



ADVANCED LIGHTBAND

User's Manual | 2003336B

Do not operate the Advanced Lightband (ALB) before reading this document. Do not operate the ALB beyond the operating limits.

The ALB does not involve any high-energy liquid, solid fuels, or any material with inherently hazardous physical or chemical properties.

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NOTE: To avoid costly test failures and program delays, all users shall completely understand this document before attempting to operate the ALB for any purpose. Copyright PSC.

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1. Introduction

The Advanced Lightband (ALB) is a space vehicle separation system. It separates space vehicles from launch vehicles.

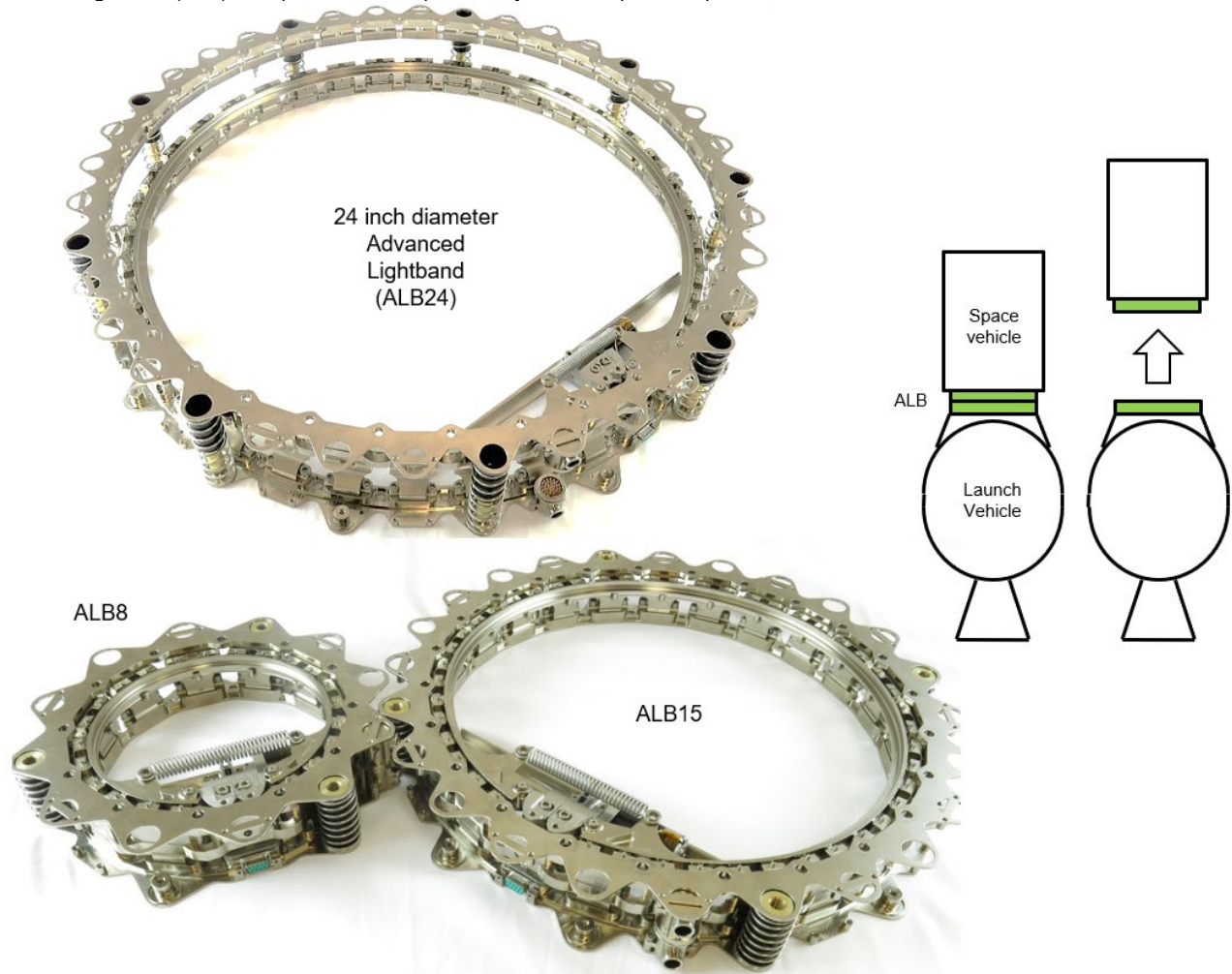


Figure 1-1: The ALB is offered in a range of sizes from 8.0 to 24.0-inch bolt circle diameter

The ALB is an advancement based on decades of work by PSC manufacturing hundreds of separation systems for commercial, government, private and university customers, in LEO, GEO and interplanetary orbits. The ALB is a patented, Commercial Off-The-Shelf (COTS) technology. It is made and verified with materials and methods consistent with high-reliability space flight hardware.

Features and benefits

1. **Easy to use** Integrate in less than 30 minutes, training is simple, only two wires to initiate, looser flatness requirements
2. **Reliable** Thousands of separation tests in development and qualification environments prove reliability.
3. **Stiffer and stronger** A 30% increase in stiffness allows higher frequency 1st modes and reduces deflection.
4. **All-inclusive product** The ALB has integrated Separation Springs, Switches and Connectors and does not require additional brackets or complex interface documentation. This reduces complexity, increasing reliability and decreasing mission cost.
5. **No consumables, non-pyrotechnic** Motor-driven eliminating need for consumable initiators.
6. **Minimal reset time** Separation tests can be repeated in minutes.
7. **Lightweight** The ALB is one third of the weight of a typical clamp band.
8. **Low-height** About one half of the height of a typical clamp band.
9. **Precise initiation** Critical separation timing of satellite swarms is enabled.
10. **Low-shock** Ideal for sensitive payloads.
11. **Low tip-off** Special testing can tune rotation rates to less than 1 deg/s
12. **Higher Separation Velocity with increased precision.** Special testing can tune delta V within 1.0 in/s. Larger springs produce more separating velocity.
13. **Backwards compatible and pyro-pulse compatible** Accepts same connector and electrical pulse as MLB.



Figure 1-2: An ALB attached to Starshine-4 during a pre-flight vibration test



Figure 1-3: Two ALB 24 Separate FX-2 and LTE-1 from SpaceX's Transporter-2 using ALB 24

2. Parameters

Parameter			Sym.	Value								Tol.	
Size	Bolt Circle Diameter [in]		D	8.000	11.732	13.000	15.000	18.250	19.848	23.250	24.000	± 0.01	
	Number of Fasteners		n	12	18	20	24	28	28	32	36		
Dimensions	Stay-Out Dimensions [in]		A	10.857	14.684	15.970	18.002	21.265	22.853	26.268	27.039	min	
			C	5.410	9.142	10.410	12.410	15.660	17.258	20.660	21.410	max	
			E	0.239	2.130	2.766	3.770	5.383	6.123	7.780	8.151	max	
	Latch-up distance [in]		H	2.100								± 0.01	
			ds	.475 to -.090	.475 to -.090	.475 to -.090	.475 to -.090	.075 to -.090	.075 to -.135	.075 to -.165	.075 to -.175		
Mass Properties (Does not include accessories)	Mass [lb _m]	Upper Assembly		1.24	1.78	1.96	2.20	2.71	3.00	3.52	3.55	± 5%	
		Lower Assembly		3.24	4.27	4.61	5.25	6.00	6.14	6.91	7.44		
		Total		4.48	6.05	6.57	7.45	8.71	9.14	10.43	10.99		
	Center of Mass [in]	X _{LB}		1.03	1.04	1.05	1.04	1.05	1.07	1.07	1.06	± 0.1	
		Y _{LB}		0.58	0.85	0.92	1.00	1.12	1.19	1.28	1.26		
		Z _{LB}		0.11	0.08	0.08	0.07	0.06	0.06	0.05	0.05		
		X _{LB} , Upper Assembly		1.60	1.61	1.61	1.61	1.61	1.61	1.60	1.61		
		Y _{LB} , Upper Assembly		0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01		
		Z _{LB} , Upper Assembly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	Inertia [lb _m ·in ²] (Measured about CM in stowed state)	X _{LB} , Lower Assembly		0.82	0.81	0.81	0.81	0.81	0.80	0.80	0.80	± 10%	
		Y _{LB} , Lower Assembly		0.80	1.20	1.31	1.41	1.62	1.77	1.93	1.86		
		Z _{LB} , Lower Assembly		0.15	0.12	0.11	0.10	0.08	0.08	0.07	0.07		
		I _{xx}		58	184	250	386	682	852	1,350	1,522		
		I _{yy}		29	87	117	179	316	393	624	705		
I _{zz}			33	102	138	212	373	466	735	826			
Loading & Boundaries	Operating limit Line Loads	X _{LB} (Axial) [lb/bolt]	Peq	1,720								± 25%	
		Y _{LB} or Z _{LB} (Shear) [lb/bolt]	Q	646									
	Stiffness about X _{LB} [lb/in]			2.34E+6	3.43E+6	3.81E+6	4.39E+6	5.34E+6	5.81E+6	6.80E+6	7.02E+6		
	Stiffness about Y _{LB} or Z _{LB} [in-lb/rad]			1.82E+7	5.76E+7	7.83E+7	1.20E+8	2.17E+8	2.78E+8	4.47E+8	4.93E+8		
	Required flatness of adjoining structure if adjoining structure is "flexible" [in] (see table 3-4)			0.004	0.007	0.008	0.008	0.009	0.011	0.013	0.013	max	
	Required flatness of adjoining structure if adjoining structure is "stiff" [in] (see table 3-4)			0.003	0.005	0.006	0.006	0.007	0.008	0.010	0.010	max	
	Electrical Initiation	Voltage, (Pin 1-4) [V]		V	24 to 32								
		Motor terminal resistance [Ohm]		Rw	5.9 to 11.4								
		Motor terminal inductance [mH]		Hm	0.746								
		Peak current [A]		Ip	5.4								
Minimum supplied current to the ALB [A]		Imin	3.3										
Time to apply power [s]		Tp	0.1 to 1										
Time to initiate [s]		Ti	0.005 to 0.035										
Time to spin down [s]		Tsd	>0.3										
Free running current, maximum [A]		Ifrmax	<0.2										
No Fire Current [A]			0.02										
Max resistance, through Lightband [Ohm]			<0.01										
Thermal-vacuum	Thermal resistance, X direction [°C/W]			0.392	0.267	0.241	0.209	0.172	0.158	0.135	0.130		
	Survival Temperature[°C]		Ts	-50 to +110									
	Operating Temperature[°C]		To	-40 to 90									
	Pressure [Torr]			<10 ⁻⁴									
Accessories	Separation Springs	Spring Radius [in]	Rs	4.788	6.701	7.344	8.360	9.992	10.786	12.493	12.878	± 0.005	
		Energy per spring [J]	e	2.45									
		Spring Constant [lb/in]	Ks	5.85									
		Force per spring, stowed [lbf]	Fss	19.9									
		Force per spring, deployed [lbf]	Fsd	8.8									
		Stroke [in]	deltas	1.890								± 0.025	
		Weight Supported per Spring when stowing [lb]	Fws	50.0								max	
		Spring assembly + fastener [lbm]		0.087									
		Maximum Qty. of Separation Springs [-]	Smax	6	9	10	12	14	14	16	18		
	Max rotational energy [J]	X		0.0003	0.0023	0.0023	0.0023	0.0008	0.0008	0.0008	0.0008		
		Y		0.0002	0.0010	0.0011	0.0011	0.0024	0.0024	0.0024	0.0024		
		Z		0.0092	0.0008	0.0028	0.0028	0.0061	0.0061	0.0061	0.0061		
	Connector and Switch Radius [in]		Rc	4.724	6.637	7.280	8.296	9.928	10.722	12.429	12.814		
	Max. sum of Sep. Connector and Switch Qty. [-]			5	8	9	11	13	13	15	17		
	Separation Connector	Energy per separation connector [J]	Kec	0.001									
		Spring Constant [lb/in]	Kc	38									
		Force per connector, stowed [lbf]	Fsc	5.1									
		Force per connector, deployed [lbf]	Fdc	1.9									
		Stroke [in]	dsc	0.110									
		Current, each pin, steady state, vacuum [A]	Iscv	3.00									
Current, each pin, steady state, STP [A]		Iscsa	5.00										
Pulsed current through pin [A]		Ipv	5.00										
Mated pin-pair contact resistance [Ohm]		Rsc	0.04								± 0.02		
Mated pair mass + fasteners [lbm]			0.099								± 0.02		
Separation Switch	Energy per separation switch [J]	Kes	0.02										
	Spring Constant [lb/in]	Ks	14.0										
	Force per switch, stowed [lbf]	Fsw	3.7										
	Force per switch, deployed [lbf]	Fds	0.9										
	Stroke [in]	dsw	0.21								± 0.05		
	Current, steady state, vacuum [A]	Iscv	5.0										
	Contact resistance [Ohm]	Rsw	<0.025										
	Mass + fasteners [lbm]		0.058								± 0.02		
Life	Deployments [-]			100									
	Storage (Stowed or Deployed) [year]			20									

Table 2-1: Parameters

3. ALB Description

3.1 Part Marking

Each ALB is marked with its assembly number and serial number in the vicinity of the DE-9 connector on the Upper Ring. The Upper and Lower Rings are matched pairs, the serial number shall match.

3.2 Tolerance on Dimensions

Precision	Tolerance [unit]
x.xxx	± 0.005
x.xx	± 0.010
x.x	± 0.030
x	± 1.000

Table 3-1: PSC distance tolerances

3.3 Mechanical Description and Interface

The coordinate system for the ALB is shown below. The $+X_{LB}$ axis originates from the Lower Ring bottom plane centered at the bolt pattern and points towards the Upper Ring. The $+Y_{LB}$ axis passes through the center plane of the Stow Screw Hole (and DE-9 connector). Unless otherwise noted, all axes in this document refer to the ALB coordinate system and all dimensions are given in inches.

