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BOOK REVIEWS

Astrodynamics 1985, Parts I and II, Vol. 58 of Advances in the Astronautical Sciences (Proceedings of the AAS/AIAA Astrodynamics Conference held on August 12–15, 1985, Vail, Colorado) edited by Bernard Kaufman, Joseph J. F. Lui, Robert A. Calico, and Felix R. Hoots. American Astronautical Society, 1986, pp. 1507, $140. Orders to Univelt, Inc., P.O. Box 28130, San Diego, CA 92128.

Astrodynamics or orbital mechanics is the application of dynamics to problems of space engineering and treats mainly the dynamical behaviour of artificial satellites and space probes. The underlying mathematical and dynamical principles are the same for astrodynamics and celestial mechanics; more often the former is treated as the engineering or practical application of the latter.

Celestial mechanics or dynamical astronomy may be said to have had its birth with the discovery of the epoch-making law of gravitation. In the three centuries that followed, one could see this science being nurtured and put on a firm mathematical foundation by the European mathematicians, who studied to a great extent and in great detail the motion of celestial bodies under the influence of gravity. This study was a mental discipline for them to gain appreciation of principles and formal relations. Beyond explaining observed natural phenomena, the theories that originated from this thinking process were never put to severe experimentation or practical application except for the determination of planetary orbits, primarily because there was no severe demand for such an exercise. But the era that was ushered in by the spectacular success of Sputnik-I in 1957 demanded from the mathematicians and celestial mechanists practical solution to real problems presented by artificial satellites in space. Practical determination of orbits became an active problem. Pragmatic experimentation, utilisation and comparison of practical solutions became, to an astrodynamist, as important a religion as explanations and formulations. Though most of the principles and applications of astrodynamics are direct outgrowths of celestial mechanics, many of the problems presented by artificial vehicles in space, required new solutions and they demanded extension and enrichment of the classical theories. And the situation continues. Today astrodynamics includes a variety of fields such as geophysics, high-altitude aerodynamics, observation and estimation, optimisation, navigation and propulsion theory. In a wider perspective it also concerns with minor planets, meteoric and cometary orbit theory and attitude dynamics.

The growth of this discipline in three decades after the advent of Sputnik-I could be compared with the nurtured development of celestial mechanics that followed the discovery of the law of gravitation; the major difference, apart from the time span, is that if the latter concentrated on intellectual perceptions the former aimed at engineering perfections. It is natural then that an international symposium on astrodynamics will address more of the practical tools and computational methods than of theoretical explanations and mathematical formulations. The papers contained in the two volumes of *Astrodynamics 1985*, under review, are not an exception to it. Here one could see a cross-section of the recent developments in astrodynamics addressing space engineering, navigation and control problem of the 1990s and beyond. The collection of papers will be very interesting and useful to the designer, the analyst, the planner and the manager engaged in space research. To the theoreticians some of the papers may give a satisfying feeling of how the abstract theories have been put into practice in realising man's age-old desire to fly to the outer planets.

The two volumes under review along with their microfische supplement, Vol. 51 in *AAS Microfische Series*, represent the proceedings of the 1985 Astrodynamics Conference jointly hosted by the Sapce Flight Mechanics Committee of the AAS and the Astrodynamics Technical Committee of the AIAA. A total of 79 full papers and 50 abstracts are included in the proceedings. These papers, presented in 18 different sessions, encompass a wide spectrum of topics in astrodynamics such as orbit dynamics, transfer dynamics, near-earth and geosynchronous orbits, attitude dynamics and control, large space structures and platforms for the 1990s, mission design, orbit determination and manoeuvre, interplanetary trajectories and navigation. To quote from the preface, "the conference papers addressed many new problems as well as revisiting some older ones".

These volumes are dedicated to the memory of the seven astronauts who perished in the explosion of the space shuttle Challenger on January 28, 1986.

