A flexible, robust attitude determination and control (ADC) system is presented for small satellite platforms. Using commercial-off-the-shelf sensors, reaction wheels, and magnetorquers which fit within the 3U CubeSat form factor, the system delivers arc-minute pointing precision. The ADC system includes a multiplicative extended Kalman filter for attitude determination and a slew rate controller that acquires a view of the Sun for navigation purposes. A pointing system is developed that includes a choice of two pointing controllers -- a proportional derivative controller and a nonlinear sliding mode controller. This system can reorient the spacecraft to satisfy a variety of mission objectives, but it does not enforce attitude constraints. A constrained attitude guidance system that can enforce an arbitrary set of attitude constraints is then proposed as an improvement upon the unconstrained pointing system. The momentum stored
by the reaction wheels is managed using magnetorquers to prevent wheel saturation. The system was thoroughly tested in realistic software- and hardware-in-the-loop simulations that included environmental disturbances, parameter uncertainty, actuator dynamics, and sensor bias and noise.

The Generic Nanosatellite Bus (GNB) is a spacecraft platform designed to accommodate the integration of diverse payloads in a common housing of supporting components. The development of the GNB at the Space Flight Laboratory (SFL) under the Canadian Advanced Nanospace eXperiment (CanX) program provides accelerated access to space while reducing non-recurring engineering (NRE) costs. The work presented herein details the development of the attitude determination and control subsystem (ADCS) of the GNB. Specific work on magnetorquer coil assembly, integration, and testing (AIT) and reaction wheel testing is included. The embedded software development and unit-level testing of the GNB sun sensors are discussed. The characterization of the AeroAstro star tracker is also a major focus, with procedures and results presented here. Hardware models were developed and incorporated into SFL's in-house high-fidelity attitude dynamics and control simulation environment. This work focuses on specific contributions to the CanX-3, CanX-4&5, and AISSat-1 nanosatellite missions.

The purpose of this work is to discuss the attitude determination and control system (ADCS) design process and implementation for a 12 kg, 6U (36.6 cm x 23.9 cm x 27.97 cm) CubeSat class nano-satellite. The design is based on the requirements and capabilities of the Application for Resident Space Object Proximity Analysis and Imaging (ARAPAIMA) proximity operations mission. The satellite is equipped with a cold gas propulsion system capable of exerting 2.5 mN m torques in both directions about each body axis. The attitude sensors include an angular rate gyro and star tracker (STR), supplemented by the payload optical array cameras. The dynamic simulation of the satellite includes extensive environmental models and analyses that show how the satellite attitude is affected by aerodynamic drag, solar radiation pressure, gravity gradient torques, and residual magnetic moments. A mechanical propellant slosh model and a reaction torque analysis of the deployable solar panel hinges approximate the internal dynamics of the satellite. A trade study is presented to justify the use of a reaction control thruster actuated system over the more traditional reaction wheel configuration. Both actuation systems are modeled to hardware specifications and their propellant and energy requirements are examined alongside pointing performance. Two methods of accounting for sensor noise and sampling rates are presented. The first is an extended Kalman filter based on the nonlinear model of a rate gyro coupled with quaternion attitude kinematics. The second presents a gyro-less angular rate observer capable of extrapolating STR measurements to the desired frequency. An additional method uses images from the payload cameras to perform frame centering maneuvers and to address the possibility of bias in the controller reference signal. Four different controllers are described to reflect the chronological progression of the ADCS design. The first controller, designed to perform long angle maneuvers and target tracking, utilizes fixed gain eigenaxis control. The same controller is then augmented with a parallel proportional-integral-derivative (PID) type control law using scheduled gains. This configuration is designed to switch between eigenaxis and PID control during imaging procedures to take advantage of the integral control introduced by the PID algorithm. To reduce system complexity, a modified eigenaxis control law, which incorporates scheduled integral control but does not require a switch to PID control, is introduced. A discrete

Page 2/12
time equivalent of the modified eigenaxis control law is also developed. Additionally, a brief description of a detumbling control law is presented. Each of the four control laws is paired and tested with the different feedback and estimation methods discussed. An extensive showcase of numerical simulation results outlines the pointing performance of each system configuration and evaluates their capabilities of meeting a 1 arcmin pointing requirement. A comparison of the different properties and performance of each control system configuration precedes the selection of the discrete modified eigenaxis control law as the best alternative.