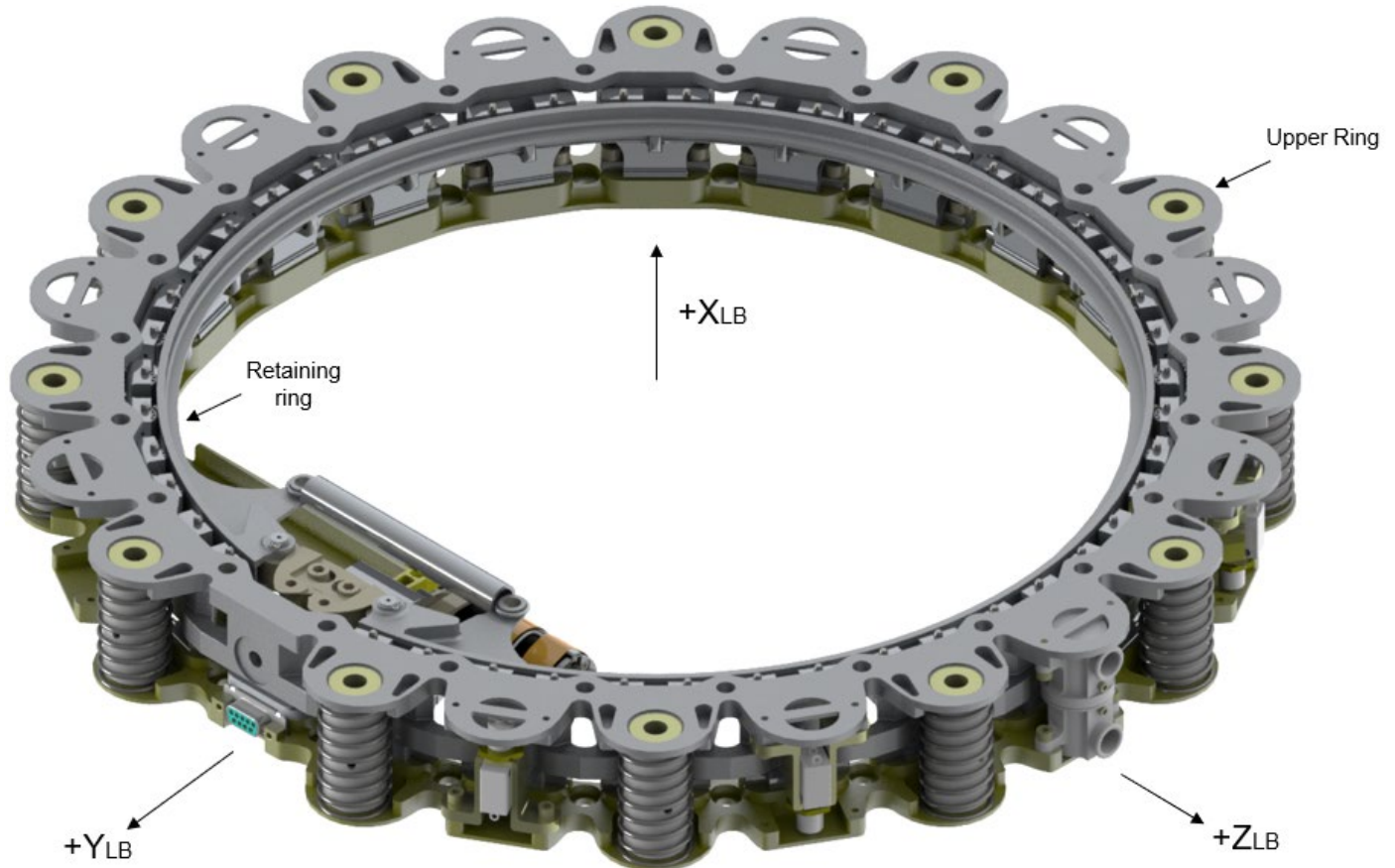


Figure 3-1: Stowed ALB

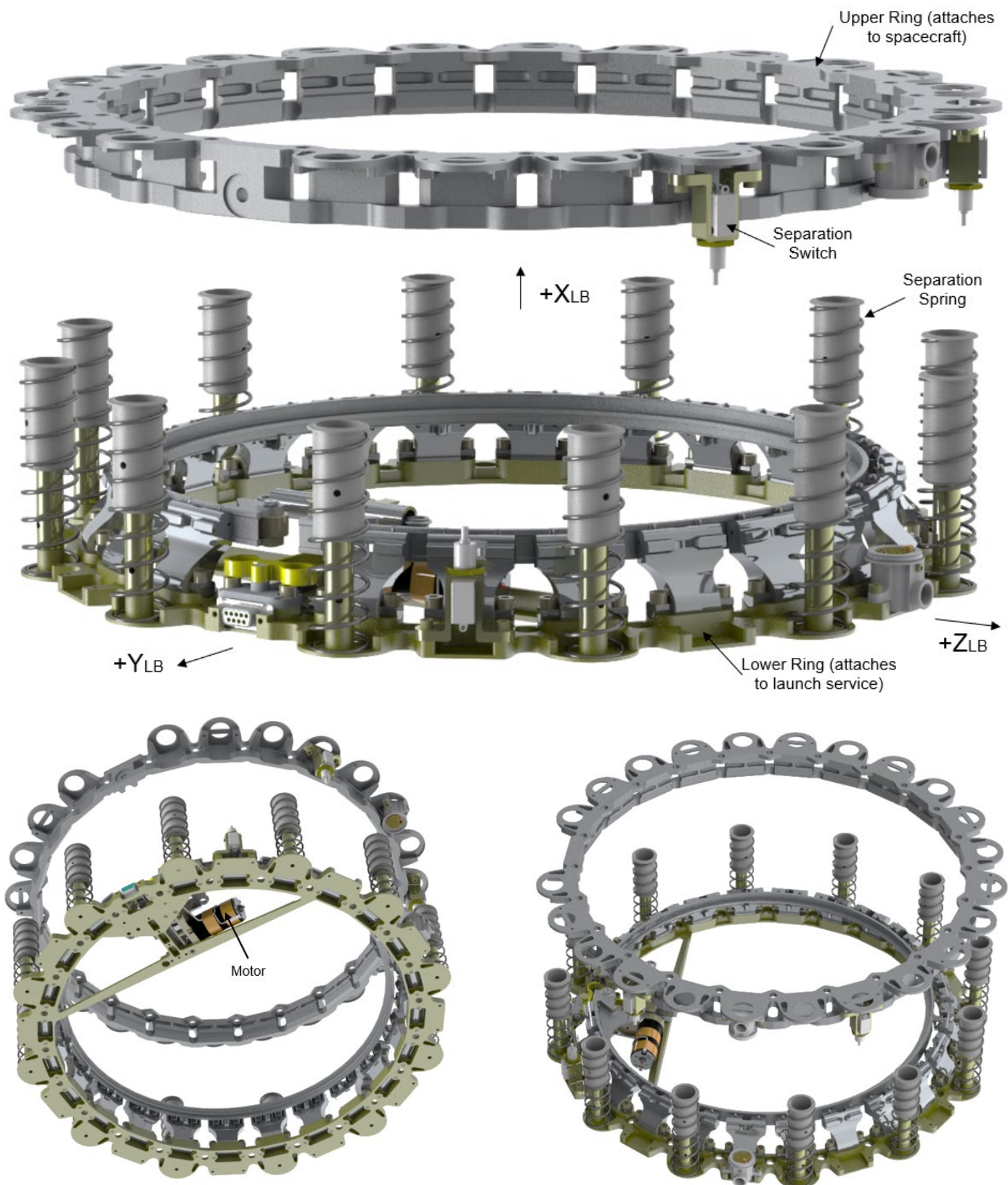
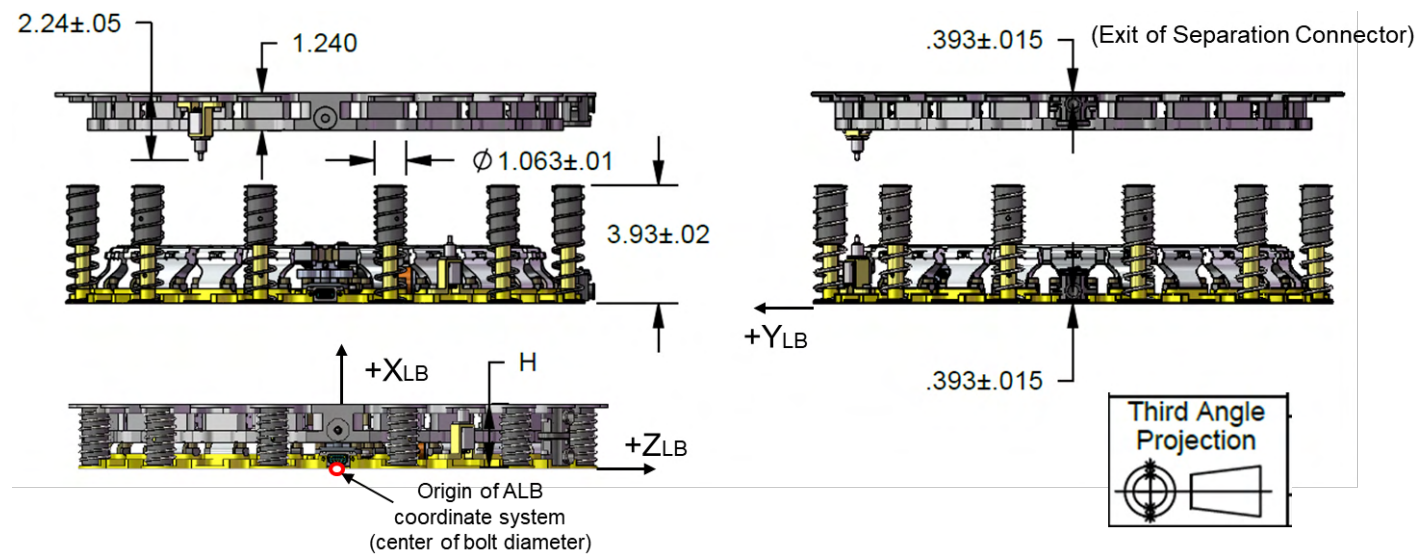


Figure 3-2: Separated ALB

**Figure 3-3: Origin, Deployed and Stowed Dimensions**

3.4 Electrical Interface

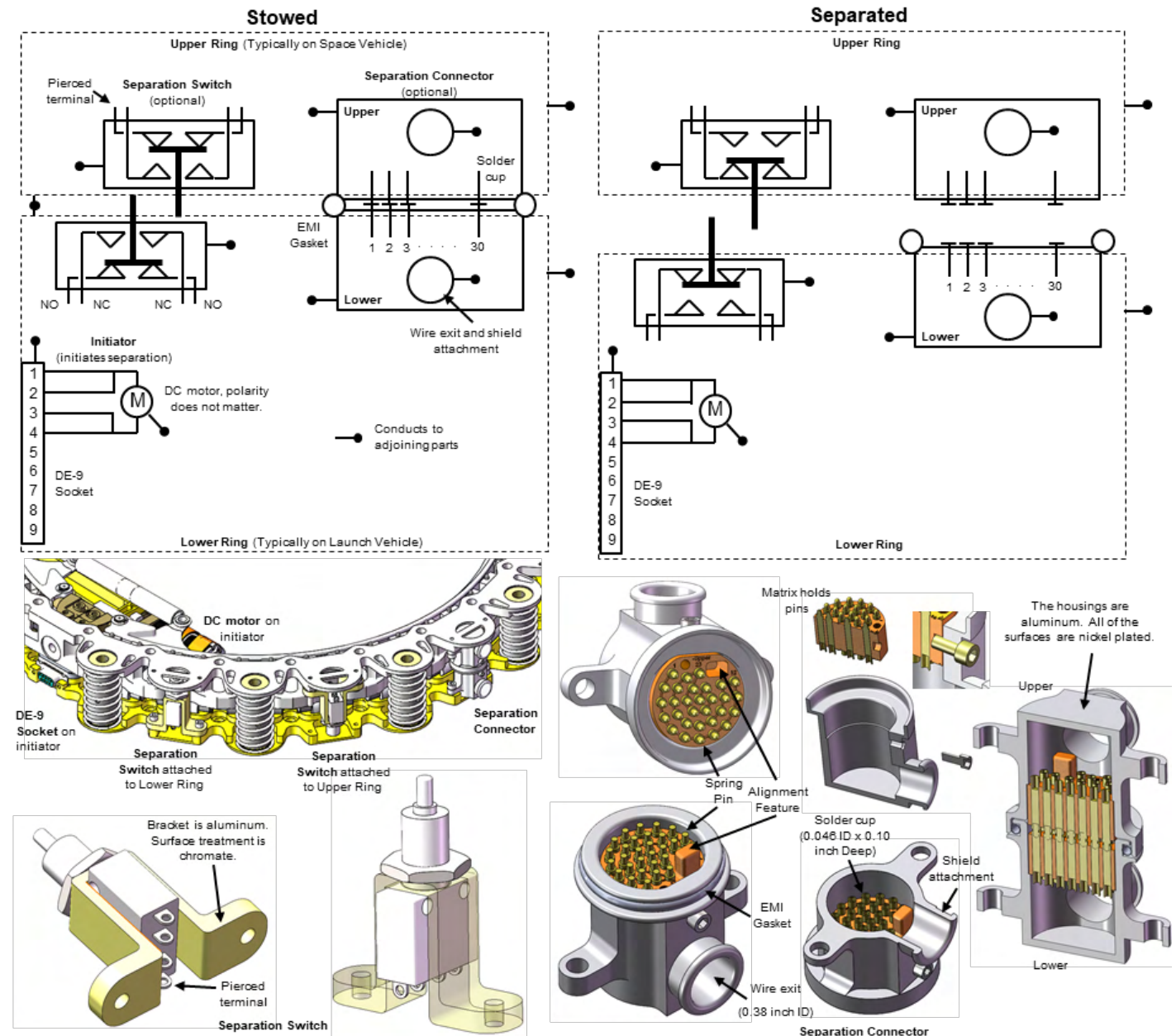


Figure 3-4: Schematic

A simple embodiment is one Separation Switch on the Upper Ring to enable the satellite when it separates. Not using a (second) Separation Switch on the Lower Ring is only advisable if the launch service will have a video record of separation or another non-contact verification of separation. Verification of separation is a critical means to help initiate a mission — managers know the satellite separated from the launch vehicle and is trying to establish communication with controllers. 22 American Wire Gage (AWG) wire is sufficient in most cases to and through the ALB.

3.5 Accessibility and Stay-out zones

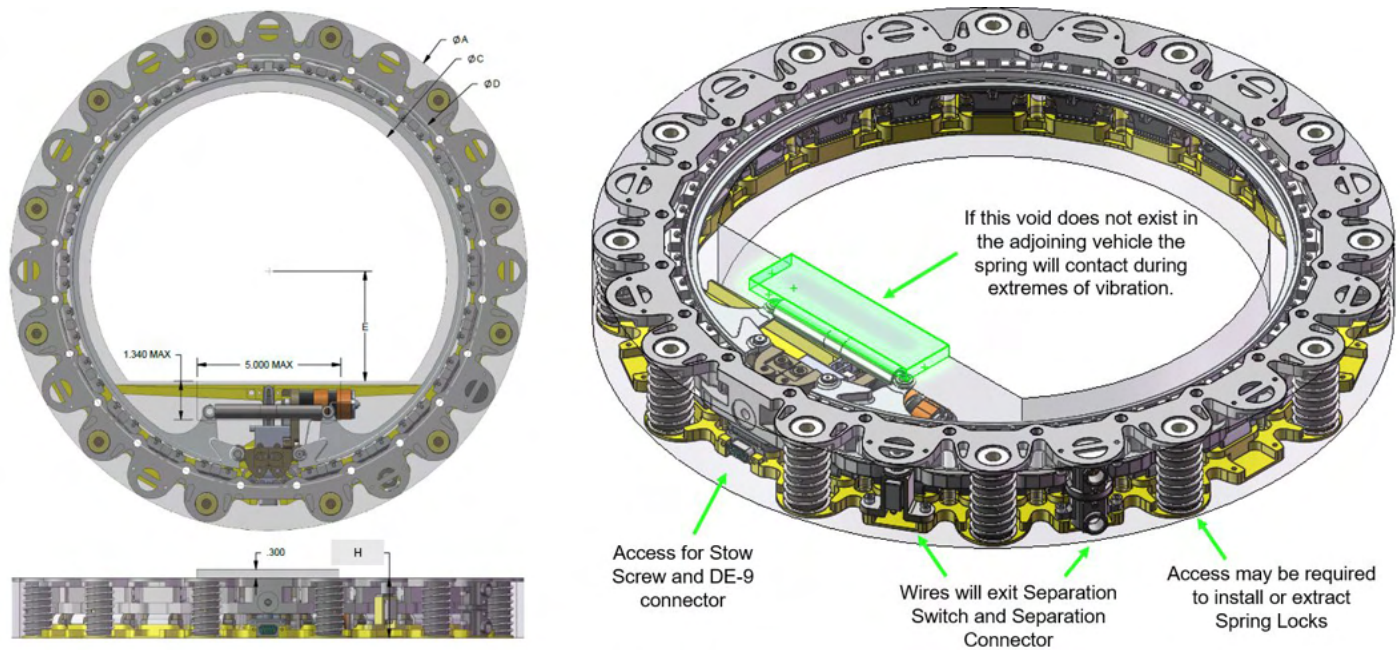


Figure 3-5: Accessibility and Stay-out zones

Access for externally accessed features include the Stow Screw, the DE-9 connector to the initiator, the wire exits from the Separation Switch and the Separation Connector and Spring Locks should be considered when joining the spacecraft to the launch vehicle and shipping container. Solar panels, rocket nozzles and other appendages may block some access in some parts of vehicular operations. See Table 2-1 for stay-out zone dimensions.

3.6 Materials and Surface Treatments

All of the materials are low outgassing as defined by ASTM-E-595: total mass loss (TML) is less than 1.0% and a collected volatile condensable materials (CVCM) is less than 0.1%. About ninety percent of the mass is Aluminum. There is no tungsten, zinc, tin, cadmium, or nylon. All of the materials and surface treatments have flight heritage. The parts (motors, switches, connector pins, DE-9, fasteners) have flight heritage. The surfaces of the ALB are conductive. The ALB is not sensitive to radiation. The ALB does not possess any integrated circuits or semi-conductors. There are no diodes, capacitors or resistors. The ALB has no static-sensitive parts.

All parts in the primary load path are not affected by hydrazine, however the Springs, Separation Connectors, Separation Switches, Motor and Wiring Harness are all not compatible with hydrazine and may be detrimentally damaged through exposure.

Part	Material	Surface treatment
Lower Ring	Aluminum 7000 series	Chemical Film per MIL-DTL-5541, Class 3, Color Gold
Upper Ring, Retaining Ring and Leaf Pin	Aluminum 7000 series	Electroless Nickel per ASTM B733-15, Type IV, 5 to 9% P SC N/A Class 4
Leaf	Aluminum 6000 or 7000 series	Electroless Nickel per ASTM B733-15, Type IV, 5 to 9% P SC N/A Class 4
Fasteners	A-286	Passivation
Lubricant	Braycote 601 EF w/ Molybdenum Disulfide	-
Motor	Copper, Neodymium, CRES	Various
Initiator	A286, 303, Nitronic 60, Titanium (0.02 lb.),	Passivation
Springs	301, 302, 304 or music wire, Delrin (Acetal) and Aluminum	Passivation, Chemical Film per MIL-DTL-5541, Class 3, Color Gold
Separation Connectors	Gold, Vespel, Aluminum 6000 series, CRES, copper	Electroless Nickel per ASTM B733-15, Type IV, 5 to 9% P SC N/A Class 4
Separation Switches and their brackets	Aluminum, epoxy, copper	Chemical Film per MIL-DTL-5541, Class 3, Color Gold (switch bracket)
Wiring Harness and DE-9 connector	Copper, Silver, Gold, ETFE, Kynar, Solder (IPC J-STD-006), DAP, CRES	-

Table 3-2: Materials and Surface Treatments

3.7 Stiffness

Stiffness is a major design driver when determining which ALB size is required for a payload. Payload stack stiffness increases with the cube of the ALB diameter (D^3). For example, a 15-inch diameter ALB is about 6.6 times stiffer than an 8-inch diameter ALB but weighs less than twice as much. Additionally, the first lateral mode frequency of the payload stack increases with the $3/2$ power of ALB diameter ($D^{1.5}$). Often, customers select the smallest allowable ALB with the intent of saving mass. However, this can increase risk of mission failure due to unintended stack dynamics. Prudent customers often use a larger ALB than required to gain stiffness margin. The small increase in ALB mass is more than offset by the need for a less stiff (i.e. massive) space vehicle structure. Stiffness values are shown in Table 2-1. Higher fidelity stiffness estimations of the ALB can be determined via FEM.

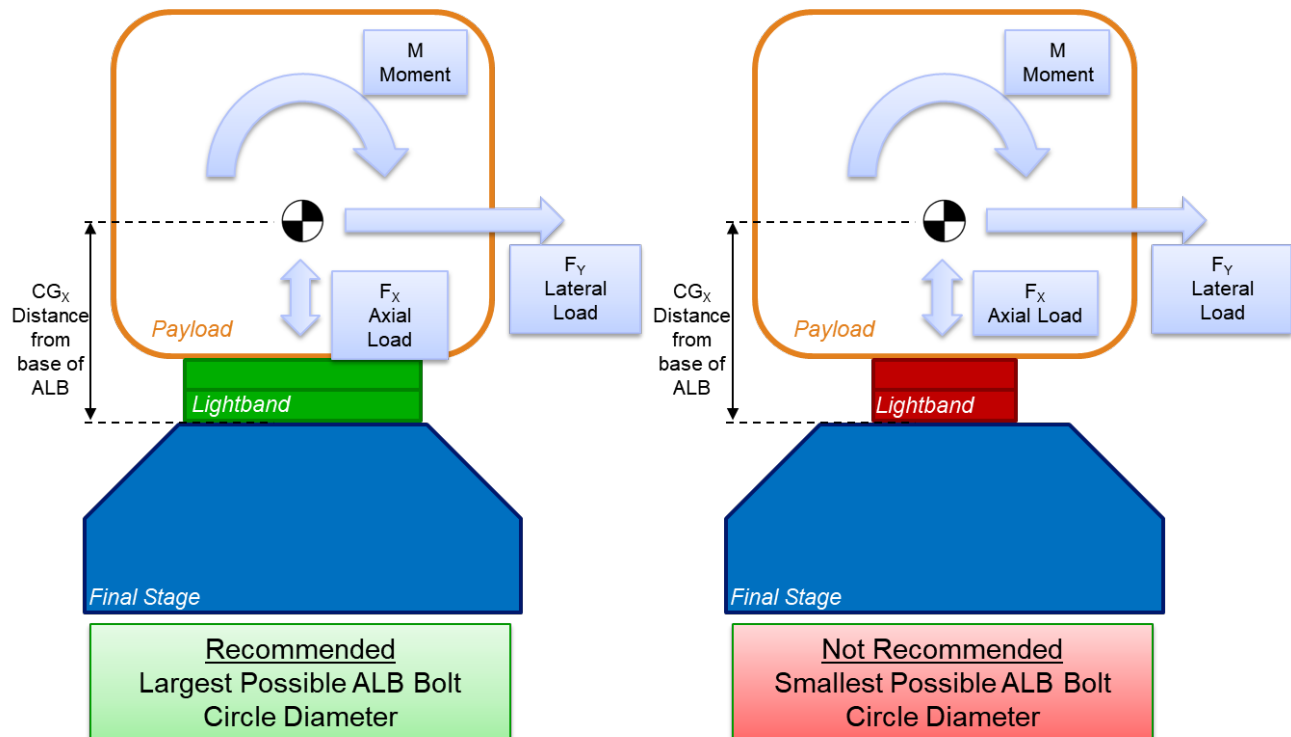


Figure 3-6: Larger diameter ALBs are stiffer and stronger than smaller diameters

3.8 Stiffness of Adjoining Structures

In order to maximize the stiffness of the satellite stack including the ALB, engineers should design robust features in the structures adjoining the ALB. As the analysis in Table 3-3 shows, thick flanges, small moment arms, and chamfers (or large radii) create much stiffer and lighter structures.


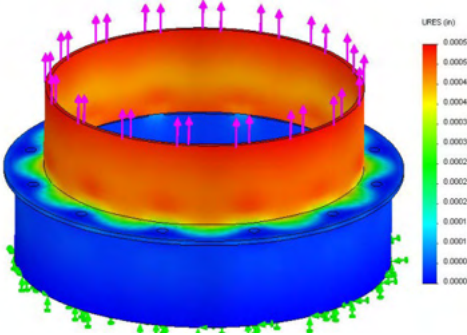

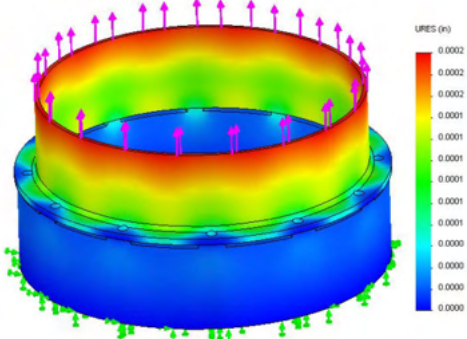
Design	Deflection Plot	Design Notes	Max Deflection Value [in]
		<ul style="list-style-type: none"> •Flanges too thin •Moment arms too large •No chamfer or fillet 	0.0005
		<ul style="list-style-type: none"> •Thicker flanges •Smaller moment arms, but fits fasteners •Chamfer added for stiffness •No significant increase in mass 	0.0002

Table 3-3: Features of adjoining structure¹

The stiffness of flanges is important relative to overall stack stiffness. If the flange stiffness is too low, the first mode lateral frequency of the entire stack can decrease detrimentally. For proper operation of the ALB, the flanges should be stiff enough to guarantee the preload of the ALB will not excessively warp the adjoining structure and vice-versa.

The stiffness increase associated with straight load-paths is illustrated below. A straight load path can double the stiffness and increase lateral frequencies by 40%.

Fasteners must be installed at every location in order to integrate the ALB. Do not skip a bolt as this will substantially decrease strength and stiffness of the ALB.

The thermal extremes of the bolted joint often drive the selection of fasteners. Users anticipating temperatures beyond +10 to +50°C should examine the preload changes associated with coefficient of thermal expansion (CTE) mismatch. In the past, missions on the Space Shuttle have driven bolted joint design to extremes because joints are expected to survive landing loads at very low temperature (-40°C). NASA-STD-5020 document outlines a thorough bolted joint analysis.

