

DESIGN AND ANALYSIS OF A LIGHT CARGO UAV PROTOTYPE

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ABSTRACT - A light cargo unmanned air vehicle (UAV) was designed, constructed, and tested in flight. This UAV was designed and build according to the specifications of the Air Cargo Challenge 2009 Design, Build & Fly European student competition. The basic aerodynamic and stability analysis that was used in the preliminary phase of the light UAV design are presented. Flight stability analysis was based on the linearized theory. The preliminary aerodynamic analysis was based on Navier-Stokes solutions for wing and wing-body configurations. The conceptual design was constructed and successfully tested. Further aerodynamic analysis for the full configuration was carried out to evaluate the performance during the flight envelope. The findings of this analysis could be utilized to further improve the aerodynamics of the existing design, and enhance stability and performance characteristics of the light cargo UAV.

TECHNICAL PAPER

1. INTRODUCTION

The technology of large and small unmanned air vehicles (UAV's) is rapidly emerging in the European countries and the US. The design principles for UAV's are similar to the principles developed over the years and used successfully for the design of commercial and general purpose aircraft. The size of UAV varies according to the purpose of their utility. In many cases the design and constructions of UAV's faces new challenges and, as a result of these new requirements, several recent works¹⁻¹⁰ are concerned with the design of innovative UAV's. Initial thrust for improved UAV designs was given due to their importance in military operations. However, nowadays there is increased interest for UAV applications in the public sector for a vast area of applications¹¹⁻¹³ ranging from rescue operations to surveillance and monitoring.

The first UAV designs that appeared in the early nineties were based on the general design principles for full aircraft and findings of experimental investigations¹⁴. Often the main limitation of commercial general purpose UAV's is low cost. An important area of UAV technology is the design of autonomous navigation systems, however, this subject is outside the scope of this work. The tremendous increase of computing power in the last two decades and developments of general purpose reliable CFD software packages made possible the use of full configuration CFD techniques for the design, evaluation, and optimization of modern UAV. Several recent works¹⁴⁻¹⁶ used CFD analysis for new UAV designs even for cases where innovative unconventional designs were employed.

The competition Air Cargo Challenge was initiated by APAE (Portuguese Association of Aeronautics & Space) in 2003, inspired by the North American Design Build & Fly (DBF) aircraft university competitions. The 2009 edition of the competition was organized by AeroUBI EUROAVIA Covilha (Association of Aeronautical Engineering of University of Beira Interior) in 28 - 30 August 2009 at Covilha, Portugal. The objective of the teams participated was to design, document, build and fly a radio controlled aircraft with the maximum payload

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Mohammad H. Sadraey



Design And Analysis Of A Light Cargo Uav Prototype:

