THIRTY FIFTH CONVOCATION ADDRESS

By

Dr K Kasturirangan

Chairman, Space Commission

Secretary, Department of Space &

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Application of Statistics in Space Endeavours - Some Challenges

Prof. MGK Menon, the President, Indian Statistical Institute, Dr KB Sinha, the Director, Prof. Rao, the Dean of Studies, Prof. G Kallianpur, Distinguished members of the Faculty, Invitees, my dear students and ladies and gentlemen.

I deem it a great privilege and honour to deliver the 35th Convocation address of Indian Statistical Institute which is distinguished as an institution of national importance, playing a pivotal role in a variety of national endeavors. I am pleased to have this opportunity of visiting this dynamic city again. It is always inspiring for me to recall the outstanding role that this region had played in shaping our national life from ancient times to the modern period in all spheres of human endeavors. The contributions of several outstanding men and women from here in fields such as arts, literature, philosophy, science, religion and political affairs are both illuminating and elevating. In short, Bengal has been the *avant-garde* of the rich cultural heritage of India. Statistically, it is exciting to note that all the Nobel Laureates of India are invariably connected with this region.

I am also particularly pleased to be in your midst today in this institution of excellence and erudition. I vividly recall how this institute from its very inception championed the cause of actively involving itself in a variety of activities relevant for development of society. I also remember how, as a young student of physics, I shared the excitement and pride that swept our country, resulting from strides India had taken in the development and application of statistics through monumental work of Professor Mahalanobis and his other distinguished colleagues here. In several ways, the role played by ISI had been pioneering. Involvement in national planning, initiation of statistical quality control movement in industry, spearheading new areas of theoretical research and diversifying into inter-disciplinary applications were some of unique steps, which characterized the outlook of the Institute to achieve excellence and maintain continuous relationship with society. With such a rich ambience, I am sure that you had ample opportunity to imbibe the significance of this heritage and to draw inspiration to shape your future. I would like to congratulate each one of you receiving honours and degrees today and wish you success in your future careers.

We are all aware of the fundamental role that the science of statistics plays in our daily lives. This is a discipline, which underpins every branch of knowledge and every endeavor in modern society. Its role in the study and measurements of economic and demographic aspects is today taken for granted. From tiny applications of averaging to the mighty modeling of dynamic weather systems, use of statistics is central to the diverse forms of human activities including governance, scientific research, trade and industrial activities, information processing, communications, housing, health, transportation, security, environment monitoring and management — to name a few. Thus statistics has become an inevitable means for describing and relating the values of social, economic, political, biological, psychological and physical data sets and generating information that assists in assimilation and synthesis of knowledge supporting the decision making process.

We are living in an age where science and technology has been progressing at a bewildering pace. This pace is accelerated by the symbiotic evolution where distinct branches of science and technology converge to result in new developments in a way that none of individual branches could have evolved separately. We see these convergences in information and communication technologies, physical and biological sciences and a host of other modern branches of knowledge. This trend that is driven by the fundamental unity of scientific approach is significant as it presents fresh opportunities for fields like statistics to constantly evolve new dimensions for research and application. Thus, as professionals in this field, you are going to have inexhaustible store of challenges. Particularly in a country like India, there are tremendous needs for application of statistics as we advance further in the development of modern technologies and as we endeavor to apply technological knowledge increasingly in economic and social functions. Even in the field of management of human resources, increased application of statistics is inevitable if we have to obtain better level of productivity.

Being deeply engaged in our national space endeavors over the past three decades, I can hardly recall any branch of space effort, which does not depend on statistics. Our space endeavors which had modest beginnings in the early sixties, are now highly diversified, but they remain strongly focused towards societal applications. One of the important branches we pursue is the remote sensing from space. Using the vantage point of space, we generate synoptic, reliable and repetitive information about the state of our natural resources. I am honoured by the esteemed presence of Prof. MGK Menon, who is the President of your institution, but who incidentally is also the leader, instrumental for guiding in past the course of this program in his capacity as the Chairman of the Planning Committee of the National Natural Resources Management System. Through the development and operation of a constellation of state-of-the-art satellites, India has gained a position of pre-eminence in the world today in this field. Several countries around the globe use the data from Indian Remote Sensing Satellites. These satellites collect data with different spatial resolutions and in different bands of electromagnetic spectrum and transfer data to the ground receiving systems in digital form. In view of the spatial extension of all these data, it is possible to process relationships among data in the domain of spatial statistics. Field data are also collected to interpret and validate satellite data, and both are stored and matched, using geographical information systems. Often, statistical inference is necessary, ranging from simple descriptive statistics to multivariate geostatistics. Classification, statistical sampling schemes and spatial interpolation are important issues to deal with. Maximum likelihood and fuzzy classification are now used intermixedly. The best of statistical skills are demanded to determine where and how to sample effectively. Interpolation from points to areas of land deserves thorough attention to take into account the spatial variability and to match different resolutions at different scales. Finally, the data have to be interpreted for making important environmental decisions. These methods now are routinely used in the task of generating information pertaining to forests, agricultural lands, built up areas, soils, wastelands and surface water bodies. Other applications of significance are the identification of zones for ground water exploitation, crop acreage and yield estimation and bio-diversity classification.

