics.** ***Cramer-Rao bound*** **and** ***Rao-Blackwellization*** **are the most frequently quoted key words in statistical and engineering literature. Special uses of** ***Cramer-Rao bound*** **have appeared in** ***Quantum Physics*****.** ***Rao-Blackwellization*** **has found applications in adaptive sampling, particle filtering in high-dimensional state spaces, dynamic Bayesian networks etc**. Other technical terms bearing his name appearing in specialized books are Rao's F and U tests in multivariare analysis, Rao-Rubin, Lau-Rao, Lau-Rao-Shanbhag and Kagan-Linnik-Rao theorems in characterization of probability distributions. Two of his papers which had a high impact on the development of statistical theory appear in the book ***Breakthroughs in Statistics*** :**1889-1990**. He is the author of 14 books and about 350 research papers. Three of his books have been translated into several European and Chinese and Japanese languages.

Times of India **dated 31 December 1988 chose C R Rao as one of the 10 top scientists of India considering all disciplines**; the list includes the outstanding scientists, all Fellows of Royal Society, J.C. Bose, S.N. Bose, S Ramanujan, Harishchandra, G.N.Ramachandran and Nobel Laureates H. Khurana , C.V. Raman and S. Chandrasekhar .

Academic qualifications

Rao received MA degree in mathematics with a first class and first rank from Andhra University (1941) and MA degree in statistics from Calcutta University (1943) with a first class, first rank and a record of marks unbeaten till now, and a gold medal. He started working in the ISI at Calcutta as a research scholar from 1943.

He was invited to work on a project at the Cambridge University, UK, which required the statistical methodology developed at the Indian Statistical Institute. Based on the work he did he earned his Ph.D. in 1948 from Cambridge University. A few years later, the university awarded him the prestigious Sc.D. degree based on a peer review of his research contributions to statistics. Up to

date he has received 31 Honorary Doctoral Degrees from universities in 18 countries in 6 continents.

Positions held

He held several important positions, as the Director of the Indian Statistical Institute, Jawaharlal Nehru Professor and National Professor in India and University Professor, University of Pittsburgh and Eberly Professor of Statistics and Director of the Center for Multivariate Analysis, Pennsylvania State University in USA.

Development of statistics in India

As the Head and later Director of the Research and Training School at the Indian Statistical Institute for a period of over 40 years, Rao developed research and training programs and produced outstanding students which *"put India not far from the center of the statistical map of the world", and earned for ISI the name of Indian School of Statistics*. During this period he also directed the training programs at the International Statistical Educational Center (ISEC) which led to the development of (statistics in the South East Asian region. Rao was the Chairman of a UN Committee, which examined the demand for statistical personnel in Asian countries and recommended the establishment of an Institute for statistical development in South East Asia. On the basis of his recommendation ASI (The Asian Statistical Institute) now known as Statistical Institute for Asia and Pacific was established in Tokyo to provide training to statisticians working in government and industrial organizations.

C.R. Rao played an important role in setting up state statistical bureaus in different states of India and developing a network of statistical agencies at the district level for collection of data. Together with the Central Statistical Organization and the National Sample Survey in planning of which, C.R. Rao played a significant role, India has one of the best national statistical systems. He Founded The Indian Econometric Society which has been active in promoting quantitative studies in economics for planning purposes.

Work in USA

C.R. Rao accepted University Professorship at the University of Pittsburgh after he took mandatory retirement from the Indian Statistical Institute (ISI) in India at the age of 60. He worked for 8 years at the University of Pittsburgh and moved to the Pennsylvania State University as Eberly Professor of Statistics, where he continues to work as the Director of the Center for Multivariate Analysis (CMA). The CMA established at his initiative serves as a meeting place for research workers from all over the world. He directed the research work of several students for the Ph.D. degree in USA. He edits a series of Handbooks on Statistics in various fields of applications for the benefit of research workers and consultants, and continues to be active in research at the age of 87.

