Lessons Learned Developing Separation Systems For Small Satellites

Walter Holemans, 20th Annual AAIA/USU Conference on Small Satellites, August 2006
Planetary Systems Corporation, 2303 Kansas Avenue, Silver Spring MD 20910, (301) 495-0737,
holemans.walter@planetarysystemscorp.com

ABSTRACT: Several lessons learned0.0p ps82.92(0.0025 on systems for small satellites are presented. The

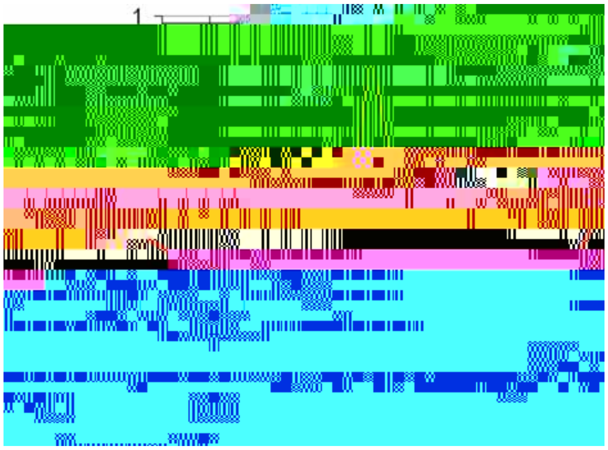


Figure 4. Random vibration level, a notional

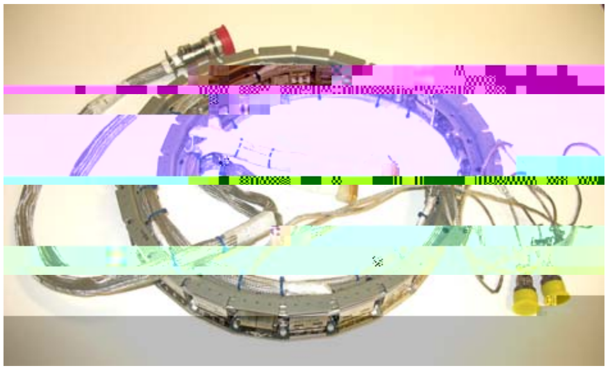


Figure 8. A fully featured 3.0 lb harness on a 5.2 lb separation system (Lightband)

A fully featured harness can weigh half as much as the separation system and cost about one third as much. Additionally volume and stiffness of the harness can grow by orders of magnitude. The connectors on the harness are often taller than the separation systems. Often an assembled harness cannot be formed after assembly because it is so stiff. It must be formed to the net shape prior to assembly. PSC engineers have seen several examples where the harness was made, modified and remade as engineers attempted to create a complete design.

Lesson Learned

Wiring harnesses are a major element of separation system design. If the net shape of the harness is not predetermined, a substantial risk of the harness not fitting may result.

LOAD PEAKING AND DISSIMILAR STRUCTURES (SQUARE PEG, ROUND HOLE)

Separation systems are often round while small satellites are often square or hexagonal. Structurally,

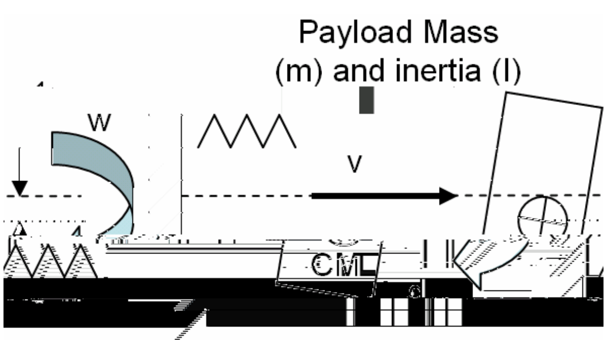
Lesson Learned

Engineers should design to the maximum allowable line load of the adjoining structures and ideally, have a design that minimizes the extremes of line loading. Such a design is also structurally efficient.

TIP-OFF, VELOCITY AND SEPARATION SPRINGS

Tip-off is the rate of rotation about any axis of a satellite as a result of the separation event. In about one in three cases, a tip-off is desired to affect dynamic stability, to induce even solar heating or to counter pre-separation rates. When tip-off is to be minimized the specification is often less than, or equal to, 1.0 degree/second/axis.

When the sum of the separation springs is not through the center of mass of the adjoining structure, tip-off will result.



w = mvd/I (1)

Where w is the tip-off rate [angle per unit time]; m is the mass of the separating vehicle; v is the relative velocity; d is the distance between the center of mass (CM) and the resultant location of the separation springs; I is the mass moment of inertia about the center of mass of the separating vehicle. This relation is for most purposes an over simplification because it assumes the other vehicle is many times more massive (>10x) and has many times more inertia (>10x) than the separating vehicle. It also assumes the pre-separation rates are all zero.