This project takes the designing and implementation of an attitude determination and control subsystem for the 3Cat-2 Mission. The system has to be able to correct the different perturbations and point the satellite to the desired orientation according to the working mode of the satellite. The subsystem has to be able to correct the different sensing perturbations and compute all the different attitude parameters to control the satellite. The design is divided in three different modes: Detumbling, Sun-safe, and Nominal. The Detumbling Mode is in charge of stabilizing the satellite rotation after the launch or when some other of the controllers has had a problem, and it induces a high rotation over the satellite. The Sun-safe is in charge of pointing the largest solar panels to the Sun to charge the batteries. Finally, the Nominal has to point the payload antennas to the Nadir (Earth Center) for performing the mission of the satellite. Each mode will make use of different sensors to save as much energy as possible. The work will be based on the usual algorithms used in different satellite missions and looking for a new and the first complex implementation of an Attitude subsystem for the Nanosatellite Laboratory.

This comprehensive handbook provides an overview of space technology and a holistic understanding of the system-of-systems that is a modern spacecraft. With a foreword by Elon Musk, CEO and CTO of SpaceX, and contributions from globally leading agency experts from NASA, ESA, JAXA, and CNES, as well as European and North American academics and industrialists, this handbook, as well as giving an interdisciplinary overview, offers, through individual self-contained chapters, more detailed understanding of specific fields, ranging through: · Launch systems, structures, power, thermal, communications, propulsion, and software, to · entry, descent and landing, ground segment, robotics, and data systems, to · technology management, legal and regulatory issues, and project management. This handbook is an equally invaluable asset to those on a career path towards the space industry as it is to those already within the industry.

Evolutionary Learning Algorithms for Neural Adaptive Control is an advanced textbook, which investigates how neural networks and genetic algorithms can be applied to difficult adaptive control problems which conventional results are either unable to solve, or for which they can not provide satisfactory results. It focuses on the principles involved, rather than on the modelling of the applications themselves, and therefore provides the reader with a good introduction to the fundamental issues involved.

This book discusses all spacecraft attitude control-related topics: spacecraft (including attitude measurements, actuator, and disturbance torques), modeling, spacecraft attitude determination and estimation, and spacecraft attitude controls. Unlike other books addressing these topics, this book focuses on quaternion-based methods because of its many
merits. The book lays a brief, but necessary background on rotation sequence representations and frequently used reference frames that form the foundation of spacecraft attitude description. It then discusses the fundamentals of attitude determination using vector measurements, various efficient (including very recently developed) attitude determination algorithms, and the instruments and methods of popular vector measurements. With available attitude measurements, attitude control designs for inertial point and nadir pointing are presented in terms of required torques which are independent of actuators in use. Given the required control torques, some actuators are not able to generate the accurate control torques, therefore, spacecraft attitude control design methods with achievable torques for these actuators (for example, magnetic torque bars and control moment gyros) are provided. Some rigorous controllability results are provided. The book also includes attitude control in some special maneuvers, such as orbital-raising, docking and rendezvous, that are normally not discussed in similar books. Almost all design methods are based on state-spaced modern control approaches, such as linear quadratic optimal control, robust pole assignment control, model predictive control, and gain scheduling control. Applications of these methods to spacecraft attitude control problems are provided. Appendices are provided for readers who are not familiar with these topics.

The University of Illinois's IlliniSat2 satellite bus is unique in that it is among only a few nano-satellites that implements three-axis, onboard attitude determination and control. Though this is an ambitious goal, it will allow for a wide range of scientific missions to be accomplished on this bus. To complete the system, an accurate attitude determination system needs to be developed. Several methods for determining the attitude state as well as mitigating system noise are explored. In particular, an extended Kalman filter is developed to obtain accurate angular rate information from noisy rate measurements. These rate measurements may be provided by either rate gyros or by successive vector measurements. A linear Kalman filter is developed to obtain an accurate attitude estimate. The attitude may be measured with two vector measurements via the TRIAD algorithm, while sensor noise may be rejected via the filter. Using these techniques the requirements for an effective attitude determination and control system are met.

