Book Reviews

Spaceflight Mechanics 1999, Volume 102 (Parts I and II), Advances in the Astronautical Sciences, edited by Robert H. Bishop, Donald L. Mackison, Robert D. Culp, and Maria J. Evans, Published for the American Astronautical Society, by Univelt, Inc., P.O. Box 28130, San Diego, California 92198, USA, 1999, pp. 1600, $280.

The two volumes record the proceedings of the Ninth Annual Space Flight Mechanics Meeting held at Breckenridge, Colorado, USA, during 7–10 February 1999. The meeting was co-sponsored by the American Astronautical Society (AAS) and the American Institute of Aeronautics and Astronautics (AIAA), and was organized jointly by the Space Flight Mechanics Technical Committee of the former, and the Astrodynamics Technical Committee of the latter. The meeting had 93 technical presentations organized in 15 sessions, and 10 non-US countries were represented among the attendees. A special feature of the meeting was that one of the sessions was devoted to MATLAB™ applications to a variety of problems in space flight mechanics.

The first session of the conference focuses on planetary explorations. The first paper of the session is of a project-management nature, dealing with the role of independent assessment in a complex, multidisciplinary, multination programme such as the International Space Station (ISS). The ISS is a laboratory, test-bed, and observatory, all in one. It requires the design, hardware, logistics, management, and operations to be all integrated. Its assembly in space requires an unprecedented number of extra-vehicular activities (EVAs, popularly known as 'space walks'), rendezvous and docking, and robotic remote manipulator system activities. With some of ISS assembly elements being the heaviest cargo items to be ever transported to space, the mission is truly one of a grand scale, presenting many new challenges in technology and management. The paper discusses the role of independent assessment by agencies, external to the main contractors and project monitors, in providing decision inputs by identifying key programmatic risks in a timely fashion. It also provides a sketch of the analytical processes involved in the assessment process. Independent assessment contributes to unbiased evaluation based on analysis and testing, and focuses on technical issues rather than budget or schedule concerns. As India progresses along the direction of creating a technology-driven society, and undertakes national projects of ever-increasing magnitude and complexity, we may have something to learn from these techno-audit concepts to minimize risk and enhance cost-effectiveness.

Mars has fired human imagination from time immemorial, first because of its colour, and later as surface structures resembling 'canals' were 'discovered' by Lowell. Now it is known to have an atmosphere, albeit rate, polar ice caps, and abundant surface water earlier in its history. Little surprise, then, that the first session offers three papers devoted to Mars exploration. Mars has been visited by several man-made craft, but manned exploration of this intriguing astronomical neighbour remains an exciting dream of the mankind. Considering the distance and human endurance, a manned trip to Mars poses extreme technological challenges, far more demanding than the moon-landing trip, which was itself a technological wonder. Numerous space transportation concepts are being weighed in order to make the problem tractable. An optimal braking/landing scheme for such a mission is the subject of one of the papers. It suggests a combination of chemical (rocket-powered) and aerobrake (braking action by atmospheric friction) retardation as a viable mechanism for Mars orbit capture. A second paper explores the broader aspects of departure energies, trip times, and entry speeds required for a manned Mars mission. The third paper on the subject dwells on the exploration aspects of possible Mars missions, concentrating at a functional level on the types, scope, and scale of activities to be carried out by human crews and the support equipment in the first manned mission, as well as by the automated systems that will arrive before the crew and that continue operating while no crew is present.

Discussion of a lunar and planetary coronagraph explorer and a paper on deflection of earth-approaching asteroids complete the first session. This second paper is of immense topical interest, even (or especially?) among the lay public as evidenced by the box-office success of yester-year's block-buster movies such as 'Deep Impact' and 'Armageddon'. But more seriously, evidence is mounting that a catastrophic or at least a damaging asteroid impact on the Earth may not be an impossibility in time scales of several generations. The spectacular multiple collision of the comet Shoemaker-Levy 9 with Jupiter in July 1994 was a dramatic reminder of the inevitability of such catastrophes in the Earth's future. We now have the technological wherewithal to detect approaching asteroids well in advance and accurately predict their impact time and location. But predicting an impending global doom offers little consolation; mitigating it, at least partially, would be a triumph of modern technology. The study on optimal deflection of menacing asteroids, possibly using a nuclear explosion, is a scientific response to this popular threat perception.

