# Estimation of Flight Measured Pressure using CFD for a Typical Launch Vehicle

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## 1. INTRODUCTION & OBJECTIVE

Aerodynamic characterization in presence of jet was carried out using CFD (PARAS-3D software [1]). Based on these, overall aero data and $C_P$ distribution over the vehicle has been generated and this data is essential for structural, mission and thermal design of the vehicle. So, external pressure data measured in flight is very useful to check the correctness of CFD data generated before the flight. Data obtained in flight are compared with the pre-flight estimated $C_P$ data using CFD. In the paper, details about these comparisons are discussed.

## 2. METHODS OF ANALYSIS

### Pressure port location:

To measure the pressure on the external surface, total 10 pressure ports were instrumented over the complete vehicle. There is one port on Pay Load Fairing (PLF), 2 ports on cylindrical region and 7 ports on $1^{st}$ stage ( 2 on flare region, 1 port on fixed fin side panel, 2 ports on shroud base and 2 ports at base of the fins). Schematic locations of external pressure ports in typical launch vehicle are given in Figure 1.

Trajectory parameters (angle of attack, dynamic pressure, Mach number etc as a function of time) were given in Figure 2. The maximum flight dynamic pressure occurs at about 48 sec of flight. The total angle of attack is $< 1^0$ for most of the Mach number regimes.

Offset correction of sensors are estimated based on the pressure measured (101350 Pa) on the day of launch. These corrections are estimated at time=0sec and assumed constant throughout the flight duration. The flight measured pressure thus obtained are converted to $C_P$ (coefficient of pressure) using the following expression

$$C_P=(P-P_\infty)/q_\infty$$

Where, P=Flight measured pressure, Pa

$P_\infty$=Free stream pressure, Pa ; $q_\infty$=Free stream dynamic pressure, Pa

## 2. RESULTS AND DISCUSSION

Locations of external pressure port on PLF of the vehicle are shown in Figure 1. Variation of $C_P$ with Mach numbers on PLF for flight is shown in Figure 3. $C_P$ palette over PLF at various Mach numbers as obtained from CFD is shown in Figure 4. At the nose cone starting point, $C_P$ reaches the maximum value due to stagnation point. In the expansion corner like ogive cylinder junction and the cylinder boat tail junction, the static pressure goes below the free stream pressure. It is noticed from the $C_P$ palette that at lower Mach numbers (M< 0.95), the expansion of flow at the ogive cylinder junction does not reach to the port location. This leads to a pressure very close to ambient value ($C_P$ ~ 0) at the port location. At M=0.95, flow over the ogive-cylinder accelerates so much that it reaches M>1.0 and gets terminated by a λ shock on the cylinder. The port location being ahead of the λ shock ends, experiences very low pressure. With increase of Mach number, the shock passes over cylinder end the pressure over port gradually increases to free-stream value. CFD data matches well with the flight measured $C_P$

except at Mach 0.95 where less expansion is observed in flight as compared to CFD as shown Figure 3. Axi-symmetric simulations are carried out over PLF using CFD++ code. The obtained data show similar behaviour like PARAS data.

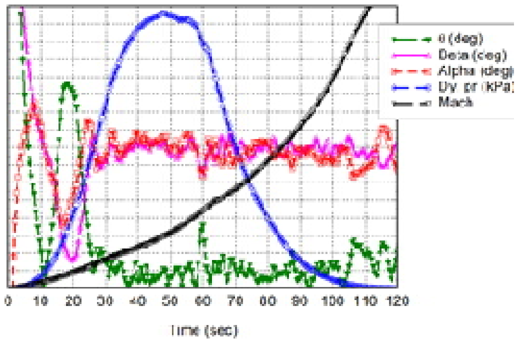
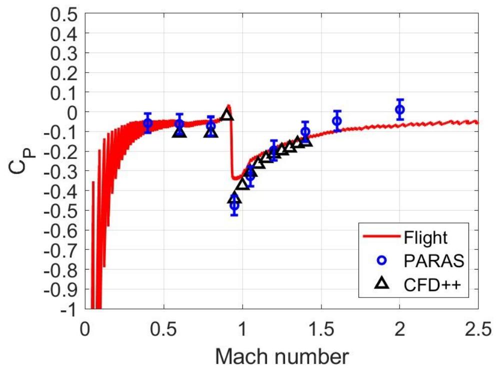



Figure 1: Location of pressure ports over the configuration;   Figure 2: Typical flight trajectory parameters



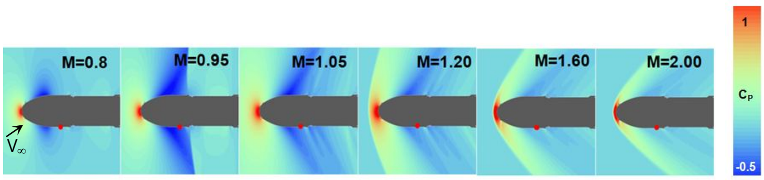




Figure 3: Comparison of $C_P$ distribution over PLF at various Mach numbers

Figure 4: $C_P$ palette over PLF at various Mach numbers

## 4. CONCLUSIONS

CFD analysis carried out over typical launch vehicle at various Mach numbers under jet-on condition. Steady pressure data has been estimated for the flight measured ports. Pre-flight estimated $C_P$ data (using CFD) is used to compare with the flight measured data CFD data estimated from PARAS-3D and CFD++ matches very well with the flight data.

## 5. REFERENCES

[1]. Harichand M V., "Acceleration of an Adaptive Cartesian Mesh CFD Solver in the Current Generation Processor Architectures", 25th International conference on High Performance Computing (HIPC-2018), Bangalore.

## 6. ACKNOWLEDGEMENT

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