Volume I opens with an invited lecture by Arche E. Roy on the recent researches on the age and stability of the solar system. This age-old problem is attempted by treating the solar system as an hierarchical n-body dynamic system where the bodies move in almost circular and near-coplanar orbits. Different methods such as analytical and numerical methods, empirical stability parameter method and the mirror theorem employed to calculate the dynamical age and the hierarchical stability are discussed. With precise, concise and lively presentation the author clearly highlights the difficulties involved in the theoretical and practical aspects of tackling this problem, as well as the pleasant vastness, challenges and potentialities it offers to an interested researcher. This paper can interest a wide spectrum of space scientists.

The remaining papers in the first volume deal with orbit and transfer dynamics, dynamics and control of rigid satellites and large space structures, space platforms for the 1990s, space servicing, mission design and applications. The realisation of a space mission is the culmination of a sequence or series of activities originating first from the embryo of conceptualisation, and then gradually growing in multiple branches of analysis, planning, simulation, fabrication, and testing. First three, namely, analysis, planning and simulation are the stepping stones for any satellite mission. Many papers presented in the orbit dynamics and transfer dynamics sessions deal with topics pertinent to these phases of a mission; the topics include orbit selection, orbit-transfer error analysis, strategy studies for a low-thrust continuous burn orbit transfer, simulation of a GPS operation segment, navigation error analysis, parametric design and mission analysis for orbit transfer, and rendezvous and docking studies. Much of the orbit-transfer studies presented here assume space shuttle launch environment, but this does not any way reduce the technical applicability of their contents. Heavy channelisation of activities for space station era is evident from the papers included in the attitude dynamics and control sessions. This orientation is natural to occur. Easy access and approach to space, flexibility of operation and many other possibilities the space shuttle and its variants promise to man, have revitalised his imagination and ego to utilise the space to his maximum efficiency. As a result, large space structures and platforms are going to be the realities of the near future. Ambitious plans for their realisation and utilisation have opened new engineering problems like control of large space structures, orbiting and deorbiting of satellites, satellite retrieval, space assembly, rendezvous and docking, design and development of application payloads, etc. Another important development is space robotics, which has been called in by the various requirements one has to meet in deployment, assembly, and retrieval. A good number of papers address robotics and associated control problems. There are a few papers dealing with application satellite missions, modeling of space dynamic environment and simulation of measurements. Some papers cover recent works on reestimating atmospheric density models with satellite data. A discussion on modeling of space plasma will be of interest to space physicists and space safety engineers.

Volume II contains papers mainly on artificial satellite theory, orbit determination and

interplanetary exploration. We should say that many of the topics treated in these papers like analytical treatment of orbit theory, fast prediction models, computational methods, design and analysis of navigation strategies have direct relevance to a professional in the orbit determination field. The papers included in the celestial mechanics session deal with both theoretical and practical aspects of artificial satellite theory. A completely analytic second-order solution of the zonal earth artificial satellite theory based on the radial intermediaries has been presented in this session; it is a variant of the Depris method. Many papers, as their abstracts show, deal with efforts to develop or utilise analytic or semianalytic methods to make long term and decay predictions of orbit fairly fast and acceptably accurate. It is a cruel fact that higher order harmonics of the Earth's potential field have always defied man's attempt to develop an all-proof analytic artificial satellite theory, applicable to all types of orbits, forcing him to make approximations and allowances lending each theory applicable only to restricted classes of orbits. Classical contributions of Brouwer, Kozai, Kiroshita and Merson are no exceptions to this. Though these theories and their variants provide powerful working tools for an orbital mechanist to operate on a particular orbit at hand, when finer accuracies are called for analytic theories shyly give way to numerical methods, especially for low-earth satellites.

Positioning and control of satellites in geostationary orbit is a highly matured subject. However, the ever-increasing commercial demand on this highly exploitable orbit and the subsequent growth of satellite population here, have opened up in the recent past, two new problems to the orbital mechanist, problems of colocation and of collision avoidance. It is no wonder the papers on geosynchronous orbits deal mainly on these two subjects. Fervency of activities to make colocation an order-of-the day is evident from these papers.