Stiffness is affected by bolted joints. A well designed bolted joint leads to greater stiffness and is less susceptible to slipping or gapping.

¹ The lower cylinder represents a Lightband. The upper cylinder with flange represents an adjoining structure. The applied load is 1,000 lb. The materials are aluminum.

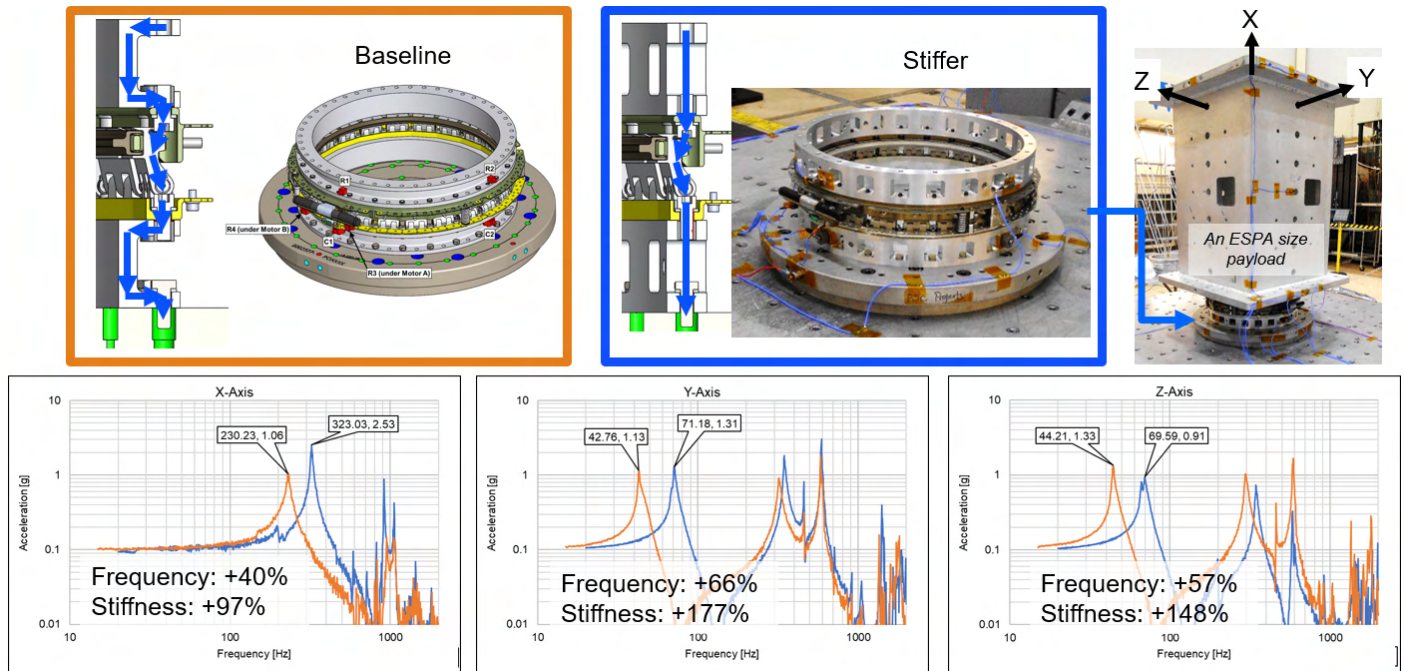


Figure 3-7: Straight load-paths from adjoining structures substantially increase stiffness

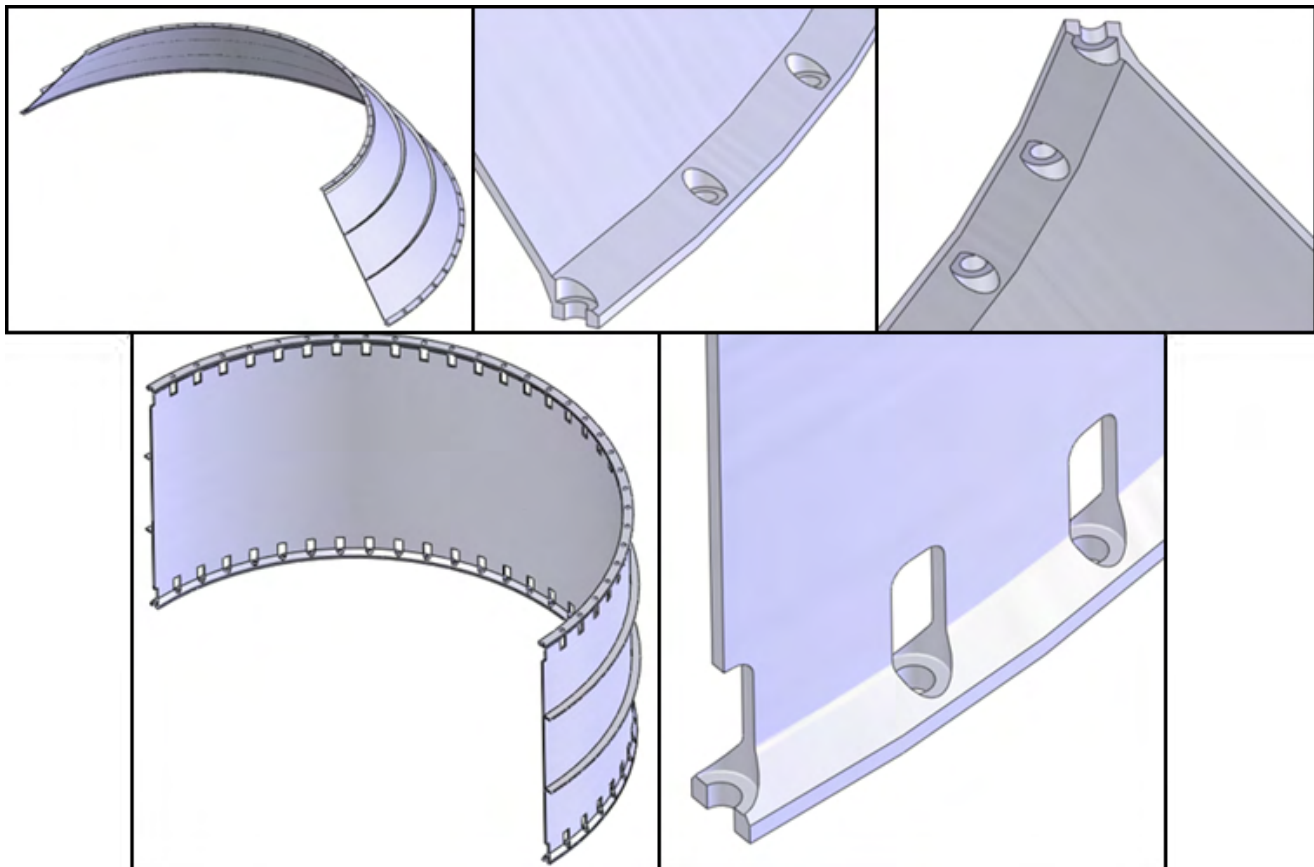


Figure 3-8: Structures with stiffest flange design. Moment arms in the flange are minimal, maximizing stiffness and strength

As noted in Table 2-1, there are two sets of required flatness for adjoining structure values. Though somewhat subjective, if the adjoining structure is relatively stiff, the required flatness will be tighter than if the adjoining structure is relatively flexible. A relatively flexible structure will conform to the flat interface better than a relatively stiff one.

The type of adjoining structure can also have an effect on operation and integration of the ALB. Users should be aware of the effects of their choice of adjoining structure before integration and adequately plan for any likely issues. See following table.




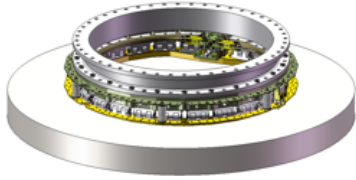
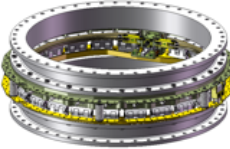
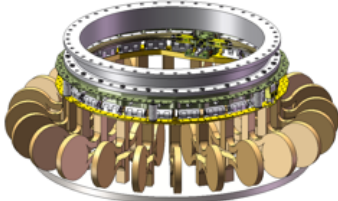
	Lightband Adjoined to...		
	Stiff Weldment, Ring, or Plate	Transition Rings	Isolation System
Typically Characterized As (See Table 2-1)	Stiff	Flexible	Flexible
Most Similar Type of Flight Adjoining Structure	Adapter plate or base plate	Adapter cone or ring	Isolation system
Flatness	Often difficult to manufacture within required flatness tolerances.	Typically meets flatness requirement.	Reduces flatness requirement.
Lightband Flexure	Often too stiff, does not allow Lightband to flex enough during operations.	Allows Lightband to flex nominally and maintains required stiffness during operation.	Provides best chance for successful Lightband integration and operation.
Shimming	Difficult to meet flatness requirements via shimming.	Less difficult to meet flatness requirements via shimming.	Not necessary.
Relative Cost to Manufacture/Procure	Low	Medium	High
Relative Cost to Ensure Manufactured Flatness	High	Medium	N/A
Side View			
Isometric View			

Table 3-4: Comparison of ALB adjoining structures

3.9 Line Load Limits

Line loading in the X_{LB} axis arises from loads in the X_{LB} direction and moments about the Y_{LB} or Z_{LB} axis. Generally, the moments about Y_{LB} and Z_{LB} generate higher line loading than axial loads. In other words, lateral load cases are typically the limiting factor in strength margin.

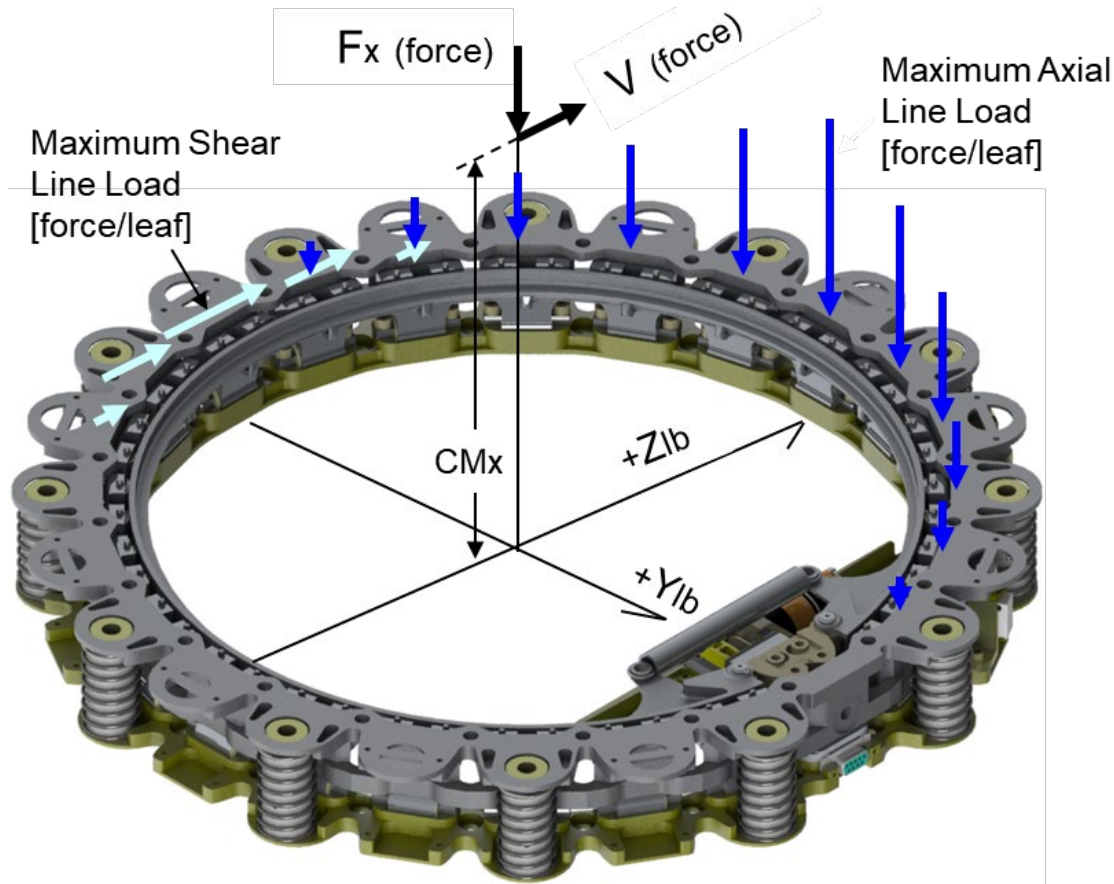


Figure 3-9: Line loading forces

Each Leaf corresponds to thru holes for fastening to the adjoining structures. The thru-holes are sized for 0.25-inch socket head cap (SHC) screws. PSC analysis and tests have shown that the as-designed fastener hole size and spacing is optimum for ALB operation. All testing at PSC is performed with 0.25-inch fasteners because PSC test cells have 0.25-28 UNF accepting threads.

Axial line loading arises from axial (X_{LB}) and lateral (Y_{LB} or Z_{LB}) loading and moments about Y_{LB} or Z_{LB} , whereas shear line loading arises from lateral (Y_{LB} or Z_{LB}) loading and moments about X_{LB} . In flight, lateral loads tend to make the greatest contribution to line loading. Maximum lateral load and axial load do not occur at the same location on the ALB and standard PSC strength testing reflects this fact.

Note: PSC documentation sometimes expresses line loading in terms of force/Leaf instead of force/bolt. ALB's have 1 less Leaf than bolt, but the difference in line load value from this computation method is accounted for in PSC qualification testing. Thus, the terms force/Leaf and force/bolt are interchangeable.

Magnitude of maximum axial line load is given by Equation (1). Direction of maximum axial line load is the same as F_x .

$$P_{eq} = \frac{|F_x|}{n} + \frac{4|VX|}{nD} \quad (1)$$

Where:

P_{eq} is maximum axial line loading [force per bolt]

F_x is axial force [force]

n is the number of fasteners in the bolt circle [-] (n is one more than the number of Leaves)

V is lateral force [force]

X is the distance from the ALB origin to the load application point in the x direction (typically the center of mass in X direction) [length]

D is the bolt circle diameter [length]

Magnitude of maximum shear line loading is given by Equation (2):

$$Q = \frac{2}{n} \left(V + \frac{|M_x|}{D} \right) \quad (2)$$

Where:

Q is the maximum shear line load [force per bolt]

V is the lateral force [force]

n is the number of fasteners in the bolt circle [-] (n is one more than the number of Leaves)

D is the bolt circle diameter [length]

M_x is the maximum applied torsional moment about the X_{LB} axis (typically negligible in-flight loading) [force x length]

The line load operating limits of P_{eq} and Q in Table 2-1 were established by applying loads (F_x and V) to an ALB in qualification strength tests. The computed line loading was reduced to establish the operating limits shown in Table 2-1. In the strength tests, the distribution of load is discontinuous because the Stow Screw occupies the space of one Leaf. Therefore, the Leaves adjacent to the Stow Screw will carry a higher percentage of load. Thus, in test, the actual line loading was higher. This peaking is naturally accounted for with equations 1 and 2.

Typically, customers launch spacecraft with a maximum line loading that is half of the operating limit because they are typically attempting to maximize stiffness (which tends to produce lower line loading).

The operating limits do not however account for peaking due to stiffness variation of adjoining structures (e.g. base plate stiffening ribs, access cutouts, walls, etc.). Customers may incorporate the ALB finite element model in their flight stack and determine the actual load distribution around the ALB. This will expose peaking due to adjoining structures and inform any derating. Naturally customers should avoid structural discontinuities to retain high line load margin.

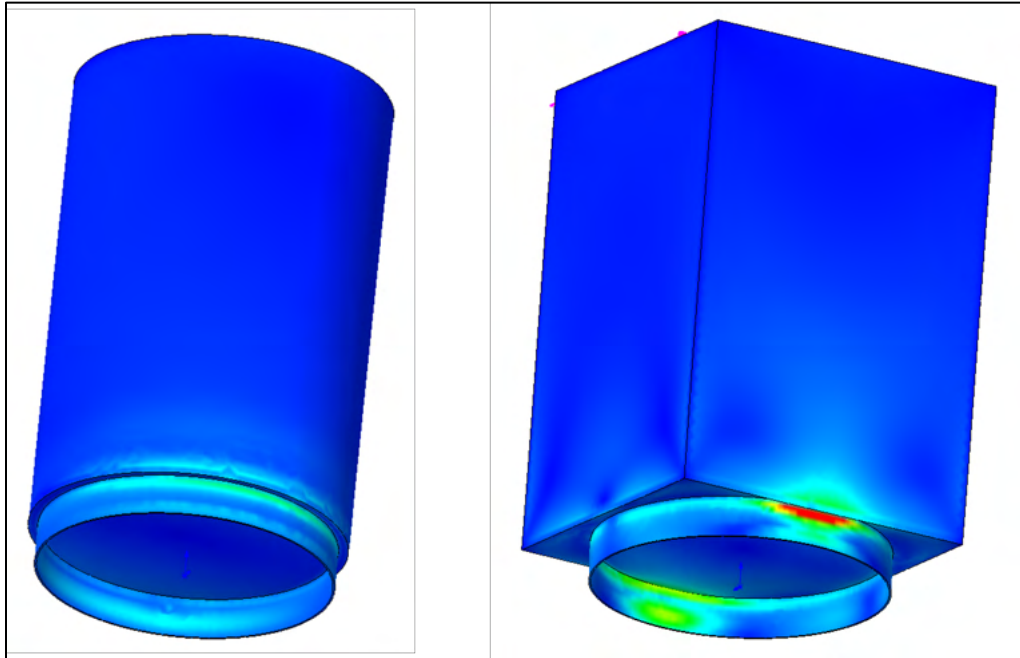


Figure 3-10: A round separation system and a square satellite can create high line loading

3.10 Flatness and Parallelism

Prior to joining, the surfaces adjoining the ALB should be flat to the specification defined in Table 2-1.



Figure 3-11: An MLB attached to a launch vehicle cone and CAD model showing resulting stress peaking that occurs when adjoining two warped surfaces

When the adjoining vehicles are extremely warped or surfaces are not parallel, an attempt to join the ALB to both adjoining structures may break or damage the ALB. Joining an ALB to only one adjoining structure will generally not increase stress because separation systems are designed to be more flexible than adjoining structures.

It may be tempting to design flexible features to attenuate stress exhibited in the warped structures that are joined. However, this can lead to an unacceptably low stiffness and first mode frequency of the entire system. To achieve both a low stress and high stiffness system, flatness of the adjoining structures must be controlled.

Isolation systems like Moog CSA Engineering's SoftRide intentionally add flexibility to joints to attenuate response. Furthermore, isolation systems offer an additional benefit in the substantial relaxation of adjoining structure flatness requirements.

Finite element models (FEMs) nominally assume perfect flatness of adjoining structures. Therefore, FEMs can obscure this potentially significant reduction in structural margin.

