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Book Reviews

Spaceflight Mechanics 2003 (Parts 1–3), Volume 114 of Advances in the Astronautical Sciences, Proceedings of the AAS/AIAA Space Flight Mechanics Meeting, February 9–13, 2003, Ponce, Puerto Rico, edited by Daniel J. Scheeres, Mark E. Pittelkau, Ronald J. Proulx and L. Alberto Cangahuala, Series Editor: Robert H. Jacobs, Published for the American Astronautical Society by Univelt, Inc., San Diego, California, USA, 2003, p. 2294, $450.

The volume is the 13th in a series of proceedings of high-value conferences in the area of space flight mechanics, jointly sponsored by two of the world's most active professional societies in the aerospace field: the American Astronautical Society (AAS) and the American Institute of Aeronautics and Astronautics (AIAA). The conference was held during February 9–13, 2003, at Ponce, Puerto Rico, not far from the famous Arecibo Observatory which houses the world's largest radar with a reflector antenna of 1000-ft diameter used for atmospheric and planetary studies. Quite aptly a lecture on the Observatory by its Director, Dr Daniel R. Altschuler, outlining its history and science contributions, was included in the conference, as also a visit to the impressive facility. In fact, the intricate cable-suspended, rail-mounted feed structure of the radar forms the cover picture of the Proceedings volumes. Another important event was the AAS Dirk Brouwer Prize Lecture "A half century of astrodynamics" by the awardee, Prof. Roger Broucke. A poignant reminder of the persisting challenges and hazards of space ventures was set up in the conference area in the form of a memorial to the astronauts killed in the tragic and still-fresh-in-the-memory Columbia Space Shuttle disaster, which included Kalpana Chawla.

Spaceflight Mechanics 2003 comes in three large volumes with a total of almost 2300 pages, each professionally hard bound in the traditional glossy black cloth cover of the series for archiving, as is worthy of its contents. The conference brought together 160 participants to hear 130 presentations, including 26 with lead authors belonging to 9 foreign countries, in 20 scheduled technical sessions organized for the most part in three concurrent sessions. At an *average* length of 17 pages each in large-format (24 × 17 cm) page size, the papers report in-depth analysis and results of frontline research in fundamental aspects of space flight mechanics as well as those associated with the increasingly diverse space applications.

The themes of the individual sessions amply reflect the diversity of the research areas, with further spread of topics within each session. The importance of some of the themes, and the consequently large number of papers in the areas, is reflected in four of the themes being split into two sessions each. These are: Formation flight, Navigation and orbit determination–Operations, Mission design, and Orbit determination. In fact, the topic of orbit determination, which is an essential discipline in space flight mechanics, appears in multiple combinations in the Proceedings–by itself as two full sessions, and further in combination with navigation in two more sessions. Another core area, relating to spacecraft attitude, appears in multiple sessions—the theory of attitude control, hardware aspects of attitude determination and control, attitude determination and control in actual space missions, and attitude determination and dynamics.

Certain complex space functions require coordinated operation of multiple satellites with precise relative orbits and/or position. Interferometry is one significant example where the spatial separation helps in establishing a longer baseline than is possible with a single satellite, leading to higher resolution of observation. Such formation flight is an important area of research in view of its theoretical and technological complexities as well as practical necessity. Beside the two sessions devoted to the subject, a third is dedicated to the related topic of tethered flights wherein satellite pairs (or larger numbers) are tied together by a flexible link (or multiple links) similar to a rope. Tethered flight is highly complex because of the additional dynamical modes of the combination. An interesting concept analysed in a paper in the session pertains to creating artificial gravity in spacecraft by tethering it to its spent rocket and spinning up the satellite–rocket pair about their common centre of mass. Such artificial gravity would help human crew by minimising loss of bone mass and improving functionality in long-duration interplanetary missions by creating a more Earth-like gravity environment. An additional degree of complexity is introduced when the tether is of variable length; such an arrangement forms the subject of another interesting paper in the session.

Artificial intelligence, especially learning systems, is increasingly being proposed for space applications to overcome the limitations imposed by complex and nonlinear system behaviour as well as lack of complete knowledge about system parameters, inputs, and environmental factors. Publications describing and analysing such systems are making more frequent appearance in system-related conferences and journals. *Spaceflight Mechanics 2003* hosts several such papers. One of these deals with an adaptive inverse iterative learning control scheme for learning very fast from very short experience in order to perform high-speed or high-precision not possible with regular feedback control. Another paper discusses the use of an autonomous artificial neural network star tracker for spacecraft attitude determination.

The *Spaceflight Mechanics* series generally introduces a number of space missions that are futuristic at the time of publication. The current volume conforms to this tradition by reporting research and design issues relating to a number of exotic missions in two dedicated sessions. The first of these reports the design of the much-delayed SIRTF (Space Infrared Telescope Facility), design and implementation of the phasing orbits of CONTOUR (COmet Nucleus TOUR) spacecraft, orbit trajectory design for the MESSENGER Mercury orbiter, options for a mission to Pluto and beyond, trajectory design for the Mars Reconnaissance Orbiter Mission, and the primary science orbit for the same mission.

The second session on Mission design comprises papers on mission planning for the space maneuver vehicle, outer-planet mission analysis using solar-electric ion propulsion, heliocentric earth trailing orbit design for a small probe concept, preliminary design of Earth–Mars cyclers using solar sails, designing phase-2 for the double-lunar swing-by of the Magnetospheric Multiscale Mission, study on recovery of escape missions, and a discussion of the CloudSat mission as a virtual platform. These papers provide a preview of the diversified and complex space missions that the world may expect to see in the coming years and possibly decades.

Overall, the bulky proceedings represented by *Spaceflight Mechanics 2003* is a gold mine of high-grade and authentic information and knowledge that the serious researcher in space sciences and technologies cannot afford to miss. The three-part volume will be a very valuable addition to most advanced science and technology libraries.

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Astrodynamics 2003, Vol. 116, Parts 1–3, Proceedings of the Astrodynamics Specialist Conference, co-sponsored by the American Astronautical Society (AAS) and the American Institute of Aeronautics and Astronautics (AIAA) held at the Big Sky Resort, Big Sky, Montana, USA between 3rd and 7th August 2003, edited by Jean de Lafontine, Alfred J. Treder, Mark T. Soyka, and Jon A. Sims. Published for the American Astronautical Society by Univelt, Inc., P. O. Box. 28130, San Diego, California 92198, USA. HC plus CD ROM, p. xxiv + 2722, $490.

The 2003 Astrodynamics Conference was dedicated to the memory of Prof. V. J. Modi of the University of British Colombia, Canada. It was almost impossible for anyone to miss him at any international conference on space science-related topics. When the Editor of this Journal invited the present reviewer he was excited to write about the Proceedings since Prof. V. J. Modi was instrumental in starting the aerospace and in particular the space dynamics activities during the 1960s at the Department of Aerospace Engineering, Indian Institute of Science, Bangalore. He gave excellent course on “Introduction to Space dynamics AE 297” and some of his students became faculty in many institutions in this country. He had instituted the Jaya Jayant Award for Excellence in Teaching at the Indian Institute of Science. He donated a large collection of his books to the Space Technology Center at the department. Just before passing away he held the Institute’s Satish Dhawan Chair as well. In the years to come it is hoped that we in this country will repay his contributions in an appropriate manner.

The advances in any subject are interesting and more so if it covers almost exhaustively the complete range of the latest topics in it. The present collection of papers contains typical examples of the above features. This review hopefully conveys the contribution to excite the people to read the original proceedings.

Part 1: Special Session 1 on Innovations in astronautics education: Satellite orbit determination (OD), GPS, an open-source simulation and modeling of spacecraft with capability for extension by the user, a position and attitude visualization software, comparison of various Mars Exploration programs, sharing of laboratory equipment across universities via the Internet, examples of spacecraft attitude failures, satellite simulator, a hardware-in-loop simulation of satellite control system using MATLAB, Simulink, Real Time Workshop and dSpace emulator.

Session 2 on Mission trajectory and design–I: Half or full revolutions return trajectories via planetary flybys, Synodic period Earth–Mars cyclers with intermediate Earth encounter, Powered Earth–Mars cyclers, Development of a propellant metric, and Parking orbit human missions to Mars.

Session 3 on Orbit control, Transfer–I: Softer thrust transient to reduce pointing errors thereby spinning rate with propellant saving, A new coupling, longitude and one year propagation (CLOP) strategy for geostationary satellite eccentricity control, simulation and real data demonstration of filter-smoother estimation of a maneuver, Plane change by third body as against one impulse, a beautiful paper using energy and angular momentum, the cardinal conservation quantities in physics, to obtain pitch programs for a launch vehicle, orbit transfer, and reentry trajectories, and guidance trajectory for radially accelerated trajectory.

Session 4 on Orbit determination, navigation: An improved deterministic radiation modeling improves OD accuracy, Demonstration of how gravity modeling beyond 10×10 terms does not improve accuracy but far beyond leads to batch filter divergence, Sigma point filters for efficient OD, Important covariance transformations for close approach calculations, Maintaining time at Mars for accurate position estimation using Kalman filter, A sophisticated satellite and test mass dynamics state estimation for drag free control, Submillimeter tracking of moving receiver using pseudolite carrier phase measurements, and OD for Triana and FKSI missions.

Session 5 on Tethers: Comparison of the performance of triangular and tetrastar configurations, Detection of such systems using multibody dynamics based on a reasonable nonzero value of the Lagrange multiplier, Dynamics of such space manipulators to determine the torques to move end effector position without the tether sustaining negative tension, Control of systems using quasilinearization and Chebyshev pseudospectral approximations, Minimum mass design for artificial gravity and abort assist during mission to Mars, End body dynamics of artificial gravity generating elastic tethers with nonplanar spinup, Dynamic stability of electrodynamic tethers in inclined eccentric orbits, and their linear stability.

