

Aircraft Control And Simulation Dynamics Controls Design And Autonomous Systems

Aircraft dynamics is the science of air vehicle orientation and control in three dimensions. The three critical flight dynamics parameters are the angles of rotation in three dimensions about the vehicle's center of mass, known as pitch, roll and yaw. Aerospace engineers develop control systems for vehicle's orientation about its center mass. The control system contain actuators, which apply forces in several directions and generate rotational forces or moments about the aerodynamic center of the aircraft and thus rotate the aircraft in pitch, roll or yaw. Aircraft Dynamics: From Modelling to Simulation provides readers with modern tools for modelling and stimulation of aircraft dynamics. The emphasis is on detailed modelling of aerodynamic thrust forces and moments. Topics include aircraft equations of motion, modelling of aerodynamic thrust forces and moments on the aircraft and analysis of aircraft static and dynamic stability. This book with specific features for assisting, motivating and engaging aeronautical/aerospace engineering students, in the challenging task of understanding the basic principles of aircraft dynamics and the necessary skills for the modelling of the aerodynamic and thrust forces and moments.

Additionally, it also provides a detailed introduction to the development of simple but very effective simulation environments for today demanding students as well as working professionals and researchers.

This paper addresses the problem of controlling the receiver aircraft to achieve a successful aerial refueling. For the performance verification of the controller, a new set of nonlinear, 6-DOF, rigid body equations of motion for the receiver aircraft has been derived. The equations are developed using the reference frame as one that is attached to, translates and rotates with the tanker aircraft. Furthermore, the nonlinear equations contain the wind effect terms and their time derivatives to represent the aerodynamic coupling involved between the two aircraft. These wind terms are obtained using an averaging technique that computes the effective induced wind components and wind gradients in the receiver aircraft's body frame. Dynamics of the engine and the actuators are also included in the study. A linear position-tracking controller has been designed using a combination of integral control and optimal LQR design. The controller does not use the information of the tanker's vortex induced wind effects acting on the receiver aircraft as well as the mass change that occurs during refueling. The performance of the controller is evaluated in the high fidelity simulation environment employing the new sets of equations of motion. The simulation and control design are applied to a tailless fighter aircraft with innovative control effectors and thrust vectoring capability. Various allocation schemes for redundant control variables are analyzed in a realistic approach maneuver to the refueling contact position behind the tanker aircraft. In this paper, the performance evaluation is presented only during the initial phase of aerial

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refueling maneuver when the receiver aircraft maneuvers to reach the refueling contact position.

Advanced Flight Dynamics aim to integrate the subjects of aircraft performance, trim and stability/control in a seamless manner. Advanced Flight Dynamics highlights three key and unique viewpoints. Firstly, it follows the revised and corrected aerodynamic modeling presented previously in recent textbook on Elementary Flight Dynamics. Secondly, it uses bifurcation and continuation theory, especially the Extended Bifurcation Analysis (EBA) procedure devised by the authors, to blend the subjects of aircraft performance, trim and stability, and flight control into a unified whole. Thirdly, rather than select one control design tool or another, it uses the generalized Nonlinear Dynamic Inversion (NDI) methodology to illustrate the fundamental principles of flight control. Advanced Flight Dynamics covers all the standard airplane maneuvers, various types of instabilities normally encountered in flight dynamics and illustrates them with real-life airplane data and examples, thus bridging the gap between the teaching of flight dynamics/ control theory in the university and its practice in airplane design bureaus. The expected reader group for this book would ideally be senior undergraduate and graduate students, practicing aerospace/flight simulation engineers/scientists from industry as well as researchers in various organizations. Key Features: Focus on unified nonlinear approach, with nonlinear analysis tools. Provides an up-to-date, corrected, and unified presentation of aircraft trim, stability and control analysis including nonlinear phenomena and closed-loop stability analysis. Contains a computational tool and real-life example carried through the chapters. Includes complementary nonlinear dynamic inversion control approach, with relevant aircraft examples. Fills the gap in the market for a text including non-linear flight dynamics and continuation methods. Aircraft Control and Simulation Dynamics, Controls Design, and Autonomous Systems John Wiley & Sons

Principles of Flight Simulation is a comprehensive guide to flight simulator design, covering the modelling, algorithms and software which underpin flight simulation. The book covers the mathematical modelling and software which underpin flight simulation. The detailed equations of motion used to model aircraft dynamics are developed and then applied to the simulation of flight control systems and navigation systems. Real-time computer graphics algorithms are developed to implement aircraft displays and visual systems, covering OpenGL and OpenSceneGraph. The book also covers techniques used in motion platform development, the design of instructor stations and validation and qualification of simulator systems. An exceptional feature of Principles of Flight Simulation is access to a complete suite of software (www.wiley.com/go/allerton) to enable experienced engineers to develop their own flight simulator – something that should be well within the capability of many university engineering departments and research organisations. Based on C code modules from an actual flight simulator developed by the author, along with lecture material from lecture series

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given by the author at Cranfield University and the University of Sheffield Brings together mathematical modeling, computer graphics, real-time software, flight control systems, avionics and simulator validation into one of the faster growing application areas in engineering Features full colour plates of images and photographs. Principles of Flight Simulation will appeal to senior and postgraduate students of system dynamics, flight control systems, avionics and computer graphics, as well as engineers in related disciplines covering mechanical, electrical and computer systems engineering needing to develop simulation facilities.