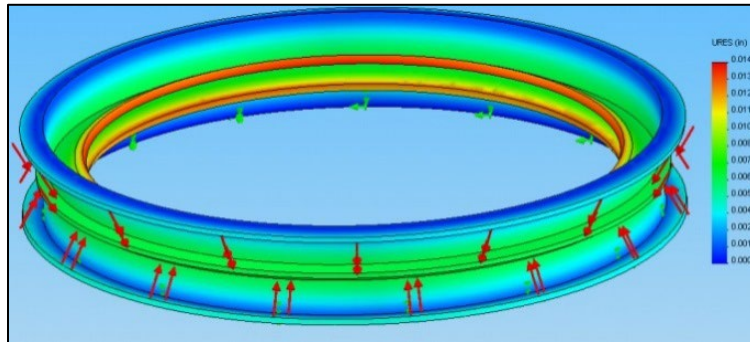


Figure 3-12: FEM simulates a clamp band separation system via radially inward preload from band tension. Warping can result

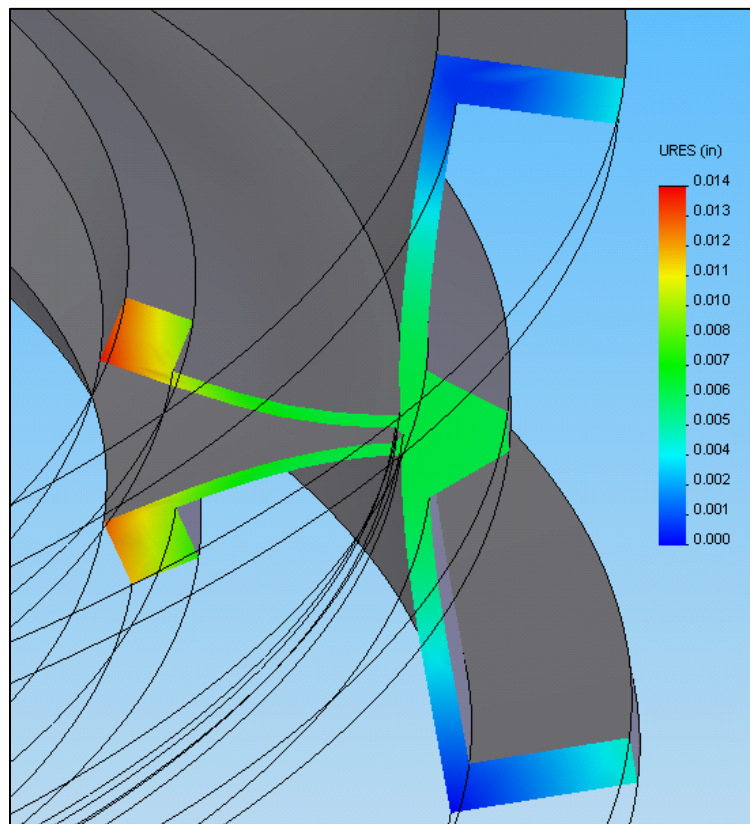


Figure 3-13: A deflection of 0.004 inches at the interface to adjoining structures is created by preload

ALBs and clamp bands embody the challenging 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 changes in internal strain as structures are joined to the ALB. A 20% change in preload as the separation system is fastened to an adjoining structure has been observed.

Easily fabricated structures adjoining separation systems may be expensive to make flat. Alternatively, structures that may be expensive to fabricate can be easy to make flat. For example, a thrust cone that interfaces the final stage engine to the launch vehicle can be easily made by riveting machined rings to conical sheets. The riveting process can stress the thrust cone. This may manifest itself as warping (a lack of flatness) when the riveted structure is removed from its much more rigid tooling. To attain flatness requirements, the riveted structure must be machined or shimmed at additional cost. As a more expensive option, the thrust cone could be directly machined from a conical forging ensuring flatness requirements are met.

Engineers should consider the fact that all manufacturing and joining processes (riveting for assembly, fastening to adjoining structures, curing of composites) increase strain energy and thus will warp structures.

3.11 SoftRide and ALB

The SoftRide Isolation System is a spacecraft vibration and shock isolation system designed to reduce launch vehicle-induced loading on the spacecraft. SoftRide is a patented product of Moog CSA Engineering (www.csaengineering.com). It has been flown successfully many times.


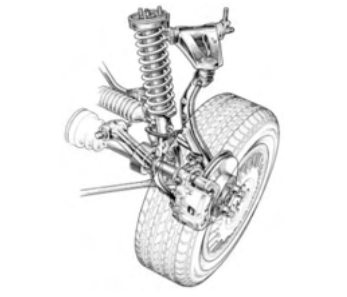

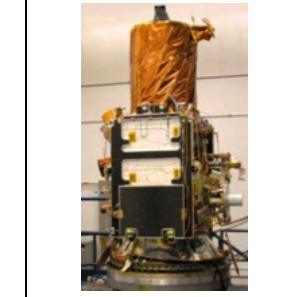
Bicycle	Car	Aircraft	Spacecraft
			

Table 3-5: Valuable payloads are isolated from detrimental external loading using spring-damper (isolation) systems

SoftRide Systems have several benefits when used in conjunction with the ALB:

1. Substantially reduce flight loads into the payload such as engine transients, random vibration, and shock.
2. Substantially reduce risk by isolating the payload from unanticipated launch load events.
3. Substantially increase damping. SoftRide damping ratio range is 3% to 25% depending on the needs of the mission.
4. Reduce stiffness requirements of the space vehicle because there is less value to a very stiff bus if it is sitting on a very flexible isolation system.
5. Reduce flatness requirements of adjoining vehicles because the isolation system is flexible.
6. Ease integration of the ALB by eliminating the need to stow the ALB to join the satellite to the launch vehicle. With the isolation system attached to the already stowed ALB, integration can occur by simply fastening the launch vehicle to the isolation system.



Figure 3-14: Moog CSA's SoftRide OmniFlex which isolates the satellite from the launch vehicle loads

Isolation systems add mass that is usually small compared to the spacecraft mass. In fact, the mass added by SoftRide is often nullified because the ALB has a lower mass than other separation systems. Isolation systems require a displacement stroke to attenuate dynamic loads.

3.12 Lifecycle

The ALB can be cycled (one cycle includes one stow and one separation) 200 times before inspection by PSC is required. This includes separation tests that PSC completes prior to shipping to the customer. Thus, the customer may typically separate the ALB about 190 times.

3.13 Rotation Rates

Rotation rates are induced by the distance between the payload's center of mass (CM) and the center of the ALB's spring force. Rotation rates may be about any axis of a space vehicle as a result of the separation event.

Rotation rates can be estimated via Equation (3). There are many variables that contribute to this rate and several simplifying assumptions have been made to compensate. Equation (3) assumes the adjoining 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. Only Separation Reliability testing can produce verifiable values for rotation rates.

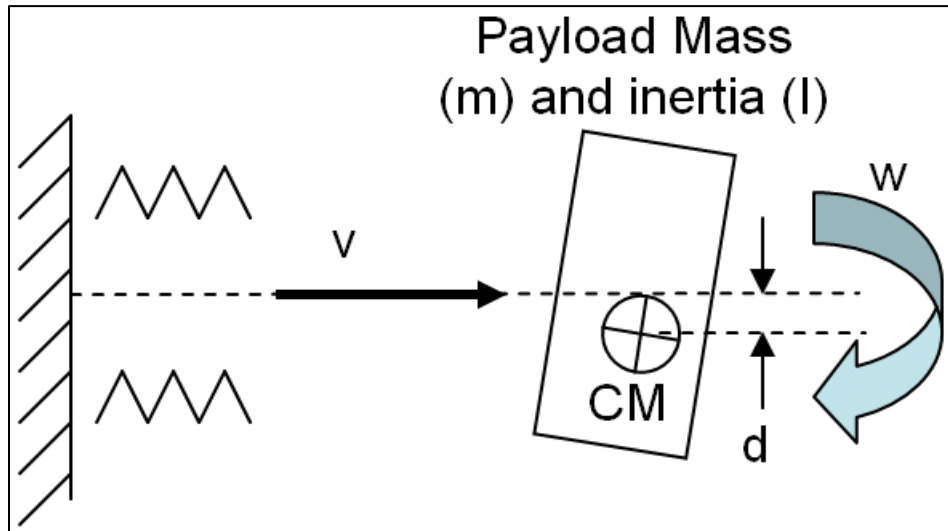


Figure 3-15: CM offset and rotation rate

$$w = \frac{mvd}{I} \quad (3)$$

Where:

w is the payload rotation rate [rad/s]

m is the mass of the payload [mass]

v is the relative velocity [length/s]

d is the distance between the CM and the resultant location of the Separation Springs [length]

I is the mass moment of inertia about the center of mass of the separating vehicle [mass·length²]

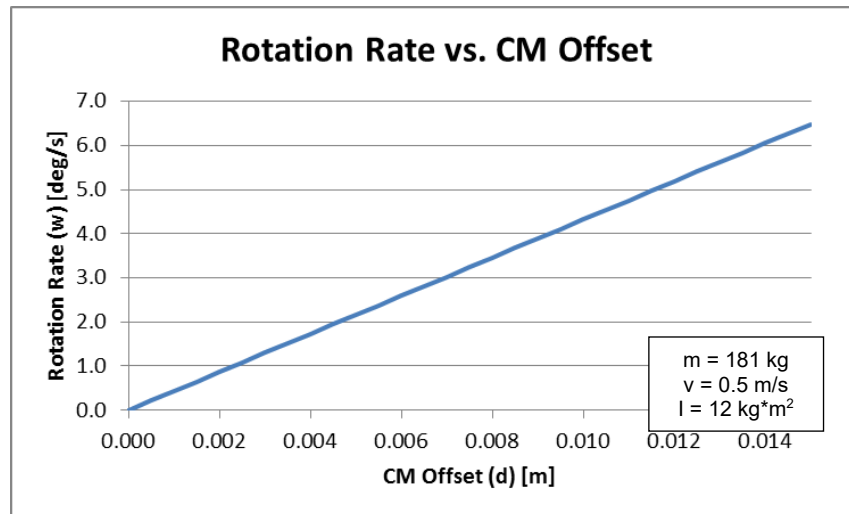


Figure 3-16: An illustration of Equation 4

The Separation Spring configuration may be adjusted on the ALB so the Springs, as a sum, act through the CM. Table 2-1 provides all the information to complete dynamic analysis of the separation event. Though typically trivial, even the effect of the spring in the Separation Switches and Separation Connectors may be incorporated into dynamic models.

Modern CAD models of spacecraft inform designers of the CM location allowing them to control it to within thousandths of an inch prior to manufacture. Testing has confidently shown that when $d = 0.0 \pm 0.01$ in the expected tip-off will be within 2 degrees per second.

Rotation rates can be beneficial. It tends to average out the temperatures on the spacecraft, and if a camera attached to the launch service is looking at the spacecraft while it is rotating after separation, mission managers can verify configuration in spaceflight. For example, are the stowed solar arrays intact?

3.14 Separation Velocity and Separation Springs

Equation (4) is used to calculate the required total separating energy, **E**, given a desired velocity between the payload and final stage.

$$E = \frac{(mM)v^2}{2(m + M)} \quad (4)$$

Equation (5) is used to calculate the estimated number of Separation Springs, **S**, required given a desired velocity between the payload and the final stage.

$$S = \frac{mM}{m + M} \times \frac{v^2}{2e} \quad (5)$$

Equation (6) is used to calculate relative velocity, **v**, between payload and final stage given a known total stored energy.

$$v = \sqrt{\left(\frac{2E(m + M)}{mM}\right)} \quad (6)$$

Where:

m is the payload mass [kg] (includes mass of ALB Upper Ring)

M is the final stage mass [kg] (includes mass of ALB Lower Ring, excludes payload mass)

v is the relative velocity between **m** and **M** [m/s] (ΔV or separating velocity)

S is the number of Separation Springs [-] (even qty. preferred)

e = 2.45 J is the stored potential energy of a single Separation Spring that is converted to kinetic energy manifested as **v**. It includes efficiency losses.

E = S • e is the total ALB separating energy manifested as **v** [J] (The stored potential energy of all Separation Springs that is converted to kinetic energy. It includes efficiency losses. See Table 2-1 for typical ranges for each ALB size.)

Example 1: velocity is known, total separating energy is desired

Payload mass, **m** = 200 kg

Final stage mass, **M** = 3000 kg

Desired relative velocity, **v** = 0.356 m/s

$$\text{Total Separating Energy, } E = \frac{(200 \text{ kg} \times 3000 \text{ kg}) \times (0.356 \frac{\text{m}}{\text{s}})^2}{2 \times (200 \text{ kg} + 3000 \text{ kg})} = 11.9 \text{ J}$$

Example 2: total separating energy is known, required number of Separation Springs is desired

Total separating energy, **E** = 11.9 J

$$\text{Number of Separation Springs, } S = \frac{11.9 \text{ J}}{2.45 \frac{\text{J}}{\text{Spring}}} = 4.86 \text{ Springs}$$

Example 3: Total separating energy is known, relative velocity is desired

Payload mass, **m** = 200 kg

Final stage mass, **M** = 3000 kg

Total separating energy, **E** = 12.25 J

$$\text{Relative velocity, } v = \sqrt{\left(2 \times 12.25 \text{ J} \times \frac{200 \text{ kg} + 3000 \text{ kg}}{200 \text{ kg} \times 3000 \text{ kg}}\right)} = 0.361 \frac{\text{m}}{\text{s}}$$

Observe that the quantity and mass of Separation Springs increases with the square of **v**. A small increase in velocity requires a significant increase in Springs. The allowable quantity of Separation Springs varies by ALB diameter.

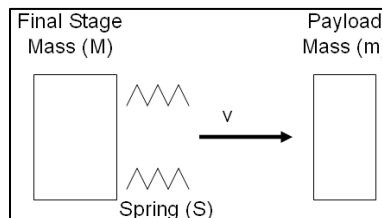


Figure 3-17: The relative velocity (v**) is created by the Separation Springs (**S**)**

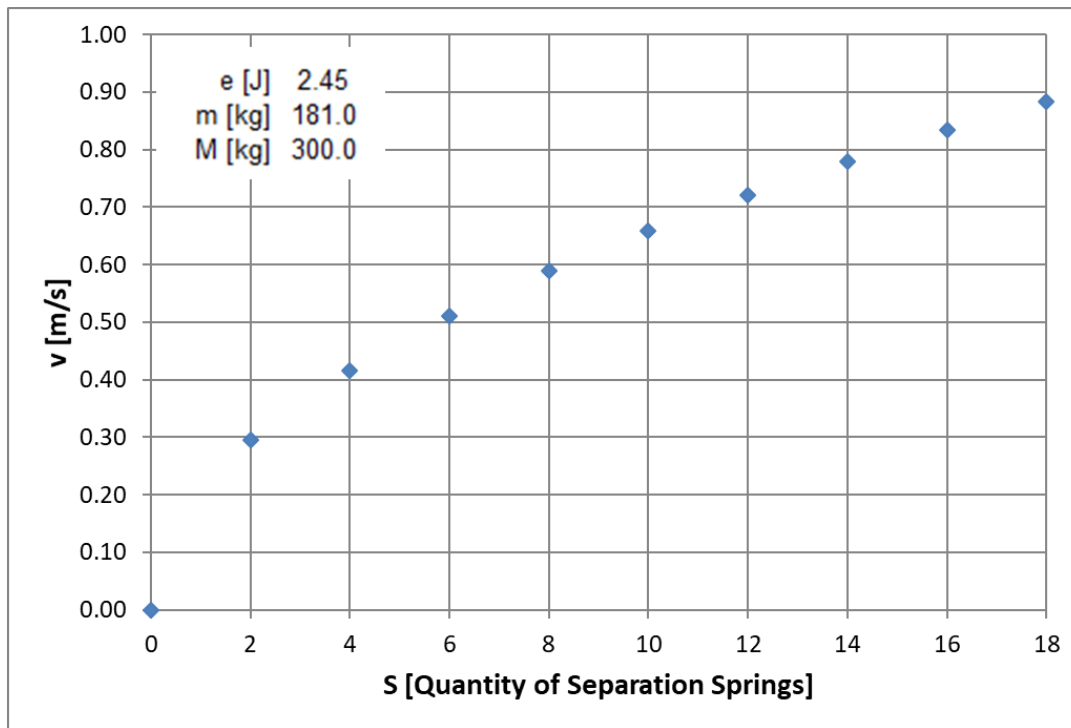


Figure 3-18: Spring quantity required increases with the square of velocity (springs are lousy rocket engines)

The location of Separation Springs, Separation Connectors, and Separation Switches need not be symmetric to minimize rotation rates. Sometimes PSC engineers will modify the location (configuration) of Separation Springs to null out rotation rate torques during Separation Reliability tests (this is a custom test).

When several payloads are on the same launch vehicle, engineers can minimize the possibility of re-contact by varying the separation velocity and direction. Angling the payloads so they push through the center of mass reduces rotation rate torques and the possibility of re-contact.

The ALB will work without any Separation Springs—it just won't have any velocity. However, if Separation Connectors or Separation Switches are installed, the ALB will separate with a very small separating velocity due to the small force of the spring plungers.

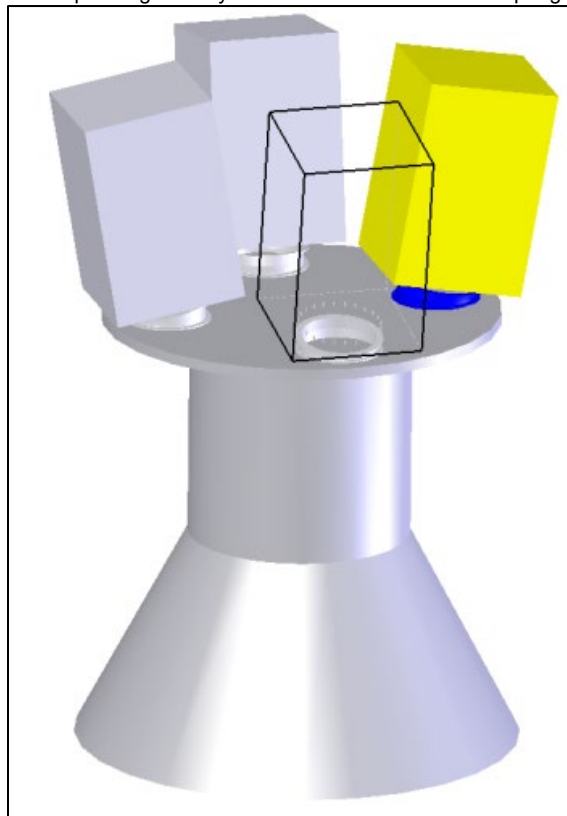


Figure 3-19: Spacecraft oriented so they reduce the moment arms between center of force and center of mass

4. Operation and Integration

4.1 Verification of Operation

Operate the ALB before or after shipping, when taken from storage, following a critical test, or when verifying launch vehicle compatibility. This will test-verify stowing, initiation, and separation operations are within the specifications of this document.

4.2 Initiation and Separating Procedure

Prior to operating the ALB, verify the launch vehicle (or a simulator of it) can meet electrical specification. Specifically, verify the supplied voltage (V), current (between I_p and I_{min}) and duration (T_p) at the DE-9 connector are within range shown in Table 2-1.

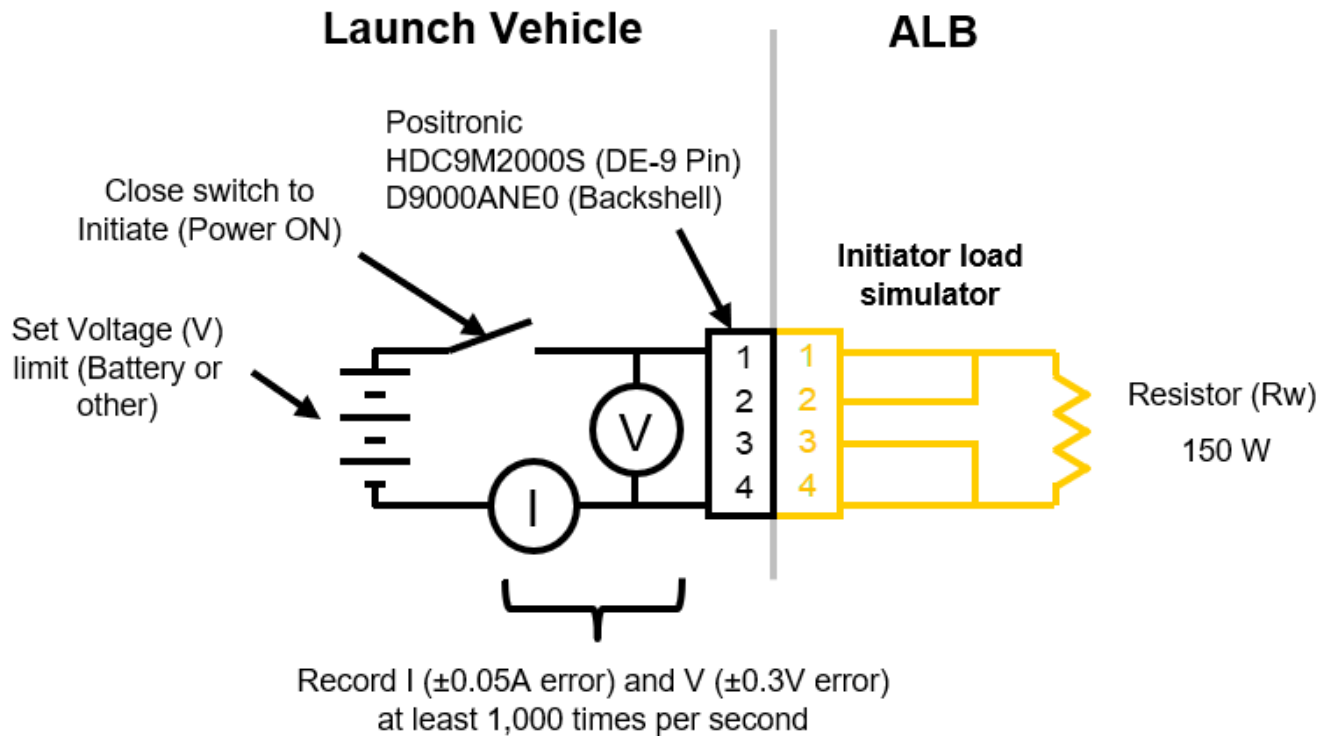


Figure 4-1: Prior to initiating an ALB, verify launch vehicle meets specification on V, I and T_p

Examine the mating (DE-9 Pin) connectors to verify cleanliness. Sources of FOD may include solder flux and potting material. At maximum T_p the resistor (R_w) may be too hot to touch. The recorded current should be equal to V / R_w . R_w may be modified to account for other sources of resistance such as the cable length and the contact resistance at another electrical junction.