Session 6 on Mission trajectory and design–II: A solar orbiter trajectory design, Another design for Mercury mission, Deep drill mission to Asteroid 4 Vesta, Single electric propulsion spacecraft to orbit the Jupiter moons Callisto, Ganymede, and Europa, Mission trajectory to avoid Saturn rings and tour its moons, Cassini tour navigation strategy to explore Saturn, and Novel interferometric optical architecture for imaging of satellite formations.

Session 7 on Orbital debris, collision probability: Shape, and geometric uncertainty for estimating collision probability, Effect of velocity uncertainty covariance for geostationary satellites, Statistical properties of Keplerian orbits, Importance of argument of perigee, and right ascension of the ascending node for GEO and Molniya orbits, Explanation for the distribution of closest approach distance based on the distribution of connected variables like eccentricity, radial distance, and inclination, Study of STERO spacecraft for collision, and demonstration of the perigee lowering strategy as the best for meeting the 25-year lifetime orbital decay guideline for GTO debris without additional maneuvering.

Part 2: Session 8 on Attitude dynamics and control–I: Magnetic attitude control for AGILE, a mission for gamma ray observation, A mixed moment gyro with momentum wheel attitude control for large-angle slew maneuvering and precision attitude control, Definitions for pointing errors, accuracy, displacement, jitter, stability and windowed stability, their metrics, and associated algorithms in time and frequency domains, Alleviation of spill over in large flexible space structures using constrained optimal regulator and estimator technique, Use of Stewart platform for vibration control and pointing, and A semi analytical approach in the combined structural and control optimization of a space station model.

Session 9 on Orbital dynamics: Qualitative demonstration of the regions of chaotic motion around the potato-shaped asteroid (433) Eros with a simple straight line model, Effect of solar gravitational perturbations on the stability of L4, L5 libration points in the restricted 3-body problem, Spheroidal potentials and gravitational attraction by a rod and a disc having applications for galaxies and large structures in the universe, Periodic orbits from generating functions, Modeling error index to compare approximate methods of relative motion, Generalization of Battin's method to obtain multiple revolution Lambert solutions, Application of Lyapunov's exponent for trajectory correction maneuver and navigation in 3-body problems, and Solution of the ubiquitous Kepler's equation using Chebyshev approximation.

Session 10 on Optimal trajectory design and optimal control: Interplanetary flight studies to Mars in about one month with advanced propulsion techniques, optimal solutions by Legendre polynomials or generating functions, Use of analytical methods to evaluate gradients in optimization problems, Combination of high-thrust chemical and low-thrust electrical engines, Utilization of nonperfectly reflecting solar sail spacecraft.

Session 11 on Attitude dynamics and control–II: Sensitivity studies of the parameters on the spinning rocket, Attitude stabilization of asymmetric rigid spacecraft using two impulsive control torques, Performance and stability of higher-order repetitive control, Frequency domain prediction of final error due to quantization in learning and repetitive control, A closed loop near optimal control using interpolating polynomials without angular velocity, An 18 degree-of-freedom controller design for disturbance rejection for the ST7 mission, and Optimal simultaneous 6-axis space vehicle command with precomputed thruster selection catalogue.

Session 12 on Formation flight–I: Designs to choose so as to minimize the effect of non-spherical Earth on the secular drifts, Insertion of Cloudsat and Calipso satellites in the A-Train constellation, Establishment and reconfiguration problems in Earth orbits, Spacecraft with flexible appendages, Video tracking of satellite testbed, and Control near L1, and L2 in Sun, Earth/Moon including solar radiation pressure.

Special Session 13 on International Space Station (ISS): Flex verification and flight experience of Russian guidance, navigation and control, flex-controller interaction during station reboost, Screening such interaction during attitude holds and steering, An innovative model reduction technique for handling flexibility, Dynamic and control analysis of flexible ISS, Symbolic code generator for the equations of motion, and Description of a plug-and-play simulation and analysis platform DSAT for studying complex systems.

Session 14 on Attitude determination, system identification: Spacecraft onboard gyro instrument calibration using simulated and real data using Kalman filter (KF), Magnetometer-based gyroless attitude and rate estimation algorithm using kinematic approach in modeling angular acceleration of spacecraft and another spacecraft dynamic model approach through the KF, Attitude determination using disturbance accommodation technique, Autonomous star tracker for mission to Pluto and Kuiper belt, An autonomous telescope attitude estimation using real-time star pattern recognition useful for amateur astronomers, Novel technique for creating nearly uniform star catalogue, Algorithm to detect the presence of a parasite satellite, and KF technique for estimating the parameters of an air-bearing spacecraft simulator.

Part 3: Session 15 on Autonomous GNC systems: Autonomous slew maneuvering and attitude control using the potential function method that is an extension of the Lyapunov method, Development and measurement of solar Doppler shift for satellite OD, Autonomous landmark tracking OD strategy, The deep impact mission to Comet Temple 1, Conceptual design of the GNC for a maintenance and repair spacecraft, An autonomous guidance and control of an Earth observation satellite using low thrust, and An orbit design for global precipitation measurement.

Special Session 16 on Neutral density and satellite drag: Review of the past, present and future satellite drag modeling capabilities, Density values derived from CHAMP/STAR accelerometer data, Separation of gravity and drag by GRACE mission, Neutral density derived from ultraviolet airglow observations, Secular decrease in thermospheric density during 1966–2002 period derived from historical orbital elements, Review of high accuracy satellite drag model that used 75–80 inactive payloads and debris, Atmospheric density correction using two line element data sets, Use of physics-based models in batch least squares filter for data assimilation and forecasting neutral density, Local density model validation by high eccentricity satellite observations, and Atmospheric behavior during solar/geophysical storm conditions.

Session 17 on Orbit control, transfer–II: Low-thrust orbit transfers based on simple control laws, optimal supersynchronous to geosynchronous, and Stationkeeping for unstable periodic orbits.

Session 18 on Constellation design coverage and analysis: A small set of satellites for midcourse tracking, interferometric observatories in circular orbits, Experience with

Globalstar constellation, Tundra constellation stationkeeping, and Application of ergodic theory for coverage analysis.

Session 19 on Aerocapture, atmospheric entry: Low-thrust guidance schemes for Earth capture trajectories, Evaluation of feasible trajectories for Earth orbit aerocapture/aerogravity assist demonstration, Past and planned activities at CNES, Entry of trajectory of Mars Rover, Aerocapture navigation at Neptune, Assistance of Titan aerogravity for capture into Saturn orbit, Uranus aerocapture, and Ballute (a cross between balloon and parachute) aerocapture at Titan.

Session 20 on Formation flight–II: A genetic algorithm-based sliding mode control for satellite pair maintenance, Guidance algorithm for reconfiguration and maintenance based on Clohessy–Wiltshire equations, Collision avoidance during rendezvous via relative motion approximation, Error analysis of satellite formations in near-circular LEO, Formation maintenance for near-circular LEO, Optimal initialization of circular formation with collision risk management, Minimum fuel or time maneuver of satellite formation, Pulsed thrust method for hover formation, and Use of power limited thrusters for maintaining periodic relative trajectories of formation.

Session 21 on Flight experience: GPS-based orbit determination for Coriolis/Windsat satellite, Star tracker experiment on Space Shuttle STS-107, Design and performance of RHESSI spacecraft magnetic attitude control system, Mars ODESSY mapping OD strategy, Early operations report on the FALCON spacecraft, and Guidance and navigation report on NOZOMI spacecraft.

Session 22 on Analytical and numerical methods: Accuracy and speed effects of variable step integration for OD and propagation, A precision orbit predictor for complex trajectory operations, Use of differentials in astrodynamics, and Multipurpose low-thrust interplanetary trajectory code.

Session 23 on Space surveillance and space catalogue: Improvements to OD algorithms for automatic catalogue maintenance, New sensor resource allocation algorithm for surveillance support of special perturbations catalogue, Characterization of surveillance sensors using normal places, and Ionospheric refraction correction in the naval space surveillance.

Appendices and Index follow the above.

General comments

The Conference papers represent generally the work carried out by students and their supervisors as a precursor to journal publications. At times in a few papers sufficient care has not been taken in formatting the figure or their titles. The kind of problems chosen provides a good training and eventual contribution to the growth of the subject. This is mentioned specifically since with a large number of institutions and scientists in the area of space science, the usefulness in India, and appropriateness should be kept in mind that would enhance their capabilities as the years pass. Similar activities can be carried out even in India due to the availability of competent manpower but regrettably there appears to be not much will or support. This will provide job opportunity and a career for many scientists and engineers. Despite a fair amount of activities in space science, unfortunately there is no proper record that would help a space historian. The activity of using the hardware and software by earlier graduate students would help in subsequent teaching activity to enable the students learn efficiently and faster. Some of these publicized softwares can be used in teaching. The concept of term papers should be encouraged in teaching. One general comment about papers using Kalman filter is that the best possible tuning of the filter parameters have to be used to get the best possible performance in particular works needing very delicate and accurate values or to show conclusively one variant of (say the sigma) the filter is better than the other. It would be interesting to have papers on the reliability and cost aspects of the mission designs for interplanetary travel.

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Spaceflight Mechanics 2004, Vol. 119, Advances in the Astronautical Sciences, Parts 1–3, Proceedings of the American Astronautical Society (AAS) and the American Institute of Aeronautics and Astronautics (AIAA) Space Flight Mechanics Meeting held at Maui, Hawi'i, USA, between 8th and 12th February, 2004, edited by Shannon L. Coffey, Andre P. Mazzoleni, K. Kim Luu, and Robert A. Glover. Published for the American Astronautical Society by Univelt, Inc., P. O. Box. 28130, San Diego, California 92198, USA. Hard Cover plus CD ROM, p. xxv + 3292, $ 560.

The advances in any subject are interesting and more so if it covers many latest topics. The present conference papers are of this nature. This review hopefully conveys the contribution to excite the people to read the original proceedings. The contents have been specifically included in some detail since for many papers just the title alone does not convey the contributions and the reviewer found it compulsive (!) to consider the summary as well as the conclusions to provide the contents in the above manner followed by general comments on typical interesting papers.