The session on mission design and analysis discusses the possibility of Earth-orbital plane changes utilizing lunar gravity-assists, space mission prototyping by students using TK Solver Plus™ software, parametric analysis of Earth-entry trajectory, and a prospective look at space surveillance and operations. In a world increasingly having to cope with the cat-and-mouse game of long-range offensive capabilities and defensive countermeasures, space-based surveillance forms the eyes and ears of the defensive system, and the last paper adds one more idea to this research-intensive field.

Structural dynamics and controls are important aspects of space structures and bodies. A difficult but prevalent problem in these areas involves the study of systems with elastic and/or fluid members. A session devoted to these topics discusses the fuel slosh problem as well as dynamics of elastic-membered bodies. An analytical paper here provides insight into the role of products of inertia caused by small mass asymmetries in spacecraft dynamics. Minimum-time control of robots, satellite passive damping, and learning/repetitive controllers are other interesting topics of the session.

Constellation-deployment of satellites offers functionalities difficult or impossible for single satellites. Large aperture synthesis, interferometric observations, etc. are some of the special advantages of constellation flying. An entire session is devoted to this topic, covering orbital dynamics, station-keeping strategies and maintenance of relative spacing, mitigation of differential perturbation, and dynamics and control of cluster orbits are covered in the session.

Arguably the most important analytical (and the most classical) aspect of space missions relate to their trajectories, and a conference on spaceflight mechanics cannot go without a session on this theme. A new technique (higher-order differential inclusion) is applied to transfer orbit optimization. Low-thrust propulsion receives emphasis because of the emergence of ion propulsion as a viable prospect. Two papers are presented in this area: one for an optimal Mars mission trajectory, and the second on the influence of coordinate system selection on trajectory optimization using the Genetic Algorithm. This last algorithm, along with Recursive Quadratic Program, is also used in another paper on optimizing interplanetary trajectories (Earth-Venus-Earth and Earth-Mars-Earth). Again, with possible application to space-based defence systems, is a study on optimal interception of an orbital craft by another at a higher altitude using upper atmospheric aerodynamic assistance.

We now come to an interesting session. The unifying theme for this one is not a particular space mission or technology. The session discusses the application of the MATLAB software to selected space-related problems. Through successive stages of evolution, MATLAB has emerged as a powerful software tool for scientific analysis of the mathematical type and the aerospace domain has become an extensive user of the software. A dedicated session by the leading professional society in space sciences is a reflection of the importance of this software to the community. The problems for which MATLAB solutions are presented include two on spacecraft attitude determination/control, and one each on separation of International Space Station and its Crew Return Vehicle, gravity-assist trajectory design, kinematics of rigid bodies, GPS simulation and analysis for reusable launch vehicles, and control design and simulation of the automated transfer vehicle.

Between the two volumes of the Proceedings, there are two sessions devoted to orbit determination. The first of these has three papers related to the Topex/Poseidon altimeter satellite: one addresses orbit determination to centimetre-level accuracy, the second focuses on near-real-time (within 24 hrs) availability of the orbital estimate, and the third considers the effects of physical factors such as radiation pressure, anomalous acceleration, and motion of the centre of mass. Two papers relate to GPS, with the first suggesting ways to mitigate the effects of selective availability (SA), and the second combining GPS and satellite laser ranging for precise orbit determination of ICESat (Ice, Cloud, and Elevation Satellite). Other interesting papers of the session concern the Gravity Recovery and Climate Experiment (GRACE) and the Mars Global Surveyor.

The second session on orbit determination (in Part II) has two articles dealing with low-Earth satellites: one utilizing accelerometry to aid precise orbit determination, and the other applying improved drag models to three specific satellites. Determination of geosynchronous orbit bias, medium-altitude orbits, and near-circular orbits, and geodynamic parameters by stochastic means are other papers here.