An important, successful area for control systems development is that of state-of-the-art aeronautical and space related technologies. Leading researchers and practitioners within this field have been given the opportunity to exchange ideas and discuss results at the IFAC symposia on automatic control in aerospace. The key research papers presented at the latest in the series have been put together in this publication to provide a detailed assessment of present and future developments of these control system technologies.

Design dynamics, control and implementation of a novel spacecraft attitude control actuator called the "Adaptive Singularity-free Control Moment Gyroscope" (ASCMG) is presented in this dissertation. To construct a comprehensive attitude dynamics model of a spacecraft with internal actuators, the dynamic of a spacecraft with an ASCMG is obtained in the framework of geometric mechanics using the principles of variational mechanics. The resulting dynamics is a general and complete model, as it relaxes the simplifying assumptions made in prior literature on Control Moment Gyrosopes (CMGs) and it also addresses the adaptive parameters in the dynamics formulation. The simplifying assumptions include perfect axisymmetry of the rotor and gimbal structures, perfect alignment of the centers of mass of the gimbal and the rotor, etc. These set of simplifying assumptions imposed on the design and dynamics of CMGs leads to
adverse effects on their performance and results in high manufacturing cost. The dynamics so obtained shows the complex nonlinear coupling between the internal degrees of freedom associated with an ASCMG and the spacecraft bus's attitude motion. By default, an ASCMG function as a Variable Speed Control Moment Gyroscope (VSCMG), and it is reduced to operate as a singularity-free CMG by spinning the rotor at a constant speed. This dynamics model is then extended to include the effects of multiple ASCMGs placed on the spacecraft bus, and sufficient conditions for non-singular ASCMG cluster configurations are obtained to operate the cluster both in VSCMG and CMG modes. The general dynamics model of the ASCMG is then reduced to that of conventional VSCMGs and CMGs by imposing the standard set of simplifying assumptions used in prior literature. The adverse effects of the simplifying assumptions that lead to the complexities in conventional CMG design, and how they result in CMG singularities, are described.

This book describes recent studies on modern control systems using various control techniques. The control systems cover large complex systems such as train operation systems to micro systems in nanotechnology. Various control trends and techniques are discussed from practically modern approaches such as Internet of Things, artificial neural networks, machine learning to theoretical approaches such as zero-placement, bang-bang, optimal control, predictive control, and fuzzy approach.

This book explores CubeSat technology, and develops a nonlinear mathematical model of a spacecraft with the assumption that the satellite is a rigid body. It places emphasis on the CubeSat subsystem, orbit dynamics and perturbations, the satellite attitude dynamic and modeling, and components of attitude determination and the control subsystem. The book focuses on the attitude stabilization methods of spacecraft, and presents gravity gradient stabilization, aerodynamic stabilization, and permanent magnets stabilization as passive stabilization methods, and spin stabilization and three axis stabilization as active stabilization methods. It also discusses the need to develop a control system design, and describes the design of three controller configurations, namely the Proportional–Integral–Derivative Controller (PID), the Linear Quadratic Regulator (LQR), and the Fuzzy Logic Controller (FLC) and how they can be used to design the attitude control of CubeSat three-axis stabilization. Furthermore, it presents the design of a suitable attitude stabilization system by combining gravity gradient stabilization with magnetic torquing, and the design of magnetic coils which can be added in order to improve the accuracy of attitude stabilization. The book then investigates, simulates, and compares possible controller configurations that can be used to control the currents of magnetic coils when magnetic coils behave as the actuator of the system.