Part 1: Special Session 1 on Solar sails-I: Format for reporting performance of gossamer solar sails, the world's first solar sail spacecraft COSMOS 1, A geostorm warning mission satellite located at 0.98 AU, NASA's integrated development of solar sail propulsion project, System demonstration of a scalable square solar sail, and Design of a solar sail geostrom warning mission which is the best choice for applying the sail technology.

Session 2 on Orbital mechanics-I: A-B-Cs of Sun-synchronous orbit mission design, Use of X-ray pulsars for spacecraft navigation which are stable like lighthouses for ships, Optimal coverage of northern hemisphere with elliptical satellite constellations, Insertion and maintenance of small Earth observation satellites including the effect of higher-order geopotentials and atmospheric drag, Recent developments in the atmospheric models used for Mars Orbiter lifetime analysis, Optimal constellation design for orbital munitions delivery system, and Design of strategies for Calipso mission to avoid sun glint.

Session 3 Special session on ACS sensor alignment and calibration: Unscented Kalman Filter (UKF) technique for spacecraft attitude and parameter estimation, Attitude determination and calibration with redundant inertial measurements, A generic object-oriented environment programming for modeling skewed multi-axes gyros, Precise attitude determination using star trackers and hemispherical resonator gyros based on Extended Kalman Filter (EKF), Autonomous focal plane calibration by an intelligent radial basis function network, KF-based spacecraft attitude estimation using star camera and three-axis gyros, Star tracker calibration and attitude control system validation for a micro satellite, and System identification of the mass and inertia characteristics of a spherical spacecraft simulator using a least square technique.

Session 4 Special Session on Space surveillance processing: A motivation for and the development of standard astrodynamic software, Safety policy for avoiding inadvertent laser illumination and damage of satellites, Automated tasker to receive positional data of space debris by space surveillance network, tools and databases to maintain space catalogue with historical examples, and Contribution of space surveillance to Columbia accident investigation in particular showing a piece from the leading edge had floated away from it on Day 2.

Session 5 on Interplanetary missions-I: An aerocapture guidance algorithm at Neptune using angle of attack as the primary control variable, Lunar-assisted mission trajectory to Mercury, Nozomi Earth swingby orbit determination under mission anomalies, Analysis of low-cost two spacecraft to the Jupiter moon Europa, Evaluation of an energy cutoff algorithm for Saturn insertion with burn interruptions, The return of Stardust spacecraft after collecting samples from interstellar dust and Comet Wild 2, Visibility analysis of mission for Mars moons Phobos and Deimos, Navigation of New Horizons spacecraft to Pluto and its moon Charon, and Options for optimal mission trajectory to near-Earth objects using low-thrust propulsion.

Session 6 on Attitude dynamics and control-I: Time varying potential function control for constrained attitude tracking, Attitude and position estimation from vector observations using vision-based technology camera, Attitude estimation from vector observations using a fast particle filter together with Genetic Algorithm (GA) and comparison with EKF and UKF, Flexible space system state and parameter estimation by simulation using KF, Figures of merit based on covariance of the attitude error vector, Attitude determination and control of a nano satellite using magnetometer and Sun sensor data using EKF, and Equal chord attitude determination using real data for the spinning CONTOUR spacecraft.

Session 7 on Optimization and control-I: A new global search to identify promising and optimize ballistic families of free return Earth–Mars cyclers, A pseudospectral method with flexibility for selecting grid points by arbitrary selection of orthogonal weights and interval, An automatic differentiation-based embedded function tool presented for orbit determination and ballistic parameter estimation, A study of guidance correcting law along aerodynamical ascent path of a space plane, Optimization of stationkeeping about the unstable Sun–Earth L2 point, Adaptive pulse width modulation control minimizing a Lynapunov function that accounts for controlled and reference systems, Optimal design of a combined feedback and iterative learning controllers, Dynamic output feedback predictive controllers for vibration suppression and disturbance rejection, and Effect of thermal field on dynamic response of structure and its interaction with control system.

Session 8 on Formation flying-I: Aspherical formations near the Libration points in the Sun-Earth/Moon system, Formation flying on orbits with arbitrary eccentricity accounting for nonspherical Earth and luni solar perturbations, Rendezvous between two spacecraft in proximate highly elliptic orbits using relative motion coordinates, Design and control of satellite formations near L2 libration point, The development of high fidelity linearised J_2 models for satellite formation flying control, Development of a highly accurate state transition matrix for relative motion using the unit sphere approach, Criteria for best configuration and Suboptimal reconfiguration for magnetospheric multiscale mission.

Session 9 on Tether satellite systems: Probability of detecting tethered satellite system using a batch filter by estimating tether accelerations per unit tether length with different end masses, lengths, and in and out of plane motions, Identification of a tethered satellite using an EKF, Command generation for tether retrieval, Equilibrium to equilibrium maneuvers of rigid electrodynamic tethers, A low-cost mission for testing in orbit a passive electrodynamic tether deorbiting system for artificial debris, Guidance and control of tethered satellite systems using pseudospectral methods, and Pointing stability and oscillatory response of a tether flying in heliocentric orbit.

Part 2: Session 10 on Collision avoidance, debris and atmospheric drag: A differential orbit correction using special perturbations fitting radar and optical data to obtain six-element state vector and ballistic coefficient to accurately estimate atmospheric density, The semi-annual thermospheric density variation from 1970 to 2002 using observational data of 13 satellites and special perturbations, Simultaneous real-time estimation of atmospheric density and ballistic coefficient due to their widely different exponential half lifetimes in the Low-Earth Orbit (LEO), Removal of arbitrary discontinuities in atmospheric density modeling, Satellite drag coefficient from 150 to 500 km with different shapes from high accuracy satellite drag model program, Disposal of objects in geosynchronous transfer orbit by atmospheric re-entry, Collision of spacecraft of various shapes with debris particle assessment, Effects of cross-correlated covariance on spacecraft collision probability, and Atmospheric density correction using the two line element (TLE) set data of LEO space objects.

Session 11 on Attitude dynamics and control-II: Application of Cayley form to general spacecraft motion, Effects of internal mass flow on the attitude dynamics of variable mass systems, Globally stabilizing saturated attitude control in the presence of bounded unknown disturbances, Influence of end, centripetal and radial burn pattern on the attitude motions of a spinning rocket, Modelling closely coupled satellite systems as quasi-rigid bodies, Optimal results for autonomous attitude control using potential function method, Design of root locus departure compensators in repetitive control based on error spectrum, and Avoidance of singularity in Euler angles by switching between different Euler angle sets.

Session 12 Special session on Optical satellite tracking systems: Accuracy assessment of the optical Maui Space Surveillance System (MSSS), The dynamic properties of rotation and optical characteristics of space debris in geostationary orbit, Wide field of view telescope development at Air Force Maui Optical Supercomputing site, Daylight astrometry and design studies for the LEO satellites, Relative orbits of geosynchronous satellites using the Cluster Orbits with perturbations of Keplerian Elements, Canadian Surveillance of space concept demonstrator, Comparison of optical and radar tracking for catalog maintenance, and High accuracy orbit updates using angles only data from MSSS.

Special Session 13 on Optimization and control-II: Stabilization of learning control in the presence of parasitic poles for short-time trajectories, Stability and performance analysis of matched basis function repetitive control in the frequency domain, Predictive feedback control for implementing optimal point to point trajectories followed by regulation, Differentiator free nonlinear proportional integral controllers for rigid-body attitude stabilization, and Primer vector theory for optimal relative waypoint flying.

Session 14 on Orbital mechanics-II: Constellation design using flower constellations, Feasibility of deployable drag enhancement by pyramidal drag sails for end of life removal of LEO objects, Design criteria for Earth-orbiting interferometric observatories in eccentric orbit with J_2 perturbations to ensure wave number coverage, A baseline vehicle for reliable low-cost access to space with scalable velocity and performance parameters, Mission analysis for deorbiting SPOT-1 satellite, Extension of Floquet theory into nonlinear regime to obtain periodic, canonical and decoupling the equations of motion, Improved aerobraking trajectory by using inertial measurement data, Partially passive inclination control of geosynchronous satellites, and Desensitized optimal orbit insertion.

Session 15 on Orbit determination-I: Improved orbit determination (OD) using high-accuracy angular observations with quality ranging data for geosynchronous satellites, GPS-based OD system for KOMPSAT-2, Improvement of estimated orbit by using single differenced LEO-GPS pseudorange measurements, Modelling the performance of the Naval Space Surveillance Fence, OD covariance based on model uncertainties for planetary and interplanetary missions, OD of Stardust from the Annefrank asteroid flyby through the Wild 2 comet encounter, OD strategy using single-frequency GPS data, and Interpolation of time varying covariance using data.

Special Session 16 on Interplanetary missions-II: Comparison of the trajectory of Space Infrared Telescope Facility with prelaunch prediction, Earth return maneuver strategies for GENESIS and STARDUST after sample collection in deep space, Design of backup orbit and proposed extended mission for GENESIS, Wilkinson Microwave Anisotropy Probe shadow avoidance maneuver analysis about the Sun Earth/Moon L2 point, Trajectory options for a Mars sample return mission, Finite burn roundtrip interplanetary trajectories with specific impulse constraints and mass discontinuities, Optimal planetary transfers via chemical and electrical engines, and Preliminary design for PHOBOS imaging and mapping.

Session 17 on Orbit determination-II: A two time scale discretization scheme for collocation, Range bias modeling for satellite catalog maintenance, Autonomous target tracking of small bodies during flybys, A variable step double integration multistep integrator, Establishment and validation of the NRL one meter telescope position, Examination of NORAD TLE accuracy using the Iridium constellation, Geosynchronous OD using real space surveillance network observations with improved radiative force modeling, and Automatic generation and integration of equations of motion by operator overloading techniques.