More than a score of papers have been presented on orbit determination and control. As position estimation in space is fundamental to space exploration, this area has always been active from the beginning of space flight itself. A revisit to Enckes method for determination and prediction of low-earth orbit, a comparison of least-square filter with extended Kalman filter for orbit determination, modeling of systematic residual errors, problem of initial orbit determination using short arc data, usage of diverse types of measurements for orbit estimation are a few of the subjects these papers deal with. Many aspects of trajectory estimation and control for near-earth and interplanetary missions, usage of satellite-to-satellite tracking, GPS, DOR and VLBI data for orbit determination have attracted attention in many a paper. These papers are all down-to-earth application oriented and there is no doubt that they will be of immense interest to both the professional and the researcher.

The contribution of the Jet Propulsion Laboratory to interplanetary exploration is second to none. Its unquestionable leadership in this field, both in theoretical development and technical advancement, is evident in the fact that most of the papers on interplanetary missions have originated from this institution. Though there was a lull in the early 80s, planetary exploration has again gained momentum with the high-priority scientific missions like Cassini to Saturn/Titan, Mariner Mark-II to Comet Wild 2, Voyager 2 to Uranus, Galileo to Jupiter, Phobos to Mars and its Moon and VRM mission to Venus. Orbit transfer and encounter geometry, orbit insertion, flyby strategy, trajectory estimation, landing, design and control of application payloads, and spacecraft design consideration are dealt with in these papers. Most of the papers have laid emphasis on design, analysis and planning aspects of their respective missions than on algorithmic details and computational methods. Thus they provide a good insight into the various problems and their possible solutions one should consider in planning such missions. These are very valuable to a mission analyst, and a mission designer.

Though the papers in these two volumes have been categorised and included under different sessions, the categorisation can only be limited, as many papers are interdisciplinary. They give a rich feast of information, extracted from experience and radical analysis, which an astrodynamist and an

orbital mechanist would always like to have access to. Contributions made by AIAA and AAS to the advancement of aeronautics and astronautics has no parallel. The information disseminated through the various publications and seminars of these prestigious institutions has in fact been an important catalyst responsible for the stupendous growth of astrodynamics in the last few decades. These two volumes, rich in content and variety, can easily be recommended to the professional astrodynamists, the researcher and space planners.

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Tethers in space edited by Peter M. Banium, Ivan Bekey, Luciano Guerriero and Paul A. Penzo. American Astronautical Society, 1987, pp. 750, $80. Orders to Univelt, Inc., P.O. Box 28130, San Diego, CA 92128.

Tether systems represent a very revolutionary and innovative approach to space transportation, what previously would have been called space propulsion. The first concept for a space tether was put forth in 1895 by that famous Russian space pioneer, Tsiolkovski. In an interesting report on terrestrial access to the weightless environment of space by mechanical means, he proposed an equatorial tower reaching beyond geostationary altitudes, to reach regions where gravity is totally eliminated! Sixty-five years later, in 1960, a Russian engineer Y. N. Artsutanov, put forth an idea that was a reversal of Tsiolkovski's tower. He conceived a tower 'anchored' in space and pointing towards earth, touching and being connected to the earth's surface at the equator. In 1969, Collar and Flower suggested very long tether connecting a satellite beyond the geostationary distance with a low-altitude satellite such that the centre of gravity was located at the geostationary distance. Subsequently, Artsutanov's idea was followed up by Pearson in 1975 who analysed the detailed tether dynamics. Around this period, systematic investigations were carried out to understand the complex dynamics of tethers in space, their utilisation for a wide spectrum of scientific and operational applications and the associated crucial technologies. In these studies, several application possibilites of tethers in space emerged. Some of the interesting ones include orbiting ULF/ELF antenna of 20 to 100 km length, tethered magnetometers and gravity gradiometers, shuttle-borne tethered satellite and electrodynamic power tether.