This book offers a complete overview of fault-tolerant flight control techniques. Discussion covers the necessary equations for the modeling of small UAVs, a complete system based on extended Kalman filters, and a nonlinear flight control and guidance system.

This third edition is a comprehensive guide to aircraft control and simulation. The updated text covers flight control systems, flight dynamics, aircraft modelling, and flight simulation from both classical design and modern perspectives, as well as two new chapters on the modelling, simulation, and adaptive control of unmanned aerial vehicles.

This book unifies all aspects of flight dynamics for the efficient development of aerospace vehicle simulations. It provides the reader with a complete set of tools to build, program, and execute simulations. Unlike other books, it uses tensors for modeling flight dynamics in a form invariant under coordinate transformations. For implementation, the tensors are converted to matrices, resulting in compact computer code. The reader can pick templates of missiles, aircraft, or hypersonic vehicles to jump-start a particular application. It is the only textbook that combines the theory of modeling with hands-on examples of three-, five-, and six-degree-of-freedom simulations. Included is a link to the CADAC Web Site where you may apply for the free CADAC CD with eight prototype simulations and plotting programs. Amply illustrated with 318 figures and 44 examples, the text can be used for advanced undergraduate and graduate instruction or for self-study. Also included are 77 problems that enhance the ability to model aerospace vehicles and nine projects that hone the skills for developing three-, five-, and six-degree-of-freedom simulations.

The 1st edition of Aircraft Dynamics: from Modeling to Simulation by Marcello R. Napolitano is an innovative textbook with specific features for assisting, motivating and engaging aeronautical/aerospace engineering students in the challenging task of understanding the basic principles of aircraft dynamics and the necessary skills for the modeling of the aerodynamic and thrust forces and moments. Additionally the textbook provides a detailed introduction to the development of simple but very effective simulation environments for today demanding students as well as professionals. The book contains an abundance of real life students sample problems and problems along with very useful Matlab codes.

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The study of the motion of manoeuvring aircraft has traditionally considered the aircraft to be rigid. This simplifying assumption has been shown to give quite accurate results for the flight dynamics of many aircraft types. As modern transport aircraft have developed however, there has been a marked increase in the size and weight of these aircraft. This trend is likely to continue with the development of future blended-wing-body and supersonic transport aircraft. This increase in size and weight has brought about a unique set of aeroelastic and handling quality issues. The aerodynamic forces and moments acting on an aeroplane have traditionally been represented using the aerodynamic derivative approach. It has been shown that this quasisteady aerodynamic model inadequately predicts the aircraft's stability characteristics, and that the inclusion of unsteady aerodynamics "greatly improves the fidelity" of aircraft models. This thesis thus presents a novel numerical simulation of an aeroelastic aeroplane for real-time analysis. The model is built around the standard six degree-of-freedom equations of motion for a rigid aeroplane using the mean-axes system, and includes unsteady aerodynamics and structural dynamics. This is suitable for pilot-in-the-loop simulation, handling qualities and flight loads analysis, and control law development. The dynamics of the structure are modelled as a set of normal modes, and the equations of motion are realised in state-space form. The unsteady aerodynamic forces acting on the aeroplane are described by an indicial state-space model, including unsteady tailplane downwash and compressibility effects. An implementation of the model is presented in the MATLAB/ Simulink environment. The interaction between the flight control system, the aeroelastic system and the rigidbody motion of the aeroplane can result in degraded handling qualities, excessive actuator control, and fatigue problems. The introduction of load alleviation systems for the management of loads due to manoeuvres and gusts is also likely to result in the handling qualities of the aeroplane being degraded. This thesis presents a number of studies into the impact of structural dynamics, unsteady aerodynamics, and load alleviation on the handling qualities of a flexible civil transport aeroplane. The handling qualities of the aeroplane are assessed against a number of different handling qualities criteria and flying specifications, including the Neal-Smith, Bandwidth, and CAP criterion. It is shown that aeroelastic effects alter the longitudinal and lateral-directional characteristics of the aeroplane, resulting in degraded handling qualities. Manoeuvre and gust load alleviation are similarly found to degrade handling qualities, while active mode control is shown to offer the possibility of improved handling qualities.

Written by leading experts in the field, this book provides the state-of-the-art in terms of fault tolerant control applicable to civil aircraft. The book consists of five parts and includes online material.