Part 3: Session 18 on Orbital mechanics-III: A simple algorithm to compute hyperbolic invariant manifolds near L1 and L2 libration points, Orbit mechanics in the Hill 3-body problem about Jupiter's moon Europa, Design of low-energy interplanetary transfers exploiting invariant manifolds of the restricted 3-body problem associated to the departure and arrival Sun-Planet-Spacecraft system, Keeping a spacecraft on the Sun–Earth line for atmospheric measurements, Minimum fuel orbits for stationkeeping of the L2 gossamer telescope for occultation mission, Launching a fleet of micro satellites to Earth–Moon L1 Lagrange point and return to LEO orbital planes via aerocapture using minimal additional velocity, Analytical gradients for gravity-assist trajectories using constant specific impulse engines, A tool for preliminary design of low-thrust-gravity assist trajectories (LTGA), and Modeling of proof mass self gravity field for laser interferometry space antenna gravitational wave detector.

Session 19 on Formation flying-II: A practical guidance methodology for relative motion of LEO spacecraft based on Clohessy–Wiltshire (CW) equations, A Lyapunov-based controller for satellite formation reconfiguration with J_2 perturbations, Cluster planning and control for spacecraft formations around Sun–Earth Lagrange points, Linear and nonlinear controllers for stationkeeping in eccentric orbits during a time interval covering a target area, An analytical body fixed low-thrust optimal control for satellite formation using CW equation, Autonomous orbit navigation of two spacecraft using relative line of sight vector measurements by EKF, Optimal trajectory generation and control for reconfiguration maneuvers of formation flying using low-thrust propulsion, Stabilization of satellite motion relative to a Coulomb spacecraft mission, Transient stability of relative motion about a stabilized trajectory.

Session 20 on Optimization and control-III: Fine tuning of a Kalman filter with a GA and gradient-based optimization methods, Maneuver design for fast satellite circumnavigation, On the relation between the local formation control law and the resulting configuration, Optimal low-thrust orbital transfers around a rotating nonspherical asteroids Vesta and Ceres, Optimal low-thrust trajectory analysis for constant and variable specific impulse thrusters generated by multiobjective evolutionary nonlinear programming, Strength Pareto genetic algorithm improvement by the addition of sensitivity analysis.

Session 21 on Interplanetary missions-III: Hopping analysis on Regolith-like surface of small asteroid such as ITOKAWA, The Mars Reconnaissance Orbiter mission plan, Preliminary results of Mars rover *in situ* radio navigation, Modeling and simulation of the terminal descent of Mars exploration Rover, Systems for pin-point (within 100m) landing at Mars, Coordinating of Mars orbiting assets to support entry, descent, and landing activities, Autonomous planetary landing with obstacle avoidance, Assessment of per-axis thruster control authority of Cassini spacecraft for low-altitude Titan flybys, and Dynamics and control of a herd of sondes guided by a blimp on Titan.

Special Session 22 on Solar sails-II: The L1 diamond configuration of four solar sail spacecraft to determine the structure of solar disturbances propagated to Earth, Optimal counter-intuitive solar sail escape trajectories, Earth escape using a slowly rotating doubly reflective solar sail, A comparison of solar sail control of center of mass and/or center of pressure in geosynchronous transfer orbits, Sensitivity of solar sail attitude control on the modeling accuracy of solar radiation pressure, An integrated simulation kit for solar sails, A 'Yank and Yaw' control system for solar sails, Robust thrust control authority for a scalable sailcraft, and Generalized models for solar sails.

Session 23 on Orbital mechanics-IV: Representation of invariant manifolds for applications in 3-body systems, The role of invariant manifolds in low-thrust trajectory design, Design of a low-energy trajectory to orbit three of Jupiter's moons using patched 3-body approximation, Coupled effects of initial orbit plane on orbit lifetime in the 3-body problem for a spacecraft around Ganymede, The dynamics of orbits in a potential field of a solid circular ring with the example of Mars, Orbits around an elongated 3D object such as the asteroid Eros, A complete series solution to the Lambert's problem, A Hamiltonian approach to eccentricity perturbations on the relative motion of spacecraft, and Design of satellite constellation for midcourse ballistic intercept.

Session 24 on Formation flying-III: The University of Missouri–Rolla design and building a pair of tethered satellites, Uniformly distributed flower constellation design and comparison with GPS and GLONASS, Geometric approach to orbital formation design, Hovercraft satellite simulation test bed, Low-thrust formation flight for astronomy satellite, Mihail satellite constellation, The design and development of the Gravity Recovery and Climate Experiment mission analysis tool, and Formation flying and constellation station-keeping in near-circular orbits.

Comments on some selected papers

Since it is not possible to comment on each and every paper, some representative papers (denoted by *** and omitting the AAS 04) are dealt with here.

In Part 1 some of the papers are: 100—on sailcraft specification and performance reporting but having the longitudinal axes along the diagonal is worrisome. A systematic variation of the axes systems from aircraft to sailcraft to satellites as also the incidence angles would be helpful. In 102, the quantisation about the status of design is good but not from 1 to 9. It is better to make such quantisations from 1 to 3 or 5 or 10 as in many fields of science and engineering. Typical interesting ones are 108 on the A-B-C of Sun synchronous orbit mission design, 109 on X-ray pulsars for spacecraft navigation, 112 on Martian atmosphere to keep the lifetime of orbiters to 25 years, 127 on cataloguing of millions of ELSETS and identify the origin of unknown objects, 128 on Columbia accident investigation, 141 on particle filters using a GA with an interesting perturbation introduced after reproduction stage (references 2 and 8 are identical!), 146 is praiseworthy for the vast details provided in it, in 148 the cost function could have been properly normalized to be equal to the number of measurements, as also 165 dealing with the difficulty of tuning of Kalman filter leading to the inability to identify tethered systems as compared to simpler batch processing techniques.

In Part 2, papers 173, 174, 175, 176, and 178 are very exciting since they handle the drag and density estimation problems due to their general menacing appearance as a product leading to identifiability problems. Few other nice papers are 190 on avoiding singularities when using Euler angles, 192 on the rotation and optical characterization of space debris in geostationary orbit, 197 comparing the optical and radar tracking for catalog maintenance, 220 on the covariance analysis for planetary and interplanetary OD, 222 on the single-frequency GPS data for orbit determination, 235 on range bias modeling for satellite catalog maintenance, 242 on automatic generation and integration of equations of motion by operator overloading techniques.

In Part 3, paper 252 based on CW offers many useful details, 261 compares the Kalman filter tuning by GA based and other techniques (though the choice of weights in the cost function is not discussed), 267 in applying Pareto front and sensitivity studies for trajectory optimization, 269 provides good details on Mars Reconnaissance Orbit plan, 272 deals with systems for pin point landing at Mars, and 275 on Cassini low-altitude Titan flybys are typical interesting ones.

Brouwer Award Lecture by David W. Dunham: ‘Try something different’ deals with the speaker’s personal experiences on spacecraft orbit design is a perspective among hundreds of other ways each human being can look at his life that could be helpful to others.

General comments

In the Foreword, it is mentioned that the session chairs and editors do not review all the papers in detail. Since it is mentioned that all such volumes have archival value it is better to have all the papers reviewed since there is no shortage of specialists who hopefully enjoy such a task. The comments could perhaps be given soon after the meeting as is done in COSPAR meetings.

Regarding the KF techniques used so prolifically in many papers, a few comments may be useful. After the publication of Gelb’s book in 1974 the tuning of the filter statistics has been the only major problem that was left out in routinely applying the KF. Though KF is prolifically used in many problems, the tuning of the above statistics has not been given as much attention as it deserved to attain a maturity level of being fairly near the optimal solution. Presently most of the tuning is manual and at times some sensitivity studies are carried out around chosen values of the statistics but these may be insufficient more often than what one would expect. In spite of EKF or its variants like unscented, particle filter, neural network approach, the ghost of tuning, is present in all of them! Though researchers talk about clarity in writing papers most of them using KF generally do not state the filter statistics utilized in generating the results so profusely displayed in their figures. Lastly it would be nice for such a gathering of researchers so regularly to propose and have some reference problems like the Kepler's equation enabling different techniques to be reported and the solutions compared during the conferences.

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Spaceflight Mechanics 2005, Advances in The Astronautical Sciences, Vol. 120, Proceedings of the AAS/AIAA 15th Space Flight Mechanics Meeting held January 23–27, 2005, Copper Mountain, Colorado (David A. Vallado, Michael J. Gabor and Prasun N. Desai, eds), Two parts, 2005, p. 2152, HC $ 390, Orders to: Univelt Inc, P.O. Box 28130, San Diego, California 92198, USA.

It is a pleasure to review the *Advances in Astronautical Sciences*, Vol. 120, edited by David Vallado, Michael Gabor, and Prasun Desai. The volume is a compilation of technical papers presented at the 15th AAS/AIAA Space Flight Mechanics Meeting. The proceedings contains 125 papers on space flight mechanics and related topics in 24 technical sessions, of which four are special sessions. The technical session topics are *formation flying, attitude, interplanetary, optimization, orbit determination, orbit mechanics, space surveillance, constellations, identification and controls, propagation, rendezvous and relative motion, 3-body,* and *tethers, Genesis mission, near-Earth orbit (NEO) and lunar missions,* and *Mars missions.* A review comprising a brief discussion of the technical papers is given below.