The volume under review presents a comprehensive account of these developments and brings together all the facets from technology, science and applications. Published for the American Astronautical Society, it represents the proceedings of the first international conference on Tethers in Space held at Arlington City, Virginia, USA, on September 17–19, 1986. The book is divided into six major sections. The 'Tutorial on what can tethers do in space' opens up enormous possibilities from studies of upper atmosphere to the planetary sciences. The section on 'Shuttle flights: Opening the era of tethers' specifically concentrates on the possible tether applications with shuttle and the proposed experiments for the joint NASA, Italian tether flight. The section 'Tether dynamics: understanding behaviour and control' studies the dynamics and control issues of the tether satellite, tether and the parent vehicle and highlights various difficulties that the tether-based system might face. Under the section 'Electrodynamics: New approaches to space power' brings a totally new area of tether applications into focus, using tethers for generating power from space plasma. A few experiments with sounding rockets have also been discussed. The section 'The space station era: tethers for science, technology and operations' focuses various applications of the tether in the NASA space station. The associated dynamics and control problems have also been studied. The section 'Technology development: the key to success' highlights the technology issues, hardware, attitude control and the design of tether systems.

The book is very timely and provides a complete spectrum of applications of the tethers in space. Even though each paper deals with a very specific aspect, in sum total, the book covers all related issues quite comprehensively. It will be very useful to persons interested in space activity, student community and scientists. Even though it deals with a very specific activity, the book does not require much *a priori* specialised knowledge to understand and appreciate.

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Electric machines and drives by John Hindmarsh. Pergamon Press Ltd, Headington Hill Hall, Oxford OX3 0BW, England, 1985, pp. xviii + 350, $17·50.

Electric machines and drives are traditional subjects and many excellent books have been written on them. However, much has changed in electrical technology following the advancements in electronics. The advent of power semiconductor devices has revolutionised the field of electrical drives. New areas of learning are being accommodated within the available time frame, and consequently, the time slots available for teaching of electric machines have been shrinking. The role of transformers and rotating machines remain as important as ever, however, and no electrical engineering course can be complete without an adequate study of electrical machines and drives. The situation demands a new approach of teaching the subject, and hence new textbooks.

The book under review is intended to meet the demands for new and concise textbooks in electric machines and drives. Written primarily as a companion volume to the author's textbook *Electrical machines and their applications*, it has been suggested as a textbook on *electrical drives* in which the subject is 'taught through worked examples, for a reader having some familiarity with basic machine theory'. The emphasis is on 'machine terminal characteristics, rather than on the internal electromagnetic design'. This is certainly the correct approach for a non-specialist course in electric drive, and textbooks which follow this approach are needed.

The book is organised through eight chapters. The first chapter deals with the basics common to all machines (rightly termed as 'foundation theory'). Subsequently, one chapter each is devoted to the study of steady-state behaviour of transformers, dc, induction and synchronous machines. Chapter Six deals with the study of transient behaviour of electric machine systems. This chapter is particularly well written and introduces the difficult concepts of thermal, electrical and mechanical transients in a simple and easy-to-understand manner. Power electronic control of dc and ac machines is briefly covered in the seventh chapter. Mathematical modelling and computer simulation of machine systems are given in Chapter Eight. Although the author considers this treatment 'somewhat limited', it provides valuable material for any serious-minded student familiar with power electronic controllers and computer programming. Useful equations relating to the bridge rectifier circuits and d-q simulations are summarised in Appendices A and B, respectively. Eighty-eight tutorial problems (with answers), organised chapterwise, have been included as Appendix C.

On the whole, the book is well written, and presents difficult concepts in concise and easy-to-understand manner. However, it does not have adequate material to qualify as independent textbook. Most of the material has been covered through worked-out examples, and the theoretical treatment often lacks in detail. It is very useful as a reference though, and a valuable addition to one's collection, but in its present form, I have some hesitation in recommending it as an independent textbook.

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Microwave engineering by Rajeswary Chatterjee. Affiliated East-West Press, 104, Nirmal Tower, 26, Barakhambha Road, New Delhi, 110001, 1988, pp. 535, Rs. 100.