Proceedings of Second International Conference in Mechanical and Energy Technology Sanjay Yadav, Abid Haleem, P. K. Arora, Harish Kumar, 2022-06-26 This book presents selected peer reviewed papers from the International Conference on Mechanical and Energy Technologies which was held on October 28 29 2021 at Galgotias College of Engineering and Technology Greater Noida India The book reports on the latest developments in the field of mechanical and energy technology in contributions prepared by experts from academia and industry The broad range of topics covered includes aerodynamics and fluid mechanics artificial intelligence nonmaterial and nonmanufacturing technologies rapid manufacturing technologies and prototyping remanufacturing renewable energies technologies metrology and computer aided inspection etc Accordingly the book offers a valuable resource for researchers in various fields especially mechanical and industrial engineering and energy technologies *Jane's All the World's Aircraft*, 1993 **Applied Mechanics Reviews**, 2000 **International Aerospace Abstracts**, 1999 *PRODUCTS & SERVICES*, 2005 **Thomas' Register of American Manufacturers**, 1996 *Government Reports Announcements & Index*, 1996 **F & S Index United States Annual**, 2006 *Conceptual Design and Prototype Development of Hale Uav* Ahmad Khan, Shuja Ur Rehman, 2015-10-05 The aim of this book is to design a High Altitude and Long Endurance HALE UAV after comparing and analyse the existing solar powered UAVs that has to be used in variety of applications as for military as well as commercial purposes The aircraft design developed is a light and low drag flying wing configuration with solar cells as major power source The Book includes the conceptual and detail design of the aircraft with stability propulsion performance structural and fluid analysis and also the fabrication of a prototype flying model for the demonstration and verification of the concept Unique Stealth Unmanned Aerial Vehicle (UAV) Houck Aircraft Design Program Timothy John Fry, 2008 This report covers the collaborative activities conducted under the leadership of the University of Dayton Research Institute on the Unique Stealth Unmanned Aerial Vehicle UAV Houck Aircraft Design Program This was organized in five phases aerodynamic evaluation of 6 inch model aerodynamic evaluation of 24 inch model design exploration for the Preferred System Concept design of Preferred System Concept and fabrication of flying prototype aircraft Overall this configuration as modeled was found not to have aerodynamic characteristics markedly better than existing small unmanned aircraft It may have potential to show benefit over existing aircraft in other areas though including structural weight required as a result of the joined tips size required to package the aircraft for man portability due to its limited span and range of c g travel owing to large longitudinal wing spacing for trim To understand potential benefits in these areas these characteristics would need to be assessed in further studies using different higher fidelity methods **Tools for the Conceptual Design and Engineering Analysis of Micro Air Vehicles** Mustafa Turan, 2025-05-22 Micro Air Vehicles MAV are a subset of Unmanned Aircraft UAS that are up to two orders of magnitude smaller than manned systems Near Earth environments such as forests caves tunnels

and urban structures make reconnaissance surveillance and search and rescue missions difficult and dangerous to accomplish. Therefore MAVs are considered ideal for these types of missions. However, the data using full size aircraft is inadequate to characterize miniature aircraft parameters due to the lower Reynolds numbers and low aspect ratio LAR wings and impact of wing propeller interactions. The main objectives of this research were to collect and synthesize the available data, tools, create a statistically integrated database, tool set of MAV designs for conceptual design trades, validate the tool set using published experimental data, synthesize and model a prototype design using conceptual and empirical analysis, highlight MAV specific design criteria and identify gaps in existing data for later research. This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it. This work was reproduced from the original artifact and remains as true to the original work as possible. Therefore you will see the original copyright references, library stamps as most of these works have been housed in our most important libraries around the world and other notations in the work. This work is in the public domain in the United States of America and possibly other nations. Within the United States you may freely copy and distribute this work as no entity individual or corporate has a copyright on the body of the work. As a reproduction of a historical artifact, this work may contain missing or blurred pages, poor pictures, errant marks, etc. Scholars believe, and we concur, that this work is important enough to be preserved, reproduced, and made generally available to the public. We appreciate your support of the preservation process and thank you for being an important part of keeping this knowledge alive and relevant.

Development of a Miniature VTOL Tail-sitter Unmanned Aerial Vehicle Jeffrey V. Hogge, 2008. The design, analysis, construction, and flight testing of a miniature Vertical Take Off and Landing VTOL tail sitter Unmanned Aerial Vehicle (UAV) prototype is presented in detail. Classic aircraft design methods were combined with numerical analysis to estimate the aircraft performance and flight characteristics. The numerical analysis employed a propeller blade element theory coupled with momentum equations to predict the influence of a propeller slipstream on the freestream flow field. Then the aircraft was analyzed using 3-D vortex lifting line theory to model finite wings immersed in the flow field. Four prototypes were designed, built, and tested, and the evolution of these prototypes is presented. The final prototype design is discussed in detail. A method for sizing control surfaces for a tail sitter was defined. The final prototype successfully demonstrated controllability both in horizontal flight and vertical flight. Significant contributions included the development of a control system that was effective in hover as well as descending vertical flight and the development of a strong but light weight airframe. The aircraft had a payload weight fraction of 14.5% and a maximum dimension of one meter, making it the smallest tail sitter UAV to carry a useful payload. This project is expected to provide a knowledge base for the future design of small electric VTOL tail sitter aircraft and to provide an airframe for future use in tail sitter research.