Formation flying refers to the relative navigation methods for several spacecraft in close formation, and is an area of active current research. Frank R. Chavez and Alan Lovell present a practical approach to relative satellite navigation through estimation of a state set that is more geometric in nature than the standard position and velocity component state vector. Christopher Scott and David Spencer in their paper titled *Optimal low-thrust reconfiguration for satellites in formation* compute and analyze the optimal reconfiguration of an n-spacecraft formation where the distances between the spacecraft are small compared to the radius of the reference orbit, and present an analytical approximation to predict optimal transfers. John Berryman and Hanspeter Schaub in their paper *Static equilibrium configurations in Coulomb spacecraft formations* examine the benefits of Coulomb control for spacecraft formations (minimal power usage, virtual lack of propellant, and low mass), and present an evolutionary algorithm to numerically search for steady-state equilibriums in which the sum of the accelerations on each satellite is zero. Geoffrey T. Huntington and Anil V. Rao solve the problem of determining minimum-fuel maneuver sequences for a four-spacecraft formation from an initial parking orbit to a desired terminal reference orbit while satisfying particular formation constraints using a newly developed direct transcription method called the *Gauss pseudo-spectral method.* Johnathan Berryman and Alan Lovell (*Application of a relative motion guidance algorithm to formation reassignment*) apply an impulse maneuver algorithm for relative motion trajectory guidance to a formation flying scenario that involves reconfiguration of a satellite cluster when one or more members of the cluster fails. Islam I. Hussein *et al.*, in their paper *Optimal formation control for imaging and fuel usage,* derive an expression relating the Modulation Transfer Function (MTF) and the trajectory of a sparse system of N telescopes, including a noise model to represent contamination of the optical signal, and is used to define a cost function for an optimal control problem including imaging and fuel performance measures. Suman Chakravorty (*On the fuel optimality of maneuvers for multi-spacecraft interferometric imaging systems*) studies the design of minimum fuel maneuvers for multi-spacecraft interferometric imaging systems, and shows that the underlying optimization problem is computationally intractable, by mapping it into a Generalized Traveling Salesman Problem. Simone D'Amico *et al*. introduce a formation flying concept able to realize the demanding baselines for synthetic aperture radar (SAR) interferometry, while minimizing the collision hazard associated with proximity operations. Steven P. Hughes *et al*. present a direct approach for minimum fuel maneuvers of distributed spacecraft in multiple flight regimes, assuming a fully nonlinear dynamics model. David Woffinden *et al*. (*On-orbit satellite inspection: A concept study and design*) discuss a small inspection satellite concept to visually monitor particular details of a large number of military, commercial, and scientific space assets, and verify it using a high-fidelity six-degree-of-freedom simulation. Rebecca L. Johnson *et al*. compare several existing models for relative satellite motion dynamics to the familiar linear time-invariant form of the Clohessy–Wiltshire-Hill's equations, with the goal of providing a formulation useful to mission planning specialists for satellite relative motion trajectories. J. E. Cochran *et al*. model the relative motion of two or more spacecraft by linearization of the equations of motion of the spacecraft from the point of view of developing guidance and control algorithms for rendezvous, stationkeeping, and interception. Satellite formation flight mission takes a long time, so long-term perturbation effects (such as the J_2 effect) should be countered to maintain the formation. For this purpose, Zhong–Sheng Wang develop a full dynamic model for the relative motion of formation flight and some stability conditions, and apply it to formation-keeping problems using small thrusters. With the development of technologies that make distributed space systems (DSS) a realistic option for incorporation into mission design, many new mission concepts have been proposed and will be proposed in the future which make use of this technology. Many of the features that make geocentric DSS architectures desirable are equally valid near libration points, such as increased sensor resolution, lower cost, and simplified development of smaller individual spacecraft. To this end, H. J. Pemicka *et al*. (*Discrete maneuver formation keeping at libration points L1 and L2*) focus on the development and analysis of discrete maneuvering techniques for maintaining a two satellite formation within required error tolerances. Station-keeping is an important requirement in formation flying. Hongming Li and Trevor Williams develop a novel method for applying solar radiation pressure to achieve the formation keeping of satellite formations at one of the collinear Sun–Earth libration points, while Chia–Chun Chao and Glenn E. Peterson (*Coordinated stationkeeping strategies for collocated geosynchronous satellites*) summarize the design and development of an effective coordinated stationkeeping strategy for multiple geosynchronous spacecraft occupying the same longitude with different control boxes and mission objectives. In the latter's own words, "The concept of isolating radial and cross-track separations at longitude crossing can avoid the prediction of in-track separation, which is always difficult to estimate with good accuracy after several days. A simplified analytic representation is derived which helps in understanding the relative motion between spacecraft. Numerical examples demonstrate the effectiveness of this method".

Attitude determination and control of spacecraft is a primary objective of all space missions. SungPiI Yoon *et al*. discuss the characteristics of these high-frequency components of Ice, Cloud and land Elevation Satellite (ICESat) attitude motion. The satellite was launched on January 23, 2003 into a near-circular Sun-synchronous orbit with 94° inclination and 590 km altitude, with the primary goal of measuring long-term changes in the volumes of the Greenland and Antarctic ice sheets through the Geoscience Laser Altimeter System (GLAS). Mark E. Pittelkau presents a calibration model for a redundant inertial measurement unit (RIMU) comprising a bias, a symmetric and an asymmetric scale factor, and two misalignment angles for each of n sense axes ($n > 3$) for a total of $5n$ parameters. Jean de Lafontaine (*Autonomous generation of guidance profiles for constrained, minimum-time, large-angle attitude manoeuvres*) presents analytical guidance algorithms that generate the commanded attitude profile (quaternion, angular velocity, angular acceleration) between specified initial and final states, under various constraints: minimum time, minimum torque, minimum angular momentum, no excitation of structural flexible modes and compatibility with an onboard implementation. Future space missions call for unprecedented levels of accuracy, reliability and high performance thereby increasing the demands on attitude determination and control system. Hence, Narendra Gollu addresses the problem of attitude accuracy by developing a *Ground based satellite attitude estimator* for evaluating the attitude accuracy and to evaluate the novel attitude determination algorithms. Chun-ping Lo and Richard W. Longman adapt high-order repetitive attitude control, and show it to be effective in eliminating periodic disturbances due to imbalances in momentum wheels, reaction wheels, control moment gyros, or cryo pumps on board spacecraft. The scheme learns from the error in previous periods of the disturbance, to adjust the command to a feedback control system in the present period. A similar adaptive approach by Masaki Nagashima and Richard W. Longman demonstrates the effectiveness of repetitive control in canceling structural vibrations in a given frequency range due to various disturbance sources. Hui Yan *et al*. investigate the use of magnetic torque for the time-optimal slew maneuver of a small satellite with dynamic input-output control laws.

Interplanetary mission design and analysis is a thrust area in modern space flight mechanics. This volume presents several interesting examples of interplanetary mission planning. Tapan R. Kulkarni and Daniele Mortari (*Low energy interplanetary transfers using halo orbit hopping method with STK/Astrogator*) investigate low energy interplanetary transfers from Earth to distant planets using halo orbit insertion at un-Planet L2 Lagrangian point. Apart from fuel efficiency, the method provides the additional advantages of maintaining a seamless radio contact with Earth and extensive exploration of the planets simultaneously. Try Lam explores the applications of distant retrograde orbits (DROs) around Europa, a dynamically interesting body. At low altitudes, Europa's harmonics cause drifts in eccentricity (among other orbital elements), which eventually leads to collision with the surface. At higher altitudes third-body perturbation from Jupiter dominates which may lead to collision or escape after a few revolutions. DRO are of particular interest due to proposed missions such as the NASA Jupiter Icy Moon Orbiter (JIMO). Daniel W. Parcher and Jon A. Sims present optimal low-thrust gravity-assist trajectories to Jupiter using nuclear electric propulsion using, Venus, double Venus, and Mars fly-by cases. Ian M. Roundhill *et al*. in their paper *Orbit determination results for the Cassini Titan-A flyby* discuss the results and performance of the orbit determination processes for the Titan-A encounter navigation during Cassini mission. Marco B. Quadrelli *et al*. carry out sensitivity analyses and simulation studies using complex orbital and attitude dynamics models describing the vehicle's dynamics arising during the low-thrust spiraling maneuvers of spacecraft, applicable to NASA's proposed Jupiter Icy Moons Orbiter mission. In another paper, Marco B. Quadrelli presents a novel approach to planetary precision landing using parafoils in an autonomous manner. James V. McAdams *et al*. devise a trajectory design and maneuver strategy for the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) mission–launched aboard a Delta II 7925H-9.5 launch vehicle on 3 August 2004 using an Earth gravity assist, two Venus gravity assists, and three Mercury gravity assists during its 6.6-year ballistic trajectory to Mercury. James K. Miller devises a constrained parameter optimization process for the MESSENGER mission, and shows the relationship of the method of explicit functions to other optimization methods such as the methods of Lagrange multipliers and gradient projection. James V. McAdams *et al*. develop an Internet-based trajectory database for the MESSENGER mission to reduce the time required to answer trajectory-specific requests from lead engineers, scientists, and public relations professionals (those providing information to educators, the media, and the public). B. Williams *et al*. present some early navigation results for the MESSENGER using radio metric tracking data from NASA's Deep Space Network in addition to optical navigation from onboard images of planet flybys. Vehicles that fly on low-thrust trajectories may spend months or years continuously thrusting to reach their destination. If a malfunction occurs that causes a loss of propulsion during a period of planned thrust, the vehicle must change something from the baseline trajectory in order to reach the target. John E. Weglian and Kurt Hack (*Recovery from a period of missed thrust during a low thrust mission to Jupiter*) analyse the requirements to complete an Earth to Jupiter mission, if a malfunction caused a brief loss of propulsion at various points in the mission. Jeremy S. Neubauer and Michael A. Swartwout investigate Lyapunov control functions (LCFs) for low-thrust vehicle guidance to achieve simple, robust, and efficient orbit transfers. A generalized state-based gain structure is employed, comparing performance to constant gain LCF and time-optimal methods across multiple missions.

