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DEDICATION

It is with great affection and regard that we dedicate this volume to Victor Szebehely who inspires one and all in the pursuit of knowledge. We have known a multitude of people but he is indeed unique in arousing in us feelings, those **searing** tender and deep feelings, we hardly get the experience in our life-time. His personality radiates a soothing aroma. And we are sure, this soothing radiation will survive the joys and all the woes of man.

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PREFACE

This volume contains the detailed text of the lectures delivered at the International Workshop on Space Dynamics and Celestial Mechanics held in Delhi, India during November 14-16, 1985. This workshop was organised under the joint sponsorship of University of Delhi, Delhi, Vikram Sarabhai Space Centre, Trivandrum (India) and the Space Programme of the University of Texas at Austin, Austin, USA.

The main objective of the workshop was to review the current state of the art in the area of Space Dynamics and Celestial Mechanics through paper presentations, key note addresses, lectures and discussions, to expose the participants to more recent developments in various techniques, analytical as well as numerical, as applicable to Space Mechanics, to identify and assess the degree of augmentations desirable in respect of software packages available for this purpose with different centres and to establish contacts with experts in the vital field with a view to facilitate the in flow of technical information.

The whole material of this volume has been organized into seven basic areas:

(i) The key note address by Professor V. Szebehely, (ii) General Celestial Mechanics, (iii) Solar System and Natural Satellites, (iv) Stellar Systems and Galaxies, (v) Orbit Determination and Satellite Theory, (vi) Attitude Motion and (vii) Mission Planning and Control.

(i) Prof. Szebehely in his key note address discusses the non-deterministic nature of celestial mechanics and its relation to stability investigations. His paper first defines the concepts to be used, lists reasons for indeterminism and offers several examples. This is followed by a discussion of stability as related to determinism. The role of uncertainties and important time scales are treated next. The existence of integrals and transformations of dynamical systems are shown to be beneficial to determinism but in fact they only delay the built in catastrophic trends.

(ii) The most well known unsolved problem of celestial mechanics is the N-Body Problem. In this part the various aspects of the two-body problem and the three-body and many body problems have been presented. We know that the so-called triangular libration points of the restricted problem of three bodies show stability provided the mass parameter of the problem is below a certain critical value. When the centrifugal, gravitational and coriolis forces are modified with proper parameters, this well known stability can undergo significant changes. Furthermore the participating primary masses in the restricted problem of three bodies are usually considered point masses. If this assumption is substituted by more realistic models where the primaries are bodies of finite dimensions with various gravitational properties, the stability is effected. One or the other problems mentioned above have been presented by Drs. Ahmed, Chaudhry, Elipe, Quidong, Sharma and Ferrindiz.

In this part the paper presented by Dr. Deprit is also included. He has studied the nature of the Critical Inclination in the Artificial Satellite Theory. He has shown that manifolds of orbits with stationary perigees are intrinsic features of the averaged main problem in this

theory; they bifurcate off the manifold of circular orbits at the points where stability flips to instability and vice-versa.

(iii) The third part of this volume is dedicated to the study of the Solar System and Natural Satellites. Drs. Kozai, Pauwels, Verma and Vicente presented papers on these subjects.

(iv) In the fourth part papers relating to problems on Stellar systems and galaxies are included. Dr. Brumberg studies the orbital evolution of massive close binary under the influence of small bodies. Dr. Galletto presents a paper on Extra Galactic Celestial Mechanics. The equation of evolution of the universe is deduced with reference to both the isotropic and the anisotropic cases without resorting to the Newtonian Theory of Gravitation.

The motion of a star in a satellite stellar system is governed by the force due to the over-all distribution of matter in the system, the force due to stellar encounters within the system and the tidal force due to the primary stellar system. Drs. Alladin and Namboodri have studied the effects of the tidal force and have shown that interacting galaxies have peculiar features like tails and bridges and counterarms of various sizes and shapes.

