

# Flight Control

Guillaume J. J. Ducard

**Introduction to Fly-by-Wire Flight Control Systems** David Kern,2021-12-18 The #1 guide to understanding the why and how of fly-by-wire flight control systems. This book is an approachable and easily understandable must-read for aviation professionals! Why don't new aircraft designs allow the pilots a mechanical control connection? This book explains how fly-by-wire fixes the top 5 problems with mechanical controls for high performance aircraft. Rather than describe a particular aircraft's design with confusing acronyms, readers will get a behind the scenes understanding for the critical concepts that apply to any modern aircraft. Because these design principles are easily described and understood, readers of this book will be armed with knowledge as they approach their flight manual procedures. Including: - Problems with mechanical flight controls - Advantages of fly-by-wire - How and why can fly-by-wire control systems fail? - Why are four computers better than one or two? - Explanations of the control laws used by business jets, fighters, and airliners - What sensors are needed, and how the system maintains control when sensors are lost - Design considerations for risk mitigation in case of component failures Buy this book to read on your next layover!

**Flight Control Systems** Roger Pratt,2000 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)

**Automatic Flight Control Systems** Mohammad Sadraey,2020-02-14 This book provides readers with a design approach to the automatic flight control systems (AFCS). The AFCS is the primary on-board tool for long flight operations, and is the foundation for the airspace modernization initiatives. In this text, AFCS and autopilot are employed interchangeably. It presents fundamentals of AFCS/autopilot, including primary subsystems, dynamic modeling, AFCS categories/functions/modes, servos/actuators, measurement devices, requirements, functional block diagrams, design techniques, and control laws. The book consists of six chapters. The first two chapters cover the fundamentals of AFCS and closed-loop control systems in manned and unmanned aircraft. The last four chapters present features of Attitude control systems (Hold functions), Flight path control systems (Navigation functions), Stability augmentation systems, and Command augmentation systems, respectively.

**Advances In Aircraft Flight Control** M B Tischler,1996-06-28 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.

**Automatic Flight Control Systems** Thomas Lombaerts,2012-01-18 The history of flight control is inseparably linked to the history of aviation itself. Since the early days, the concept of automatic flight control systems has evolved from mechanical control systems to highly advanced automatic fly-by-wire flight control systems which can be found nowadays in military jets and civil airliners. Even today, many research efforts are made for the further development of these flight control systems in various aspects. Recent new developments in this field focus on a wealth of different aspects. This book focuses on a selection of key research areas, such as inertial navigation, control of unmanned aircraft and helicopters, trajectory control of an unmanned space re-entry vehicle, aeroservoelastic control, adaptive flight control, and fault tolerant flight control. This book consists of two major sections. The first section focuses on a literature review and some recent theoretical developments in flight control systems. The second section discusses some concepts of adaptive and fault-tolerant flight control systems. Each technique discussed in this book is illustrated by a relevant example.

**The Interpretation of Flying Qualities Requirements for Flight Control System Design** ,1985 A study was conducted to design an experimental flight test program for the Total In-Flight Simulator (CTIFS) directed toward the interface between flying qualities requirements and flight control system design criteria. The eventual goal is to provide an interpretation or translation of flying qualities requirements for use by the flight control system designer. Specifically, an angle of attack and pitch rate command system matrix involving both short term and long term dynamics are specified for evaluation. A major objective of the research was to demonstrate that flying qualities criteria and flight control system configuration or architecture can be independent. Finally, additional configurations are proposed to evaluate the efficacy of dynamic decoupling.

**CONDUIT: A New Multidisciplinary Integration Environment for Flight Control Development** ,1997 A state-of-the-art computational facility for aircraft flight control design, evaluation, and integration called CONDUIT (Control Designer's Unified Interface) has been developed. This paper describes the CONDUIT tool and case study applications to complex rotary- and fixed- wing fly-by-wire flight control problems. Control system analysis and design optimization methods are presented, including definition of design specifications and system models within CONDUIT, and the multi-objective function optimization (CONSOL-OPTCAD) used to tune the selected design parameters. Design examples are based on flight test programs for which extensive data are available for validation. CONDUIT is used to analyze baseline control laws against pertinent military handling qualities and control system specifications. In both case studies, CONDUIT successfully exploits trade-offs between forward loop and feedback dynamics to significantly improve the expected handling qualities and minimize the required actuator authority. The CONDUIT system provides a new environment for integrated control system analysis and design, and has potential for significantly reducing the time and cost of control system flight test optimization.

**Fundamentals of Design of Piloted Aircraft Flight Control Systems: Automatic flight control systems for piloted aircraft** United States. Navy Department. Bureau of Aeronautics,1952

**Flight mechanics and flight control for a multibody aircraft** Köthe, Alexander,2019-06-26 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 (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 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, 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.

