Launch Vehicle Interface: Constraints on Spacecraft Mechanical Configuration

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Abstract

This paper details the constraints on spacecraft mechanical configuration due to the Launcher Interface. The effect of Launch Vehicle interface specifications like Envelope, Lift-off Mass (LOM), the Physical Parameters and the Launch loads etc. on mechanical configuration of the spacecraft is provided.

1. Introduction

Evolution of the configuration of any spacecraft is dictated by the payload and its support systems it has to carry and the constraints imposed by the available Launch Vehicle(s) which can place it in the required orbit. The various inputs required for the spacecraft mechanical configuration is shown in Figure-1.

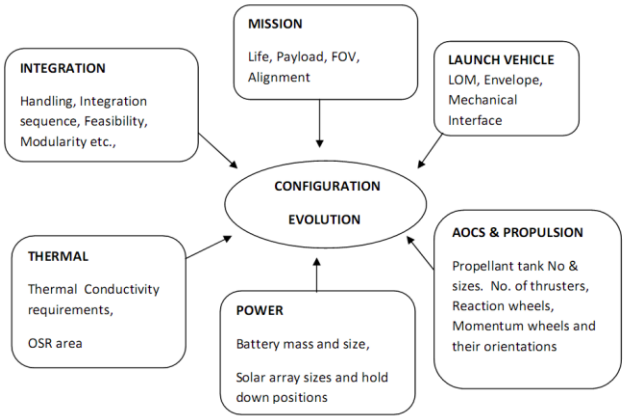

Figure 1: Inputs to Spacecraft Mechanical Configuration

The choice of the Launcher determines the spacecraft envelope, the lift-off mass (LOM), the physical parameters, its interface in the launch configuration and the launch loads it has to be designed. Thus the spacecraft mechanical configuration is directly affected by the choice of Launch Vehicle.

2. Envelope Constraint

The spacecraft envelope in the Launch Configuration must reside within the specified dynamic envelope of the Launcher. This poses the constraint / requirement on the following subsystem of the spacecraft: -

- Structure and its dimensional details
- Deployment Mechanism for the appendages like Solar panel, Reflectors etc.
- Thermal radiation area (Optical Solar Reflector-OSR) and its configuration.

3. Lift off Mass & Physical parameters constraint

The lift off mass and centre of gravity (C.G) of the spacecraft has to be within the specified limit of the launcher. ARIANE-V[1] specification on lateral axis centre of gravity (d) for 3-axis stabilized spacecraft is given in Figure-2. Longitudinal centre of gravity for ARIANE-V[1] with 1194 Adaptor is 2400mm for the spacecraft LOM of 7000 Kgs from the separation plane. Similarly, maximum dynamic unbalance (Є) corresponding to the angle between spacecraft longitudinal geometric axis and the principal inertia axis, shall be $Є \leq 1°$ to ensure the proper separation conditions in spin-up mode of the spacecraft as per ARIANE-V[1] user manual.

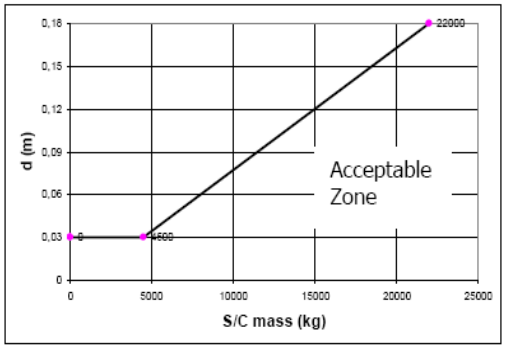

Figure 2: ARIANE-V specification on C.G.

This poses the constraint / requirement on the following subsystem of the spacecraft: -

- Mass of every subsystem including the Propellant mass, thus life of the spacecraft.
- The locations of the subsystem on the spacecraft.
- Balancing requirement with Balance mass penalty, if any.

4. Interface to the Launcher Constraint

Spacecrafts are usually clamped along with the launch vehicle adaptors using a clamp band which poses certain dimensional constraints and tolerances on the spacecraft interface rings. The interface ring has also to meet the strength and stiffness specification of the Launcher. The vehicle adaptors along with the clamp band provide the stay out area requirement, on any nearby element protrusions from the spacecraft, to ensure proper assembly and separation of spacecraft. Thus it affects both the structure realization and location of subsystem elements at those areas.

5. Launch Load Constraint

The types of load that are experienced by the spacecraft during Launch are Quasi-static loads, Sinusoidal vibration, Random Vibration, Acoustic and Shock loads. Spacecraft need to be designed and tested for all these specifications along with the spacecraft fundamental frequency requirement provided by the Launcher. Typical fundamental frequency requirements of PSLV[2] , GSLV[3] and ARIANE-V[1] are given in Table –1.

Launch vehicle	*Fundamental frequency, Hz	
	Spacecraft axis	
	Longitudinal	Lateral
PSLV	>35	>18
GSLV	>31	>10
ARIANE-V	>31	>8

Note:

*Frequency requirement vary with respect to Lift Off Mass of spacecraft, c.g and launch vehicle fundamental modes

Table 1: Frequency Requirements

The fundamental frequencies of the spacecraft are directly proportional to square root of stiffness to the mass of the spacecraft. Hence, the design of spacecraft subsystem elements like structure, mechanical housings for the electronic packages, appendages etc. must take care to maximize the stiffness for the given mass to meet this launcher requirement. The Quasi-static load specification provides the spacecraft strength requirement.

6. Summary

The Launcher interface thus plays a major role in the mechanical configuration of the spacecraft and needs to be firmed up much in advance. It also provides input for subsequent design, integration and testing phase, hence, it affects the overall project realization also.

7. References

[1] ARIANE-V Users Manual – Issue 5 , July,2011
[2] PSLV Users Manual – Issue 4 , March,2005
[3] GSLV Users Manual – Issue 2 , January,2004