In addition to controlling the motion of a space body as a point, i.e. its trajectory, it is also necessary to determine and control its altitude, i.e. its motion about its centre of gravity. This is the last session reported in Part I, and has six papers covering a range of topics from H_∞ controller design with nonlinear actuators, through bifurcation analysis, adaptivity in the presence of large system model errors, and limit cycles for improved performance in self-tuning learning control systems, to Floquet stability analysis of disturbances. Control of attitude presupposes its determination, and this aspect is considered in a session reported in Part II of the volume. An interesting paper from Germany outlines a very fine (~1 arcsec) altitude determination and control system for small satellites which are recently emerging as low-cost options for pursuing space science. A hybrid system (CCD star tracker and 3-axis gyros), RADARSAT precession, gyrocompassing by intermittent GPS interferometry, and multipath rejection in GPS-based attitude determination through adaptive Kalman filtering are other topics presented here.

Moving over to orbital mechanics, the recent interest on asteroids again comes out by way of three papers: on the dynamic environment of an asteroid, on the stability of orbits around small bodies, and on resonance in polar orbits about ellipsoidal bodies. The first of these has direct application to the asteroid 433 Eros, the target of the NEAR mission mentioned earlier. An orbital control strategy, an astrodynamic software, and an aspect of a 3-body problem are other topics addressed.

Man's venture into space may be only decades old, but in this limited period, we have managed to litter the near-earth space sufficiently with debris to cause concern for future space missions. This concern is reflected in a session with six papers. One compares optical versus radar observation of debris, while another presents results from an orbital observatory. Also discussed in the session are probability of close approaches, orbital conjunctions and collision prediction, errors in ephemeris prediction, and perturbation effects on debris in supersynchronous.

Unlike near-Earth missions, deep space probes cannot be readily controlled through two-way communication because of the long ratio propagation delay. Thus self-contained autonomous navigation system for such missions is a topic in the session on navigation and control. The diversity of the area is exemplified by papers on star pattern recognition, numerical data fitting, rendezvous problem, and orbit attainment and maintenance.

Tethered satellites are an area of much study and development. The dynamics of tethered configurations is the focus of an entire session, which also has a paper on the identification of such satellites. The final session, dedicated to satellite tracking and targeting, has a 3-part paper on satellite tracking using ambient RF, besides those on selective availability effect reduction on post-processed orbits, variation of parameter methods, and improved low-Earth orbit prediction through refined atmospheric density variation estimation.

Spaceflight Mechanics 1999 is exhaustive in scope, broad in coverage, deep in treatment, and represents the state of the art in the discipline. The two parts constituting the volume are a treasure-house of information for the space scientist and engineer.

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Discovering mathematics with Maple edited by Roelof J. Stroeker and Johan F. Kaashoek, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1999, pp. 248, sFr. 58.

Scientific analysis starts with the requirement of understanding the problem at hand and then to utilize the results for conversion into products. Mathematical description gives us the precise statement of the problem and the conditions. Simple problems use a few arithmetic procedures. It is not always as simple as this but it compels and demands more rigorous involvement. Sometimes new mathematical objects are to be created to match the demands of the problem. Algebraic arguments support us for the creation of new mathematical objects and the topological imagination gives us the possible choices. The immediate next stage, conversion, makes use of arithmetic exercises and produces the required end result—the product. Thus the creation and production coexist in the sense of the above description. In such an environment, the computer algebra—Maple, if understood properly, is an handy tool throughout the full life cycle of the problem–solution phase. The variety of mathematical objects—sets, lists, procs, etc. — created are most wonderful when applied for the search of solutions. The packages that are used with the word 'with' to use the necessary support functions in the rest of the program cycle is most user-friendly too. The advanced graphics and the statistics packages, are quite handy tools for scientific exploration, to name a few.

If Maple can be introduced to the student at an early stage of mathematics career, possibly, (s)he has more chance to learn and use, appreciate and wonder, begin to create and make contributions. *Discovering mathematics with Maple* is a good choice for a beginner. Unlike the command reference books on Maple, it introduces every aspects in an educative way and step-by-step description. The exercises, given for practice are quite commendable in the level of grade and spurt, suitable for beginners. In fact, the overall structure of the book is so well designed that I am able to locate the appropriate location and form of a command after first reading of the book. I hope every member of maple-user community appreciates the book and the authors' effort. The usage of Maple has helped me build friendship with many researchers at the Indian Institute of Science to share many scientific thoughts and evolution. Therefore, Maple is a friend-maker too.