Optimization is an important topic in space flight research, with applications ranging from trajectory design to attitude control. Most of the current papers on the topic deal with nonlinear optimization associated with two-point boundary value problems (TPBVP). The difficulty of solving TPBVP by indirect numerical techniques comes from their often nonlinear, coupled formulation and the inability to specify the initial adjoint variables accurately enough to ensure convergence. C. F. Minter and T. J. Fuller-Rowell propose a robust algorithm based on first solving a simplified analytic version of the problem, and then adopt a single shooting method in augmented steps. Prashant Patel *et al*. devise a shape-based method which assumes a path, and then solves for the optimal acceleration to maintain the path. This is an inverse of the traditional spacecraft trajectory optimization approaches attempted to find a thrust profile that produces an optimal trajectory, and requires only a single TPBVP. Scott Zimmer *et al.* determine trajectories that optimize a combination of fuel consumption and observability. Although the example problems all involve transfers from low-Earth orbit to geostationary Earth orbit, the technique can be applied to a transfer between any initial and final states. Paul Williams presents two trajectory optimization papers (*A comparison of differentiation and integration based direct transcription methods* and *Hermite–Legendre–Gauss–Lobatto direct transcription methods in trajectory optimization*). S. R. Vadali and R. Sharma present a novel power series solution method for developing feedback controllers for finite-time, nonlinear optimal control problems with terminal constraints. Terminal constraints on the state variables are handled using Lagrange multipliers. Jose J. Guzman proposes that primer vector theory can be considered as a byproduct of applying calculus of variations (COV) techniques to the problem of minimizing the fuel usage of impulsive trajectories, and presents several examples. Ossama Abdelkhalik and Daniele Mortari use genetic algorithms to search for the minima of two specially selected cost functions based on optimality definitions and mission objectives, while Samantha Infeld and Walter Murray present a method for optimizing the trajectory design for libration point missions and control strategy concurrently. Simulation of optimal models is covered in *Development of SAMURAI–Simulation and animation model used for rockets with adjustable Isp* by Tadashi Sakai *et al*. and *6-DOF simulation* and *modeling of the optimal method of ejection for the orbital express launch interface ring* by Michael W. Weeks. The paper by Andrew J. Sinclair *et al*. is the only one on kinematic optimal control problem, which is addressed for N-dimensional reorientation and is solved while minimizing a quadratic function of the angular velocity (a constant-rate rotation in each principal plane).

Orbit determination has been an ongoing activity for the past three hundred years, ever since Gauss presented his *Theoria Motus.* The papers in the volumes range from determination of geosynchrounous orbits using observations and accurate disturbance models (Zachary J. Folcik *et al*. and Benjamin Visser *et al*.) to *Low earth orbit prediction accuracy using optical data* by David Wiese and Chris Sabol, and *ICESat precision orbit determination over solar storm period* by Hyung-Jin Rim *et al*.

It is very interesting to see that analytical orbit mechanics still remains a topic of active research in the present age of fast digital computers and numerical methods. Papers on orbital mechanics consider either perturbations to two-body orbits, or multi-body gravitational fields. N. Jeremy Kasdin and Egemen Kolemen use a Hamiltonian approach to derive the equations of motion for an object relative to a circular reference orbit. By solving the Hamilton–Jacobi equation, the constants of the relative motion called epicyclic elements are derived. Examples include a simple no-drift condition that allows for bounded orbits in the presence of J_2 forces, the relative motion deviations due to eccentricity, second-order terms, and co-orbiting objects. Marco B. Quadrelli (*Dynamic stability and gravitational balancing of multiple extended bodies*) considers a noninvasive compensation scheme for precise positioning of a massive extended body in free fall using gravitational forces caused by surrounding source masses. B. F. Villac and J. Aiello (*Mapping long-term stability regions* *with application to distant retrograde orbits*) address the determination and characterization of long-term stability regions around periodic orbits (i.e. small, bounded variations in the state of a spacecraft for several hundred to a thousand years) using a modern numerical tool for the detection of chaotic motion: the Fast Lyapunov Indicator (FLI). M. E. Paskowitz and D. J. Scheeres in their paper titled *Orbit mechanics about planetary satellites including higher order gravity fields* explore orbit mechanics about a planetary satellite in the Hill 3-body problem. The Jupiter Icy moons Orbiter (JIMO) Europa mission is used as an example, using a model that includes the tidal force and the J_2 and J_3 gravity effects. Megan Mitchell and Todd J. Mosher investigate the astrodynamics of the International Space Station (ISS) and analyze NASA trajectory predictions, using a program to model the ISS orbit while taking into account viewing restrictions including lighting conditions, docking events, and station maneuvers.

Orbit propagation is related to orbital mechanics in that it addresses the time evolution of orbital elements due to gravitational, atmospheric, and solar radiation perturbations. A number of papers develop various propagation models–both analytical and numerical–and apply them to interesting problems. J. Pelaez *et al*. discretize a tether using several beads distributed along its length, and present a special perturbation method based on Euler parameters and optimized for easy computer implementation, speediness and accuracy. Matt Berry and Liam Healy derive a variable-step Stoermer–Cowell integrator with a non-summed, double-integration multistep integrator, implemented with a Shampine–Gordon style error control algorithm that uses an approximation of the local error at each step to choose the step size for the subsequent step, and compare it to several other multistep integrators, including the fixed-step Gauss–Jackson method, and the Gauss–Jackson method with s-integration. Martin Lara and Juan F. San-Juan investigate the secular motion of a spacecraft around the Jovian moon Europa using a model that takes into account the gravitational potential of Europa up to the second order, and the third body perturbation in Hill's approximation. Ryan S. Park and Daniel J. Scheeres (*Nonlinear mapping of Gaussian state covariance and orbit uncertainties*) define and evaluate a theory of nonlinear phase flow and uncertainty propagation, and use it to map the phase volume and statistics of the spacecraft state both linearly and nonlinearly to analyze the effect of dynamical instability on the spacecraft uncertainty distribution. Vasiliy S. Yurasov *et al*. describe a technique for estimating the fluctuations between the actual atmosphere density and a chosen atmosphere density model, using observation data of the Two Line Element set data associated with catalogued inactive payloads and debris. The total number of such drag-perturbed space objects reaches several hundred at any given time. The element sets for these space objects are updated as an ordinary routine operation by the space surveillance system. Charles Martin Reynerson describes a finite plate elements method for determining the drag coefficient of spacecraft in low-Earth orbits, and validate the model using experimental data for hypersonic molecular beams and DSMC methods.

Systems parameter identification and control techniques are valuable in every spacecraft mission. Papers on the topic range from optimal experiment design by iterative learning (Richard W. Longman and Minh Q. Phan), robust system identification algorithm by orthogonal polynomial-based artificial neural network (Puneet Singla *et al*.), to *Inverse dynamics approach to NMPC based real-time optimal feedback control of robots* by Jie Zhao *et al*. and modeling and control of a Fizeau-type interferometer in the elliptic, restricted three-body problem of the Sun and Earth–Moon Barycenter system (Prasenjit Sengupta and Srinivas R. Vadali).

In a session devoted to near-Earth and lunar missions, papers focus on the problem of intercepting asteroids in Earth's vicinity, as well as on lunar trajectories, and include *Analysis and identification of three asteroid (NEO) rendezvous missions*, *Trajectory design for a lunar mission to the South Pole-Aitken Basin*, *Landing uncontrolled probes on airless bodies*, *Strategies for near Earth object impact hazard mitigation*, and *Deflection of potentially hazardous objects*. In a related session on space-based surveillance, attention is focused on space debris monitoring and cataloging, and several papers are presented discussing special observational platforms, processes, and statistical risk models. In a related topic of three-body motion, a large variety of papers are presented ranging from *Solar sail transfer trajectory design and station-keeping control for missions to the sub-L1 equilibrium region* by Mike Lisano, and Dale Lawrence, and *Virtual exploration by computing global families of trajectories with supercomputers* by Rodney L. Anderson, to analytical work such as *Trajectories leaving a sphere in the restricted three body problem* by C. von Kirchbach *et al*.

In the present age, a great emphasis is placed on satellite constellations for observation and telecommunication. For this reason, an entire session is devoted to the design and analysis of spacecraft constellations. Papers include the design of flower constellations, and relative flower constellations for observation from low orbits, coverage optimization, station-keeping techniques, and geometry and distance constraint optimization for geosynchronous constellations.

Rendezvous and relative orbital motion is a general area encompassing formation flying, debris mitigation, and constellation. Hence, analytical and numerical techniques for relative motion are addressed in papers such as *Comparison of several solutions of elliptic rendezvous problem* by Jung Hyun Jo *et al*., *Guidance and control for highly constrained rendezvous* by Craig J. Van Beusekom and Piero Miotto, *Guidance for autonomous rendezvous in a circular orbit* by Rafael Yanushevsky, and *Safe or emergency fault protection approaches for spacecraft* by Kenny Epstein *et al*.

As part of NASA's Discovery Program, *Genesis* is the first NASA mission since the Apollo Program to return samples collected in deep space. Launched in August 2001, *Genesis* collected solar wind constituents near the Earth–Sun L1 point over a period of about 29 months through March 2004 with an additional five months required subsequently for Earth return. After collecting solar wind samples for more than two years while orbiting the Sun-Earth Libration point, the *Genesis* spacecraft released its Sample Return Capsule (SRC) containing the science samples on September 8, 2004. The final location of the landed SRC, which is well within the allowed recovery area in the Utah Test and Training Range, shows that the operation of the *Genesis* spacecraft, including the navigation, leading up to the SRC's atmospheric entry, was successful and accurate. However, the touchdown was harder than expected due to unsuccessful parachute deployment. The papers on the special topic of *Genesis* describe the various aspects of mission design and analysis. Kenneth Wiliams *et al*. discuss how the original strategy for Earth approach was revised to maximize the safety of people and property on the ground in light of possible anomalies and contingencies, while preserving the capability to meet nominal entry requirements. Dong-suk Han *et al*. describe *Genesis* orbit determination activities during the final approach and atmospheric entry phase, covering the phase from the spin calibration to the SRC release. J. Greg McAllister (*Genesis Earth return propulsion system and mass properties modeling*) outline the successful prelaunch analysis tool design and the in-flight 'tuning' required to maintain the mass and propulsion models. Prasun Desai and Dan Lyons describe the high-fidelity six-degree-of-freedom simulation that was developed to substantiate the robustness of the *Genesis* entry, descent, and landing to assure all entry mission requirements were satisfied. Other papers on the topic include *Human safety analysis for the Genesis sample return mission, Public risk assessment of off-nominal Genesis entries, Genesis backup orbit contingency analysis,* and *Genesis extended mission trajectory design.*

The usage of tethers in attitude stabilization and orbital transfers has been a topic of research for the past several decades. In two sessions devoted to tethers, papers ranging from stability analysis of Coulomb and electrodynamic tethers for attitude control and orbital transfer to input shaping techniques for satellite retrieval and tethered satellite parameter identification have been presented. Of note are *Optimal control of the deployment of a spinning tethered formation* by Paul Williams, and *Preliminary orbit determination of a tethered satellite using angles-only measurements* by Cherish Quails and David A. Cicci.

