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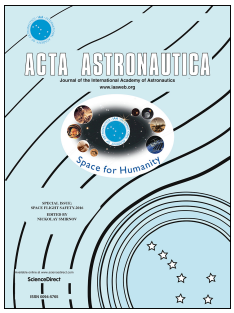

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Development of Small Solid Rocket Boosters for the ILR-33 Sounding Rocket

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Abstract
This paper gives an overview of the development of a 6000 Newton-class solid rocket motor for suborbital applications. The design configuration and results of interior ballistics calculations are given. The initial use of the motor as the main propulsion system of the H1 experimental in-flight test platform, within the Polish Small Sounding Rocket Program, is presented. Comparisons of theoretical and experimental performance are shown. Both on-ground and in-flight tests are discussed. A novel composite-case manufacturing technology, which enabled to reach high propellant mass fractions, was validated and significant cost-reductions were achieved. This paper focuses on the process of adapting the design for use as the booster stage of the ILR-33 sounding rocket, under development at the Institute of Aviation in Warsaw, Poland. Parallel use of two of the flight-proven rocket motors along with the main stage is planned. The process of adapting the rocket motor for booster application consists of stage integration, aerothermodynamics and reliability analyses. The separation mechanism and environmental impact are also discussed within this paper. Detailed performance analysis with focus on propellant grain geometry is provided. The evolution of the design since the first flights of the H1 rocket is covered and modifications of the manufacturing process are described. Issues of simultaneous ignition of two motors and their non-identical performance are discussed. Further applications and potential for future development are outlined. The presented results are based on the initial work done by the Rocketry Group of the Warsaw University of Technology Students' Space Association. The continuation of the Polish Small Sounding Rocket Program on a larger scale at the Institute of Aviation proves the value of the outcomes of the initial educational project.

Keywords
Rocket, Sounding rocket, Solid rocket motor, Solid propellant, Booster, ILR-33

1. Introduction

Solid rocket motors (SRM) are historically the earliest rocket propulsion components ever used. Because of their disadvantages, such as moderate specific impulse and non-restartability, they do not match the requirements for several space applications. However, the ease of obtaining a high level of thrust is an advantage for using them as booster stages and to propel sounding rockets. Numerous solid rocket motors originally developed for ballistic missiles are used in launch vehicles. SRM remains dominant within space and defence industry due to the fact that it allows to eliminate the storage problems and lowers the costs of manufacturing and usage. While solid rocket engine's specific impulses demonstrated in vacuum have remained nearly constant for the last 50 years [1], recent advancements in computational modelling [2] and novel energetic compounds [3] give prospects for performance enhancement.

With greater activity in the field of rocket technology and political support for space technology development in Poland in recent years, increased interest in low-cost access to space is observed [4–6]. Polish solid rocket technology for space applications has its origins in the Meteor Sounding Rocket Program [7–8] initiated in the late 60's led by the Institute of Aviation in Warsaw. Hundreds of flights were carried out. The altitude of over 100 km was reached by Meteor 2K rocket. This led to the development of early concepts of a nano-launch vehicle. However, due to its military potential and the resulting Soviet political pressure, the Meteor program had to be prematurely cancelled. Nowadays the Warsaw Institute of Aviation focuses on developing key technologies connected with in-space and launch vehicle propulsion. Small scale laboratory tests focus on using hydrogen peroxide [9–10] as the oxidizer in liquid propulsion systems. In-flight testing of larger hybrid propulsion system with the use of two SRMs as boosters is planned in the near future. The SRM was originally used for educational purposes [11] in the Polish Small Sounding Rocket Program. The history of its development and its present status are given in the following paragraphs of this paper.

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