After verifying the launch vehicle (or a simulator) is operating within specification, attach the DE-9 pin connector from launch vehicle (LV) to the DE-9 socket on the ALB. Torque both of the screws per Figure 4-11.

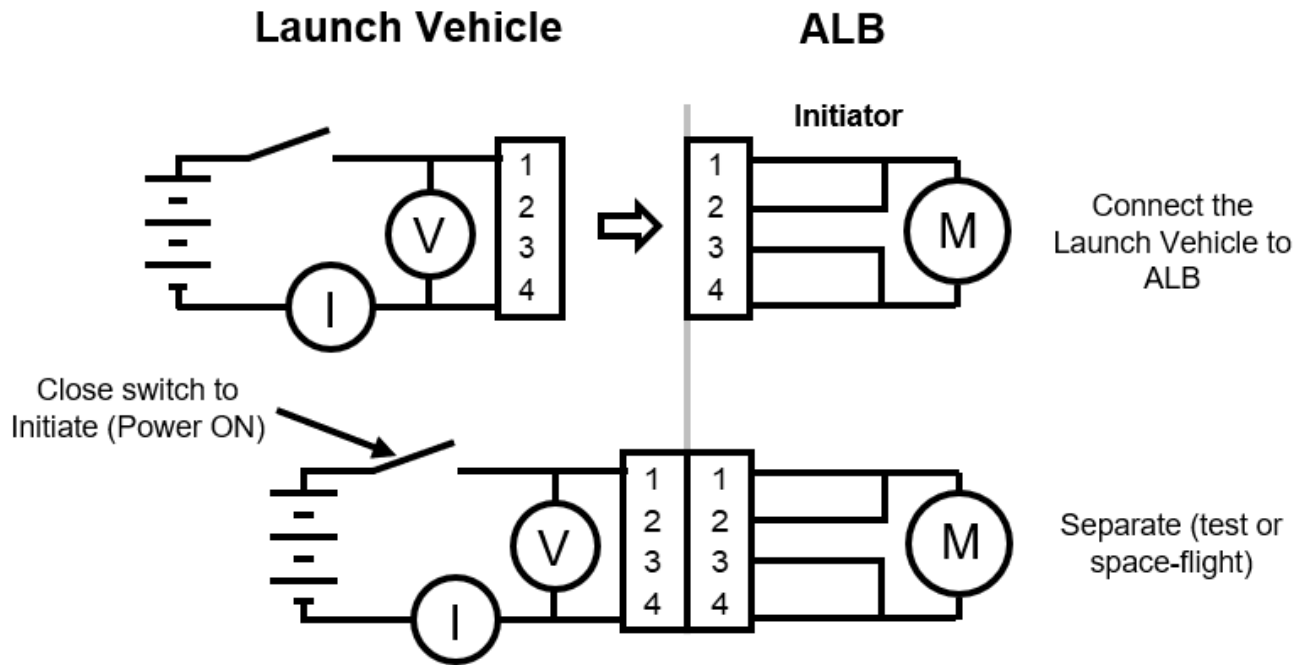


Figure 4-2: Schematic to Initiate ALB separation

If this is a ground test, ensure the separating half is properly restrained. If the Spring Locks are installed at every Separation Spring, there will be minimal energy to separate the Rings (just the force from any accessories). If the Spring Locks are not installed the Rings will push apart. Collisions can damage the ALB. To initiate separation, close switch to Power ON for duration T_p . The Upper Ring will separate from the Lower Ring. After Initiation, the space vehicle will be separated; free of the launch vehicle (or free of Lower Ring supporting structure). The motor can be heard rotating at about 60 cycles a second after T_i .

Note: This continued motor/cam rotation is not detrimental and may be mistaken for 60 Hz 'AC noise' in data acquisition.

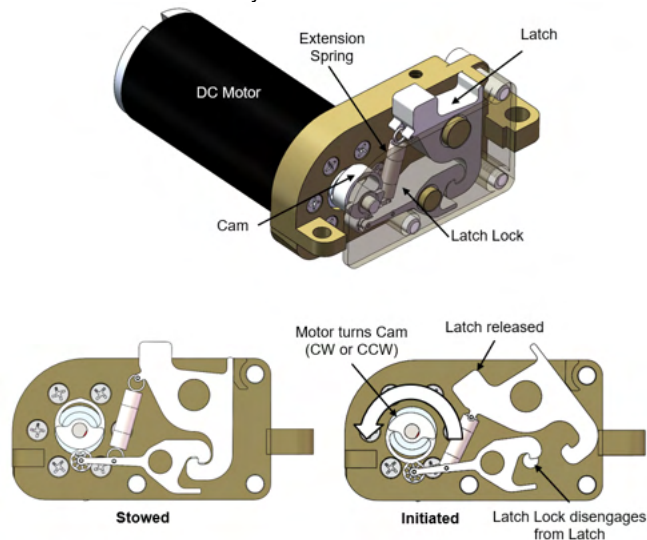


Figure 4-3: The powered motor causes initiation

Sampling the current (I) and voltage (V) produces valuable verification and diagnostic information. Torque margin is directly indicated, which aids reliability estimates and informs engineers of any performance exceedance or trend towards an exceedance. The slope of the voltage decay indicates friction torques within the Initiator. Measuring during the flight use and before and after critical operations aids verification. Launch service providers shall always measure, record, and report V and I to PSC.

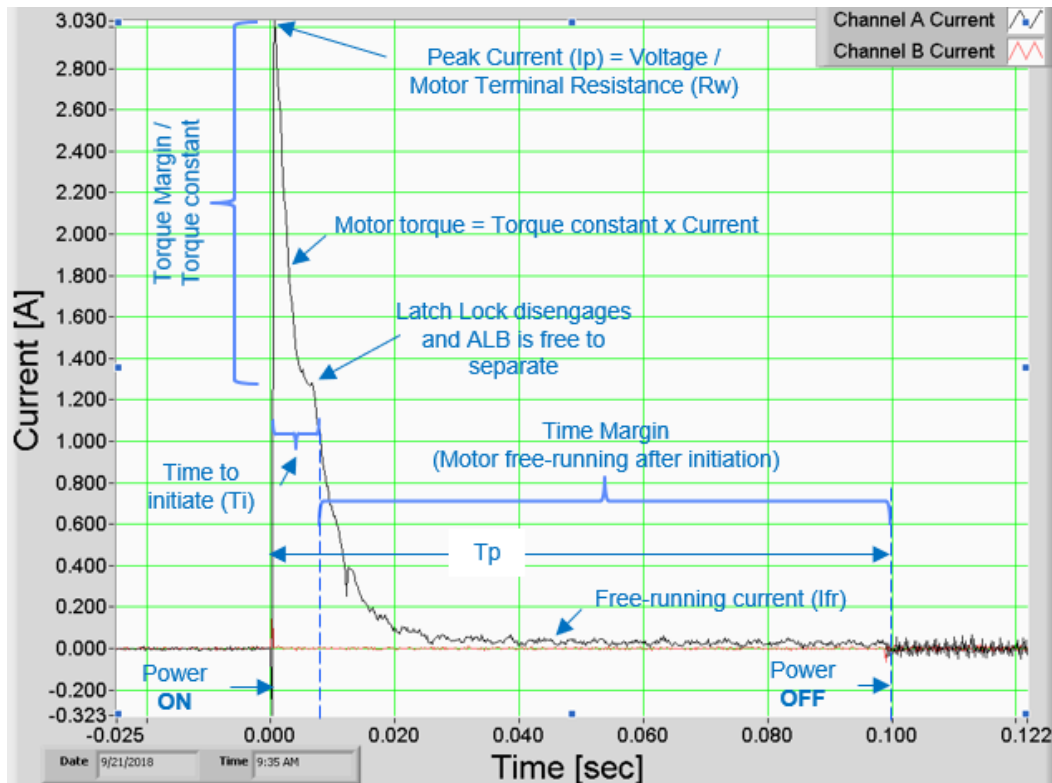


Figure 4-4: Initiator current example (values may vary)

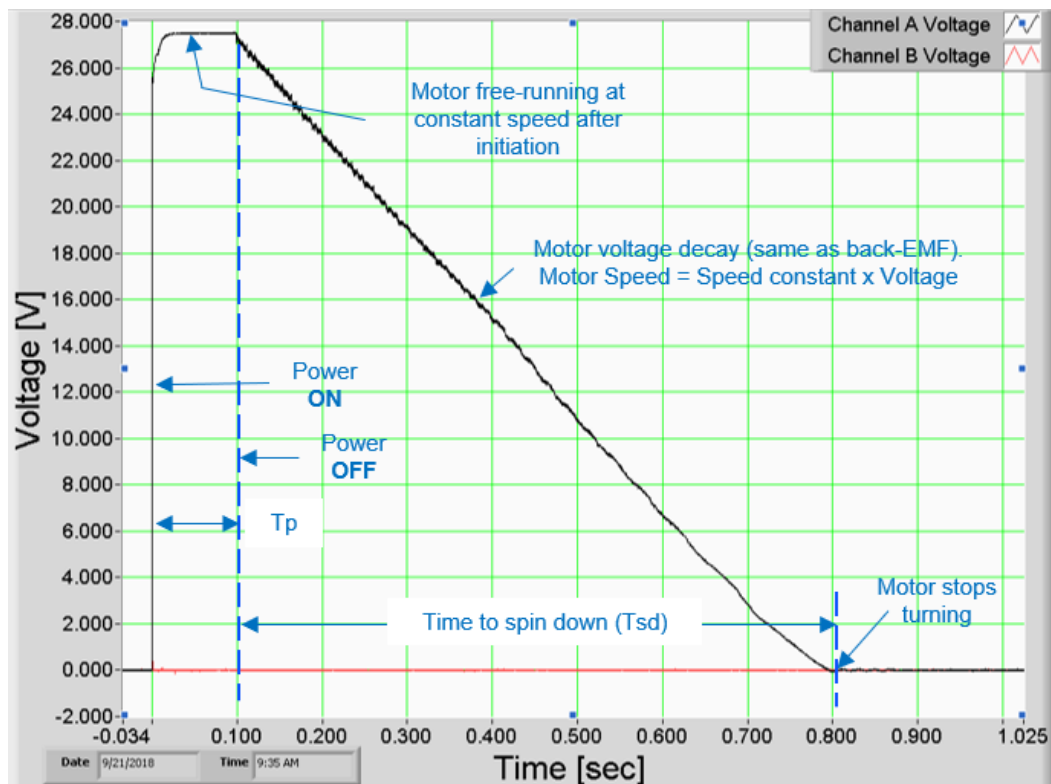


Figure 4-5: Initiator voltage example (values may vary)

Monitoring initiation can be done with the following circuit, schematically identical to Figure 4-1 and Figure 4-2. The switch is depressed for a duration greater than T_p minimum. Some user practice may be required to ensure proper switch activation (this can be done with the test circuit). In some switch designs switch bouncing is prevalent; this looks like noise in the telemetry and should be avoided. If desired, a timer relay may be used instead of the switch.

Channel A on the O-Scope measures V. Channel B measures current by measuring voltage across a 1-ohm resistor. Caution: A common ground among the power supply and oscilloscope may degrade measurements or damage data acquisition equipment.

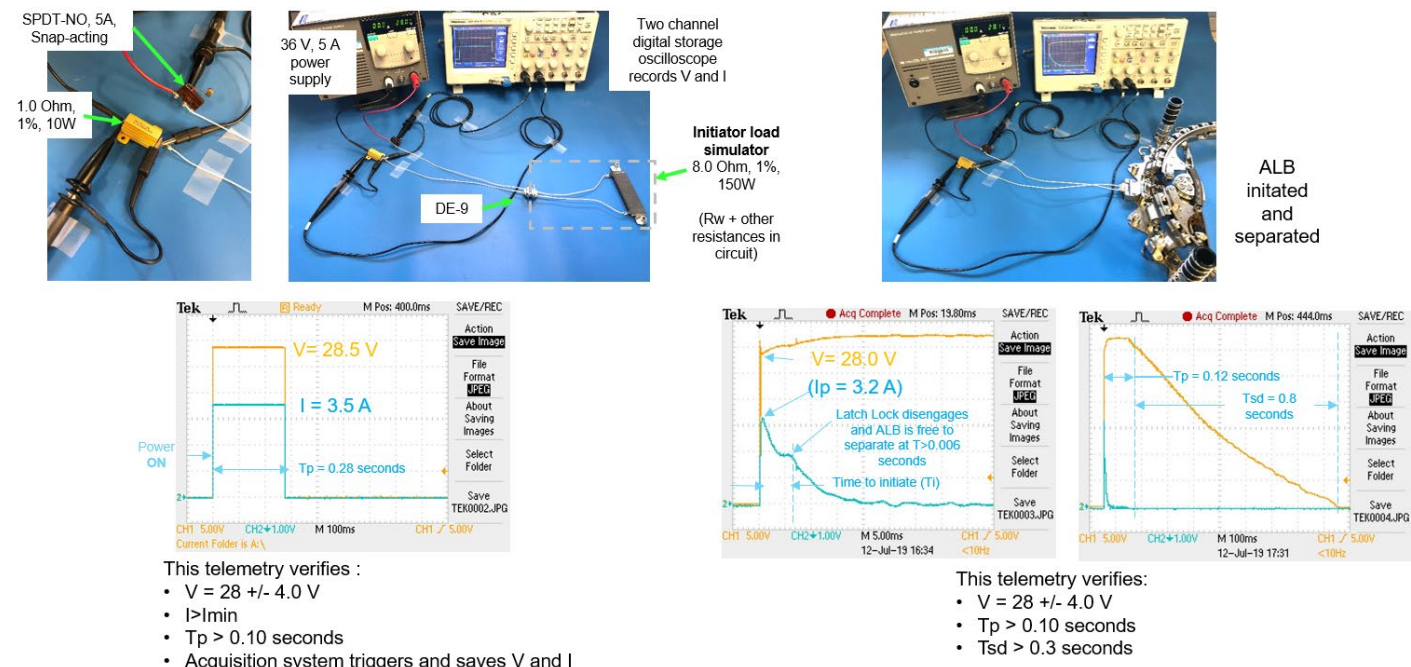


Figure 4-6: Benchtop configuration to initiate ALB

A simple means to initiate an ALB separation is completed with three in-series 9.6 V batteries (28.8 V) and a two-wire cable. If the batteries are drained (an open circuit voltage $< 27.0 \text{ V}$) the initiator can stall (and not initiate). Such batteries typically have too high an internal resistance to source the required minimum current, I_{\min} . A flight battery or power supply must have $> I_{\min}$. The 9.6 V batteries will typically provide a below specification current which may be acceptable in benchtop test but *is not* acceptable in space-flight or other critical tests. So, while simple and convenient, this scheme prevents users from measuring important parameters.

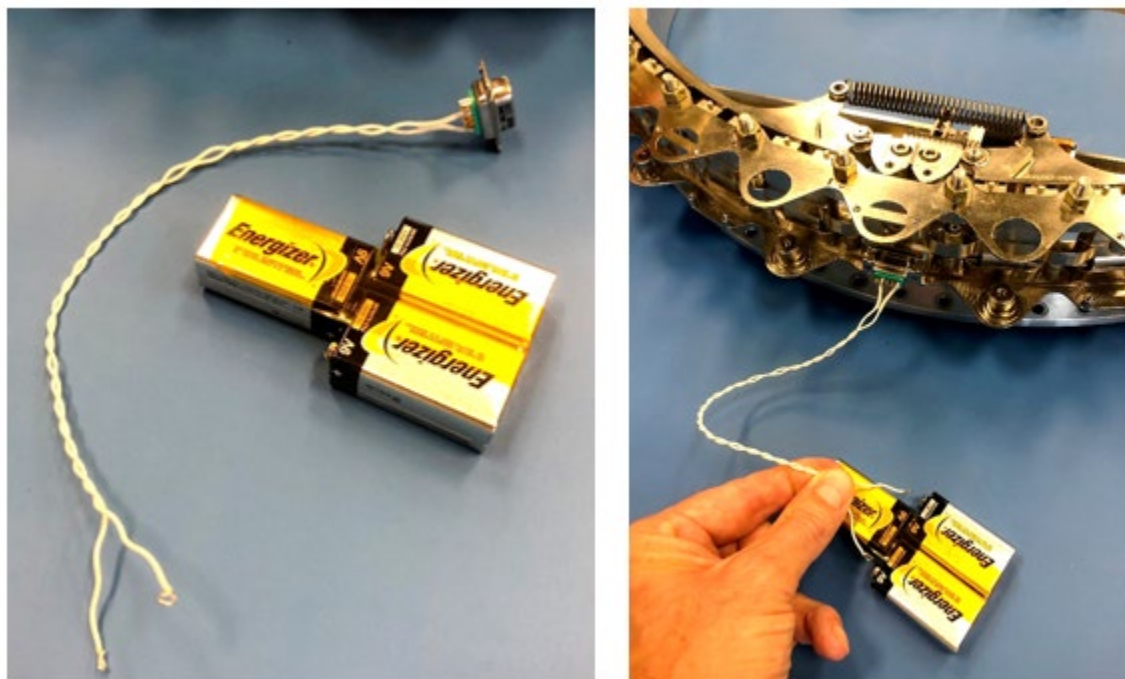


Figure 4-7: The simplest initiation circuit

4.3 Separation

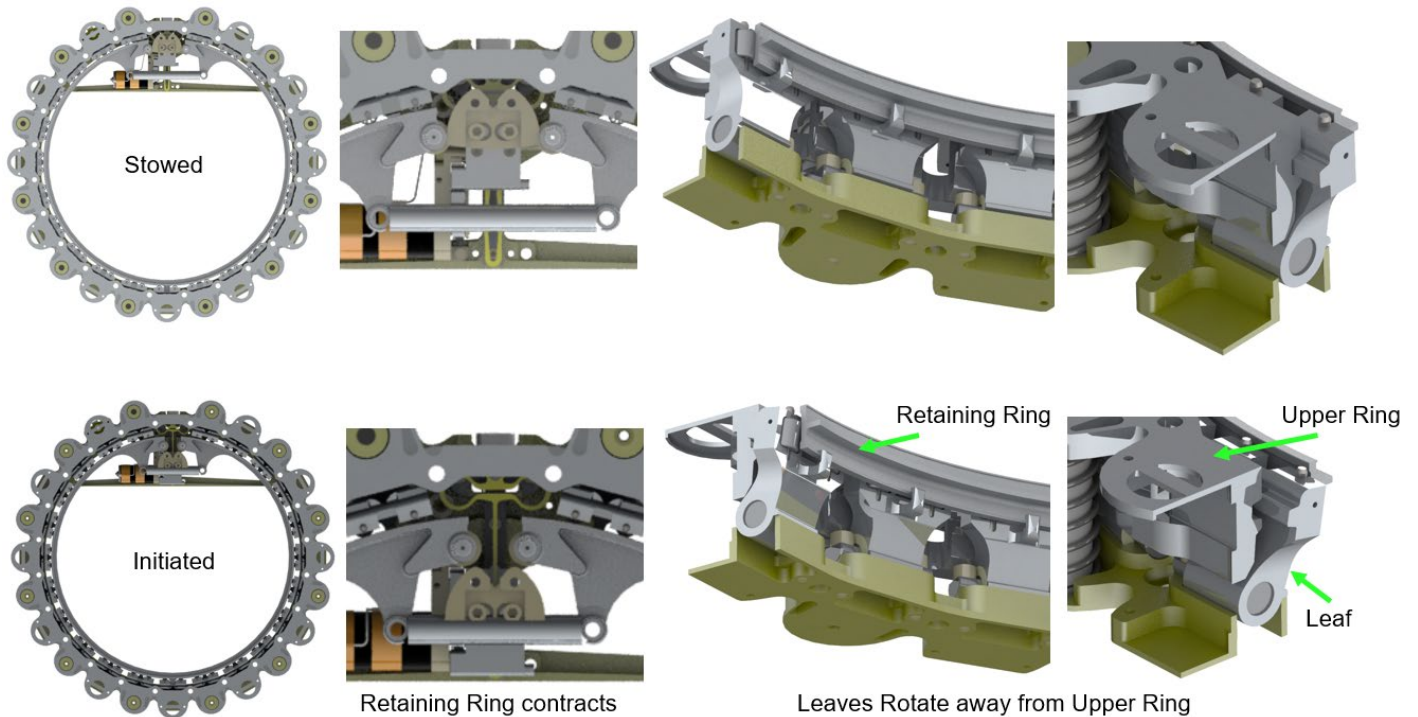


Figure 4-8: After initiation, the Retaining Ring contracts pulling the Leaves away from the Upper Ring



Figure 4-9: User's may compute the height the Upper Ring attains and catch the Upper Ring. Don't fail.

