VARIED PAYLOAD PERFORMANCE OF THE SOUNDING ROCKETS

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ABSTRACT

The payload performance analysis of the typical sounding rocket has been taken for observation in this paper. Payload of any rocket depicts the objective of the mission. This payload is more effective in determining the peak parameters of the rocket such as the peak altitude and the impact range. The peak parameters of the typical sounding rockets have been found for varied payloads with varied launch elevation angles (LEA). The Payloads taken for analysis are 50,100,150,200 and 250 kg. The LEAs taken for the analysis are 77,78,79,80 and 81 degrees. It is observed that the peak parameters have a heavy impact over the payloads and LEA variations leading to a drastic change. The analysis was done using 6-DoF performance simulator.

Keywords:

impact range,
launch elevation angle,
payloads,
peak altitude,
six degrees of freedom,
sounding rockets

I. INTRODUCTION

A sounding rocket, sometimes called a research rocket, is an instrument-carrying rocket designed to take measurements and perform scientific experiments during its sub-orbital flight. The rockets are used to carry instruments from 50 to 1,500 kilometers above the surface of the Earth, the altitude generally between weather balloons and satellites. The payloads are mostly sensing instruments depending on the mission objective. The payloads are fixed based on the requirement and type of research at the required altitude. The payloads can be taken to the required altitude with the help of a suitable propulsive unit. Sounding rockets are mostly efficient in the study of upper atmospheric researches, aeronomy researches and microgravity studies and experimental researches.

A common sounding rocket consists of a solid-fuel rocket motor and a science payload. Larger, higher altitude rockets have 2 to 3 stages to increase efficiency and payload capability. The free-fall part of the flight is an elliptic trajectory with vertical major axis allowing the payload to appear to hover near its apogee. The average flight time is less than 30 minutes, usually between five and 20 minutes. The rocket consumes its fuel on the first stage of the rising part of the flight, then separates and falls away, leaving the payload to complete the arc and return to the ground under a parachute.

The applications of the sounding rockets are Aeronomy, microgravity research, x-ray and ultraviolet astronomical studies. Aeronomy is the science of the upper region of the atmosphere. Research in aeronomy provides valuable data about this region of the atmosphere. Atmospheric tides dominate the dynamics of the mesosphere and lower thermosphere, essential to understanding the atmosphere as a whole.

X-ray astronomy is an observational branch of astronomy which deals with the study of X-ray observation and detection from astronomical objects. X-radiation is absorbed by the Earth's atmosphere, so instruments to detect X-rays must be taken to high altitude by balloons, sounding rockets, and satellites. X-ray astronomy is the space science related to a type of space telescope that can see farther than standard light-absorption telescopes, such as the Mauna Kea Observatories, via x-ray radiation.

The term micro-g environment (also µg, often referred to by the term microgravity) is more or less a synonym of weightlessness and zero-g, but indicates that g-forces are not quite zero, just very small. Sounding Rocket Flights were devoted to microgravity research in low Earth orbit. A "stationary" micro-g environment would require travelling far enough into deep space so as to reduce the effect of gravity by attenuation to almost zero. This is the simplest in conception, but requires traveling an enormous distance, rendering it most impractical.

II. PROBLEM DESCRIPTION

The main objective of launching a sounding rocket is to research the upper region of the atmosphere. The required altitude for the research is preplanned or found to use the instrumental payloads. These payloads have a huge impact on the propulsive unit thereby producing a change in the peak altitude.

The take-off thrust/lift of mass are the main factor proportional to the payloads and propulsive efficiency. This paper was to analyze the effect of sounding rocket when the payloads are varied with different launch elevation angles (LEA).

III. METHODOLOGY

Many methodologies have been followed to find the peak parameters such as peak altitude, impact range for various launch elevation angles. The method used in this paper is to find the peak altitude and impact range with various fixed launch angles and payloads.

First method is to find the peak altitude and impact range using fixed launch elevation angle and varying payloads in the ascending order of 50kg.

Second method is to find the same peak altitude and impact range using fixed payloads and varying launch elevation angles in the order of one degree.

IV. SOFTWARE DESCRIPTION AND INPUTS

A 6-DoF performance simulator has been used for analyzing the performance of the typical two staged sounding rocket. The simulator is capable of simulating: the motion of a sounding rocket (up to three stages) from lift-off to impact, motion on the launcher, despin dynamics due to rigid yo-yo system, accelerations at any given point on the vehicle, static and dynamic imbalance effects, geo-magnetic field components in body coordinate system, the effect of parachutes (up to three stages) on the translational motion and the effect of pitch - yaw asymmetry in aerodynamics and moment of inertia.