Small Unmanned Fixed-wing Aircraft Design Andrew J. Keane, András Sóbester, James P. Scanlan, 2017-08-29. Small Unmanned Fixed wing Aircraft Design is the essential guide to designing, building, and testing fixed

wing UAVs or drones It deals with aircraft from two to 150 kg in weight and is based on the first hand experiences of the world renowned UAV team at the UK s University of Southampton The book covers both the practical aspects of designing manufacturing and flight testing and outlines and the essential calculations needed to underpin successful designs It describes the entire process of UAV design from requirements definition to configuration layout and sizing through preliminary design and analysis using simple panel codes and spreadsheets to full CFD and FEA models and on to detailed design with parametric CAD tools Its focus is on modest cost approaches that draw heavily on the latest digital design and manufacturing methods including a strong emphasis on utilizing off the shelf components low cost analysis automated geometry modelling and 3D printing It deliberately avoids a deep theoretical coverage of aerodynamics or structural mechanics rather it provides a design team with sufficient insights and guidance to get the essentials undertaken more pragmatically The book contains many all colour illustrations of the dozens of aircraft built by the authors and their students over the last ten years giving much detailed information on what works best It is predominantly aimed at under graduate and MSc level student design and build projects but will be of interest to anyone engaged in the practical problems of getting quite complex unmanned aircraft flying It should also appeal to the more sophisticated aero modeller and those engaged on research based around fixed wing UAVs *Automated Low-Altitude Air Delivery* Johann C. Dauer, 2021-11-02 This book investigates Unmanned Aircraft Systems UAS with a payload capacity of one metric ton for transportation The authors provide a large variety of perspectives from economics to technical realization With the focus on such heavy lift cargo UAS the authors consider recently established methods for approval and certification which they expect to be disruptive for unmanned aviation In particular the Specific Operations Risk Assessment SORA and its impact on the presented technological solutions and operational concepts are studied Starting with the assumption of an operation over sparsely populated areas and below common air traffic diverse measures to further reduce operational risks are proposed Operational concepts derived from logistics use cases set the context for an in depth analysis including aircraft and system design safe autonomy as well as airspace integration and datalinks Results from simulations and technology demonstrations are presented as a proof of concept for solutions proposed in this book *Design of Unmanned Aerial Systems* Mohammad H. Sadraey, 2020-02-20 Provides a comprehensive introduction to the design and analysis of unmanned aircraft systems with a systems perspective Written for students and engineers who are new to the field of unmanned aerial vehicle design this book teaches the many UAV design techniques being used today and demonstrates how to apply aeronautical science concepts to their design Design of Unmanned Aerial Systems covers the design of UAVs in three sections vehicle design autopilot design and ground systems design in a way that allows readers to fully comprehend the science behind the subject so that they can then demonstrate creativity in the application of these concepts on their own It teaches students and engineers all about UAV classifications design groups design requirements mission planning conceptual design detail design and design procedures It

provides them with in depth knowledge of ground stations power systems propulsion systems automatic flight control systems guidance systems navigation systems and launch and recovery systems Students will also learn about payloads manufacturing considerations design challenges flight software microcontroller and design examples In addition the book places major emphasis on the automatic flight control systems and autopilots Provides design steps and procedures for each major component Presents several fully solved step by step examples at component level Includes numerous UAV figures images to emphasize the application of the concepts Describes real stories that stress the significance of safety in UAV design Offers various UAV configurations geometries and weight data to demonstrate the real world applications and examples Covers a variety of design techniques processes such that the designer has freedom and flexibility to satisfy the design requirements in several ways Features many end of chapter problems for readers to practice Design of Unmanned Aerial Systems is an excellent text for courses in the design of unmanned aerial vehicles at both the upper division undergraduate and beginning graduate levels