In her Preface to the book Professor Chatterjee has stated that this book is designed for senior under- and post-graduate students in electronics, electrical communication and electrical engineering. She also states that it would be equally useful to those engaged in research, design and development in more specialised branches of electromagnetic engineering. This textbook, according to the author, presupposes a knowledge of the fundamentals of microwave engineering.

The book is divided into twelve chapters of which the first two chapters, namely, Introduction and Fundamental EM theory deal with the basics starting from the historical work, electrostatic fields, conductors, dielectrics, conductivity, capacitance, conservation of change, magnetic field, magnetic current, inductance, electrical displacement, leading to first and second laws of electromagnetic induction. The author continues the subject with the concepts of electric and magnetic currents, application of boundary conditions in the vicinity of current sheet, infinitely thin linear current filaments to evolve normal and surface impedance terms. The electromagnetic wave equations in dielectrics and conductors, solution in Cartesian coordinates, solution of Maxwell's equations in source-free region, vector and scalar potentials and the phenomenon of radiation is gone into. In this chapter the subject has been dealt with with clarity and logically arranged so that the student gets a good grounding on the analytical procedures as well as the associated physical phenomenon leading to the establishment of currents and fields in matter. The problems given at the end of Chapter 2 consolidates the concepts evolved so far.

Chapter 3 deals with scalar and vector wave equations and their analytical solution in Cartesian, cylindrical and spherical coordinates so that the student is made thoroughly familiar with the relation between the wave solution and the coordinate system. Though not explicitly brought out, the generalised solutions of vector wave equations highlight the modal form. The student will do well to attempt the problems given at the end of this chapter.

Chapter 4 deals with Surface waveguides starting with characteristics of surface waves, conditions for formation of surface waves and the Goubau Line. In my opinion, this topic of formation and existence of waves in unbounded media could have been dealt with either in Chapter 10 on Microwave antennas or before it as Chapter 9.

Chapters 5, 6 and 7 deal with the classical treatment of passive microwave networks including filters. The lumped constant equivalents of discontinuities in waveguides and microwave components is very clearly enumerated, analysed and concluded with typical examples. The model solutions for waveguide discontinuities, their lumped constant equivalents and the heuristic methods of analysis further consolidate the ideas and enable the student in Chapter 7 to relate the classical filter theories with equivalent waveguide discontinuity elements and cavities. Perhaps a few more problems at the end of Chapter 7 would have made the student consolidate his concepts.

Chapter 8 on Ferrite (non-reciprocal microwave) devices is well written and deals with phenomenon of propagation of em waves in such media. The subject is illustrated by examples of gyrator and circulators. The YIG-tuned devices have also been described. An important class of ferrite device, namely, the phase shifter which finds extensive application in phased array antennas has been unfortunately omitted.

Chapter 9 deals with the microwave semiconductor devices, classification based on device structure, varactor, Schottky barrier, PIN, Gunn, Impatt, Trapatt devices and their microwave application. Prof. Chatterjee has dealt with the subject very lucidly and clearly so that any designer using these devices will not have difficulties in arriving at typical configurations.

Chapter 10 dealing with microwave antennas is well written linking clearly the field theory, the circuit concepts and the design aspects. The concepts of gain, radiation pattern, array pattern are clearly enunciated. The distinction between resonant antenna elements and travelling wave antennas has been adequately treated. This chapter ends with leaky-wave, surface wave and frequency independent antenna concepts which would be providing a broad background for the student.

Chapter 11 on Microwave communication deals with line of sight and troposcatter communication system in the microwave region more as an introduction to this subject. The topics on ground wave and sky way propagation and the derivation of the classical radar equation have been treated more for familiarisation of the reader with these topics.

Chapter 12 on Microwave measurements is well written and would give the student a very clear idea of the importance of VSWR in microwave measurements, the use of slotted line in the determination of the VSWR and relating to the impedance, the various techniques for determination of circuit parameters of microwave networks, components such as magic tee, directional couplers, diaphragms, etc. The coverage on the measurement of dielectric properties, ferromagnetic material characterisation, O-factor of cavity resonators, measurements of electromagnetic field and attenuation is lucid and appropriate. Most probably the experiments relating to Harms-Goubau resonator, Harms-Goubau line or reflex Klystron appear to be specific and can be skipped without greatly losing the overall experimental requirements of a course in microwaves.