The study of flight dynamics requires a thorough understanding of the theory of the stability and control of aircraft, an appreciation of flight control systems and a grounding in the theory of automatic control. Flight Dynamics Principles is a

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student focused text and provides easy access to all three topics in an integrated modern systems context. Written for those coming to the subject for the first time, the book provides a secure foundation from which to move on to more advanced topics such as, non-linear flight dynamics, flight simulation, handling qualities and advanced flight control. About the author: After graduating Michael Cook joined Elliott Flight Automation as a Systems Engineer and contributed flight control systems design to several major projects. Later he joined the College of Aeronautics to research and teach flight dynamics, experimental flight mechanics and flight control. Previously leader of the Dynamics, Simulation and Control Research Group he is now retired and continues to provide part time support. In 2003 the Group was recognised as the Preferred Academic Capability Partner for Flight Dynamics by BAE SYSTEMS and in 2007 he received a Chairman's Bronze award for his contribution to a joint UAV research programme. New to this edition: Additional examples to illustrate the application of computational procedures using tools such as MATLAB®, MathCad® and Program CC®. Improved compatibility with, and more expansive coverage of the North American notational style. Expanded coverage of lateral-directional static stability, manoeuvrability, command augmentation and flight in turbulence. An additional coursework study on flight control design for an unmanned air vehicle (UAV). Discusses the fundamental principles and theory of aircraft control and simulation. Covers modeling and dynamic analysis, stability evaluation, multivariable control theory and computer-aided design techniques. The inclusion of earth orbital mechanics lays the groundwork for a discussion of the theory for suborbital aircraft now under development. Contains examples of actual designs from the aircraft industry plus exercise problems.

Annotation Bridging the gap between academic research and real-world applications, this reference on modern flight control methods for fixed-wing aircraft deals with fundamentals of flight control systems design, then concentrates on applications based on the modern control methods used in the latest aircraft. The book is written for practicing engineers who are new to the aviation industry, postgraduate students in strategic or applied research, and advanced undergraduates. Some knowledge of classical control is assumed. Pratt is a member of IEEE and is UK Member for AIAA's Technical Committee on Guidance, Navigation and Control. Annotation c. Book News, Inc., Portland, OR (booknews.com)

Explore Key Concepts and Techniques Associated with Control Configured Elastic Aircraft A rapid rise in air travel in the past decade is driving the development of newer, more energy-efficient, and malleable aircraft. Typically lighter and more flexible than the traditional rigid body, this new ideal calls for adaptations to some conventional concepts. Flight Dynamics, Simulation, and Control: For Rigid and Flexible Aircraft addresses the intricacies involved in the dynamic modelling, simulation, and control of a selection of aircraft. This book covers the conventional dynamics of rigid aircraft, explores key concepts associated with control configured elastic aircraft, and examines

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the use of linear and non-linear model-based techniques and their applications to flight control. In addition, it reveals how the principles of modeling and control can be applied to both traditional rigid and modern flexible aircraft. Understand the Basic Principles Governing Aerodynamic Flows This text consists of ten chapters outlining a range of topics relevant to the understanding of flight dynamics, regulation, and control. The book material describes the basics of flight simulation and control, the basics of nonlinear aircraft dynamics, and the principles of control configured aircraft design. It explains how elasticity of the wings/fuselage can be included in the dynamics and simulation, and highlights the principles of nonlinear stability analysis of both rigid and flexible aircraft. The reader can explore the mechanics of equilibrium flight and static equilibrium, trimmed steady level flight, the analysis of the static stability of an aircraft, static margins, stick-fixed and stick-free, modeling of control surface hinge-moments, and the estimation of the elevator for trim. Introduces case studies of practical control laws for several modern aircraft Explores the evaluation of aircraft dynamic response Applies MATLAB®/Simulink® in determining the aircraft's response to typical control inputs Explains the methods of modeling both rigid and flexible aircraft for controller design application Written with aerospace engineering faculty and students, engineers, and researchers in mind, Flight Dynamics, Simulation, and Control: For Rigid and Flexible Aircraft serves as a useful resource for the exploration and study of simulation of flight dynamics.

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Morphing Aerospace Vehicles and Structures provides a highly timely presentation of the state-of-the-art, future directions and technical requirements of morphing aircraft. Divided into three sections it addresses morphing aircraft, bio-inspiration, and smart structures with specific focus on the flight control, aerodynamics, bio-mechanics, materials, and structures of these vehicles as well as power requirements and the use of advanced piezo materials and smart actuators. The tutorial approach adopted by the contributors, including underlying concepts and mathematical formulations, unifies the methodologies and tools required to provide practicing engineers and applied researchers with the insight to synthesize morphing air vehicles and morphing structures, as well as offering direction for future research.

Computer Assisted Design (CAD) environments have become important devices for the design and evaluation of flight control systems. This report documents the CAD environment DASMAT, which stands for Delft University Aircraft Simulation Model and Analysis Tool. It operates in the computing environment MATLAB/SIMULINK, having highperformance numeric computation and visualization functionalities. The essential element in the DASMAT package is a generic nonlinear simulation model conceived with well-defined and generalized interfaces. After a short introduction of DASMAT, this book focuses on the models, signals and variables present in the DASMAT package. The operational aspects for the simulation and analysis tools are discussed next, followed by the application of the DASMAT package for control design purposes. Aircraft operating as so-called High Altitude Platform Systems (HAPS) have been considered as a complementary technology to satellites since several years. These aircraft can be used for similar communication and monitoring tasks while operating at a fraction of the cost. Such concepts have been successfully tested. Those include the AeroVironment Helios and the Airbus Zephyr, with an endurance of nearly 624 hours