This is a master's project report submitted to the mechanical engineering department of the University of Hawai‘i at Mānoa. It discusses the design and simulated performance of the Attitude Determination and Control Subsystem of a 3U cube satellite named Ho'oponopono (H2). H2 was developed at the UH Mānoa College of Engineering's Small-Satellite Laboratory. Its mission was to aid in the radar calibration process of U.S. Air Force radar stations by providing a calibration source in orbit. Its gravity-gradient ADCS was designed to point H2 in the nadir direction for the entirety of its mission lifetime. The unique issues associated with achieving gravity-gradient stabilization is discussed. To
ensure that the functionality and performance requirements were satisfied, the Nanosatellite Attitude Dynamics &
Determination Simulator (NADDS) was developed and used to determine the energies and times required for H2 to achieve
nadir pointing.

Attitude Determination and Control Systems (ADCS) are critical to the operation of satellites that require attitude
knowledge and/or attitude control to achieve mission success. Furthermore, ADCS systems only operate as designed in the
reduced friction, micro-gravity environment of space. Simulating these characteristics of space in a laboratory
environment in order to test individual ADCS components and integrated ADCS systems is an important but challenging
step in verifying and validating a satellite's ADCS design. The purpose of this thesis is to design and develop an ADCS
testbed capable of simulating the reduced friction, micro-gravity environment of space within the Massachusetts
Institute of Technology's Space Systems Laboratory. The ADCS testbed is based on a tabletop style, three degree of
freedom, rotational air bearing, which uses four reaction wheels for attitude control and a series of sensors for
attitude determination. The testbed includes all the equipment necessary to allow for closed loop testing of individual
ADCS components and integrated ADCS systems in the simulated inertial environment of space. In addition to the physical
ADCS testbed, a MATLAB Simulink based model of the ADCS testbed is developed to predict the performance of hardware
components and software algorithms before the components and algorithms are integrated into the ADCS testbed. The final
objective of this thesis is to validate the operation of the ADCS testbed and simulation to prepare the tool for use by
satellite design teams.

This thesis investigates a new concept for the flexible design and verification of an ADCS for a nanosatellite
platform. In order to investigate guidelines for the design of a flexible ADCS, observations of the satellite market
and missions are recorded. Following these observations, the author formulates design criteria which serve as a
reference for the conceptual design of the flexible ADCS. The research of the thesis was carried out during the
development of TU Berlin's nanosatellite platform TUBiX20 and its first two missions, TechnoSat and TUBIN. TUBiX20
targets modularity, reuse and dependability as main design goals. Based on the analysis of design criteria for a
flexible ADCS, these key design considerations for the TUBiX20 platform were continued for the investigations carried
out in this thesis. The resulting concept implements the ADCS as a distributed system of devices complemented by a
hardware-independent core application for state determination and control. Drawing on the technique of component-based
software engineering, the system is partitioned into self-contained modules which implement unified interfaces. These
interfaces specify the state quantity of an input or output but also its unit and coordinate system, complemented by a
mathematical symbol for unambiguous documentation. The design and verification process for the TUBiX20 ADCS was also
elaborated during the course of this research. The approach targets the gradual development of the subsystem from a
purely virtual satellite within a closed-loop simulation to the verification of the fully integrated system on an air-
bearing testbed. Finally, the concurrent realization of the investigated concept within the TechnoSat and TUBIN
missions is discussed. Starting with the individual ADCS requirements, the scalability of the approach is demonstrated