The book is a welcome addition as a textbook to those who are pursuing or wanting to know more about microwaves from the design point of view. The treatment in this case is on classical lines and has adequate figures and graphs to illustrate the topics. The value of this book to a research worker would have been considerably enhanced if the coverage had included planar transmission lines and antennas, role of Green's function, integral equation formulation of the solutions plus computational electromagnetics.

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Design of bridges by N. Krishna Raju. Oxford & IBH Publishing Co Pvt Ltd, Park Hotel Building 17, Park Street, Calcutta 700016, 1988, pp. 395, Rs. 85.

The book is intended to meet the requirements of under- and post-graduate students of the civil, structural and transportation engineering streams and practising engineers in the area of designing different types of bridges. Required theory, detailed design and structural drawings of the following types of bridges are presented: (1) stone masonry arched bridges, (2) reinforced concrete slab culvert, (3) skew slab culvert, (4) pipe culvert, (5) reinforced concrete box culvert, (6) reinforced concrete Tee beam and slab bridge deck, (7) steel plate girder bridge (deck type), (8) composite bridge–continuous reinforced concrete slab over steel plate girders, (9) prestressed concrete bridge, (10) reinforced concrete rigid frame bridge, (11) steel trussed bridge (through type), (12) reinforced concrete balanced cantilever bridge, (13) reinforced concrete continuous bridge. Standards for highway bridge loading are given in the first chapter and design of different types of bridge bearings and general details about cable-stayed bridges are given in the last two chapters. A total of fifty selective publications are listed for reference and further study.

Designs are worked out to conform to the specifications of codes of Indian Roads Congress, IS: 456 and IS: 1343. The emphasis is more on the presentation of design details and thumb rules used in them. The theory is minimal. A knowledge of structural analysis, reinforced concrete, prestressed

concrete and the structural steel theory is assumed on the part of the reader. The topics covered meet the requirements of curricula of bridge design of many Indian engineering colleges. The design steps, illustrative drawings and the examples provided for practice would be useful to the students preparing for examinations in bridge design.

The author is to be congratulated for the effort put in the preparation of typical designs of a number of important bridges normally come across and collectively presenting them in a single volume. The book, hence, would also be a useful addition to the libraries of practising engineers engaged in the design of bridges.

Attention should, however, be paid to the following while bringing out future editions of the book:

(1) The paper used is thin and the print is visible on the reverse also.
(2) The cost appears to be rather on the higher side.
(3) In design of bridges normally one would expect to find the design of super and substructures. Most of the work presented is on the design of bridge decks, and there is little on the structural design of piers, abutments and their foundations. The addition of structural designs and details of bridge substructure would enhance its value.
(4) A number of thumb rules have been presented as part of the theory of design of components. If sources to these rules are given an interested reader can study the original publications to fully appreciate their genesis and limitations.
(5) In the design of prestressed concrete bridge (Chapter 10), details of the connection between the prestressed concrete girder and the slab should be given.
(6) Some figures are not to scale.

A few typographical errors are noted, but they do not, in general, affect the reading of the text.

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Information technology–research and development—critical trends and issues prepared by the Office of Technology Assessment of the Congress of the United States of America, Pergamon Press, New York, 1985, pp. 342, $75.

The Office of Technology Assessment (OTA) was created in 1972 by the United States Congress with the basic objective of helping legislative policymakers anticipate and plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives. Requests for studies are made by the Congress to OTA. This is one such study undertaken during 1984–85 documented in this report.