Dr. Alagar has presented the problem of determining the trajectories of a tachyonic celestial object in a Schwarzschild field.

(v) In part V papers relating to orbit determination and satellite theory are included. A large number of artificial earth satellites are put in orbit at low altitudes. The dominant perturbation on their orbit is due to atmospheric drag. Dr. Henrard has presented an analytical drag theory of an artificial satellite with small eccentricity. All the formulas are presented in explicit form from osculating elements at epoch to osculating elements at date. Dr. Ferrer and his coauthors have revised the zonal earth satellite theory.

Dr. R.B. Singh has presented the analysis of nonlinear planar oscillation of a satellite launched in an elliptical orbit under the influence of external forces of general nature such as accretion and tidal effects etc.

(vi) This part is devoted to the study of the Attitude Determination of Satellites. Dr. Kovalevsky's paper deals with the attitude determination of the Hipparcos satellite. Dr. Goel and his co-authors have presented a study on the magnetic yaw-roll control and momentum dumping for the SROSS spacecraft and in another paper they have presented a study on the attitude and orbital control system for the Indian Remote Sensing (IRS) satellite to be put into sun-synchronous 10° 0' Clock polar orbit during 1986. Dr. Nath and his colleague's paper is dedicated to the attitude determination of a powered launch vehicle.

(vii) The Indian Space Research Organisation (ISRO) sent a very strong delegation of about 50 scientists to participate in the Workshop. A large number of scientific papers of very high standard were presented. Some of the papers could not be included in this volume due to various reasons beyond the control of the editor. This part of the volume is dedicated to the mission planning and control and some of the papers in this category were presented by scientists of ISRO. Papers on Jettisoning Dynamics, Zoom Software, Optimal Injection with near synchronous orbit and proportional navigation trajectories, orbit

correction etc. have been presented by Drs. Biswas, Carrou, Eckstein, Leibold, Raja Singh and Mahapatra.

Several papers were dicated to the fundamentals such as Hamiltonian Mechanics, BMK theory, Lunar theory, Resonance theory and Stability. Lectures on bifurcation, on integrability, on regularization, on manifolds, on deterministic and non-deterministic systems etc. are included.

The most of the lectures delivered were lucid and understandable to the participants who had solid background in Dynamics and Celestial Mechanics. Each lecture was followed by free and frank discussions. We do thank all the participants who took keen interest in the deliberations of the Workshop.

As the readers will agree, the Workshop gave an opportunity to the participants to know the most recent developments in the area of Space Dynamics and Celestial Mechanics and to make contacts with scientists coming from every corner of the world.

At the end of the Workshop the Indian Scientists passed a resolution which was also approved by the non-Indian Scientists. The resolution is given at the end of the book.

We are most grateful to the authorities of the University of Delhi, Delhi; Vikram Sarabhai Space Centre, Trivandrum and the Space Programme of the University of Texas at Austin, Austin for sponsoring this Workshop. We do express our thanks to the Department of Science and Technology, Delhi; the University Grants Commission, Delhi; the Council of Scientific and Industrial Research, Delhi; the Department of Training and Sponsored Research Delhi; the Tata Institute of Fundamental Research, Bombay; the Indian Space Research Organisation and the Sahitya Kala Parishad, Delhi which supported our Workshop. Finally, we do thank all the organisations which supported many participants to attend this Workshop.

At the end, I would like to thank Dr. (Mrs.) Usha Gupta who devotedly and tirelessly assisted me in the preparation of this volume. She is my student, my colleague and my friend. My thanks are also due to Drs. S.A. Ali, B.S. Yadav, G.C. Ahuja, A. Iqbal, M.L. Agarwal, P.P. Hallan, S.C. Jethi, D.S. Jaggi, V. Sharda and Mr. H.R. Mehra for assisting me in organising the Workshop. I would also like to thank all the members of the International Organising Committee, Advisory Committee and the Local Organising Committee for their valuable advise in planning and successful completion of the Workshop.

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