**Integrated Avionics Instruments and Flight Control Systems Specialist (F-16) (AFSC 32657C)** Dennis M. Holliday, 1985

Test Techniques for Flight Control Systems of Large Transport Aircraft Yakui Gao, Gang An, Chaoyou Zhi, 2021-02-16 Test Techniques for Flight Control Systems of Large Transport Aircraft offers theory and practice of flight control system tests. It is a systematic and practical guide, providing insights to engineers in flight control, particularly those working on system integration and test validation. Ten chapters cover an introduction to flight control system tests, equipment tests and validation, software tests and validation, flight control law and flying qualities evaluation, tests of flight control subsystems, integration and validation based on the iron bird, ground-based test, flight-tests, airworthiness tests and validation, and finally, the current status and prospects for flight control tests and evaluation. Presents flight control system integration tests and validation for large transport aircraft Includes the most advanced methods and technologies available Details the latest research and its applications Offers theoretical and practical guidance that engineers can use Considers the state-of-the-art and looks to the future of flight control system tests

*Flight Control and Fire Control System Manuals* Northrop Corporation NORAIR Division, 1952

Aviation Safety and Pilot Control National Research Council, Division on Engineering and Physical Sciences, Commission on Engineering and Technical Systems, Committee on the Effects of Aircraft-Pilot Coupling on Flight Safety, 1997-03-28 Adverse aircraft-pilot coupling (APC) events include a broad set of undesirable and sometimes hazardous phenomena that originate in anomalous interactions between pilots and aircraft. As civil and military aircraft technologies advance, interactions between pilots and aircraft are becoming more complex. Recent accidents and other incidents have been attributed to adverse APC in military aircraft. In addition, APC has been implicated in some civilian incidents. This book evaluates the current state of knowledge about adverse APC and processes that may be used to eliminate it from military and commercial aircraft. It was written for technical, government, and administrative decisionmakers and their technical and administrative support staffs; key technical managers in the aircraft manufacturing and operational industries; stability and control engineers; aircraft flight control system designers; research specialists in flight control, flying qualities, human factors; and technically knowledgeable lay readers.

**Fault Tolerant Flight Control** Christopher Edwards, Thomas Lombaerts, Hafid Smaili, 2010-04-18 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.

**Aircraft Control and Simulation** Brian L. Stevens, Frank L. Lewis, Eric N. Johnson, 2015-10-02 Get a complete understanding of aircraft control and

simulation Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems, Third Edition is a comprehensive guide to aircraft control and simulation. This updated text covers flight control systems, flight dynamics, aircraft modeling, and flight simulation from both classical design and modern perspectives, as well as two new chapters on the modeling, simulation, and adaptive control of unmanned aerial vehicles. With detailed examples, including relevant MATLAB calculations and FORTRAN codes, this approachable yet detailed reference also provides access to supplementary materials, including chapter problems and an instructor's solution manual. Aircraft control, as a subject area, combines an understanding of aerodynamics with knowledge of the physical systems of an aircraft. The ability to analyze the performance of an aircraft both in the real world and in computer-simulated flight is essential to maintaining proper control and function of the aircraft. Keeping up with the skills necessary to perform this analysis is critical for you to thrive in the aircraft control field. Explore a steadily progressing list of topics, including equations of motion and aerodynamics, classical controls, and more advanced control methods Consider detailed control design examples using computer numerical tools and simulation examples Understand control design methods as they are applied to aircraft nonlinear math models Access updated content about unmanned aircraft (UAVs) Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems, Third Edition is an essential reference for engineers and designers involved in the development of aircraft and aerospace systems and computer-based flight simulations, as well as upper-level undergraduate and graduate students studying mechanical and aerospace engineering.

**Advanced Techniques for Clearance of Flight Control Laws** Chris Fielding,Andras Varga,Samir Bennani,Michiel Selier,2003-07-01 In this book recent results of the GARTEUR (Group for Aeronautical Research and Technology in Europe) Action Group FM (AG11) are presented. The book focuses on analysis techniques for the flight clearance of highly augmented aircrafts, including contributions of 20 European aeronautical organisations such as National Research Centers, Aerospace Industries and Universities. The tasks and requirements of the Industrial Clearance Process for Flight Control Laws are presented as well as classical and particularly new analysis methods. The different methods are evaluated and compared and their potential application to Civil Aircraft is demonstrated.

**Fault-tolerant Flight Control and Guidance Systems** Guillaume J. J. Ducard,2009-05-14 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.

*Advances in Flight Control Systems* Maria Agneta Balint,2011-04-11 Nonlinear problems in flight control have stimulated cooperation among engineers and scientists from a range of disciplines. Developments in computer technology allowed for numerical solutions of nonlinear control problems, while industrial recognition and applications of nonlinear mathematical models in solving technological problems is increasing. The aim of the book *Advances in Flight Control Systems* is to bring together reputable researchers from different countries in order to provide a comprehensive coverage of advanced and modern topics in flight control not yet reflected by other books. This product comprises 14 contributions submitted by 38 authors from 11 different countries and areas. It covers most of the currents main streams of flight control researches, ranging from adaptive flight control mechanism, fault tolerant flight control, acceleration based flight control, helicopter flight control, comparison of flight control systems and fundamentals. According to these themes the contributions are grouped in six categories, corresponding to six parts of the book.

Robust Flight Control Jean-Francois Magni,Samir Bennani,1997-03-07 In October 1994, 22 organisations throughout Europe accepted a challenge to solve a specific robust flight control design problem. The results of that design challenge, presented at the GARTEUR Specialists' Workshop in Toulouse, France in April 1997, are reported here. Two flight control benchmarks are considered, based on the automatic landing phase of a large cargo aircraft and on the control of a military aircraft. Methods applied include: classical control; multi-objective optimisation; eigenstructure assignment; modal multi-model approach; LQ, Lyapunov and H<sub>2</sub>-techniques;  $\mu$ -synthesis; nonlinear dynamic inversion; robust inverse dynamics estimation; model predictive control and following; and fuzzy control. Involved in the definition of the benchmarks and the evaluation process have been representatives from the European aeronautical industry, bringing a strong link with flight control law design practice.

Airplane Flight Dynamics and Automatic Flight Controls Jan Roskam,1998

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