In another special session, papers devoted to Mars mission analysis and design are presented. This is a feature of all modern conferences in astrodynamics and space flight mechanics. A. Davighi *et al*. propose *A nuclear powered Cycler to Mars,* while David K. Geller and Andrew Vaughan discuss *An analysis plan for the Mars telecommunications orbiter rendezvous* and *Autonomous navigation flight experiment.* Jill L. Hanna Prince and Scott A. Striepe address *Simulation capabilities for Mars reconnaissance Orbiter* (MRO) which was launched in August 2005 and will achieve Mars orbit insertion in March 2006. Dolan Highsmith *et al*. describe the orbit reconstruction of *Mars Express* (MEX) with the specific goal of estimating the atmospheric density near periapsis and evaluating its variability and predictability, and to validate the covariance analysis assumption of atmospheric variability for the MRO. Aymeric Kron and Jean de Lafontaine present a strategy for six-degrees-of-freedom control of a Mars Lander module during its aerodynamic entry phase.

The volume presents a snapshot of current focus on space flight research, and is valuable in either initiating graduate-level research, or undergraduate projects devoted to special topics, methods, and procedures in space dynamics. The topics are well organized, although some overlap has occurred in selecting the topics for individual sessions. I recommend the volume to any student or worker in astrodynamics, space flight mechanics, or spacecraft dynamics and control.

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History of rocketry and astronautics, AAS History Series, Vol. 26, edited by D. C. Elder and G. S. James. American Astronautical Society, San Diego, 2005.

This volume, the latest in the *History Series* published by the American Astronautical Society, is the proceedings of the 31st History Symposium of the International Academy of Astronautics, held in Turin, Italy, during October 6–10, 1997. The 25 papers included in this volume were presented in three sessions of the symposium.

Glimpses of history of rocketry and space transportation have been included in several books of the AIAA Educational Series, e.g. the brief but interesting summary of the history of rocket propulsion in C. D. Brown's book *Spacecraft propulsion*, and the historical perspectives of the different areas of space transportation in the book *Space transportation: A system approach to analysis and design* by W. Hammond. However, the AAS effort in producing so many fine volumes on *History of rocketry and astronautics* is unique.

The emphasis of this volume is shown by its organization. It is divided into three parts: *The pioneers of the space age, rocketry and astronautics: Programme overviews,* and *Developments during the space age*. The volume begins with a tribute to late Bill Hilton, an outstanding aerospace engineer, whose contributions to space technology certainly deserve recognition by the worldwide space community. The 25 papers included in the volume form its 25 chapters. Part I includes 5 chapters. Chapters 1 and 2 discuss the continuing influence of Konstantin Tsiolkovsky, a Russian Schoolteacher of mathematics, on the evolution of space technology. It is amazing to learn that this physically impaired schoolteacher (he became deaf at the age of 9), before anyone else, mathematically worked out the theory of spaceflight and specified that liquid-fueled rockets would get us into space. As early as 1897, he derived the formula for rocket movement, now known by the aerospace students as the "Tsiolkovsky Equation". Tsiolkovsky used the "thought experiment" as effectively as his contemporary Albert Einstein, to develop, understand, and improve his scientific speculations on space travel. Chapter 3 outlines the theoretical and technical contributions of Dr Wernher von Braun's Doctoral Thesis in rocket science. Dr Braun's doctoral work along with the use of German Army test rig at Kummersdorf allowed the excellent launches in the winter of 1934 of two Aggregate II rockets (nicknamed Max and Moritz) from Borkum Isle, both of them reaching an altitude of 2,200 m. The little known contributions of the Russian engineer, Vlacheslav Kovtunenko, to the history of astronautics are described in Chapter 4 and later in Chapter 14. Chapter 5 discusses how Yves Le Prieur, the genius French inventor, developed the first air-launched black powder rockets for their successful use in World War I against German hydrogen-filled zeppelins and battlefield observation balloons.

Part II begins with Chapter 6 which highlights the breakthrough in US rocket research after the US acquired much of the equipment, complete V-2s, and the German engineering and research talents at Penemunde towards the end of World War II. In fact, this was one of the roots that Rocketdyne, the largest producer and developer of liquid propellant rocket engines in the US, sprung from in 1955. Chapter 7 presents a chronological description of the British space policy decisions following the successful launch of the dog Laika onboard Sputnik 2 in October 1957. Chapter 8 presents the concept and the birth of the "Sun-synchronous" satellite. Chapter 9 deals with liquid propellant rocket developments in Japan in an endeavour to develop radio-controlled missiles in the final stage of World War II. When World War II ended, almost all invaluable materials and documents on solid and liquid propellant rocket engine development during the war were destroyed by the Japanese for fear of being marked war criminals. This discontinuity was an unfortunate setback for the Japanese space program development. It may be noted that, ironically, many landmark inventions and innovations originally used to fight big wars causing destruction and devastation, were harnessed later for the benefit and welfare of humankind. Thus, history of development and progress of science and technology has a great role in reminding the human civilization both faces of science and technology developments—the evil face of destruction and the serene face of human welfare. In Chapter 10, Christian Lardier presents a retrospective of the ramjet development work in Russia following Rene Lorin's 1913 concepts. Chapter 11 traces the history of developments of high-energy lasers in the US to defend against ballistic missiles. Beginning with the gas dynamic laser, which was considered for the space-based ICBM defense in 1968 and continued until the 1980s, it later continued with the hydrogen fluoride laser to meet the goals of the SDIO mission in the United States. Remembrances of 50 years of liquid rocket development programme in France are presented in Chapter 12. It is interesting to learn that like USA, France also banked on the Penemunde propulsion talents for its post-World War II rocket development programme. In 1945, General de Gaulle decided to transfer to France the German propulsion scientists and technicians of the research centre at Penemunde. Beginning with the simple sounding rockets powered by nitric acid and turpentine and then moving to more powerful Diament rockets with N_2O_4 and UDMH propellants and finally to the most powerful Ariane rockets with the cryogenic engine for the third stage, the SEP's Vernon facility in 50 years became Europe's leader in liquid rocket development.

Part III is mainly devoted to the post-World War II developments in rocketry. It begins with recalling in Chapter 13 the contributions of Mitchell Sharpe, a highly gifted technical writer and one of the most widely acclaimed space historians, to space history. The achievements of Jury Vasiljevich Kondratjuk, a pioneering early 20th Century space flight theorist, are presented in Chapter 14. Chapter 15 describes the post-Sputnik I intense political pressure put on Sergei Parlovich Korolev, the Chief Designer of Vostok, to continue demonstrating the Soviet Union's world leadership in manned space exploration. The joint Soviet/Syrian space mission is summarized in Chapter 16—the great interest of the Syrian people to see the lift-off of a Soyuz rocket at the dawn of 22 July 1987 as it carried on board the Syrian General Muhammad Ahammad Fares along with two other Russian cosmonauts. On 4 October 1957, the Russians created a landmark surprise by launching the world's first satellite, Sputnik 1, and shortly thereafter Sputnik 2 with the dog Laika onboard, thus opening the space era for mankind. On the 40th anniversary of the launch of Sputnik 1, the remembrances of its development are presented in Chapter 17. Again, marking the 50th anniversary of the first rocket mail (rocket post) experiment by the Rocket Research Institute Inc. (RRI), the world-leader in nongovernmental rocket mail transport and cargo rocket research, Chapter 18 summarizes the RRI developments and initial use of four types of propulsion systems to propel RRI rocket post flight vehicles. Interestingly, as George James, one of the editors of this volume, highlights in this paper (Chapter 18), even today weather emergency situations exist where the only method of supplying isolated areas during raging storms with high priority medical supplies would be through short-range cargo rockets when even helicopters may find it too dangerous to fly. The history of the US Space and Rocket Centre in Alabama, one of the largest space museums, about which Dr Wernher von Braun commented “the finest of its kind in the world”, is documented in Chapter 19. The history of launching the first cruise missile X422 by France is described in Chapter 20. The creation of new space-related technology has never been easy. Very often the obstacles were political or professional rivalry. The thick cold war climate between Russia and America in the 1950s and 1960s, and the doctrinal rivalry between the US Air Force and Office of the Secretary of Defense (OSD), ultimately led to the cancellation of USAF’s Dyna-Soar, an engineering acronym for Dynamic Soaring, which was planned by the USAF as a reusable shuttle to perform orbital reconnaissance and nuclear bombardment missions. Even Senator J. F. Kennedy’s most dramatic missile-gap speech on the Senate floor and later President Kennedy’s Administration could not stop the demise of Dyna-Soar, which was announced cancelled by the Johnson Administration in December 1963. This political go/no-go decisions in the cold war climate and the doctrinal and professional rivalry that marred the Dyna-Soar project, is discussed in Chapter 21. The floating launch programme in the US (US Navy’s HYDRA project), in the USSR (SLBMs), and the insurmountable political problems which in 1993 doomed the US/Russian joint venture to convert Russian SLBMs into floating launch satellite boosters, are discussed in Chapter 23. The history of the first Soviet rocket test range, Kapustin Yar, which in 1969 became an International cosmodrome after the successful launch of the international satellite Intercosmos-1, is described in Chapter 22. Later, the Indian satellites Aryabhata and Bhaskara, the French satellite Sneg-3, and many others were launched into space from this cosmodrome. The history of two Russian organizations, Khrunichev Space Centre and NPO-Energomash, is discussed in the last two chapters, 24 and 25, respectively. While the history of Khrunichev Space Centre is the history of development of Russian strategic aviation, intercontinental ballistic missiles, and advanced space technology including launch vehicles, spacecraft, and orbital stations, that of NPO-Energomash, the oldest Russian enterprise dealing with rocket engines, is the history of Russian liquid propellant rocket development. It is interesting to note that the deafening thunder of the Russian liquid rocket engines, RD-107 and RD-108, in operation prompted President Kennedy to announce in a special message to the American Congress on 25 May 1961, that the Soviet Union had pioneered space exploration because it had high thrust engines. It had been precisely that factor that put the Soviet Union in the lead in space exploration.