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(26 days). All these HAPS aircraft have a high-aspect-ratio wing using lightweight construction. In gusty atmosphere, this results in high bending moments and high structural loads, which can lead to overloads. Aircraft crashes, for example from Google's Solara 50 or Facebook's Aquila give proof of that fact. Especially in the troposphere, where the active weather takes place, gust loads occur, which can lead to the destruction of the structure. The Airbus Zephyr, the only HAPS aircraft without flight accidents, provides only a very small payload. Thus it does not fully comply with the requirements for future HAPS aircraft. To overcome the shortcomings of such single-wing aircraft, so-called multibody aircraft are considered to be an alternative. The concept assumes multiple aircraft connected to each other at their wingtips. It goes back to the German engineer Dr. Vogt. In the United States, shortly after the end of World War II, he experimented with the coupling of manned aircraft. This resulted in a high-aspect-ratio wing for the aircraft formation. The range of the formation could be increased correspondingly. The engineer Geoffrey S. Sommer took up Vogt's idea and patented an aircraft configuration consisting of several unmanned aerial vehicles coupled at their wingtips. However, the patent does not provide any insight into the flight performance, the flight mechanical modeling or the control of such an aircraft. Single publications exist that deal with the performance of coupled aircraft. A profound, complete analysis, however, is missing so far. This is where the present work starts. For the first time, a flying vehicle based on the concept of the multibody aircraft will be analyzed in terms of flight mechanics and flight control. In a performance analysis, the aircraft concept is analyzed in detail and the benefits in terms of bending moments and flight performance are clearly highlighted. Limits for operation in flight are shown considering aerodynamic optimal points. The joints at the wingtips allow a roll and pitch motion of the individual aircraft. This results in additional degrees of freedom for the design through the implementation of different relative pitch and bank angles. For example, using individual pitch angles for individual aircraft further decreases the induced drag and increases flight performance. Because the lift is distributed symmetrically, but not homogeneously along the wingspan, a lateral trim of the individual aircraft in formation flight becomes necessary. The thesis presents a new method to implement this trim by moving the battery mass along half the wingspan, which avoids additional parasite drag. Further, a complete flight dynamics model is provided and analyzed for aircraft that are mechanically connected at their wingtips. To study this model in detail, a hypothetical torsional and bending spring between the aircraft is introduced. If the spring constants are very high, the flight dynamics model has properties similar to those of an elastic aircraft. Rigid-body and formation eigenmotions can be clearly distinguished. If the spring constants are reduced towards zero, which represents the case of the multibody aircraft, classical flight mechanics eigenmotions and modes resulting from the additional degrees of freedom are coupled. This affects the eigenstructure of the aircraft. Hence, normal motions with respect to the inertial space as known from a rigid aircraft cannot be observed anymore. The plant also reveals unstable behavior. Using the non-linear flight dynamics model, flight controllers are designed to stabilize the plant and provide the aircraft with an eigenstructure similar to conventional aircraft. Different controller design methods are used. The flight controller shall further maintain a determined shape of the flight formation, it shall control flight, bank and pitch angles, and it shall suppress disturbances. Flight control

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theories in the time domain (Eigenstructure assignment) and in the frequency domain (H-infinity loop-shaping) are considered. The resulting inner-control loops yield a multibody aircraft behavior that is similar to the one of a rigid aircraft. For the outer-control loops, classical autopilot concepts are applied. Overall, the flight trajectory of the multibody aircraft above ground is controlled and, thus, an actual operation as HAPS is possible. In the last step, the flight controller is successfully validated in non-linear simulations with complete flight dynamics.