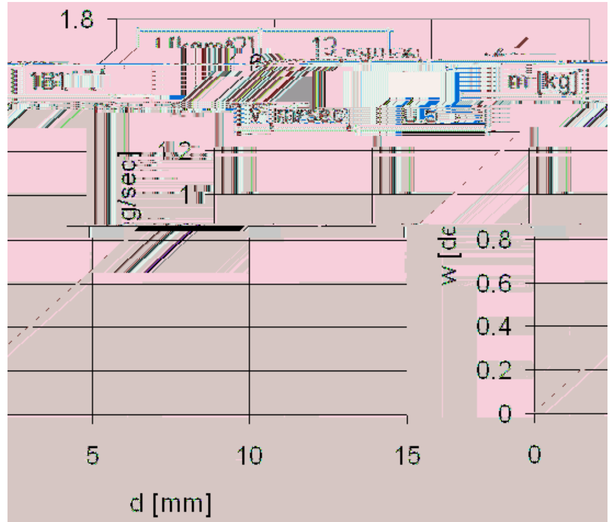
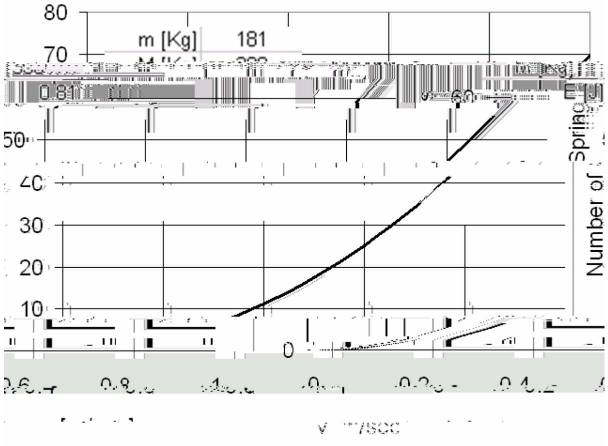


Figure 11. An illustration of equation 1

The separation springs may be moved on a separation system so they push through the CM. However it may be easier to move the CM. The lower the delta-V required, the lower the tip-off.

Sometimes tip-off is desired as this may beneficially produce even solar heating or dynamically stabilize the vehicle. In such cases, migrating the separation springs to one side of the CM or allowing the CM offset (d) to be significant affects the desired tip-off.urposepeds.143( )]Ts may bMelo


m [Kg]
181
80
70
50
40
30
20
10
0
Number of
Spring

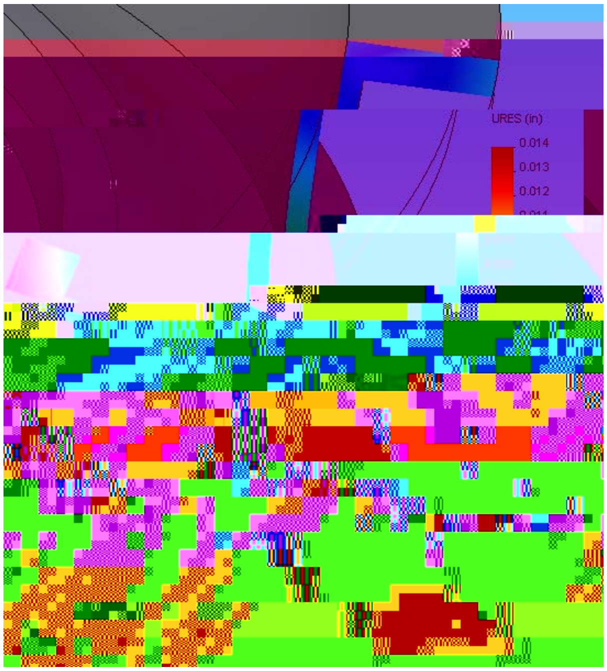


Figure 17 In the cross section of a V-band a warp of 0.004 inches at the interface to adjoining structures is created by preload

V-bands embody the perverse nature of mechanical assembly: not only do they warp in proportion to preload, but a warp applied to them can affect their preload. Critically as many mechanisms engineers have observed in test, the structural performance (strength and stiffness) is highly correlated to preload.

PSC engineers often observe substantial changes in internal strain as structures are joined. A 20% change in preload as the separation system is fastened to an adjoining structure has been observed.

Just as changing the boundary conditions in the FEM will change the stress, so too bounding a separation system will change the stress in a separation system.

PSC engineers have found a flatness maximum rate of 0.00015 inches per inch to be a sufficient flatness specification. In a 38 inch diameter separation system, this equates to and overall flatness of 0.005 inches. This is a nominal specification. When adjoining structures are more flexible, flatness may be changed.

Structures adjoining separation systems that are easy to make, may be expensive to make flat. Alternatively, structures that are expensive can be easy to make flat. For example, a thrust cone from the final stage engine to the launch vehicle interface can be made by riveting machined rings to conical sheets. The riveting process can stress the thrust cone. This may manifest its self as warping (i.e. lack of flatness) when the riveted structure is removed from its tooling. To attain flatness requirements, the riveted structure must be machined at additional set-up and cost.

Alternatively, the thrust cone could be directly machined from a coarse conical forging.

Engineers should consider the conjecture that all manufacturing and joining processes (riveting foring process .