4.4 Verifying Latch-up

After initiation, latch-up of the Sliding Bracket to the Flexure is verified by measuring dimension 'ds'. For a valid latch-up the dimension must be within the range specified in Table 2-1. A failure to meet the 'ds' requirement might cause higher tip-off and in some extreme cases, a failure to separate.

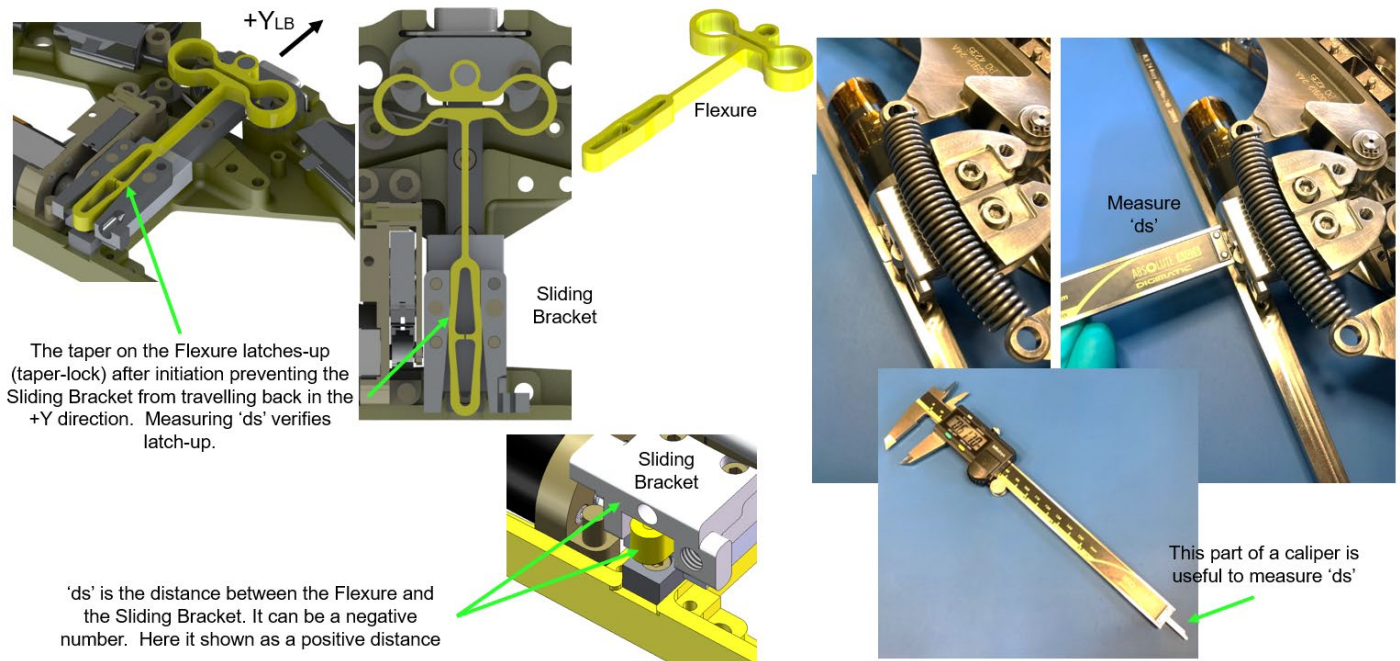


Figure 4-10: Verifying Latch-up by measuring 'ds'

4.5 Attaching Springs, Separation Connectors and Separation Switches

Users may be expected to attach the Separation Switches, Separation Connectors, and Separation Springs to the ALB and attach the ALB to adjoining vehicles. Unless otherwise noted, the accepting threads in the ALB do not include locking patches, adhesives, helical coils or other inserts. Testing has conclusively shown the following bolted joints are sufficient for spaceflight.

Users should always verify the threaded junctions (screw and accepting thread) are clean of detrimental FOD. While free-running, if a screw feels rough, assume it needs to be cleaned or may need to be discarded. All junctions are right-handed threads. Do not loosen, tighten, or modify any other junctions than those shown below. Keep auditable records of assembly and torque. Only use calibrated torque wrenches.

Section 15 Appendix A: ALB Accessories has detailed descriptions of each accessory and their parameters.

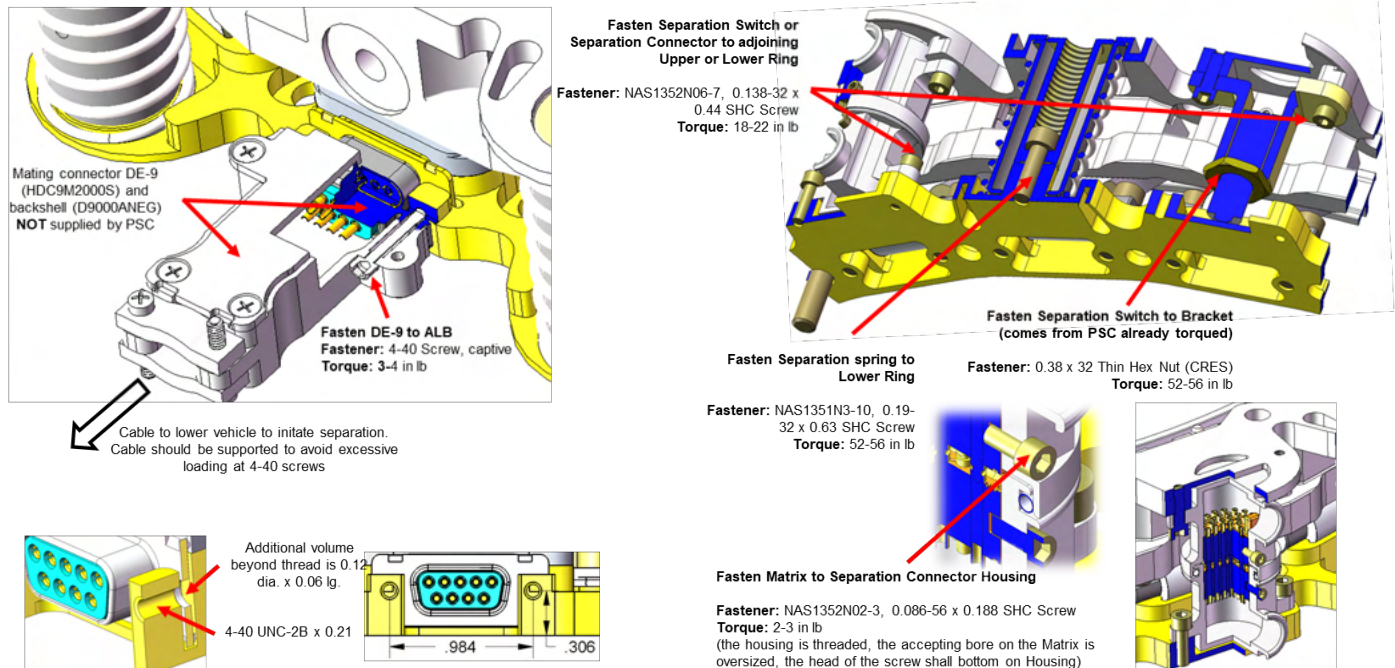


Figure 4-11: Fasteners and torques for accessories

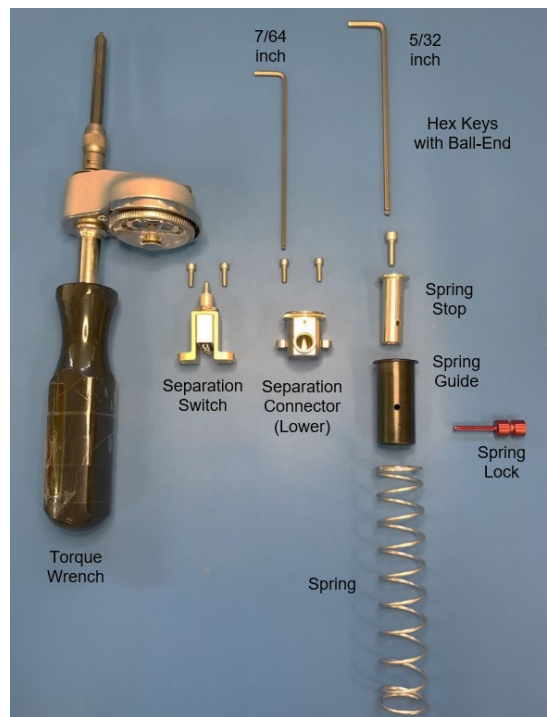


Figure 4-12: Tools and parts

4.5.1 Attaching Separation Spring

See Figure 4-11, Figure 4-12, and Figure 4-13.

1. Determine the location of the Springs. See Section 3.13.
2. Verify Lower Ring accepting threads.
3. Place the .19-32 x .63 SHC fastener inside of the Spring Stop
4. Place the Spring Stop inside the Spring Guide.
5. Slide the Compression Spring around the Spring Guide.
6. Install Spring on Lower Ring. Verify spring is concentric with circular lip on Lower Ring. Compress Spring enough so the screw is free running for the first few turns. Turn Screw until Spring Stop mates to Lower Ring.
7. Align Spring Lock hole radially outward.
8. Torque .190-32 x .63 SHC fastener per Figure 4-11.
9. Ensure Spring is retained by Spring Guide and Spring Guide is retained by Spring Stop.
10. Ensure the Spring is concentric with circular lip on Lower Ring.

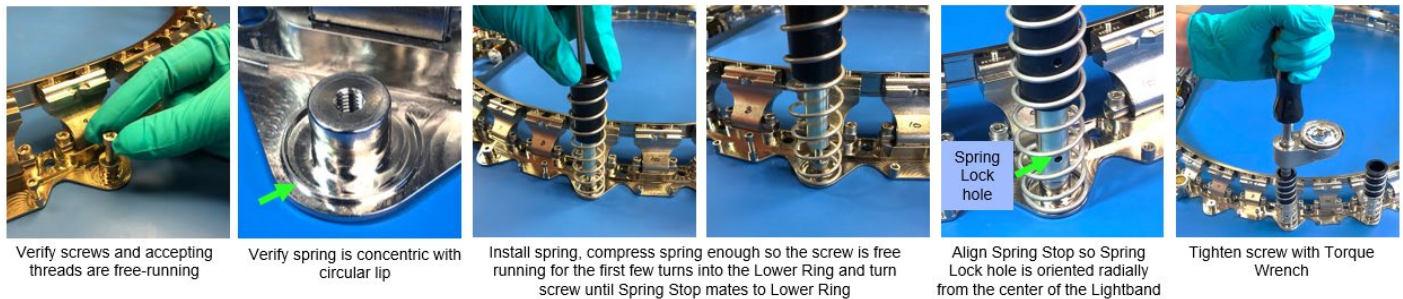


Figure 4-13: Attaching Separation Springs

4.5.2 Attaching Separation Switches

See Figure 4-11, Figure 4-12, and Figure 4-14

1. Determine the location of the Separation Switches.
2. Verify Upper or Lower Ring accepting threads.
3. If required, attach the Switch Bracket to the Separation Switch. Torque per Figure 4-11.
4. Attach .138-32 x .44 SHC fastener to the Switch Bracket.
5. Install Switch onto Upper or Lower Ring. Turn screws until Switch Bracket mates to Ring.
6. Torque .138-32 x .44 per Figure 4-11.

When installing Separation Switches on a Stowed ALB, it's often easier to install the plunger first and compress against the interfacing surface, then pivot the Switch/Bracket into place and install the fasteners.

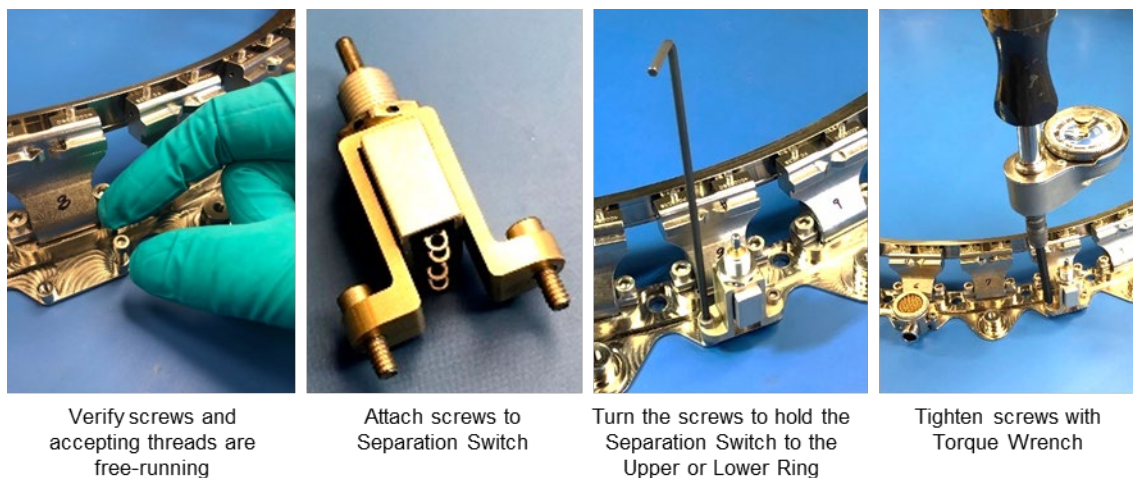


Figure 4-14: Attaching Separation Switches

4.5.3 Attaching Separation Connectors

See Figure 4-11, Figure 4-12, and Figure 4-15

Separation Connector fasteners shall be torqued only when the ALB is in the stowed condition. Both halves of the Separation Connectors shall be installed but loose during their initial stow operation. The Separation Connector halves need to be able to self-align during the stow operation. Torque the Separation Connector fasteners per Figure 4-11. Note there is limited access to torque these fasteners. Separation Connectors cannot be installed on a Stowed ALB, the Connectors cannot slide past the lip of the Upper Ring Flange.

1. Determine the location of the Separation Connectors.
2. Verify Upper Ring and Lower Ring accepting threads.
3. Attach .138-32 x .44 SHC fastener to the Separation Connector halves.
4. Install Separation Connector halves onto Upper Ring and Lower Ring. Turn screws until Separation Connectors mates to Ring, then back off ~1 turn. Separation Connectors shall be loose during initial ALB mate/stow to allow for proper alignment.
5. Verify all Spring contact pins are below the mating surface of the connector housing.
6. **After Stowing**, torque Separation Connectors .138-32 x .44 SHC fasteners per Figure 4-11.



Figure 4-15: Attaching Separation Connectors

4.6 Attaching to adjoining structures

Fasten Upper Ring to Upper Vehicle (Satellite)
On bolt circle diameter 'D'
NOT supplied by PSC

Fastener: NAS1351N4-12, 0.25-28 x 0.75 SHC Screw
Torque: 115-125 in lb
Though Hole: 0.271±.005 in
True Position: Ø .01 in (constrained)
Flange thickness: 0.18 in
No room for washer

Fasten Lower Ring to Lower Vehicle (Launch vehicle)
On bolt circle diameter 'D'
NOT supplied by PSC

Fastener: NAS1351N4-12, 0.25-28 x 0.75 SHC Screw
Torque: : 115-125 in lb
Though Hole: 0.281 ±.005 in
True Position: Ø .01 in (constrained)
Flange thickness: 0.12 in
No room for washer

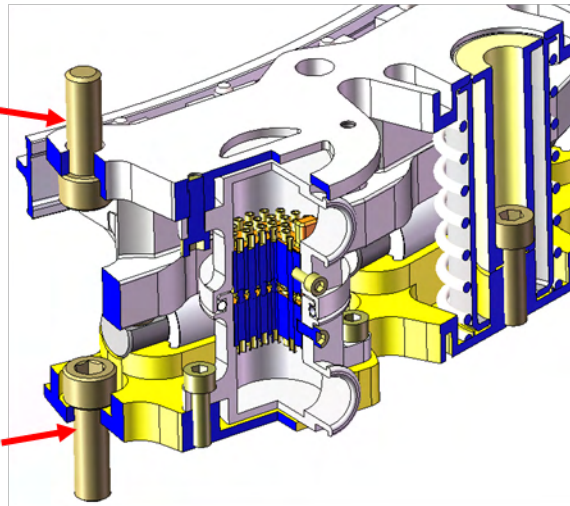
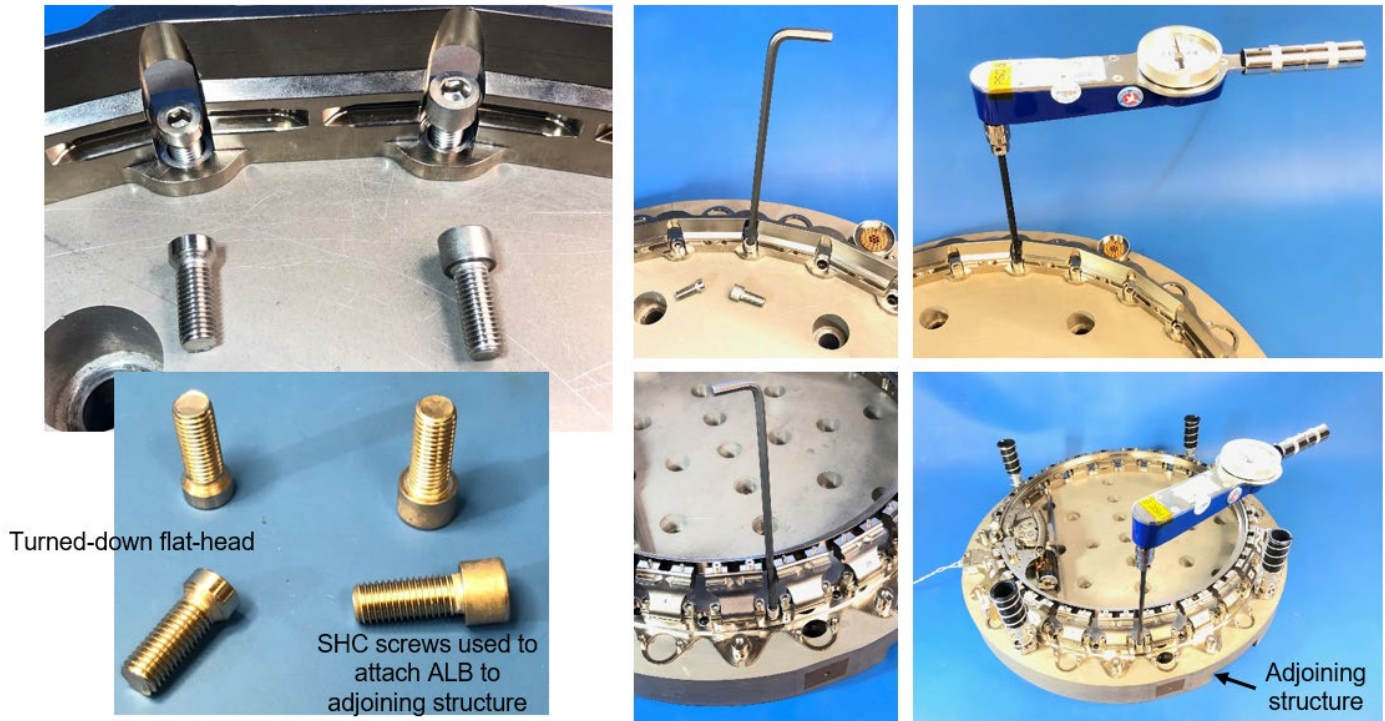


Figure 4-16: Fasteners and torques for adjoining structures



Turned-down flat-head

SHC screws used to
attach ALB to
adjoining structure

Though not essential, turned-down flat head screws may be used to align the Lightband bolt pattern to the pattern on the adjoining structure to within 0.005 inches

Install all the screws

Use a torque wrench to
tighten the screws

Figure 4-17: Attaching the ALB to adjoining structures

Ensure adjoining structures meet the flatness requirement in Table 2-1.