Provides the basics of spacecraft orbital dynamics plus attitude dynamics and control, using vectrix notation Spacecraft Dynamics and Control: An Introduction presents the fundamentals of classical control in the context of spacecraft attitude control. This approach is particularly beneficial for the training of students in both of the subjects of classical control as well as its application to spacecraft attitude control. By using a physical system (a spacecraft) that the reader can visualize (rather than arbitrary transfer functions), it is easier to grasp the motivation for why topics in control theory are important, as well as the theory behind them. The entire treatment of both orbital and attitude dynamics makes use of vectrix notation, which is a tool that allows the user to write down any vector equation of motion without consideration of a reference frame. This is particularly suited to the treatment of multiple reference frames. Vectrix notation also makes a clear distinction between a physical vector and its coordinate representation in a reference frame. This is very important in spacecraft dynamics and control problems, where often multiple coordinate representations are used (in different reference frames) for the same physical vector. Provides an accessible, practical aid for teaching and self-study with a layout enabling a fundamental understanding of the subject. Fills a gap in the existing literature by providing an analytical toolbox offering the reader a lasting, rigorous methodology for approaching vector mechanics, a key element vital to new graduates and practicing engineers alike. Delivers an outstanding resource for aerospace engineering students, and all those involved in the technical aspects of design and engineering in the space sector. Contains numerous illustrations to accompany the written text. Problems are included to
Small satellites use commercial off-the-shelf sensors and actuators for attitude determination and control (ADC) to reduce the cost. These sensors and actuators are usually not as robust as the available, more expensive, space-proven equipment. As a result, the ADC system of small satellites is more vulnerable to any fault compared to a system for larger competitors. This book aims to present useful solutions for fault tolerance in ADC systems of small satellites. The contents of the book can be divided into two categories: fault tolerant attitude filtering algorithms for small satellites and sensor calibration methods to compensate the sensor errors. MATLAB® will be used to demonstrate simulations. Presents fault tolerant attitude estimation algorithms for small satellites with an emphasis on algorithms’ practicability and applicability Incorporates fundamental knowledge about the attitude determination methods at large Discusses comprehensive information about attitude sensors for small satellites Reviews calibration algorithms for small satellite magnetometers with simulated examples Supports theory with MATLAB simulation results which can be easily understood by individuals without a comprehensive background in this field Covers up-to-date discussions for small satellite attitude systems design Dr. Chingiz Hajiyev is a professor at the Faculty of Aeronautics and Astronautics, Istanbul Technical University (Istanbul, Turkey). Dr. Halil Ersin Soken is an assistant professor at the Aerospace Engineering Department, Middle East Technical University (Ankara, Turkey).

Fundamentals of Space Systems was developed to satisfy two objectives: the first is to provide a text suitable for use in an advanced undergraduate or beginning graduate course in both space systems engineering and space system design. The second is to be a primer and reference book for space professionals wishing to broaden their capabilities to develop, manage the development, or operate space systems. The authors of the individual chapters are practicing engineers that have had extensive experience in developing sophisticated experimental and operational spacecraft systems in addition to having experience teaching the subject material. The text presents the fundamentals of all the subsystems of a spacecraft missions and includes illustrative examples drawn from actual experience to enhance the learning experience. It includes a chapter on each of the relevant major disciplines and subsystems including space systems engineering, space environment, astrodynamics, propulsion and flight mechanics, attitude determination and control, power systems, thermal control, configuration management and structures, communications, command and telemetry, data processing, embedded flight software, survivability and reliability, integration and test, mission operations, and the initial conceptual design of a typical small spacecraft mission.

This book explores topics that are central to the field of spacecraft attitude determination and control. The authors provide rigorous theoretical derivations of significant algorithms accompanied by a generous amount of qualitative discussions of the subject matter. The book documents the development of the important concepts and methods in a manner accessible to practicing engineers, graduate-level engineering students and applied mathematicians. It includes detailed examples from actual mission designs to help ease the transition from theory to practice and also provides prototype algorithms that are readily available on the author’s website. Subject matter includes both theoretical derivations and practical implementation of spacecraft attitude determination and control systems. It provides detailed
derivations for attitude kinematics and dynamics and provides detailed description of the most widely used attitude parameterization, the quaternion. This title also provides a thorough treatise of attitude dynamics including Jacobian elliptical functions. It is the first known book to provide detailed derivations and explanations of state attitude determination and gives readers real-world examples from actual working spacecraft missions. The subject matter is chosen to fill the void of existing textbooks and treatises, especially in state and dynamics attitude determination. MATLAB code of all examples will be provided through an external website.