You will recall that long ago ISI pioneered in developing models for forecasting agricultural yields based on statistical techniques. The advent of space based remote sensing provided a new capability to improve the horizon and accuracies of estimation of areas under various crops and prediction of their yields — thus providing a new dimension to the field of spatial statistics. Estimation of acreages under agriculture for large areas like states demands handling of very large volume of data and significant efforts in ground truth data collection. In order to provide timely pre harvest estimates, use of sampling techniques has become inevitable. These and other statistical techniques are central to the methodologies developed for obtaining agricultural acreage estimates for any specified geographical area such as a state or district.

Significant developments have also taken place in pre-harvest forecasting of yields, using remote sensing data. Methodologies have been developed involving use of both single date and multi-date digital data. While methodologies based on single date data make use of non-linear regression models which relate vegetation index derived from satellite observation to the yields, the techniques involving multi-date data relate the spectral data gathered by satellites to the crop growth profiles and their yields. Such models have been successfully applied for pre-harvest acreage production estimates at an accuracy of 90% with 90% confidence for major crops, namely, wheat, rice, sorghum, cotton, mustard and groundnut.

There are several areas where research contributions in the field of statistics could advance the state of the art and improve the performance of predicting crop acreage and yields. Such areas include studies on sampling designs, techniques for selection of sites for ground truth, choice of optimum time for collection of data, analysis of influence of spectral, spatial and temporal resolutions on prediction accuracies, improvement in classification accuracies and techniques for effective use of new spectral data such as microwave data. There is considerable potential for increased collaboration between space laboratories and institutions like ISI to take up some of these challenging areas of research.

Realizing the need to have a more comprehensive multiple forecasts for major crops of the country at national, state and district level, a framework for Forecasting Agricultural Output using Space, Agro-meteorology and Land-based observation (FASAL) has been formulated in cooperation with the Department of Agriculture and Co-operation, who will implement this scheme. FASAL envisages an integrated approach to crop production estimate and will be undertaken through a National Center for Crop Forecasting. The task of perfecting a multi-disciplinary forecasting system for national agricultural output is a formidable challenge and statisticians have an important role to play here. There will be demand for improved techniques for discrimination among various crops, and for using the full potential of new developments in sensors. There are also challenges in developing methods for early warning of disasters, methods of damage assessment in post disaster situation, and improvement of models relating to atmospheric transmission effects on electromagnetic radiation used in sensing and communications.

Apart from crop assessment, there are several other areas of natural resources management, where statistical techniques are playing key role. For instance, in deforestation assessment, trees of different species under various agro-climatic conditions are distinguished by modeling their texture as visible in the remote sensing imagery. Texture modeling uses advanced concepts of statistics like Marcov random fields. The extent of deforestation is detected and quantified in terms of parameters of such models.

Remote Sensing and its applications offer tremendous potential for statisticians to undertake work relevant to future developments. Statistical concepts and techniques for extraction of ocean physical parameters, developments relating to terrain modeling, processing of hyper spectral data and eventual movement towards issues in three dimensional remote sensing are some of the future challenges in this area.

Self reliant strategy in Indian Space Program has fructified in terms of our capability to build satellites meeting global standards and reliable space launch vehicles. The Indian Polar Satellite Launch Vehicles that can launch 1000 kg class of remote sensing satellites into polar sun synchronous orbits are now operational. During its last launch on May 26, 1999, this vehicle successfully launched three satellites including two small foreign satellites. The Geostationary Launch Vehicle, GSLV, whose maiden test flight is scheduled during February 2001 is another major development. In all these programmers, a host of statistical tools are widely and regularly utilized. While it is extremely difficult to mention all the areas of applications, I would like to highlight a few significant ones.

Launch vehicle design involves use of multiple disciplines. Optimisation of design aspects of various subsystems assumes great importance for realizing overall efficiency of the launch vehicle system. Stochastic optimization methods involving a variety of random search procedures, Genetic algorithms, Taguchi methods and simulated annealing are basic tools for the multi-disciplinary optimization (MDO). These are utilized in the context of preliminary orbit determination as well as regular orbit determination.

As launch vehicles are complex systems, they undergo extensive testing during development, generating voluminous data. During actual flights also, data are systematically gathered in order to optimize performance further and ensure reliability. These data are used for modeling and smoothing. Parametric or non-parametric statistics, hypothesis testing methodologies, regression analysis are routinely made use of for this purpose. Estimation procedures such as the method of maximum likelihood estimation, filtering techniques such as Kalman filter and its variants, and time series analysis involving auto regressive moving average or Gauss-Markov processes are being employed for system identification, estimation of aerodynamic coefficients from flight as well as ground test data.