The report consists of nine chapters. After an introductory and summary chapter the study details the environment for R and D in information technology (in the United States) in the second chapter. The third chapter presents the results of selected case studies in information technology research and development. The case studies are in the areas of advanced computer architecture, fibre optics communication, software engineering and artificial intelligence. The effects of deregulation and divestiture on research is discussed in Chapter 4. The fifth chapter examines education and human resources for research and development. The next chapter proposes new roles for universities in R & D. Chapter 7 takes a look at foreign information technology research and development, in particular the Japanese challenge. In Chapter 8, the place of information technology R & D in the context of US Science and Technology policy is examined. The concluding chapter looks at technology and industry.

The conclusions of the study are summarised in the report. In brief, it notes that US has been a leader in information technology and that the area is still in its infancy. The current R & D programs are strong and viable but future needs have to be reassessed keeping in view the strong Japanese challenge. This has led to greater industry support for short term R & D projects inhouse and in universities. Universities which were traditionally emphasising basic research are re-examining their roles with respect to applied research and are forming new types of relationships with industry and government. Many state governments look to universities to provide the stimulii for attracting and growing high-tech industries. Currently Defence Department funds over 80 per cent of the research and that there is a need for non-defence agencies to increase funding, particularly to fulfill civilian needs. The study also brings out the government's concern that there is considerable R & D information outflow from US to others without a balancing inflow. It recommends tighter control on flow of technical information to other countries on 'national security grounds'. We are already seeing the effect of this recommendation. For instance, free flow of university-developed software outside USA has now been restricted. The report also observes that the need for sophisticated computing resources for scientific research is growing and its costs are becoming higher. Further, rapid obsolescence demands higher budgets for computing resources. The high budgets are essential to foster research in software engineering and microelectronics.

Lastly, the report notes that a rapid increase in the deployment of resources, both monetary and human, for research in information technology may create manpower shortage in other areas of research. This has to be watched carefully.

Overall the report is well researched and documented. The writing style is also very good. It is of great value to policy makers in universities, industry and government.

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Turtle geometry (The computer as a medium for exploring mathematics) by Harold Abelson and Andrea diSessa. The MIT Press, 55, Hayward Street, Cambridge, MA 02142, USA, 1981, pp. 477, $30. Indian orders to Affiliated East-West Press Pvt. Ltd, 25, Dr. Muniappa Road, Kilpauk, Madras 600010.

This book has grown out of extensive work done at MIT under the leadership of Prof. Saymour Papert on Logo. Prof. Papert pioneered the idea of teaching children through a discovery method propounded in his book *Mindstorms*. The powerful role of computers in learning was realised by Prof. Papert. Many computer-based learning systems have been superficial emphasising rote learning. This book is different. It uses tracings which can be made on a computer's display screen by a computer-controlled 'turtle' whose movements can be described by suitable computer programs. Using extremely simple commands such as FORWARD x, RIGHT x, LEFT x, REPEAT a point on a display screen can be moved and create patterns. The authors point out that even very simple programs using these commands produce geometric designs whose symmetry and regularity provoke investigations in geometry and number theory.

The book used the computer effectively to introduce geometry and applied mathematics at the high school or undergraduate level. The use of an interactive graphics terminal lets a student explore very advanced topics such as finite differential geometry without stating that this is what is being done.

The book has nine chapters. It begins with an introduction to turtle geometry and writing programs to move the turtle on the screen. It illustrates drawing many complex figures. Chapter 2 shows how to

model patterns of growth such as in biology. In Chapter 3, turtle methods and coordinate methods for drawing both two- and three-dimensional drawings shown in perspective are compared. Chapter 4 discusses the topology of curves in the plane and applies topological principles to the design of an algorithm that enables the turtle to escape from any maze. Chapter 5 presents geometry of curved surfaces. Chapters 6, 7 and 8 extend this perspective to simulate drawings on surfaces of a cube, a sphere and highlights some important ideas such as linearity, symmetry groups and invariance. The last chapter uses computational exploration of curved surfaces to provide the framework to study Einstein's General Theory of Relativity and for simulating the motion of particles in a gravitational field as predicted by the theory.

The book is very original and highly readable. It is strongly recommended to anyone interested in innovative teaching of mathematics.

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