Roger D. Werking Head, Attitude Determination and Control Section National Aeronautics and Space Administration/Goddard Space Flight Center Extensiye work has been done for many years in the areas of attitude determination, attitude prediction, and attitude control. During this time, it has been difficult to obtain reference material that provided a comprehensive overview of attitude support activities. This lack of reference material has made it difficult for those not intimately involved in attitude functions to become acquainted with the ideas and activities which are essential to understanding the various aspects of spacecraft attitude support. As a result, I felt the need for a document which could be used by a variety of persons to obtain an understanding of the work which has been done in support of spacecraft attitude objectives. It is believed that this book, prepared by the Computer Sciences Corporation under the able direction of Dr. James Wertz, provides this type of reference. This book can serve as a reference for individuals involved in mission planning, attitude determination, and attitude dynamics; an introductory textbook for students and professionals starting in this field; an information source for experimenters or others involved in spacecraft-related work who need information on spacecraft orientation and how it is determined, but who have neither the time nor the resources to pursue the varied literature on this subject; and a tool for encouraging those who could expand this discipline to do so, because much remains to be done to satisfy future needs.

This book explores topics that are central to the field of spacecraft attitude determination and control. The authors provide rigorous theoretical derivations of significant algorithms accompanied by a generous amount of qualitative discussions of the subject matter. The book documents the development of the important concepts and methods in a manner accessible to practicing engineers, graduate-level engineering students and applied mathematicians. It includes detailed examples from actual mission designs to help ease the transition from theory to practice and also provides prototype algorithms that are readily available on the author’s website. Subject matter includes both theoretical derivations and practical implementation of spacecraft attitude determination and control systems. It provides detailed derivations for attitude kinematics and dynamics and provides detailed description of the most widely used attitude parameterization, the quaternion. This title also provides a thorough treatise of attitude dynamics including Jacobian elliptical functions. It is the first known book to provide detailed derivations and explanations of state attitude determination and gives readers real-world examples from actual working spacecraft missions. The subject matter is chosen to fill the void of existing textbooks and treatises, especially in state and dynamics attitude determination. MATLAB code of all examples will be provided through an external website.
This book discusses all spacecraft attitude control-related topics: spacecraft (including attitude measurements, actuator, and disturbance torques), modeling, spacecraft attitude determination and estimation, and spacecraft attitude controls. Unlike other books addressing these topics, this book focuses on quaternion-based methods because of its many merits. The book lays a brief, but necessary background on rotation sequence representations and frequently used reference frames that form the foundation of spacecraft attitude description. It then discusses the fundamentals of attitude determination using vector measurements, various efficient (including very recently developed) attitude determination algorithms, and the instruments and methods of vector measurement. With available attitude measurements, attitude control designs for inertial point and nadir pointing are presented in terms of required torques which are independent of actuators in use. Given the required control torques, some actuators are not able to generate the accurate control torques, therefore, spacecraft attitude control design methods with achievable torques for these actuators (for example, magnetic torque bars and control moment gyros) are provided. Some rigorous controllability results are provided. The book also includes attitude control in some special maneuvers, such as orbital-raising, docking and rendezvous, that are normally not discussed in similar books. Almost all design methods are based on state-space modern control approaches, such as linear quadratic optimal control, robust pole assignment control, model predictive control, and gain scheduling control. Applications of these methods to spacecraft attitude control problems are provided. Appendices are provided for readers who are not familiar with these topics.

This book presents advanced case studies that address a range of important issues arising in space engineering. An overview of challenging operational scenarios is presented, with an in-depth exposition of related mathematical modeling, algorithmic and numerical solution aspects. The model development and optimization approaches discussed in the book can be extended also towards other application areas. The topics discussed illustrate current research trends and challenges in space engineering as summarized by the following list: • Next Generation Gravity Missions • Continuous-Thrust Trajectories by Evolutionary Neurocontrol • Nonparametric Importance Sampling for Launcher Stage Fallout • Dynamic System Control Dispatch • Optimal Launch Date of Interplanetary Missions • Optimal Topological Design • Evidence-Based Robust Optimization • Interplanetary Trajectory Design by Machine Learning • Real-Time Optimal Control • Optimal Finite Thrust Orbital Transfers • Planning and Scheduling of Multiple Satellite Missions • Trajectory Performance Analysis • Ascent Trajectory and Guidance Optimization • Small Satellite Attitude Determination and Control • Optimized Packings in Space Engineering • Time-Optimal Transfers of All-Electric GEO Satellites Researchers working on space engineering applications will find this work a valuable, practical source of information. Academics, graduate and post-graduate students working in aerospace, engineering, applied mathematics, operations research, and optimal control will find useful information regarding model development and solution techniques, in conjunction with real-world applications.

