Effect of separation motor firing on the aerodynamics of a typical launch vehicle using CFD

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Extended Abstract

Launch vehicles are of multi stages to enhance the payload capability. As the vehicle gains altitude, the spent stages are separated from the ongoing stages. There are several mechanisms to separate the spent stages from the on-going stages, for example drag assisted separation, spring-separation, jet-induced separation. The vehicle that is considered here for the study is having two strapons and a core. The exit plane of core nozzle is 0.42d (d=core diameter) ahead of that of strapon nozzle exit plane. The strapons are separated from the ongoing stages by jettisoning motors located at the strapon nose and base, which are placed in such a way that the jet coming out from the motor impinge on the core vehicle. They are circumferentially placed at angular locations of 5, 20 and 36 degree towards the core (Figure-1). Flow simulations over this launch vehicle are carried out to understand the flow physics at the instant of separation. It is observed that at the instant of separations, due to ignition of the jettison motors, the ongoing vehicle faces an instantaneous very high axial load as well considerable change in normal forces and centre of pressure locations.

Numerical Simulation:

CFD code PARAS-3D has been used to simulate the flow over this configuration. Standard K-ε turbulence model has been used as closure for RANS simulations. The jet pressure ratio considered for the CFD simulations is as follows-

Parameter	Ambient	Jettison motor -jet	Core-jet
Mach number	5.75	2.864	4.244
Jet pressure ratio	-	25792	820

As the jettison motors are aligned towards the core. Hence the flow coming out of the motor will impinge on core. it is expected that once the jets are fired. As the jet pressure ratio is very high, the flow field over the core will change. Numerical simulations have been carried out with and without considering the jettison jets to assess such changes as estimate its effect on the forces and moments acting on core.

Results and discussion:

The jettison motor jets are highly under expanded as it comes out of the nozzle. Owing to very high jet pressure ratio, jettison motor jets expand to almost maximum to match with the free stream pressure. In radial direction, they expand so much that it reaches up to the plane joining strapon-core centre **(Figure-2).** Due to this high expansion, jettison motor-jets reach close to heat shield boat-tail. The flow over the heat shield base also gets affected. In the absence of any jettison motor jet, the strapon shock is very close to the strapon nose. But due to the presence of jettison jets, the strapon nose shock shifts ahead and the strength of shock is also more. Similarly, at the rear end of the strapons, the shape of the core jets is affected by these jets. The jets boundaries get compressed at the side close to the jettison motor.

Temperature distribution:

As the intertank skirt(ITS) region is very close to the strapon nose and jettison motors are embedded to the strapon nose, the flow field and thermal environment at this region will be affected by these jets. A differential variation in the temperature is noticed in ITS due to the asymmetry in the location of the jettisoning jets. The jets expand and hit the dome directly at one side, while some amount of flow passes through the passage between the domes from one side to other side. Near the outer boundary, the temperature is maximum due to the local stagnation point.

The nose region of the vehicle faces high surface temperature that is due to the local stagnation of flow at the nose of heat shield. Along the heat shield length the temperature falls as we move downstream as expected. Downstream to the cone cylinder junction, the surface faces the hot jets coming out of the jettisoning motors of strapons. Due to these interaction and subsequent shock formation, the surface temperature increases to a value of 3350K. Variation in temperature is noticed as we move along the core length. This is due to the impingement of the jettisoning jets on the dome.

Forces on core:

The forces acting on the core with and without jettison jet is shown in Table 1. When there is no jet impingement, the forces on the core are due to upstream flow and the mutual interaction between the flow past core and strapon. When the jettison motors are on, large forces and moments are experienced by core motor. The drag force reduces by 65% and centre of pressure of the ongoing vehicle shifts towards nose.

Conclusions:

Numerical simulations are carried out to study effect of jettison motor jet impingement on the core vehicle. It is observed that the flow field around the vehicle changes as the motors is fired. The surface temperature also increases drastically at that instant. Momentarily the vehicle drag force reduces. To take care of the high temperature, the thermal protection system design also needed to address properly.