Flugzeuge in der Form von sogenannten Höhenplattformen (engl. High-Altitude Platform Systems, HAPS) werden seit einigen Jahren als kostengünstige Ergänzung zu teuren Satelliten betrachtet. Diese Flugzeuge können für ähnliche Kommunikations- und Überwachungsaufgaben eingesetzt werden. Zu den gegenwärtigen Konzepten solcher Fluggeräte, die bereits erfolgreich im Flugversuch eingesetzt wurden, zählen der Helios von AeroVironment und der Airbus Zephyr, der eine Flugdauer von fast 624 Stunden (26 Tagen) erreicht hat. Alle diese HAPS-Flugzeuge besitzen einen Flügel langer Streckung, der in Leichtbauweise konstruiert ist. Hieraus resultieren in böiger Atmosphäre hohe Biegemomente und starke strukturelle Belastungen, die zu Überbelastungen führen können. Flugunfälle beispielsweise von Googles Solara 50 oder Facebooks Aquila belegen dies. Insbesondere in der Troposphäre, in der das aktive Wetter stattfindet, treten Böenlasten auf, die die Struktur zerstören können. Der Airbus Zephyr, der bisher als einziges HAPS-Flugzeug frei von Flugunfällen ist, besitzt nur eine sehr geringe Nutzlast. Daher kann er die Anforderungen an zukünftige HAPS-Flugzeuge nicht vollständig erfüllen. Um die Schwachstellen solcher Ein-Flügel-Konzepte zu überwinden, wird in dieser Arbeit ein alternatives Flugzeugkonzept betrachtet, das als Mehrkörperflugzeug bezeichnet wird. Das Konzept geht von mehreren, an den Flügelspitzen miteinander verbundenen Flugzeugen aus und beruht auf Ideen des deutschen Ingenieurs Dr. Vogt. Dieser hatte in den USA kurz nach Ende des Zweiten Weltkrieges bemannte Flugzeuge aneinanderkoppeln lassen. Hierdurch ergab sich ein Flugzeugverbund mit einem Flügel langer Streckung. Damit konnte die Reichweite des Verbundes gesteigert werden. Geoffrey S. Sommer griff die Idee von Vogt auf und ließ sich eine Flugzeugkonfiguration patentieren, die aus mehreren, unbemannten Flugzeugen besteht, die an den Enden der Tragflächen miteinander gekoppelt sind. Die Patentschrift gibt jedoch keinen Einblick in die Flugleistungen, die flugmechanische Modellierung oder die Regelung eines solchen Fluggerätes. Vereinzelt existieren Veröffentlichungen, die sich mit den Flugleistungen von gekoppelten Luftfahrzeugen beschäftigen. Eine tiefgreifende, vollständige flugmechanische Analyse fehlt jedoch bisher. Hier setzt die vorliegende Arbeit an. Ein Fluggerät basierend auf dem Konzept des Mehrkörperflugzeugs wird erstmalig hinsichtlich der Flugmechanik und Flugregelung untersucht. In einer Flugleistungsbetrachtung wird das Flugzeugkonzept genau analysiert und die Vorteile hinsichtlich der Biegemomente und der Flugleistungen klar herausgestellt. Die Grenzen des Einsatzes im Flugbetrieb werden mithilfe aerodynamischer Optimalpunkte aufgezeigt. Über die Lager an den Flügelspitzen, die eine relative Roll- und Nickbewegung der Flugzeuge untereinander ermöglichen, ergeben sich durch die Einstellung unterschiedlicher Längslage- und Hängewinkel zusätzliche Freiheitsgrade im Entwurf. Die Verwendung unterschiedlicher Nicklagewinkel der einzelnen Flugzeuge reduziert beispielsweise den induzierten Widerstand weiter und steigert die Flugleistung. Durch die symmetrische,

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entlang der Spannweite jedoch nicht homogene Auftriebsverteilung ist auch eine laterale Trimmung der einzelnen Flugzeuge in der Formation notwendig. Hier stellt die Arbeit eine neuartige Möglichkeit vor, um diese Trimmung ohne zusätzlichen parasitären Widerstand mittels Verschiebung der Batteriemasse entlang der Halbspannweite umzusetzen. Weiterhin wird ein vollständiges flugdynamisches Modell für über mechanische Lager verbundene Luftfahrzeuge aufgestellt und analysiert. Für diese Analyse wird eine hypothetische Torsions- und Biegefeder zwischen den Flugzeugen modelliert. Sind die Federsteifigkeiten hinreichend hoch, besitzt das flugdynamische Modell Eigenschaften, die einem elastischen Flugzeug entsprechen. Starrkörper- und elastische Eigenbewegungsformen sind in diesem Fall klar separiert. Bei immer weiterer Reduzierung, bis auf eine Federsteifigkeit von Null, kommt es zu Kopplungen zwischen den klassischen, flugmechanischen Eigenbewegungsformen und den Moden aus den zusätzlichen Freiheitsgraden. Dies stellt den Auslegungsfall für das Mehrkörperflugzeug dar. Hierbei verändert sich die Eigenstruktur (engl. eigenstructure) des Flugzeugs und normale, bei einem starren Flugzeug beobachtbare Bewegungen gegenüber dem inertialen Raum sind nicht mehr erkennbar. Zusätzlich zeigt die Strecke instabiles Verhalten. Basierend auf dem nichtlinearen, flugdynamischen Modell werden mit verschiedenen Methoden Regler entworfen, die die Regelstrecke stabilisieren und dem Flugzeug eine Streckenstruktur zuweisen, die derjenigen klassischer Flugzeuge ähnelt. Zudem soll durch die Regler eine vorgegebene Form des Flugzeugverbundes beibehalten werden, die Fahrt, der Längs- und Rolllagewinkel sollen geregelt und Störungen unterdrückt werden. Als Auslegungsverfahren werden Theorien der Zustandsregelungen im Zeitbereich (Eigenstrukturvorgabe) und Frequenzbereich (H-infinity loop-shaping) verwendet. Hierdurch wird durch die inneren Regelschleifen ein Verhalten des Mehrkörperflugzeugs erzielt, das dem eines starren Flugzeugs entspricht. Für die äußeren Regelschleifen werden anschließend klassische Konzepte von Autopiloten verwendet. Im Ergebnis ist eine Regelung des Flugweges über Grund des Mehrkörperflugzeugs und somit ein tatsächlicher Betrieb als HAPS möglich. Die Funktionalität des Reglers wird abschließend in nichtlinearen Simulationen mit vollständiger Flugdynamik verifiziert.