In order to reflect the increasing importance and interest of the microsatellites in high technology and scientific applications in space, the Colloquium on Microsatellites as Research Tools was organized to promote its usage and technology development and to foster the international cooperation, especially in the area of the Asia pacific region. Attended by 150 participants from 18 countries the colloquium was organized into five major themes: regional development, lessons learned, innovations, scientific applications, and education. A special session was organized as...
well by the organizing committee and supported by the National Space Program Office to present its development of the Taiwan’s satellite program and the current status of ROCSAT-1 which is scheduled to be launched at the beginning of 1999. Two main conclusions were drawn from the material presented: microsatellite in general is a very good means for doing space research and technology development, and a suitable vehicle to promote international collaborations.

With about 200,000 entries, StarBriefs Plus represents the most comprehensive and accurately validated collection of abbreviations, acronyms, contractions and symbols within astronomy, related space sciences and other related fields. As such, this invaluable reference source (and its companion volume, StarGuides Plus) should be on the reference shelf of every library, organization or individual with any interest in these areas. Besides astronomy and associated space sciences, related fields such as aeronautics, aeronomy, astronautics, atmospheric sciences, chemistry, communications, computer sciences, data processing, education, electronics, engineering, energetics, environment, geodesy, geophysics, information handling, management, mathematics, meteorology, optics, physics, remote sensing, and so on, are also covered when justified. Terms in common use and/or of general interest have also been included where appropriate.

The aim of this book is to provide an overview of recent developments in Kalman filter theory and their applications in engineering and scientific fields. The book is divided into 24 chapters and organized in five blocks corresponding to recent advances in Kalman filtering theory, applications in medical and biological sciences, tracking and positioning systems, electrical engineering and, finally, industrial processes and communication networks.

Space-based observations have transformed our understanding of Earth, its environment, the solar system and the universe at large. During past decades, driven by increasingly advanced science questions, space observatories have become more sophisticated and more complex, with costs often growing to billions of dollars. Although these kinds of ever-more-sophisticated missions will continue into the future, small satellites, ranging in mass between 500 kg to 0.1 kg, are gaining momentum as an additional means to address targeted science questions in a rapid, and possibly more affordable, manner. Within the category of small satellites, CubeSats have emerged as a space-platform defined in terms of (10 cm x 10 cm x 10 cm)-sized cubic units of approximately 1.3 kg each called "U's." Historically, CubeSats were developed as training projects to expose students to the challenges of real-world engineering practices and system design. Yet, their use has rapidly spread within academia, industry, and government agencies both nationally and internationally. In particular, CubeSats have caught the attention of parts of the U.S. space science community, which sees this platform, despite its inherent constraints, as a way to affordably access space and perform unique measurements of scientific value. The first science results from such CubeSats have only recently become available; however, questions remain regarding the scientific potential and technological promise of CubeSats in the future. Achieving Science with CubeSats reviews the current state of the scientific potential and technological promise of
CubeSats. This report focuses on the platform's promise to obtain high-priority science data, as defined in recent decadal surveys in astronomy and astrophysics, Earth science and applications from space, planetary science, and solar and space physics (heliophysics); the science priorities identified in the 2014 NASA Science Plan; and the potential for CubeSats to advance biology and microgravity research. It provides a list of sample science goals for CubeSats, many of which address targeted science, often in coordination with other spacecraft, or use "sacrificial," or high-risk, orbits that lead to the demise of the satellite after critical data have been collected. Other goals relate to the use of CubeSats as constellations or swarms deploying tens to hundreds of CubeSats that function as one distributed array of measurements.

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