National and International awards

For his pioneering contributions to statistical theory and applications, Rao received numerous awards. **He has been elected to the National Academy of Sciences, USA, American Academy of Arts and Science, Fellowship of Royal Society (UK Academy of Sciences, FRS), Indian National Science Academy, Lithuanian Academy of Sciences and Third World Academy of Sciences**. He was made an Honorary Member of the International Statistical Institute, International Biometric Society, Royal Statistical Society (UK), Finnish Statistical Society, Portuguese Statistical Society, Institute of Combinatorics and Applications and World Innovation Foundation, and **Honorary Life Fellow (limited to 11 persons at any time) of King's College, Cambridge, UK.** He has been the President of all prestigious statistical associations, the International Statistical Institute, Institute of Mathematical Statistics, USA and the International Biometric Society. He was inducted into the Hall of Fame of the National Institution for Quality and Reliability, Chennai Branch, for his contributions to industrial statistics and the promotion of quality control programs in Indian industries. **At the Berlin conference of the International Statistical Institute held in 2003, Rao received the prestigious *International Mahalanobis Prize for lifetime achievement in statistics and the promotion of best statistical practice.***

He received numerous medals: Gold Medal of Calcutta University, Wilks Medal of the American Statistical Association, Wilks Army Medal, Guy Medal in Silver of the Royal Statistical Society(UK), Megnadh Saha Medal and Srinivasa Ramanujan Medal of the Indian National Science Academy, J.C.Bose Gold Medal of Bose Institute and Mahalanobis Centenary Gold Medal of the Indian Science Congress.

He received Bhatnagar award of the Council of Scientific and Industrial Research, India. (He donated the entire prize money to Prime Minster's Defense Fund saying that country's need is greater than that of an individual scientist in fighting unprovoked aggression).

The Government of India honored him with the second highest civilian award, *Padma Vibhushan* for "outstanding contributions to Science and Engineering / Statistics", and also instituted a cash award in honor of C R Rao, *"to be given once in two years to a young statistician for work done during the preceding 3 years in any field of statistics"*.

International conferences were held in USA, India, Canada and Switzerland and special issues of the prestigious journals like *Statistical Planning and Inference, Linear Algebra and its Applications, Sankhya* and several festschrift volumes were published in his honor.

For his outstanding achievements Rao has been honored with the establishment of an institute named after him, **C.R.Rao Advanced Institute for Mathematics, Statistics and Computer Science,** in the campus of the University of Hyderabad, India.

National Medal of Science Laureate (USA)

Rao was honored by the President of the USA with the prestigious National Medal of Science "*as a prophet of new age*" with the citation, "*for his pioneering contributions to the foundations of statistical theory and multivariate statistical methodology and their applications, enriching the physical, biological, mathematical, economic and engineering sciences*". This honor is given only to five or six scientists from all disciplines every year. He is the fourth Indian to receive the medal since its inception 50 years ago.

A product of India

C.R. Rao is purely an Indian product having received all his education in India and making original contributions to statistics while working in India at the Indian Statistical Institute for 40 years before he took mandatory retirement on attaining the age of sixty. In reply to a query put to him as to what particular achievement he is most proud of, C.R. Rao replied, **"It is the outstanding contributions my students are making to statistical theory and practice." C.R.Rao supervised the research work of 50 students, who in turn produced over 300 Ph.D.'s**

Faces of Science

C.R.Rao's photo with a write up of his work is included in the recent book on *Faces of Science* by Marianna Cook, featuring the work of scientists of the last century who made fundamental contributions to science, published by W.W.Norton & Company. His portrait was exhibited for the public in the Gallery of Arts and Science of the New York Academy of Sciences during the period Sept 9-Oct 14, 2005.

Faces from the History of Probability and Statistics

C.R.Rao is the only Indian included in the above publication (available on web site, **faces from the history of probability and statistics)** by John Aldrich, University of Southampton,UK, describing the work of 35 major contributors to the development of probability and statistics since 1650 AD.