This simulator has provision to input Cld, Clp, Cnα& Xcp values of upper stage fins with after body effect during complete vehicle phase and option of output to be either in 'SI' unit or 'MKS' unit.. It uses either Euler angle approach or direction cosine method. It considers the effects of winds, fin & thrust misalignments, fin cant and propulsion characteristics of individual spin rockets, ignition delay and failure of spin rockets, the geometrical effect and dynamical effect of oblateness of earth, vacuum thrust or sea level thrust, wind magnitude and direction, wind velocity components in topo-centric inertial system or zonal and meridional wind components, thrust oscillations and effects of perturbation in design parameters on performance.

The inputs data are being fed in as thrust-time profile, aerodynamic data and atmospheric data. They are as followed.

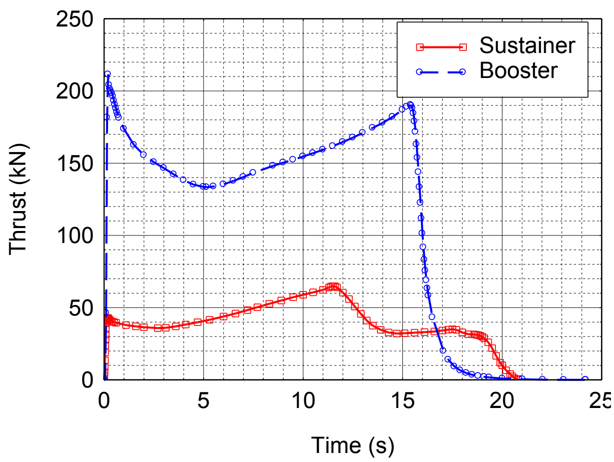

Fig.1. Thrust-Time Profile of the Rocket

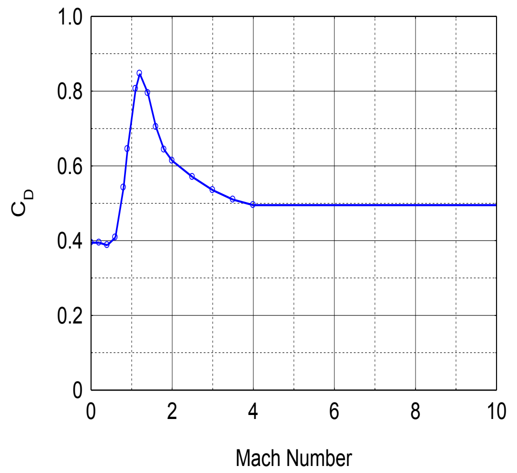

Fig.2. Drag Coefficient with respect to Mach No.

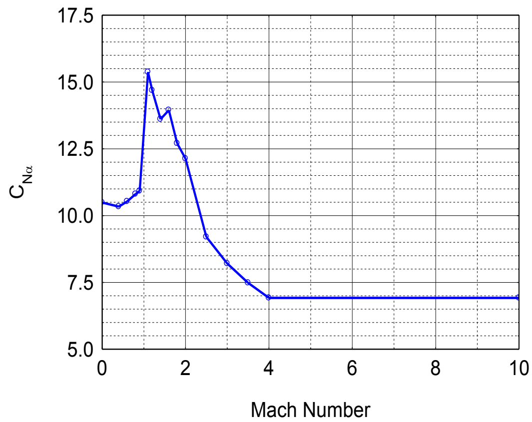

Fig.3. Normal Force Coefficient with respect to Mach No.

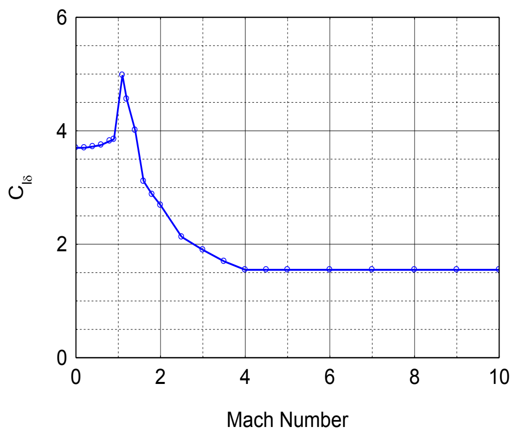

Fig.4. Rolling moment coefficient derivative due to booster fin cant Vs Mach No.

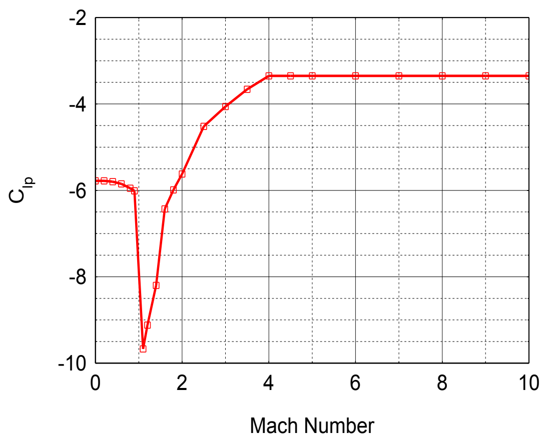

Fig.5. Dynamic Derivative (Roll damping moment coefficient derivative due to rolling velocity) Vs Mach No.

