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MULTIDISCIPLINARY OPTIMISATION OF SINGLE-STAGE SOUNDING ROCKETS USING SOLID PROPULSION

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Existing sounding rockets are based on earlier proven designs and often utilize surplus military solid rocket motors. Therefore commonly non-optimal, in terms of performance for a given payload, configurations are utilized. This paper presents a methodology for finding close-to-optimal, in terms of launch mass minimization, design configurations for small unguided sounding rockets. A numerical, multidisciplinary approach is used. During the optimization process vehicle sizing and corresponding aerodynamics modelling is done. The implemented flight simulation module is simplified due to unknown, during the conceptual design phase, rocket mass distributions along vehicle major axes. Special attention is given to propulsion system sizing and thrust level selection. This paper presents optimization of sounding rockets with lift capabilities equivalent to sending small payloads above the Von Karman line. The ultimate aim of this paper is to present methods to improve sounding rocket performance at an early stage of design, to enable conducting more efficient microgravity research. Various concepts, such as using different expansion ratio nozzles for different payload envelopes and masses, are discussed. Optimization results for maximizing the apogee of a small sounding rocket are presented. Due to the lack of published corresponding research, guidelines for future sounding rocket developments, based on numerical investigations, are given. The significance of the study is due to the emergence of new sounding rocket designs, without use of surplus motors, and the possibility to improve vehicle efficiency after a few decades of little alteration.

Abbreviations

AP	Ammonium Perchlorate
CFRP	Carbon Fibre Reinforced Plastic
COTS	Commercially-of-the-Shelf
DLR	Deutsches Zentrum für Luft- und Raumfahrt (English: German Aerospace Center)
HTPB	Hydroxyl-Terminated Polybutadiene
MDO	Multidisciplinary Optimisation
SL	Sea Level
SRM	Solid Rocket Motor
SSRP	Small Sounding Rocket Program
WUT	Warsaw University of Technology

Keywords

sounding rocket; multidisciplinary optimisation; suborbital vehicle; solid rocket motor; rocket aerodynamics;

1. Introduction

Despite the emergence of reusable vehicles to the suborbital space transportation market, expendable sounding rockets remain the main tool for conducting atmospheric research. Since World War 2 numerous sounding rocket programs have been initiated around the world. Apart from enabling microgravity research and serving as in-flight test platforms, they give the opportunity to fill in the technical gap separating nations from launch vehicle technology. This space transportation development path was used in all national programs, which finally led to operational launch vehicles. Nowadays similar efforts are undertaken by private entities. Initial sounding rocket development led New Zealand's RocketLab to supporting funding to develop a small launch vehicle. A similar step-by-step strategy is realised by Spanish PLD Space. Small sounding rockets are valuable technology demonstrators and remain the baseline for research requiring microgravity experimentation of 3 to 15 minutes duration. While hybrid rocket propulsion for sounding rockets is of great interest [1, 2, 3, 4, 5] and may enable conducting more flexible missions, solid rocket motors remain the most common choice for propelling suborbital payloads. Most launch sites do not have infrastructure for supporting launches of vehicles using liquid or hybrid propellants. This may change with the emergence of new commercial space players introducing disruptive solutions, including reusable suborbital vehicles. However, until these solutions are not operational, their