A turned-down flat head fastener has a conical feature that tends to force alignment. However, flat head fasteners should not be used to permanently fasten the ALB to an adjoining structure. Washers are not used to attach the ALB to adjoining structures.

Typical fasteners and torques for adjoining structures listed in Figure 4-16.

4.7 Vertical and Horizontal Integration to Adjoining Vehicles

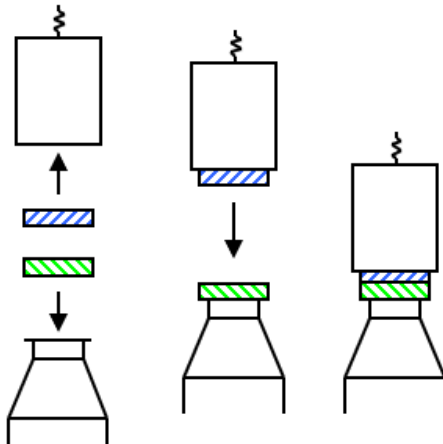
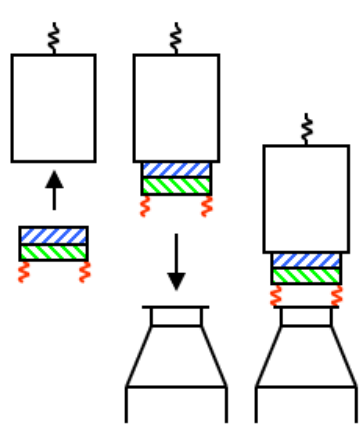
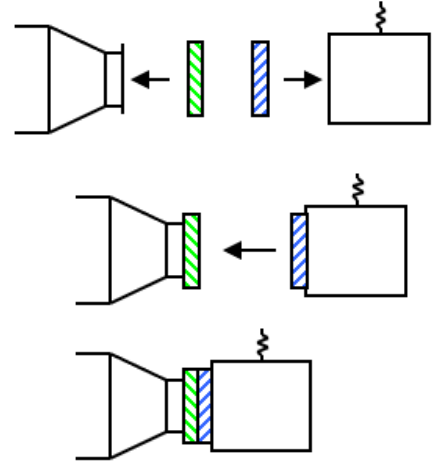
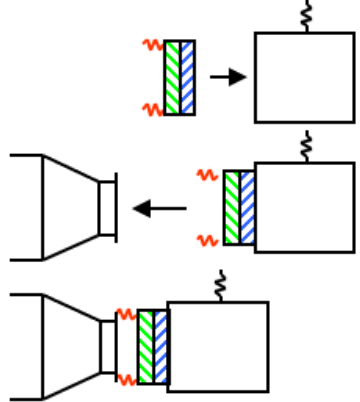
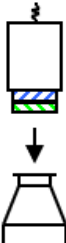





	Without Isolation System	With Isolation System
Vertical Integration		
Horizontal Integration		
Remarks	 <p>This works but accessing the fasteners from the outside of the ALB can be time consuming (about an hour)</p>	<div style="display: flex; justify-content: space-around;"> <div>   <p>Spring – damper of isolation system</p> <p>Upper Ring</p> <p>Lower Ring</p> </div> <div>    <p>Spring compliance system</p> <p>Space vehicle</p> <p>Final stage of launch vehicle</p> </div> </div>

Figure 4-18: Typical vertical and horizontal integration methods

The compliance of the entire stack needs to be assessed to properly integrate the ALB. When the ALB is stowed as part of the integration process, the entire system will be structurally indeterminate. If the space vehicle and Upper Ring are too far from the Lower Ring or improperly aligned, the ALB will have to pull the space vehicle down and vice versa. To minimize this effect, a compliance spring and/or a more precise control of space vehicle position in all six degrees of freedom is necessary.



Figure 4-19: Horizontal and vertical integration

Flatness of the adjoining surfaces should be within the flatness requirement. See Table 2-1. If flatness requirements are not met by the structure, shims (epoxy or metal) can be used to attain the required flatness.

Flexible adjoining structures may distort while lifting to mate the structures. Simple static analysis can expose any detrimental distortion due to lifting hard-points and weight.

4.8 Stow Procedure

4.8.1 Compress the Separation Springs

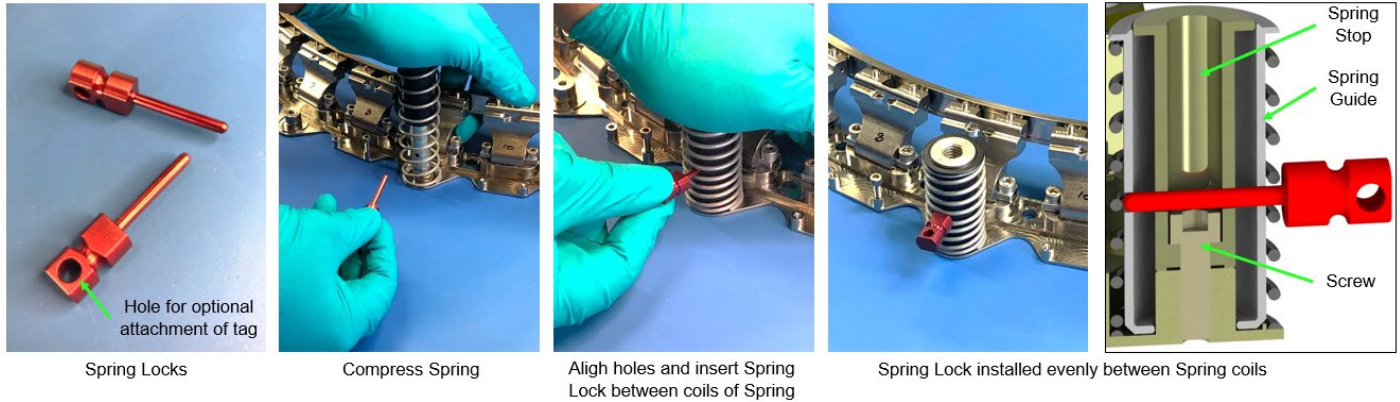


Figure 4-20: Compressing Springs and Installing a Spring Lock

4.8.2 Aligning the Upper Ring to the Lower Ring

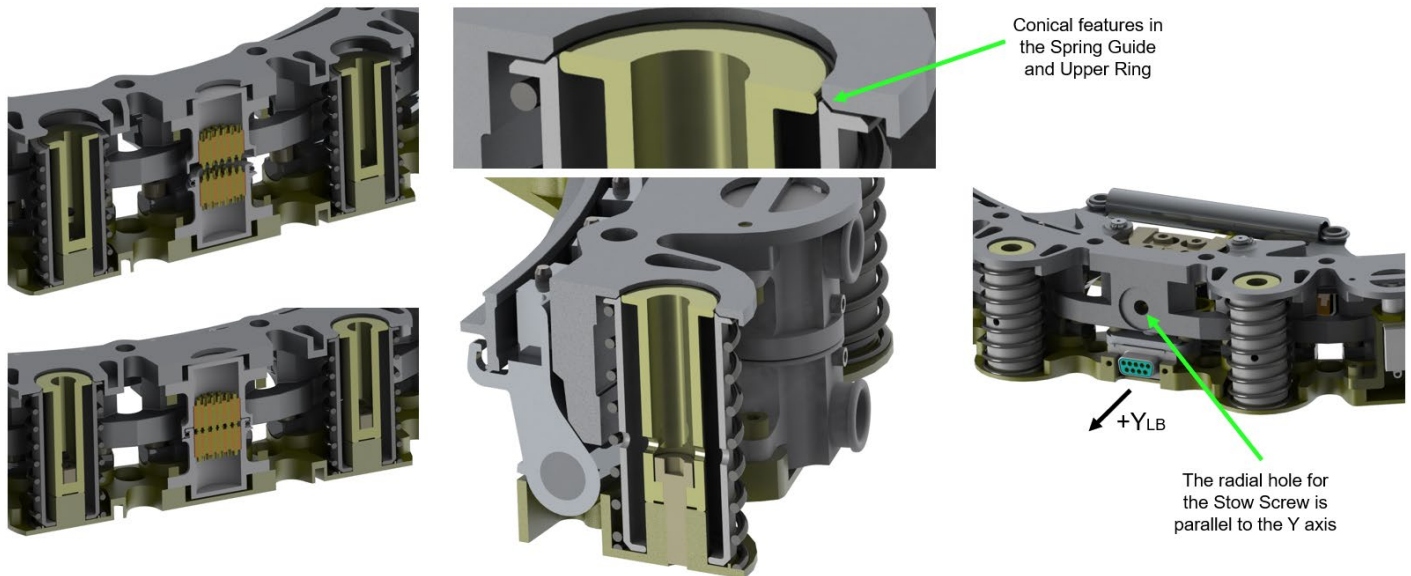


Figure 4-21: Aligning the Upper and Lower Ring

If this is the first instance the Separation Connector is stowed, loosen the screws holding it to the ALB so it may self-align during the Stow procedure.

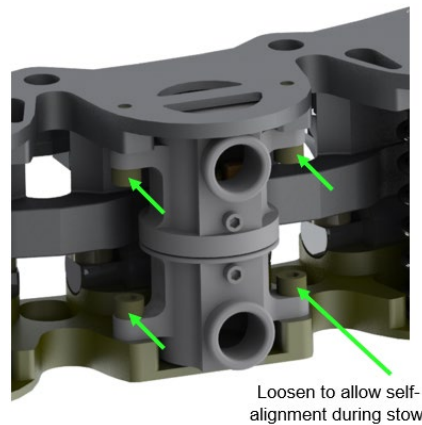


Figure 4-22: Loosening screws on Separation Connector

4.8.3 Installing the Stow Screw

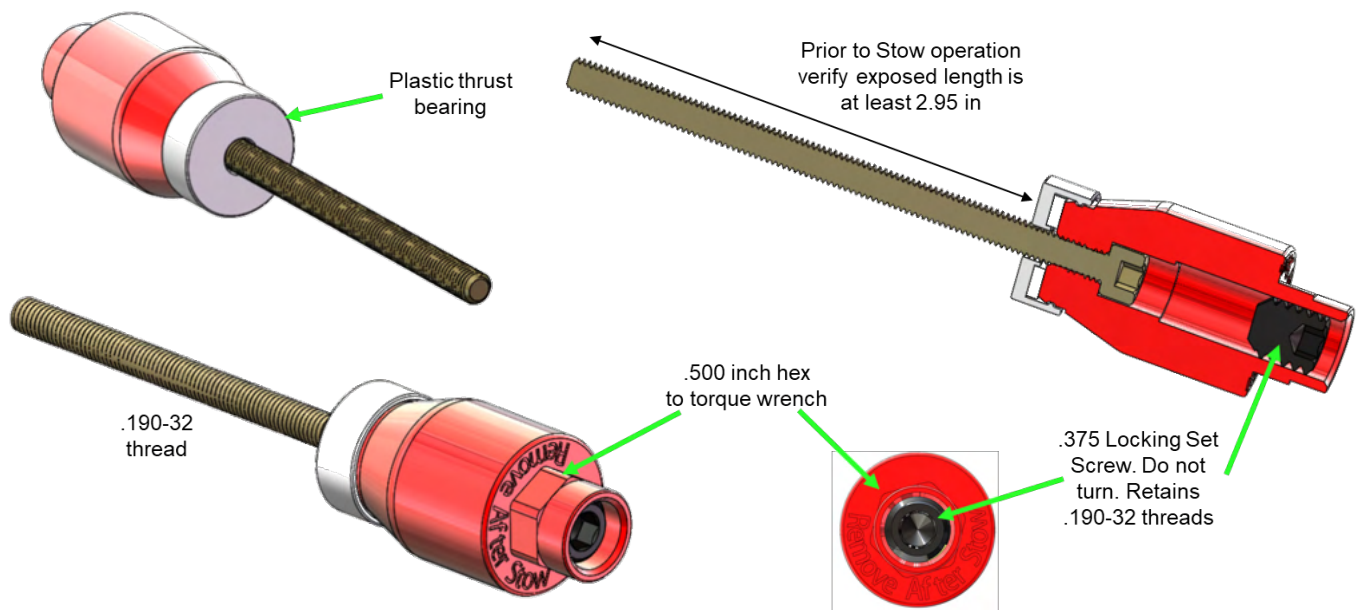


Figure 4-23: Stow Screw

To gain a sense of the free running torque and verify there is no likelihood of cross-threading, install the Stow Screw (from the -Y_{LB}) into the Sliding Bracket and turn by hand CW. See Figure 4-24. If there is roughness, cross threading, or more than 1-in lb of free running torque STOP and inspect the screw.

The Stow Screw may be worn out or the thread at the tip may be deformed. The Stow Screw may be cleaned or replaced. In the unlikely event the accepting thread in the Sliding Tube is at fault, contact PSC for guidance.

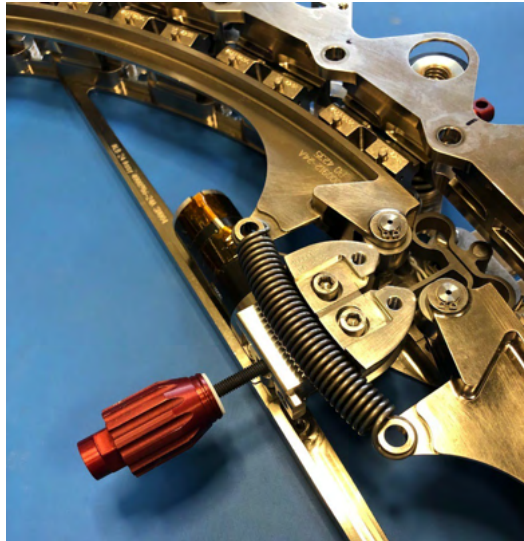


Figure 4-24: The quality of the threaded junction is verified by turning the Stow Screw into the Sliding Bracket from the inside (not enough room on ALB8 for this operation)

If it's the first time a Separation Connector is installed, make sure the fasteners holding it to the ALB are loose allowing the Separation Connectors to self-align during the stow process. Place the Upper Ring on the compressed Separation Springs.

If installed, the Separation Switch and Connectors will push the Upper Ring in +X_{LB} direction about 0.2 inches. To overcome the force of the Separation Switch (F_{sw}) and Separation Connector (F_{sc}), compress the Upper Ring against the stowed Separation Springs. The required compression force can be calculated from the quantity of Separation Switches and Separation Connectors and Table 2-1. The compression is so the radial hole in the Upper Ring is co-axial to the accepting thread in the Sliding Bracket. Install the Stow Screw through the Radial Hole and thread into the Sliding Bracket. The Stow Screw must run freely as it did when the Upper Ring was not present. If it feels rough, the Stow Screw is wearing against the radial hole in the Upper Ring. See Figure 4-25 and Figure 4-26 for expected torque values.

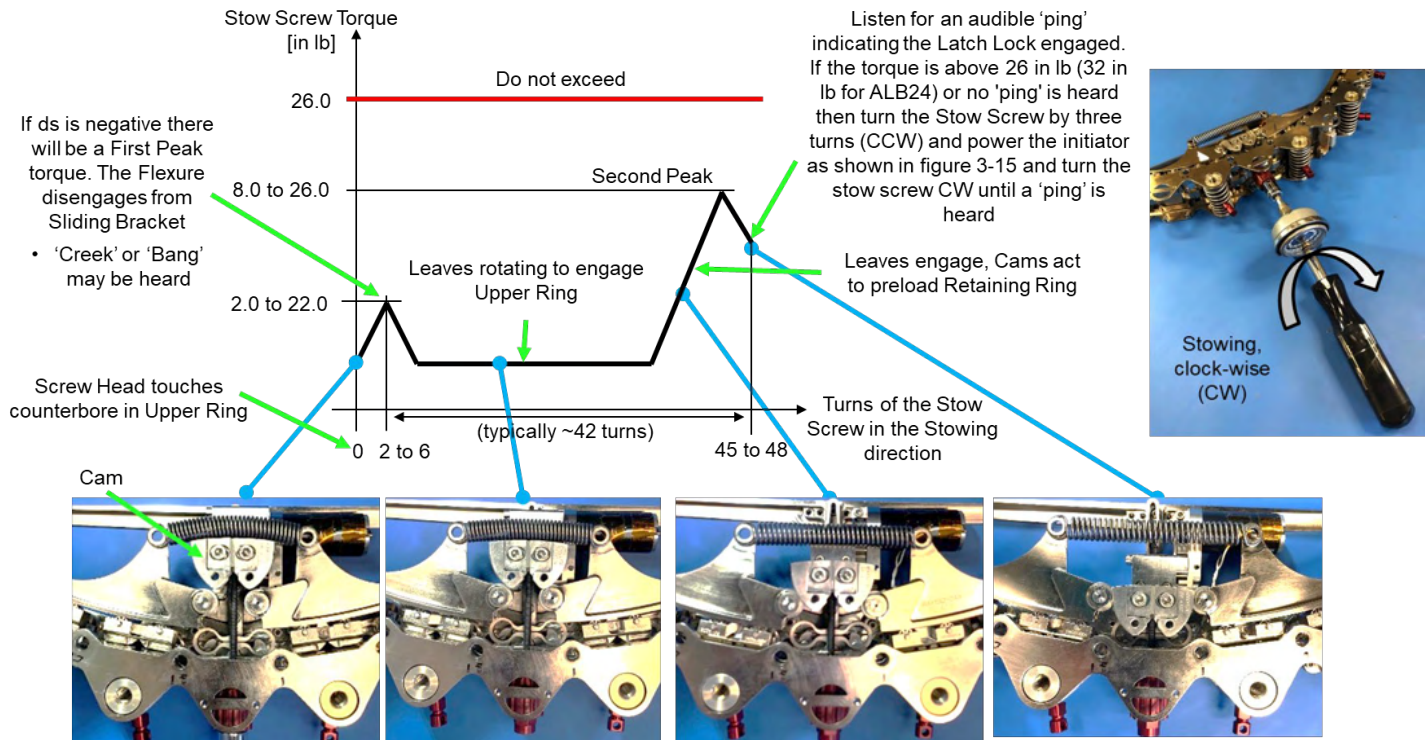


Figure 4-25: Stow Screw turns vs. Stow Screw torque, d_s less than .075 (-.135 to .075)