This book can be used to develop simple or complex dynamic models of generic flight vehicles (atmospheric or spacecraft) controlled by multiple types of effectors such as, engines, TVC, aero-surfaces, reaction jets, reaction-wheels, and CMGs. The book can also be used in predicting the performance and characteristics of new flight vehicle concepts based on vehicle data, such as, aerodynamic parameters, mass properties, trajectories, etc. The book begins with the basic flight vehicle dynamics. Then the equation of motion is extended to include more advanced dynamic effects. The derivation of a mixing logic for combining multiple types of effectors is included, and also an algorithm for trimming multiple types of effectors. There is also a chapter describing methods for evaluating performance characteristics of flight vehicles directly from data, bypassing the dynamic analysis. The book includes theoretical material and multiple design examples of: aircraft, launch vehicles, re-entry vehicles, and rocket-planes, with detailed information that is typically not included in technical papers or other textbooks. The examples demonstrate complete designs, provide hands-on experience and are useful for training students or younger engineers in modeling of flight vehicles, trimming the control effectors, analyzing controllability, maneuverability

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and other performance characteristics of conceptual flight vehicles based on vehicle data. The examples also serve as a user's manual for the software tool by demonstrating how to perform the various analytic functions in multiple vehicle applications.

This book provides a single comprehensive resource that reviews many of the current aircraft flight control programmes from the perspective of experienced practitioners directly involved in the projects. Each chapter discusses a specific aircraft flight programme covering the control system design considerations, control law architecture, simulation and analysis, flight test optimization and handling qualities evaluations. The programmes described have widely exploited modern interdisciplinary tools and techniques and the discussions include extensive flight test results. Many important 'lessons learned' are included from the experience gained when design methods and requirements were tested and optimized in actual flight demonstration.

The updated revision of the well-respected book on analyzing aircraft performance This Second Edition of the bestselling Aircraft Control and Simulation has been expanded and updated to include the latest technological advances in the field. In addition, a new section on basic aerodynamics, aircraft configuration, and static stability makes this complex material more accessible to beginners. This comprehensive guide discusses the fundamental principles and theory of aircraft control and simulation. It also covers modeling and dynamic analysis, stability evaluation, multivariable control theory, and computer-aided design techniques. The inclusion of topics from geodesy and gravitation lays the groundwork for a discussion of the theory for suborbital aircraft now under development. Special features of this new edition include: New and updated computer calculations using MATLAB® A new section on basic aerodynamics, aircraft configurations, and static stability Coverage of new MIMO design techniques, robustness theory, and nonlinear design Complete with examples of actual designs from the aircraft industry plus exercise problems, Aircraft Control and Simulation, Second Edition is an excellent reference for anyone involved in the design and modeling of aerospace vehicles and an outstanding text for both undergraduates and graduate students.

????:Helicopter theory

The control of space, aerial and underwater vehicles requires moment generation mechanisms to change their orientation. In addition to or in place of conventional moment generation actuators, internally moving-mass actuation has been proposed and/or used for such vehicles. The primary principle for mass-actuation is to reposition gravitational force to change the associated moment while the secondary effect may come from the inertial force due to the motion of the masses. Recent development/miniaturization in flight control sensor, computing and actuation, and electric motors and expansion of applications for small UAV (Unmanned Aerial Vehicle) offer a potential for implementation of internal mass-actuation in small UAV. The massactuation offers various advantages over the conventional mechanisms in airplane flight such as reduced drag and lift loss due to aerodynamic control surface deflections, simplified wing and tail design,

improved lift-generation performance of wing, smaller radar signature for stealth aircraft. This dissertation research investigates the feasibility and benefit of mass-actuation of a small UAV in various flight phases and full missions consisting of all these flight phases and transitions between them. Three different configurations of the same airplane are considered: (1) aero-actuated, conventional airplane with three standard aerodynamic control surfaces, aileron, elevator and rudder, (2) mass-actuated, a mass moving along the fuselage to mainly generate pitching moment, and another mass moving along the wing to generate rolling moment, and (3) mass-rudder actuated, mass-actuation as in case-2 augmented with a rudder. The airplane is an electric powered and has a single propeller at the nose. A full 6-DOF (Degrees of Freedom) nonlinear equations of motion are derived, including the terms modeling inertia forces induced by the motion of the internal masses, and the effect of this internal mass motion on the variation of the center of mass and inertia matrix. The dynamics of the electric motor of the propeller and the servos of the actuators are also modeled. The effect of the propeller on the dynamics of the aircraft is also included. Modeling also includes electric power consumption by the electric motor driving the propeller, and servos of the aerodynamic and mass actuators. An integrated simulation environment is developed that includes all these factors and can be switched between the different configurations defined above. Trim analyses of all three configurations of the airplane are carried out in all four flight conditions (steady climb, cruise, steady turn, steady descent). Trim analyses consider all the constraints of the control and state variables such as limits on the deflections of the aerodynamic surfaces, position of the mass actuators, battery provided voltage, and angle of attack. These analyses demonstrate the feasibility of flying the airplane with mass-actuation only within varying speed ranges depending on the actuation mechanism. The results also show the benefit of mass-actuation over the conventional aero-actuation in terms of range and endurance especially in cruise flight, as compared to the other two configurations. In the second phase of the research, controllability of the airplane with each actuation mechanisms is determined and compared over the feasible speed range of each trim condition. A new relative controllability metrics is defined and calculated for this purpose. This analysis, based on the linearized model of the aircraft in each trim flight condition, show that the mass-actuation provides full controllability with various degree over the speed ranges. Once the controllability is verified, an LQR-based gain scheduling controller is designed for each aircraft configuration to track commanded climb/descent rate, altitude, airspeed, and turn rate. These controllers are implemented in the integrated simulation environment to simulate various flight profiles including full missions that start with a hand-launch of the airplane, climb to a specified altitude, and cruise at that altitude with various commanded speed, and loiter with commanded left and right turn rates, and descend to land with varying approach speed. These simulations also demonstrate the feasibility potential benefits,

and/or limitations of mass actuation.