Experimentally, the Maple cd, attached with the book was loaded onto a pc and a new student was asked to use it in his own way for learning. As expected, I observed psychological happy mood and good feeling, and an immediate self-preparation for further dip into. He made the start with the book, continued, and now, he praises both mathematics and Maple.

Maple will convert many other students too.

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Mathematics from Leningrad to Austin, Vols I and II, by Rudolph Lorentz, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1997, pp. 538, sFr. 198.

The two-volume collection under review is a collection of some of the important papers of G. G. Lorentz edited by his son and mathematician R. A. Lorentz.

G. G. Lorentz was born in St. Petersburg in 1910 and had his college education in Tbilisi. Under the suggestion of his teachers he shifted to the School of Mathematics and Mechanics, University of Leningrad in 1928. He graduated in 1931 but had a hard life because of 'Stalinist terror' and then the Second World War. After a brief life at some refugee camps he and his wife finally arrived in Germany. He taught at a couple of universities there before migrating to Canada in 1949. He moved again in 1953 to USA where they settled down.

In spite of the job uncertainties, life in refugee camps, and changing topics because of the interests of colleagues at various places, Lorentz managed to adapt himself quickly and continue to be productive. He wrote papers steadily, supervised many Ph.D. students, wrote books and in many other ways contributed to the mathematical life of wherever he happened to be.

The following extract from the editor's introduction gives an idea of the contents:

> This "selecta" contains approximately two thirds of the papers my father wrote from 1932 to 1994. These papers are divided into four fields. The first volume contains the papers on 1) Summability and Number Theory and 2) Interpolation. The second volume contains the fields 3) Real and Functional Analysis and 4) Approximation Theory. Each of these four groups of papers is introduced by a review of the contents and significance, respectively of the impact of these papers. The first volume contains, in addition, an autobiography, a complete list of publications, a list of doctoral students and four unpublished essays on mathematics in general: a) A report on the University of Leningrad b) On the work of the mathematical mind c) Proofs in Mathematics d) About Mathematical Books.

The autobiographical note and the four hitherto unpublished essays in the first volume make for very interesting reading and are highly recommended. As for the research papers, they are divided into four major areas he worked in and each part is prefaced by a commentary by experts in that area. These commentaries place Lorentz's contribution in proper perspective and are immensely helpful.

As with the collected/selected works of any influential mathematician, these volumes are indispensable for university libraries and research institutes.

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Clifford (geometric) algebras, with applications in physics, mathematics, and engineering edited by William E. Baylis, Birkhauser Verlag AG, Klosterberg 23, CH-4010 Basel, Switzerland, 1999, pp. 536, sFr. 98.

The volume is a collection of a large number of lectures given at the 1995 Summer School on Theoretical Physics of the Canadian Association of Physicists (CAP) held at Banff, Alberta. Clifford algebras are named after the English mathematician William Kingdon Clifford who lived in the second half of the 19th Century who developed ideas introduced by H. G. Grassmann. Clifford algebras are an extension of the real number system which include vectors and their products and are useful in describing geometric transformations on higher-dimensional objects. It turns out that representations of spins in elementary particle physics realize certain Clifford algebras. The book has 33 chapters, with the first being a useful introduction to the subject. Chapter 2 by P. Lounesto also has a very useful introduction and a little history and then introduces some new methods and presents new results. Other chapters (3–6) describe geometric algebras. Some chapters describe the mathematics that is developed on Clifford algebras. Then come chapters (7–11) with definite applications in physics including rigid-body dynamics, electromagnetism, and the theory of the electron. The latter is formulated in terms of Dirac's spacetime algebra and is a tool in the analysis of all aspects of electron physics. A large number of chapters (12–16) cover applications in gravitation. Later chapters (17–27) take up the inter-twining of the matters in these earlier chapters. Towards the end of the collection one finds chapters on more mathematical properties of the algebras and even applications in engineering and also a chapter on implementing them on symbolic manipulation languages.

In summary, this collection of lecture notes is an invaluable addition to any library as a comprehensive source of information on Clifford algebras.

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