This volume, the 17th in the AAS series in space history, is an important title bringing together a wealth of information on the history of development of the concept and technology of rocketry and astronautics since the beginning of the 20th Century. Although the emphasis of the volume is on the history of development of man’s access to space, it also brings out in its wake the ‘space race’ between the two superpowers the US and the erstwhile USSR in the 1950s and 60s, and subsequently the ‘space race’ resulting in the weapons race, with the two superpowers vying in all fields of weaponry, including the strategic rocket forces. However, although this volume is a well edited one, there are a few shortcomings, which must be mentioned. It contains some duplication of material, which was perhaps inevitable since it is based on papers written by different authors and often from different countries. In my view, a more serious discrepancy in this volume is the fact that there is no single chapter devoted to the contributions of Dr R. H. Goddard, who is certainly one of the greatest pioneers of the development of rocketry in the US. It may be recalled that in 1926, Dr Goddard flew the world's first successful liquid fueled rocket in the US with liquid oxygen and gasoline. To this reviewer this omission is a serious lapse in this volume. Besides, this reviewer also felt somewhat disappointed to note the absence of any paper dealing with the contributions of India in the development of the Space Age. At least a paper on the Indo/Russian joint venture in1984 when an Indian Air Force pilot Rakesh Sharma went into space along with the Russian cosmonauts, could have found a place in this volume. However, these shortcomings do not detract substantially from the quality of the volume.

The typography, figures, and printing are of high quality, and the secondary features are quite impressive. Another strength of this volume is its wealth of numerous old photographs, many of which are of immense historical and archival value. Finally, on balance, I am pleased to have the review copy of this volume in my library as an excellent sourcebook of information on the history of exploring the heavens.

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PID controllers for time delay systems by G. J. Silva, A. Datta and S. P. Bhattacharyya, Birkhauser, 2005, p. 330, $79.95.

The problem of designing controllers under which all of the roots of a given real polynomial lie in the open left of the complex plan plays an important role in the theory of stability of linear time-invariant systems. A polynomial for which such a property holds is said to be Hurwitz. Many conditions have been proposed for ascertaining the Hurwitz stability of a given real polynomial without determining the actual roots. Results of this nature were first obtained by Routh, Hurwitz, and Hermite in the 19th century.

The main contribution of the present book is the efficient computation of the entire set of PID controllers achieving stability and various performance specifications such as gain and phase margins and H_{∞} norms of the closed-loop transfer functions. The computation is efficient because it reduces most often to linear programming with a sweeping parameter, which is typically the proportional gain. This is achieved by developing some preliminary results on root counting, which generalize the classical Hermite–Biehler Theorem, and also exploiting some fundamental results of Pontryagin on quasi-polynomials to extract useful information for controller synthesis. The results apply to plants without and with time delay. For linear systems with delay, we have to move from the realm of polynomials to that of the quasi-polynomials.

Chapter 1 presents an overview of control theory, PID controllers, summarizing some of the currently available techniques for PID controllers design.

The Hermite–Biehler theorem states that a given real polynomial is Hurwittz if and only if it satisfies a certain interlacing property. This result has played an important role in studying the parametric robust stability problem. However, when a given polynomial is not Hurwitz stable, the Hermite–Biehler (HB) theorem does not provide any information about the root distribution of the polynomial. Recent research has produced several generalizations of the above HB theorem to the case of real polynomials that are not necessarily Hurwitz. Some of the generalizations are introduced in Chapter 2.

In Chapter 3, Generalized HB theorem is utilized to get all the stabilizing feedback gains. Even though the problem can be solved using classical approaches such as Nyquist stability criterion and the RH criterion, it is not clear how to extend these methods to the more complicated cases where PI and PID controllers are involved. By using the generalized HB theorem, an elegant procedure is developed that can be extended to the aforementioned cases.

In the case of the RH criterion, the solution of the PID stabilization involves inequalities that are highly nonlinear and make this a complicated task. In Chapter 4, a method is proposed by the generalized HB theorem, for determining the stabilizing PID gains for a given plant by a rational transfer function. The characterization of all the stabilizing PID controllers involves the solution of a linear programming problem. The characterization is analogous to the YJBK parameterization of all stabilizing controllers with the difference that the YJBK parameterization cannot incorporate constraints on the controller order or structure whereas the characterization presented here includes the PID structure constraints from the very beginning. For a fixed value of k_c, we have to determine the stabilizing values for k_i and k_d. Since there are two variables here, closed-form solution is not possible to get. Instead, a linear programming problem has to be solved for each fixed k_c.

When the system under study involves time delays, the HB theorem for polynomials cannot be used. Linear time invariant systems with delays give rise to characteristic functions known as quasi-polynomials. Pontryagin was one of the first researchers to study these quasi-polynomials. He derived necessary and sufficient conditions for the roots of a given quasi-polynomial to have negative real parts. Furthermore, he used such conditions to study the stability of certain classes of quasi-polynomials. These and some other preliminary results are described in Chapter 5. Conventional method of using first-order Pade’ approximation can prove inadequate for determining the set of stabilizing PID parameters for a time delay system. When higher-order Pade’ approximations are used, it is no longer possible to obtain analytical expressions for the stabilizing PID gains.

In Chapter 6, a solution to the problem of stabilizing a first- or second-order plant with time delay using a proportional controller is presented. The solution is based on the results presented in Chapter 5 for quasi-polynomials and computes the complete set of stabilizing gains. Examples are included to illustrate the application of these results.

In Chapter 7, complete analytical characterization of all stabilizing PI gain values are provided for first-order plus time delay systems. In Chapter 8, the method is extended to that of PID controllers. The range of admissible proportional gains is first determined in closed form. Then for each proportional gains in this range, the stabilizing set in the space of the integral and derivative gains is shown to be either a trapezoid, a triangle, or a quadrilateral. Methods are given for both the open-loop stable systems and also for open-loop unstable first-order plus time delay systems.

In Chapter 9, some tools that are useful when designing a PI or a PID controller for a first-order system with time delay are provided. These tools show the importance of knowing the set of controller parameter values that stabilize the closed-loop system derived in previous chapters. This chapter also provides a solution to the problem of robust stabilizing given delay-free interval plant family using the PID controller.

In Chapter 10, an analysis of some PID tuning techniques, such as Ziegler–Nichols technique, Chien, Hrones and Reswick (CHR) method, the Cohen–Coon method and IMC method, that are based on first-order models with time delays is presented. Using the characterization of all stabilizing PID controllers derived in Chapter 8, each tuning rule is analyzed to first determine if the proportional gain values dictated by that rule lie inside the range of admissible proportional gains. Then the integral and derivative gain values are examined to determine conditions under which the tuning rule exhibits robustness with respect to controller parameter perturbations. The range of delay time-to-time constant values that ensures robustness was determined for each tuning methods.

In Chapter 11, an approach is presented for solving the problem of finding the set of all PID controllers that stabilize an arbitrary-order plant with time delay. The procedure is based on a connection linking Pontryagin's results on quasi-polynomials to the Nyquist criterion.

The last chapter (Chapter 12) presents a summary of algorithms that can be used to generate the entire set of stabilizing PID controllers for single input–single output (1) continuous-time rational plant of arbitrary order, (2) discrete-time rational plants with arbitrary order, and (3) continuous-time first-order plants with time delay. The theoretical development of these results is quite involved and technical, which could make the results inaccessible to practicing engineers. However, the algorithms that result are straightforward and can be easily programmed on a computer. Chapter 12 presents these PID stabilization and design algorithms, devoid of detailed mathematical proofs, and show via examples how these algorithms can be used by industrial practitioner to carry out computer designs. In particular, the graphical displays of feasible design regions using two- and three-dimensional graphics should appeal to control designers and are very suitable for computer-aided design.

In summary, the book is of interest to graduate students and researcher working in control engineering. The materials presented are understandable to graduate students interested in control engineering.

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Wood pole overhead lines by B. Wareing, The Institution of Engineers and Technology, London, 2005, p. 332, £49/$85.

The book *Wood pole overhead lines* by B. Wareing is an excellent treatise on the subject. The author has dealt with the design, erection and maintenance aspects in detail. Statutory regulations and conformance with standards have also been taken care of. It is interesting to note the details to which the author has gone to study the behaviour of different types of conductors, clamps, fittings, etc. The tabular information is also useful.

132kV wooden pole HV transmission is bound to be economical compared to standard lattice-type towers not only with respect to material cost but also with respect to right of way cost of land. A comparison of cost would have helped. Application for tropical countries with high temperature and humidity and inferior quality of wood could also have helped readers.

The author has given interesting coverage of over-voltage possibilities and severity against lighting which is quite useful. The coverage on failure modes and maintenance and inspection practices is very good. The treatment of the subject with good model calculations would prove useful for utilities designing overhead transmission lines for the first time.

The book is free from errors and will be useful as a comprehensive guide and handbook for utilities going for wooden pole transmission up to 132 kV. It is recommended as a good textbook for utilities' training department and operation staff.

Following observations are made on select chapters:

Chapter 1: The author rightly mentions that a well-designed overhead line in flat and open areas is far less expensive than cable and more liked by farmers who can work without fear while ploughing their land.

Chapter 4: Use of meteorological data, mapping of worst case conditions and a probabilistic approach to design with a certain risk factor. The changes brought about in designer's responsibility with increased privatization and how it leads to more innovative design principles.

Chapter 5: A good correlation between sag, tension, wind speed and type of conductors that is required for best performance is brought out. The use of vibration dampers is explained well. Failure modes of conductors are explained.

Chapter 8: Page 115. Horse conductor data given in Table 8.2 shows 6/3,35 as stranding data, whereas para 3 below it has 19 strands each of 2.79 mm dia.

Chapter 9: The description on novel conductors is good particularly because INVAR is being recommended for EHV lines where operation up to 200°C is possible for high-power corridors, particularly river crossings, etc.

Chapter 19: The author has nicely dealt with the future possibilities including use of robotics, and composite insulators.

The authors are to be commended for good work.

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