Unmanned Aircraft Design Mohammad H. Sadraey, 2024-09-07 This book provides fundamental principles design procedures and design tools for unmanned aerial vehicles UAVs with three sections focusing on vehicle design autopilot design and ground system design The design of manned aircraft and the design of UAVs have some similarities and some differences They include the design process constraints e g g load pressurization and UAV main components autopilot ground station communications system sensors and payload A UAV designer must be aware of the latest UAV developments current technologies know lessons learned from past failures and they should appreciate the breadth of UAV design options The contribution of unmanned aircraft continues to expand every day and over 67 countries are developing and employing UAVs for both military and civil scientific purposes A UAV system is much more than a reusable air vehicle or vehicles UAVs are air vehicles they fly like airplanes and operate in an airplane environment They are designed like air vehicles they have to meet critical air vehicle requirements A designer needs to know how to integrate complex multi disciplinary systems and to understand the environment the requirements and the design challenges and this book is an excellent overview of the fundamentals from an engineering perspective This book is meant to meet the needs of newcomers into the world of UAVs The materials are intended to provide enough information in each area and illustrate how they all play together to support the design of a complete UAV Therefore this book can be used both as a reference for engineers entering the field or as a supplementary text for a UAV design course to provide system level context for each specialized topic The second edition is extensively revised Some of the new terminologies concepts and specific unmanned aircraft systems are introduced The revisions make the book clearer and easier to understand and will add number of new subjects in areas that have become more prominent in the unmanned aviation world

Unmanned Aircraft Design Mohammad Sadraey, 2017-09-19 This book provides fundamental principles design procedures and design tools for unmanned aerial vehicles UAVs with three sections focusing on vehicle design autopilot design and ground system design

The design of manned aircraft and the design of UAVs have some similarities and some differences. They include the design process constraints e.g. load, pressurization and UAV main components: autopilot, ground station, communication, sensors and payload. A UAV designer must be aware of the latest UAV developments, current technologies, know lessons learned from past failures and they should appreciate the breadth of UAV design options. The contribution of unmanned aircraft continues to expand every day and over 20 countries are developing and employing UAVs for both military and scientific purposes. A UAV system is much more than a reusable air vehicle or vehicles. UAVs are air vehicles; they fly like airplanes and operate in an airplane environment. They are designed like air vehicles; they have to meet flight-critical air vehicle requirements. A designer needs to know how to integrate complex multi-disciplinary systems and to understand the environment, the requirements and the design challenges and this book is an excellent overview of the fundamentals from an engineering perspective. This book is meant to meet the needs of newcomers into the world of UAVs. The materials are intended to provide enough information in each area and illustrate how they all play together to support the design of a complete UAV. Therefore, this book can be used both as a reference for engineers entering the field or as a supplementary text for a UAV design course to provide system-level context for each specialized topic.

Aerodynamic Design of Long Endurance Convertible UAV Yuchen Leng, 2020. The research objective is to establish a complete methodology for long endurance unmanned aerial vehicle (UAV) with vertical take-off and landing (VTOL) capability or transitioning UAV. In the thesis, key technical challenges will be identified and simulated using reduced-order models to form a rapid engineering method in assisting aerodynamic design of such vehicles. In view of maximizing the performance of long endurance transitioning UAVs, critical technologies include: 1. propulsion-airframe integration, 2. aerodynamic effects of flight control configuration, 3. system-level overall aerodynamic optimization. Calculating methods for each problem will be developed based on existing theories. The solution will be validated with campaigns of high-fidelity numerical simulation such as URANS or Boltzmann Lattice Method. Component or full configuration experiments will also be conducted using low Reynolds Number wind tunnel at ISAE. Studies on the propulsion integration will be conducted within the first year. In transition flight, propeller performance at high incidence differs significantly from cruise flight and the close presence of wings also alters lift and drag distribution. For this reason, a reduced-order model for propeller at high incidence angle will be developed based on Leishman's BEMT method. 1. The skewed slipstream will be modelled by modifying conventional method such as Selig. 2. Propeller model will be combined with a propeller-wing interaction analysis based on Veldhuis. 3. To study critical parameters during transition flight, the static and dynamic aerodynamic force and moments generated by control surfaces are critical for robust transition flight control and therefore a configuration study will then be conducted comparing potential transitioning UAV configurations with different propeller arrangements and flight control surface layouts. Following the work by McCormick⁴ and Phillips⁵, detailed study on the longitudinal and lateral aerodynamic moment characteristics of different configurations will be carried before summer