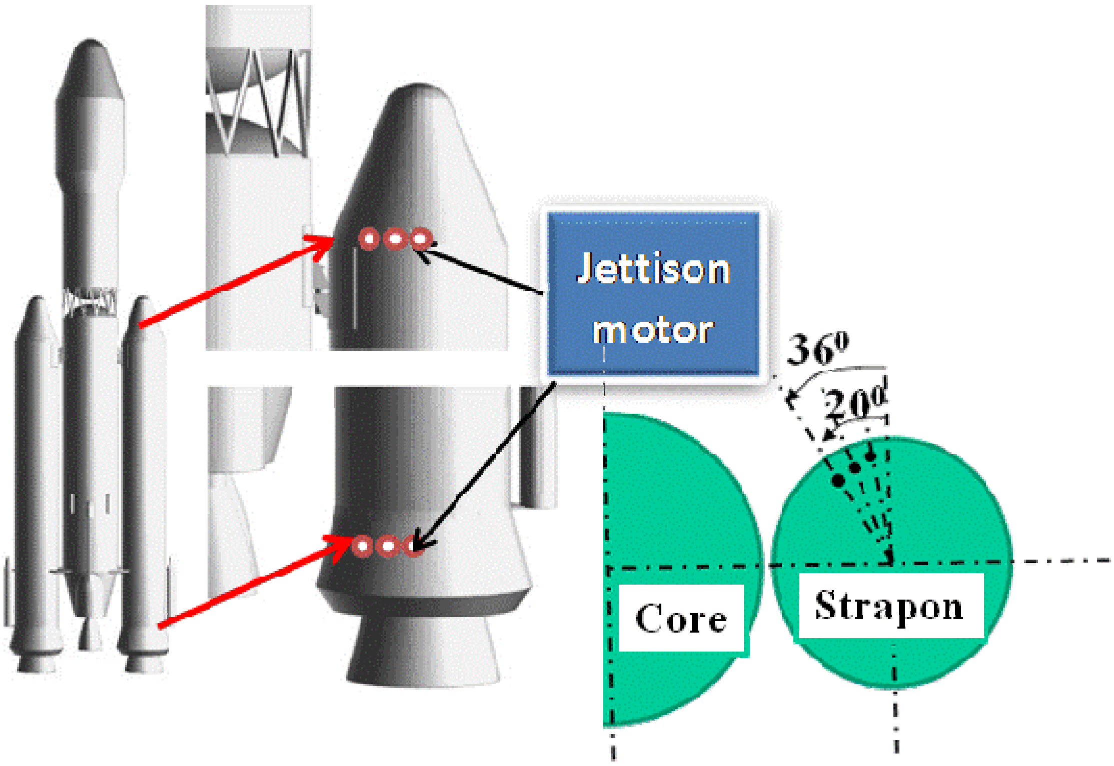

Figure-1: Schematic outline of the launch vehicle

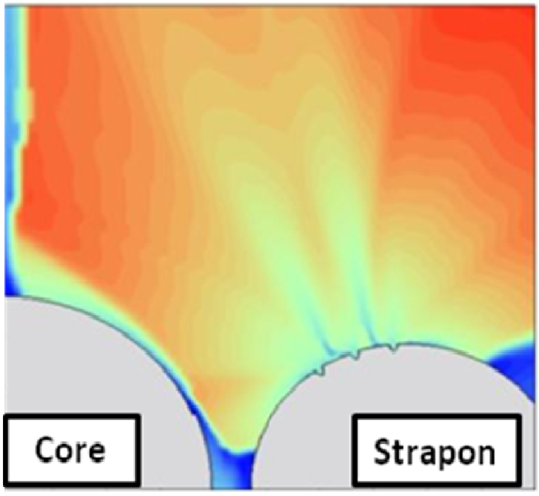

Figure-2: Mach number palette

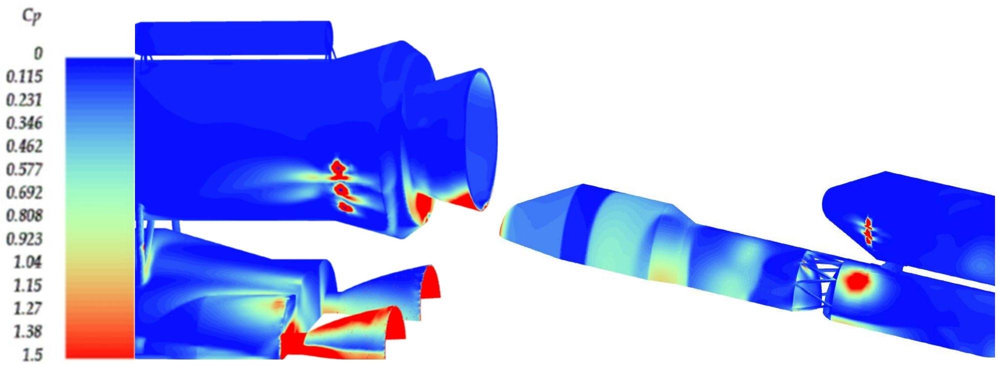

Figure-3: Cp distribution at the nose and base region of the vehicle

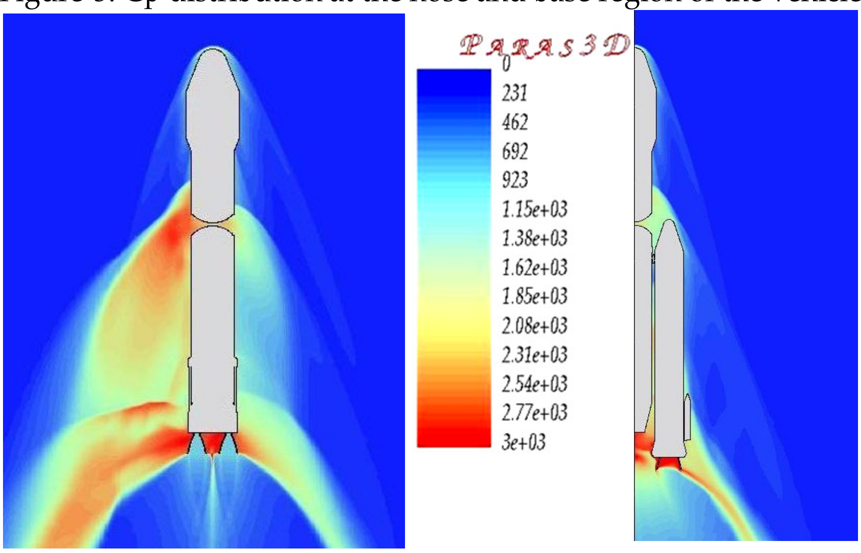

Figure-4: Temperature palette along the vehicle length

Table-1: Aerodynamic force coefficients on the core.

	C_A	X_{CP} of core (in terms of d)
Before firing	0.31	4.1
After firing	0.11	3.5