From the early machines to today's sophisticated aircraft, stability and control have always been crucial considerations. In this second edition, Abzug and Larrabee again forge through the history of aviation technologies to present an informal history of the personalities and the events, the art and the science of airplane stability and control. The book includes never-before-available impressions of those active in the field, from pre-Wright brothers airplane and glider builders through to contemporary aircraft designers. Arranged thematically, the book deals with early developments, research centers, the effects of power on stability and control, the discovery of inertial coupling, the challenge of stealth aerodynamics, a look toward the future, and much more. It is profusely illustrated with photographs and figures, and includes brief biographies of noted stability and control figures along with a core bibliography. Professionals, students, and aviation enthusiasts alike will appreciate this readable history of airplane stability and control.

The Book The behaviour of helicopters and tiltrotor aircraft is so complex that understanding the physical mechanisms at work in trim, stability and response, and thus the prediction of Flying Qualities, requires a framework of analytical and numerical modelling and simulation. Good Flying Qualities are vital for ensuring that mission performance is achievable with safety and, in the first and second editions of Helicopter Flight Dynamics, a comprehensive treatment of design criteria was presented, relating to both normal and degraded Flying Qualities. Fully embracing the consequences of Degraded Flying Qualities during the design phase will contribute positively to safety. In this third edition, two new Chapters are included. Chapter 9 takes the reader on a journey from the origins of the story of Flying Qualities, tracing key contributions to the developing maturity and to the current position. Chapter 10 provides a comprehensive treatment of the Flight Dynamics of tiltrotor aircraft; informed by research activities and the limited data on operational aircraft. Many of the unique behavioural characteristics of tiltrotors are revealed for the first time in this book. The accurate prediction and assessment of Flying Qualities draws on the modelling and simulation discipline on the one hand and testing practice on the other. Checking predictions in flight requires clearly defined mission tasks, derived from realistic performance requirements. High fidelity simulations also form the basis for the design of stability and control augmentation systems, essential for conferring Level 1 Flying Qualities. The integrated description of flight dynamic modelling, simulation and flying qualities of rotorcraft forms the subject of this book, which will be of interest to engineers practising and honing their skills in research laboratories, academia and manufacturing industries, test pilots and flight test engineers, and as a reference for graduate and postgraduate students in aerospace engineering.

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Flying Qualities, requires a framework of analytical and numerical modelling and simulation. Good Flying Qualities are vital for ensuring that mission performance is achievable with safety and, in the first edition of *Helicopter Flight Dynamics*, a comprehensive treatment of design criteria was presented. In this second edition, the author complements this with a new Chapter on Degraded Flying Qualities, drawing examples from flight in poor visibility, failure of control functions and encounters with severe atmospheric disturbances. Fully embracing the consequences of Degraded Flying Qualities during the design phase will contribute positively to safety. The accurate prediction and assessment of Flying Qualities draws on the modelling and simulation discipline on the one hand and testing methodologies on the other. Checking predictions in flight requires clearly defined 'mission-task-elements', derived from missions with realistic performance requirements. High fidelity simulations also form the basis for the design of stability and control augmentation systems, essential for conferring Level 1 Flying Qualities. The integrated description of flight dynamic modelling, simulation and flying qualities forms the subject of this book, which will be of interest to engineers in research laboratories and manufacturing industry, test pilots and flight test engineers, and as a reference for graduate and postgraduate students in aerospace engineering. The Author Gareth Padfield, a Fellow of the Royal Aeronautical Society, is the Bibby Professor of Aerospace Engineering at the University of Liverpool. He is an aeronautical engineer by training and has spent his career to date researching the theory and practice of flight for both fixed-wing aeroplanes and rotorcraft. During his years with the UK's Royal Aircraft Establishment and Defence Evaluation and Research Agency, he conducted research into rotorcraft dynamics, handling qualities and flight control. His work has involved a mix of flight testing, creating and testing simulation models and developing analytic approximations to describe flight behaviour and handling qualities. Much of his research has been conducted in the context of international collaboration – with the Technical Co-operation Programme, AGARD and GARTEUR as well as more informal collaborations with industry, universities and research centres worldwide. He is very aware that many accomplishments, including this book, could not have been achieved without the global networking that aerospace research affords. During the last 8 years as an academic, the author has continued to develop his knowledge and understanding in flight dynamics, not only through research, but also through teaching the subject at undergraduate level; an experience that affords a new and deeper kind of learning that, hopefully, readers of this book will benefit from.