2019 for transition flight regime Final phase of the thesis will be devoted to integrating various reduced order models for propulsion integration flight control analysis and classic cruise performance analysis to form a platform for overall aerodynamic optimization to assist design long endurance transitioning UAV The method will be demonstrated through a prototype analysis consistent with specifications from DelairTech Through collaboration with ENAC a prototype will be manufactured to demonstrate the developed technologies The prototype design will incorporate flight control law implemented by Paparazzi autopilot platform and data acquired from actual flight tests will further validate the methodology in operational environment The final methodology of aerodynamic design will be available in the form of open source computer program as well as published manuscript Refs 1 Leishman Gordon J Principles of helicopter aerodynamics with CD extra Cambridge university press 2006 2 Selig Michael S Modeling propeller aerodynamics and slipstream effects on small UAVs in realtime AIAA Paper 7938 2010 3 Veldhuis L M Review of Propeller Wing Aerodynamic Interference ICAS 2004 24th international congress of the aeronautical sciences 2004 4 McCormick Barnes Warnock Aerodynamics aeronautics and flight mechanics Vol 2 New York Wiley 1995 5 Phillips Warren F Mechanics of flight John Wiley Sons 2004

Design

Optimization of Unmanned Aerial Vehicles Athanasios Papageorgiou, 2019-11-13 Over the last years Unmanned Aerial Vehicles UAVs have gradually become a more efficient alternative to manned aircraft and at present they are being deployed in a broad spectrum of both military as well as civilian missions This has led to an unprecedented market expansion with new challenges for the aeronautical industry and as a result it has created a need to implement the latest design tools in order to achieve faster idea to market times and higher product performance As a complex engineering product UAVs are comprised of numerous sub systems with intricate synergies and hidden dependencies To this end Multidisciplinary Design Optimization MDO is a method that can identify systems with better performance through the concurrent consideration of several engineering disciplines under a common framework Nevertheless there are still many limitations in MDO and to this date some of the most critical gaps can be found in the disciplinary modeling in the analysis capabilities and in the organizational integration of the method As an aeronautical product UAVs are also expected to work together with other systems and to perform in various operating environments In this respect System of Systems SoS models enable the exploration of design interactions in various missions and hence they allow decision makers to identify capabilities that are beyond those of each individual system As expected this significantly more complex formulation raises new challenges regarding the decomposition of the problem while at the same time it sets further requirements in terms of analyses and mission simulation In this light this thesis focuses on the design optimization of UAVs by enhancing the current MDO capabilities and by exploring the use of SoS models Two literature reviews serve as the basis for identifying the gaps and trends in the field and in turn five case studies try to address them by proposing a set of expansions On the whole the problem is approached from a technical as well as an organizational point of view and thus this research aims to propose solutions that can lead to better

performance and that are also meaningful to the Product Development Process PDP Having established the above foundation this work delves firstly into MDO and more specifically it presents a framework that has been enhanced with further system models and analysis capabilities efficient computing solutions and data visualization tools At a secondary level this work addresses the topic of SoS and in particular it presents a multi level decomposition strategy multi fidelity disciplinary models and a mission simulation module Overall this thesis presents quantitative data which aim to illustrate the benefits of design optimization on the performance of UAVs and it concludes with a qualitative assessment of the effects that the proposed methods and tools can have on both the PDP and the organization

Unmanned Aerial Vehicle Design and Technology

T. Hikmet Karakoc, Emre Özbek, 2023-11-17 Unmanned Aerial Vehicle Design and Technology provides readers with a comprehensive introduction to unmanned aerial systems UAS technology basics The book presents clear concise guidance on UAS system design components control and operations fundamentals Additional chapters look at unmanned aerial regulations and ethics and the historical background of UAS technology This textbook offers a well rounded look at unmanned flight technology making it an ideal primer for aviation and aerospace students and anyone interested in learning more about unmanned aerial systems including engineers technicians drone and flight hobbyists and civil aviation organization officials

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