Knowledge of wind loads and its dynamics is very important in the design and testing of launch vehicles. Multi variety regression models are being employed for realistic wind modeling. Expectation - Maximization (EM) algorithms are put to use for the estimation of statistics from measured wind profiles with missing entries. It is not uncommon that launch vehicles undergo certain extreme wind stress conditions just prior to launch when support structures are withdrawn. Extreme value distributions such as Gumbel and Double exponential distributions are utilized for the assessment of the extreme loads experienced by the launch vehicle at launch pad.

A launch vehicle mission, although lasts only for about twenty minutes is extremely complicated to simulate in terms of the numerous performance parameters, events and their inter-relationships. Monte-Carlo methodologies are widely used for analyzing mission performance. They assist in arriving at tolerance limits of system as well as subsystem parameters satisfying mission accuracy objectives. These are also utilized in studies relating to launch authorization strategies, launch feasibility and launch risk assessment.

As ISRO plans to update the capacity of launch vehicles in keeping with international trends and national needs, several challenges arise in the areas of design, validation, test and simulation exercises, where the role of statistics is essential. Integration of reliability models into extensively used simulation method such as Monte Carlo models, use of Fuzzy logic concepts in the analysis of control systems, further developments in time series analysis to predict, dynamic factors like wind conditions during launch are some examples of challenges which are to be met.

Over forty years of global human endeavors of space launching, particularly by major space powers, have resulted in the growth of man-made debris in earth orbit, causing concern to international community. Study of debris is complicated by the presence of large number of particulate matter, which cannot be tracked from earth. Advanced statistical concepts are made use of for characterizing the environment of orbital debris, their life and decay in orbits and evaluation of the probability of their impacts with operational spacecraft. Statistical fragmentation models have been developed to derive debris population that cannot be tracked from ground.

Statistical tools find wide use for ensuring quality in the design and development of space systems through analysis, modeling and apportionment of reliability, and through quality control during manufacturing. Statistical simulation techniques are widely used to characterize dynamics of control systems of space vehicles and the developments control margins. They also find use in assessment of separation among multiple satellites, design of orbital constellation and for mission analysis.

Let me briefly now turn to another important area where statistical techniques are increasingly demanded. All radio communications including satellite communications make use of statistical principles. Multiple access to radio channels are often modeled as random events as in case of the ALOHA protocol, which is extensively used in low-cost data networks.

Advent of Direct-to-Home digital satellite transmissions have provided possibility of direct access by individuals to satellite media. For designing Media Access Control (MAC) layers in satellite channels, the communication signal packets arriving at different satellite ground terminals such as Very Small Aperture Terminals (VSATs) are treated as Poisson distribution. Another set of applications in this field pertains to the conservation of bandwidth (capacity) and power. Here, we take advantage of the statistical nature of voice to preserve satellite power using voice activation techniques. Other example is increasing the robustness of satellite channels, which are prone to Gaussian noise, using clever coding techniques like forward error correcting (FEC) codes, which compress information in digital form by suppressing the redundant bits. Another example is the fading in mobile satellite channels, which are "Raisian" in nature. Such mobile channels produce burst errors that are corrected using block codes like Reed-Solman coding. Finally, I would like to mention the case of the statistical entropy advantage in speech and video, which are beneficially used to compress voice and images to reducecostly power and bandwidth in the satellites. So, we could transmit up to six TV channels in one satellite transponder as compared to the only one analog TV channel possible a few years back. I would conclude by mentioning that these are several challenging problems for statisticians in the area of digital signal processing, data compression and secure communications, which can be exciting.

Space systems ushered in a revolution in connectivity by connecting people in remote rural areas and on a global scale. The developments in past few years in the fields of microelectronics and computing technologies have opened up several new possibilities. The Internet's ability to connect people together in new and innovative ways has made it an astonishingly growing medium. These developments provide new avenues for building an information-based society where intellectual capital could be exploited. While the advances in computing technologies have given new directions for development of statistics through possibilities for real time data analysis and for speedy development of new statistical procedures, they also increased the risk for routine application of the statistical techniques without adequate attention to interpretation aspects. The professional statisticians have a special responsibility to create proper awareness and to educate users.

My dear graduates, I strongly believe that the new millennium will see India progressing rapidly in all spheres. Her role will be more and more significant as the world itself moves towards knowledge-based society. Each one of you can contribute in this process, through your intellectual capabilities and strength of your character.

I wish you all the very best and pray that you are endowed with necessary strength, courage and wisdom to bring welfare to yourselves and your fellow beings.