This book constitutes the thoroughly refereed post-workshop proceedings of the Third International Workshop on Modelling and Simulation for Autonomous Systems, MESAS 2016, held in Rome, Italy, in June 2016. The 33 revised full papers included in the volume were carefully reviewed and selected from 38 submissions. They are organized in the following topical sections: human machine integration and interfaces; autonomous systems and MS frameworks

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and architectures; autonomous systems principles and algorithms; unmanned aerial vehicles and remotely piloted aircraft systems; modelling and simulation application.

Aircraft Control Allocation Wayne Durham, Virginia Polytechnic Institute and State University, USA Kenneth A. Bordignon, Embry-Riddle Aeronautical University, USA Roger Beck, Dynamic Concepts, Inc., USA An authoritative work on aircraft control allocation by its pioneers Aircraft Control Allocation addresses the problem of allocating supposed redundant flight controls. It provides introductory material on flight dynamics and control to provide the context, and then describes in detail the geometry of the problem. The book includes a large section on solution methods, including 'Banks' method', a previously unpublished procedure. Generalized inverses are also discussed at length. There is an introductory section on linear programming solutions, as well as an extensive and comprehensive appendix dedicated to linear programming formulations and solutions. Discrete-time, or frame-wise allocation, is presented, including rate-limiting, nonlinear data, and preferred solutions. Key features: Written by pioneers in the field of control allocation. Comprehensive explanation and discussion of the major control allocation solution methods. Extensive treatment of linear programming solutions to control allocation. A companion web site contains the code of a MATLAB/Simulink flight simulation with modules that incorporate all of the major solution methods. Includes examples based on actual aircraft. The book is a vital reference for researchers and practitioners working in aircraft control, as well as graduate students in aerospace engineering.

This text provides a comprehensive guide to the derivation of computational models from basic physical mathematical principles, giving the reader sufficient information to be able to represent the basic architecture of air vehicles and their embedded systems.

The design, development, analysis, and evaluation of new aircraft technologies such as fly by wire, unmanned aerial vehicles, and micro air vehicles, necessitate a better understanding of flight mechanics on the part of the aircraft-systems analyst. A text that provides unified coverage of aircraft flight mechanics and systems concept will go a long

Flight Vehicle Dynamics and Control Rama K. Yedavalli, The Ohio State University, USA A comprehensive textbook which presents flight vehicle dynamics and control in a unified framework Flight Vehicle Dynamics and Control presents the dynamics and control of various flight vehicles, including aircraft, spacecraft, helicopter, missiles, etc, in a unified framework. It covers the fundamental topics in the dynamics and control of these flight vehicles, highlighting shared points as well as differences in dynamics and control issues, making use of the 'systems level' viewpoint. The book begins with the derivation of the equations of motion for a general rigid body and then delineates the differences between the dynamics of various flight vehicles in a fundamental way. It then focuses on the dynamic equations with application to these various flight vehicles, concentrating more on aircraft and spacecraft cases. Then the control systems analysis and design is carried out both from transfer function, classical control, as well as modern, state space control points of view. Illustrative examples of application to atmospheric and space vehicles are presented, emphasizing the 'systems level' viewpoint of control design. Key features: Provides a comprehensive treatment of dynamics and control of various flight vehicles in a single volume. Contains worked out examples (including MATLAB examples) and end of chapter homework problems. Suitable as a single textbook for a sequence of undergraduate courses on flight vehicle dynamics and control. Accompanied by a website that includes additional problems and a solutions manual. The book is essential reading for undergraduate students in mechanical and aerospace engineering, engineers working on flight vehicle control, and researchers from other engineering backgrounds working on related topics.

Presents the established principles underpinning space robotics with a thorough and modern

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approach. This text is perfect for professionals in the field looking to gain an understanding of real-life applications of manipulators on satellites, and of the dynamics of satellites carrying robotic manipulators and of planetary rovers.

This work uses a fundamental approach to the problem of simulating the flight of flexible aircraft. To this end, it integrates into a single formulation the pertinent disciplines, namely, analytical dynamics, structural dynamics, aerodynamics, and controls. It considers both the rigid body motions of the aircraft, three translations (forward motion, sideslip and plunge) and three rotations (roll, pitch and yaw), and the elastic deformations of every point of the aircraft, as well as the aerodynamic, propulsion, gravity and control forces. The equations of motion are expressed in a form ideally suited for computer processing. A perturbation approach yields a flight dynamics problem for the motions of a quasi-rigid aircraft and an 'extended aeroelasticity' problem for the elastic deformations and perturbations in the rigid body motions, with the solution of the first problem entering as an input into the second problem. The control forces for the flight dynamics problem are obtained by an 'inverse' process and the feedback controls for the extended aeroservoelasticity problem are determined by the LQG theory. A numerical example presents time simulations of rigid body perturbations and elastic deformations about 1) a steady level flight and 2) a level steady turn maneuver.

Waszak, Martin R. (Technical Monitor) and Meirovitch, Leonard and Tuzcu, Ilhan
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AEROSERVOELASTICITY; AERODYNAMICS; FLEXIBLE WINGS; AIRCRAFT MANEUVERS; FLIGHT SIMULATION; AIRCRAFT CONTROL; ROLL; SIDESLIP; YAW; ELASTIC DEFORMATION; EQUATIONS OF MOTION; LINEAR QUADRATIC GAUSSIAN CONTROL; FEEDBACK CONTROL

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