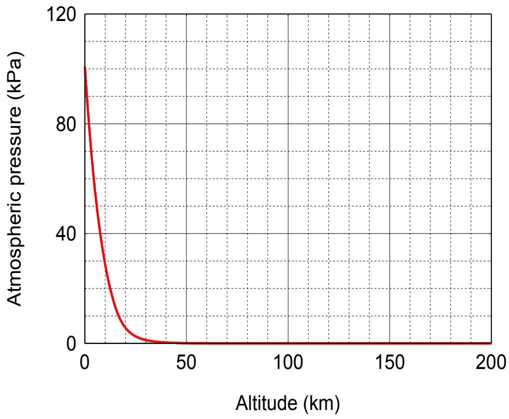

Fig.6. Altitude Vs. Atmospheric Pressure

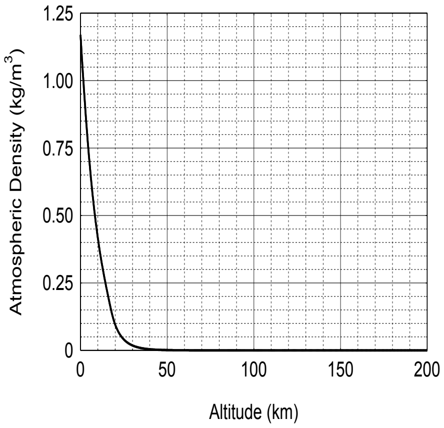

Fig.7. Altitude Vs. Density

Fig.1 shows the thrust-time profile of the sounding rocket for both booster and sustainer. Fig.2 –Fig.5 shows the aerodynamic data inputs. Fig.6 and Fig.7 shows the atmospheric data inputs.

V. RESULTS AND DISCUSSION

The result has been plotted by the simulator. Fig.8 shows the peak altitude of the rocket for each LEA. Fig.9 shows the combined plots of Altitude Vs Impact range for various LEA and payloads.

The results were for the LEA of $79^0,80^0,81^0,82^0,83^0,84^0$ and 85^0. The results were for the payload of 50,100,150,200 and 250 kg.

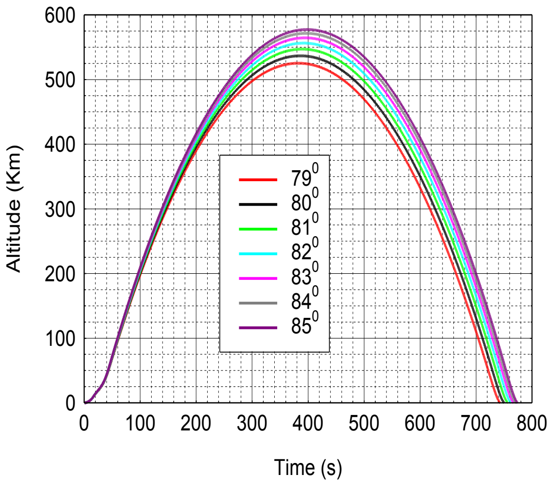

Fig.8. Time Vs. Altitude for various Launch Elevation Angles

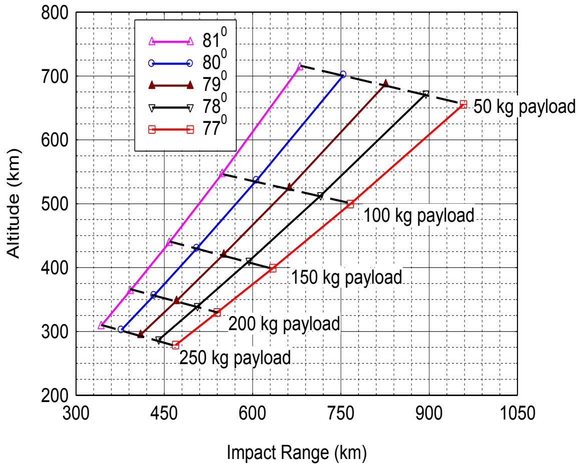

Fig.9. Performance of sounding rocket for various LEA with different payloads

VI. CONCLUSION AND FUTURE WORKS

The peak parameters such as altitude and impact range of the sounding rockets are completely dependent on the LEA and payload mass used. Other factors the parameters depend are the propulsion system and the wind data for the launch site.

It was found when the launch angle was increased for a fixed payload, the peak altitude increases by over 5-20 kms and the impact range of the rocket increases by nearly 10-30 kms. Similarly when the payload was increased for a fixed LEA, the peak altitude decreases by 60-100 kms and the impact range decreases by over 100-120 kms.

The future works can be done to obtain the higher peak altitude and lower impact range with heavier payloads, since sounding rockets form the base for all rocketry and pre-launch vehicle test with varied propellants.

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