Peer reviews of Rao's research contributions to statistics

1. **S. Amari**, a renowned mathematician from Japan

> *Dr. Rao is a great scholar beyond the framework of statistics, which he himself has founded. It is a big surprise to see that his influence has been effective and has played a great role for more than half a century to produce fruitful developments in several scientific disciplines.*
> *"The idea of connecting statistics and differential geometry was too early at that time (1945). However, after nearly half a century, Rao's idea has been developed to become one of most active and important topics in information*

sciences, connecting statistics, information theory, control and statistical physics."

2. In an article entitled **The Statistical Century** published in the *Royal Statistical Society News* (Vol 22, Jan 1995), the Distinguished American Statistician **Bradley Efron** stated:

> *Karl Pearson's famous chi-square paper appeared in the spring of 1900, an auspicious beginning to a wonderful century for the field of statistics. The first half of the century was the golden age of statistical theory, during which our field grew from ad hoc origins, similar to the current state of computer science, into a firmly grounded mathematical science. Men of the intellectual calibre of Fisher, Neyman, Pearson, Hotelling, Wald, Cramer and* ***Rao*** *were needed to bring statistical theory to maturity.*

3. A review of C.R. Rao's book, **Linear Statistical Inference and its Applications**, by the famous statistician, **W.G. Cochran** in the *Journal of the Franklin Institute* states the following:

> *C.R. Rao would be found in almost any statistician's list of the five outstanding workers in the world of Mathematical Statistics today. His book represents a comprehensive account of the main body of results that comprise modern statistics theory*.

4. **Professor B. Efron**, President of the American Statistical Association mentions in the Issue 327, September 2004, of AMSTAT while introducing the article by C.R. Rao on *Reflections on the past and visions for the future* :

> *C.R. Rao, Eberly Professor Emeritus in the Stat. Dept. at Penn State is a towering figure in the postwar development of statistical theory. Among his great many honors, he was recently awarded the National Medal of Science, the government's highest scientific prize.*

5. **S. Karlin**, Mathematician who won President's medal:

> *C.R. Rao is among the worldwide leaders in statistical science over the last five decades. His research, scholarship, and professional service have had a profound influence in the theory and applications of statistics and are incorporated into standard references for statistical study and practice.*
>
> *C.R. Rao is not only a highly creative theoretician but was attracted and labored with many data sets in health, biology, psychology and social sciences*.

6. Citation while awarding Hon. D.Sc. by the Ohio State University

> *Among the international community of scholars, you are widely acknowledged as one of the world's foremost statisticians. In the complex realms of statistics and higher mathematics, your research and scholarly writing have opened new doors of understanding. The statistical theories and applications, which bear your name, attest to the fundamental contributions you have made to your field and to the larger body of man's knowledge. Numerous honors and awards have followed, in tribute to an unusually distinguished and productive*

life of inquiry. You have earned the highest accolade of all, the esteem of your peers throughout the world of scholarship.

7. Press release by Government of India on appointment as **National Professor** (limited to 12 at any time)

Government has appointed C.R. Rao, an eminent statistician, as National Professor. Professor Rao is an outstanding and creative thinker in the field. He was appointed by Professor Mahalanobis as full-fledged professor of the Indian Statistical Institute at the early age of 29 in recognition of his creativity.

8. **The Institute of Combinatorial Mathematics and its Applications** elected C.R. Rao as an Honorary Member with the citation:

as the world's leading expert in statistical design theory.

9. **P. Armitage**, Professor of Statistics, Oxford University, UK, writes in a review of *Statistical Analysis and Inference* (Ed. Y. Dodge):

*C. Radhakrishna Rao is **a polymath** amongst statisticians. …Rao's research interests include social, industrial and economic applications. He has been (and still is) an influential teacher especially in third world countries. …The group of papers are interspersed with quatrains from Rubaiyat of Omar Khayyam of Naishapur, whose hedonistic nihilism seems to accord ill with C.R. Rao's outlook:" Myself when young did eagerly frequent/ Doctor and Saint ,and heard great Argument/ About it and about: but evermore/ came out by the same door as I went". Those of us who have frequented C.R.'s company have invariably found new doors open.*