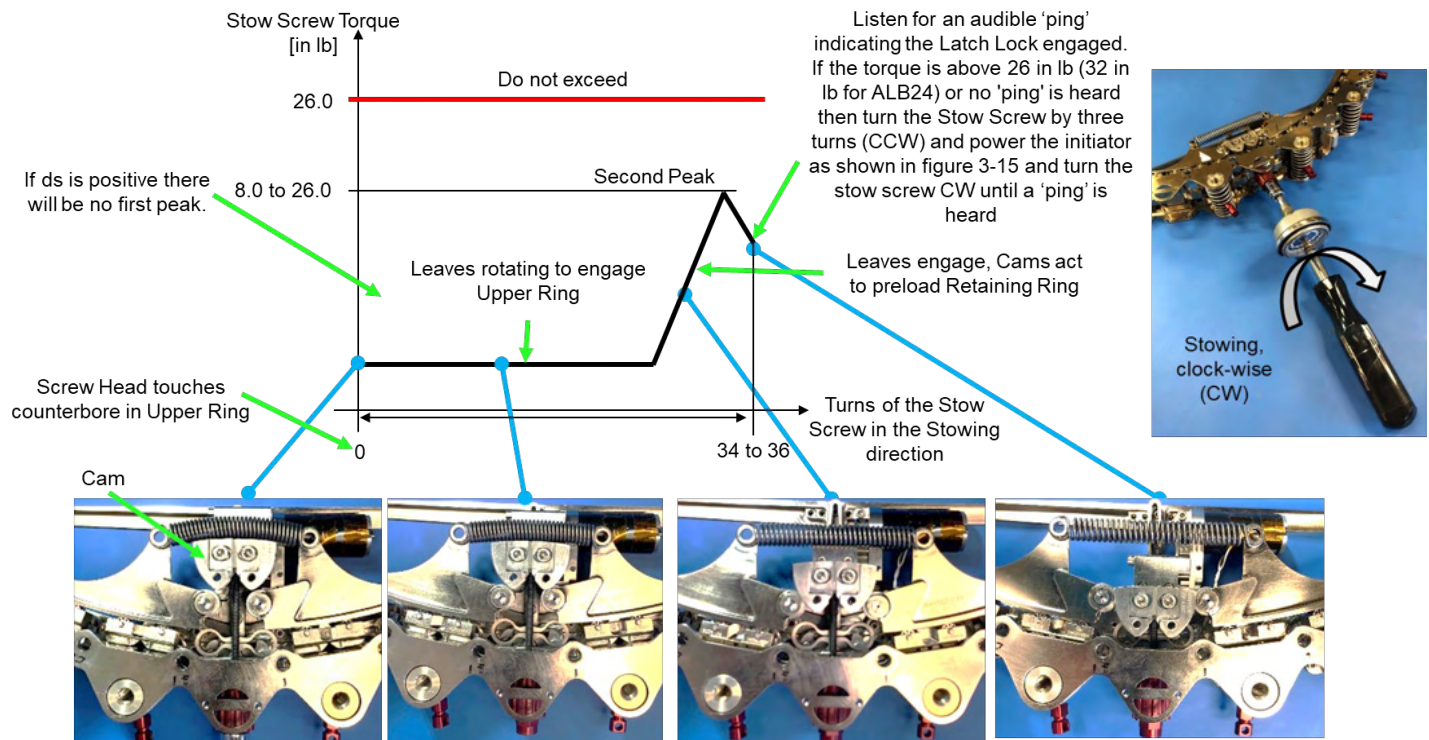


Figure 4-26: Stow Screw turns vs. Stow Screw torque, d_s greater than .075

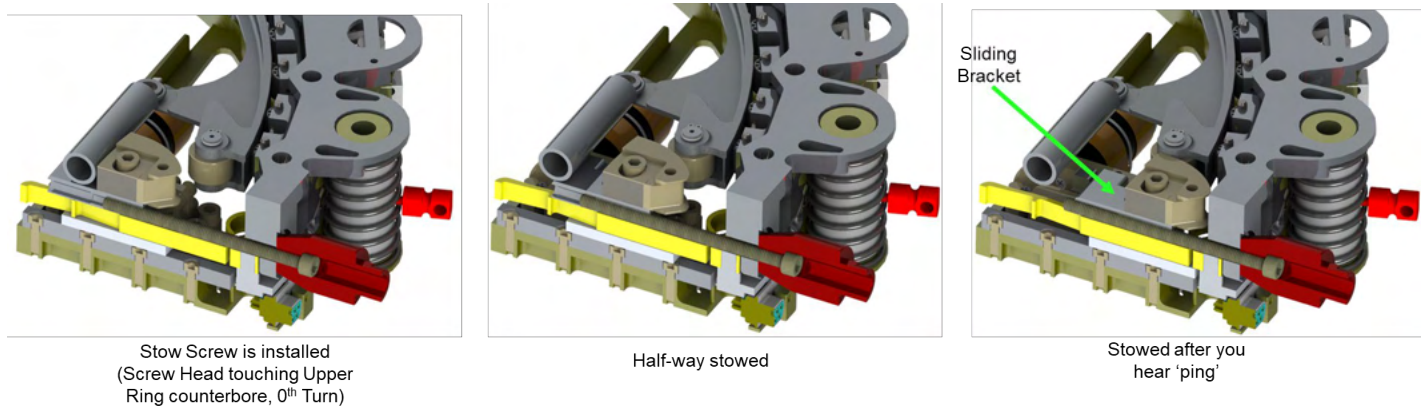


Figure 4-27: Sectional view of stowing

Stow the ALB by turning the Stow Screw Assy for the prescribed number of turns while monitoring torque. See Figure 4-25 or Figure 4-26 (depending on ds) and Figure 4-27. Stop when the “ping” is heard, the max turns are reached, or max torque is noted. Surpassing the max number of turns or torque may detrimentally damage the ALB, see Figure 4-29. If the number of turns are lost track, contact PSC. In some integration environments, loud background noise can make hearing the “ping” difficult. ALB stow can also be verified visually by looking at the Latch through use of a borescope between the ALB Leaves. See Figure 4-28. If you would like more information on this visual verification method, contact PSC and request document 2003815- ALB Stow Visual Verification.

Once Stowed, confirmed through “ping” or visually, fully remove the Stow Screw Assembly. As the Screw is loosened, the load will transfer from the Screw to the ALB Latch, and the Sliding Bracket should move ~ 0.02 in the $-Y_{ALB}$. Remove the Spring Locks.

Caution: If the Stow Screw is not removed, the ALB will not separate. If the Spring Locks are not removed, there will be zero separation energy.

If the screws attaching the Separation Connector were loosened to allow self-alignment, torque all of them now.

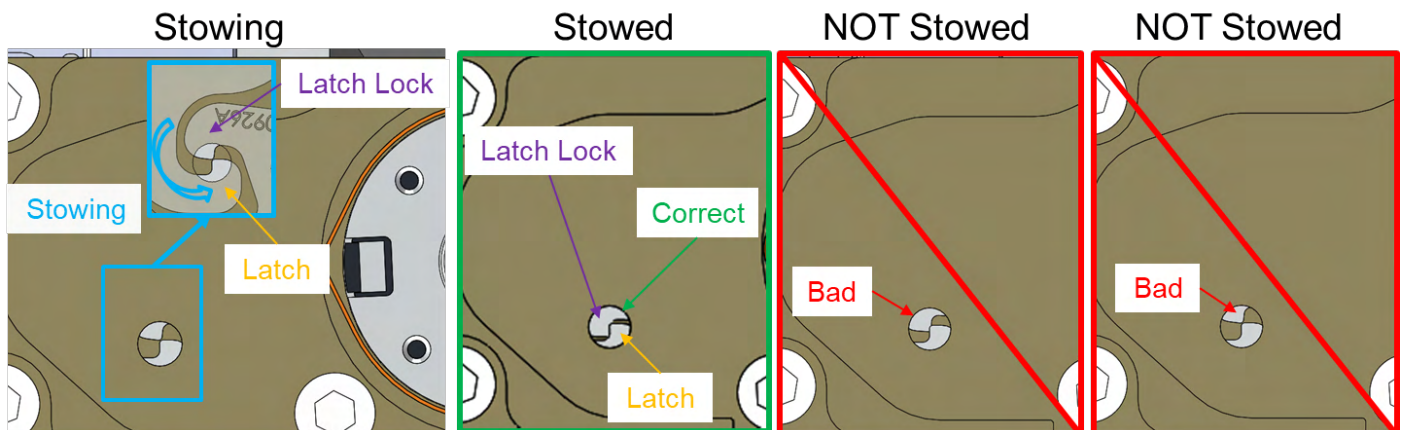


Figure 4-28: Visual Verification of Stowed Latch

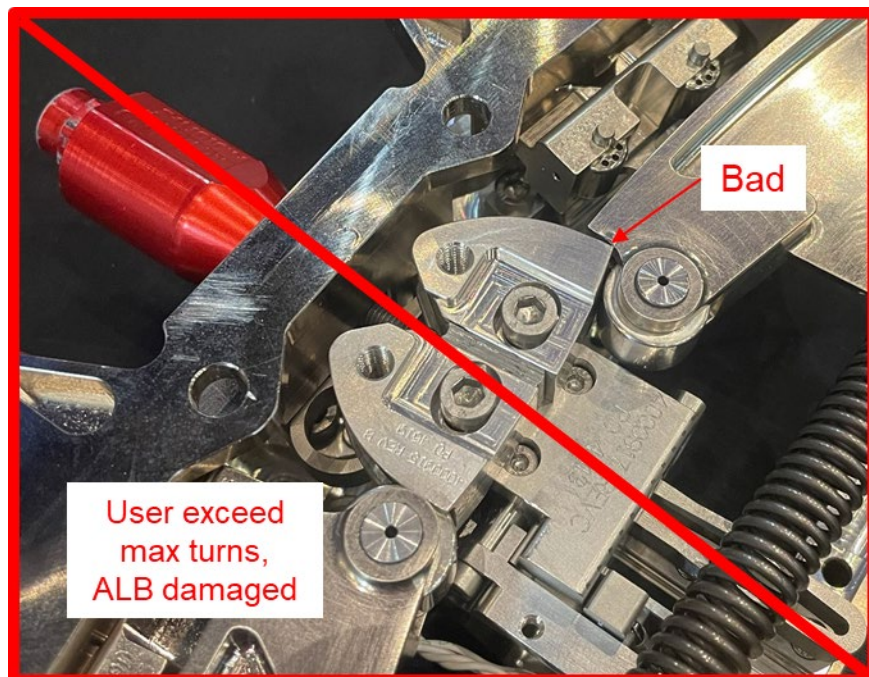


Figure 4-29: ALB over stowed, max turns exceeded

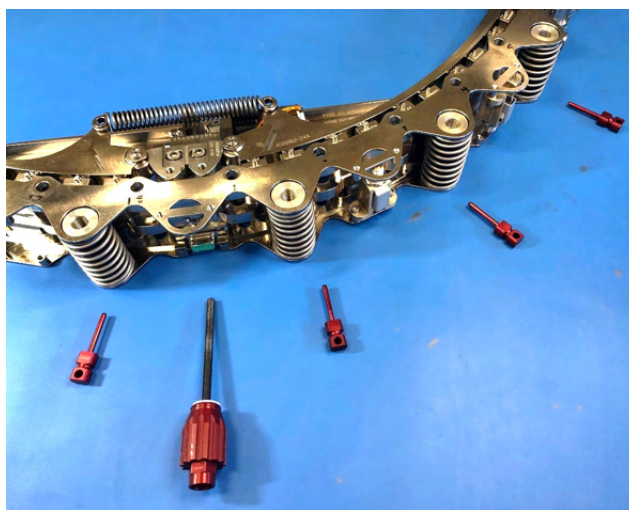


Figure 4-30: Remove the Stow Screw and all Spring Locks



After stow, tighten the screws holding the separation connector(s) to the ALB with a torque wrench

Figure 4-31: Tightening the screws holding the Separation Connectors

5. Reliability, Failure Modes and Anomaly Reporting

ALB reliability will be maximized by strictly adhering to the procedures in this document. Over a thousand separation tests on more than 20 ALBs before, during, and after critical development and qualification tests (thermal-vacuum, shock, vibration, strength, separation reliability, etc.) over several years show reliability and confidence.

5.1 Failure Modes, Effects and Preventative Actions

Failure Mode	Effect(s)	Preventative Action
Operator fails to remove Stow Screw prior to initiation	Failure to separate	Follow procedures
Operator fails to remove Spring Locks prior to initiation	Lower separation velocity and/or higher rotation rates	Follow procedures
Initiator voltage or current is too high or too low; too short or too long	Failure to initiate or damage to initiator	Follow procedures
Subsystems loosen (Switch, Connector, Spring)	Decreased performance, debris	Verify and record torque at all fasteners joining subsystems
Cross-threading screw	Screw is seized, proper assembly is prevented	Verify all screws and their accepting threads are within specification and free running
Flatness of interfacing boundaries are out of tolerance.	System will not stow or will be difficult to stow.	Inspect boundary interfaces
FOD in DE-9 connector	Increased electrical resistance	Inspect and clean pins and sockets prior to mate
Operator fails to follow stow procedure, exceeds max torque or max turns	ALB detrimentally damaged, requires PSC rework	Procedures, checklists, PSC provided training
Loopbacks in Separation connector are too long to allow proper seating of Matrix	Pins are damaged	Verify Matrix seats properly before integration to ALB
Stow screw torque is exceeded or operator turns past 'Ping'	ALB won't deploy	Adhere to operating procedures, checklists and training

Table 5-1: Failure Modes, Effects and Preventative Actions

5.2 Anomaly Reporting

If an anomaly occurs, contact PSC immediately at support@planetarysystemscorp.com. PSC will attempt to respond in a timely manner. To facilitate the review of data, avoid confusion, and expedite response, PSC requests the following:

1. Stop immediately and maintain the existing configuration (if safe).
2. Thoroughly document the state of the Lightband with pictures and notes. Verify the quality and focus of every picture prior to sending.
3. Provide the three prior operation's electrical profiles (if applicable to anomaly) as an Excel file. Ensure all data is properly formatted, titled, graphed and labeled. Sending only the raw oscilloscope .CSV files will increase PSC's response time. Ensure all date labels correspond to the actual event date.
4. Provide a copy of the as-run procedure.
5. Provide any relevant operation details including, but not limited to:
 - a) Adjoining structures. To what is the Lightband bolted?
 - b) How many Lightband operations have been performed?
 - c) Reason for operation. Was it an environmental test, avionics verification, integration, etc.? This informs potential failure modes.
 - d) Are all components accessible? Are there any access restrictions? Is the Lightband in a clean room?

6. Testing

PSC completes acceptance testing on standard flight ALBs prior to delivery. EDU ALBs only receive build verification tests. PSC's testing of the ALB does not include the customer's wiring harness. Typically, Transition Rings are fastened to the ALB during testing to mimic flight-like structural, thermal, and dynamic boundary conditions. There is no fixed sequence for acceptance tests. PSC writes, executes, and approves all test plans. PSC also takes any corrective action if anomalies arise. PSC may employ a lot testing strategy, at PSC discretion (i.e. all units within one lot may not receive all testing).

Special (Custom) testing is not included and adds cost and schedule.

Test	Standard or Special?
Build Verification (pre-BCR)	Standard
Random Vibration Test	Standard
Thermal Vacuum Test	Standard
Separation Reliability Test	Special (Custom)
Strength Test	Special (Custom)
Shock Test	Special (Custom)

Table 6-1: Standard vs Custom test summary

6.1 Test Summary

Test	Parameter	Qualification	Protoflight	Flight (Acceptance)	EDU
Build Verification	Preload Tuning [-]	proprietary	proprietary	proprietary	proprietary
	Benchtop Operations [-]	≥7	≥7	≥7	≥7
Random Vibration	Level [grms], ± 1 dB	14.1	14.1	10.0	Not Performed
	Duration [s/axis], +10%/-0%	180	60	60	
TVAC	Temp [°C], ±3.0 °C	-50 to 110	-29 to 66	-24 to 61	Not Performed
	Cycles, min [-]	10	8	4	
	Separations [-]	6	2	1	
Shock	Levels	See Figure 6-4	See Figure 6-4	Not Performed	Not Performed
	Impacts/axis	3	2		
	Strategy	positive & negative	maxi max		
Separation	Separations, min [-]	100	5	Not Performed	Not Performed
Strength	Axial Line Load [lbf/bolt]	2064	Not Performed	Not Performed	Not Performed
	Shear Line Load [lbf/bolt]	775			
Fatigue	Axial Line Load [lbf/bolt]	See Figure 6-7	Not Performed	Not Performed	Not Performed
	Cycles	See Figure 6-7			

Table 6-2: Test Summary

6.2 Build Verification

The ALB is tuned to achieve optimal retention and separation characteristics. Throughout build the ALB is stowed and deployed to verify nominal operation. The Springs elongate, and the Separation Switches and Separation Connectors change state. Transition Rings are fastened to the ALB to produce flight like structural boundary conditions. These verifications are completed during the build process prior to Build Complete Review (BCR) and do not have stand-alone test procedures.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Benchtop Separations	Separations [-]	>100	≥7	≥7	≥7

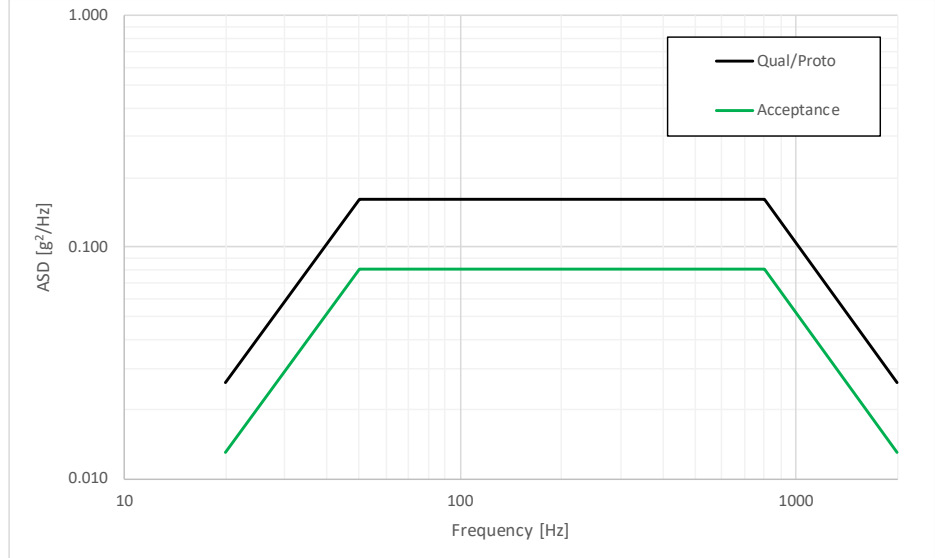


Figure 6-1: Benchtop Separation Testing

6.3 Component Random Vibration

The ALB is exposed to random vibration in three orthogonal excitation axes to verify workmanship and demonstrate a capability to survive transport or flight vibration.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Component Random Vibration	Level [g _{rms}]	14.1±1dB		10±1dB	Not Performed
	Duration [s/axis]	180+18/-0	60+6/-0	60+6/-0	
	Excitation Axes [-]	X, Y, Z			



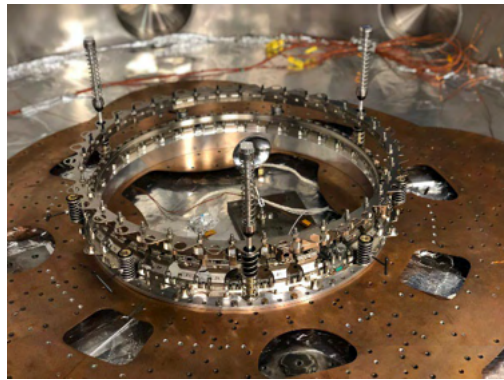
Frequency [Hz]	ASD [g²/Hz]		
	Qual	Protoflight	Acceptance
20	0.026	0.026	0.013
50	0.160	0.160	0.080
800	0.160	0.160	0.080
2000	0.026	0.026	0.013

Figure 6-2: Random Vibration Testing

6.4 Thermal Vacuum

The ALB is exposed to temperatures and pressures of spaceflight. ALB is initiated and separated in a vacuum at a temperature extreme and initiation voltage extreme.

Test	Parameter	Use			EDU
		Qualification	Proto-Flight	Acceptance (Flight)	
Thermal Vacuum	Temperature (±3) [°C]	-50 to +110	-29 to +66	-24 to +61	Not Performed
	Pressure [Torr]	<1.0E-4			
	Cycles [-]	≥10	≥8	≥4	
	Separations [-]	≥6	2	1	



Qualification TVAC Ops			
Op	Cycle	Temp	Voltage
1	0.5	-50.8	22
2	1	108.6	34
3	1.5	-38.6	22
4	2	88.3	34
5	9.5	-41.1	34
6	10	88.2	22

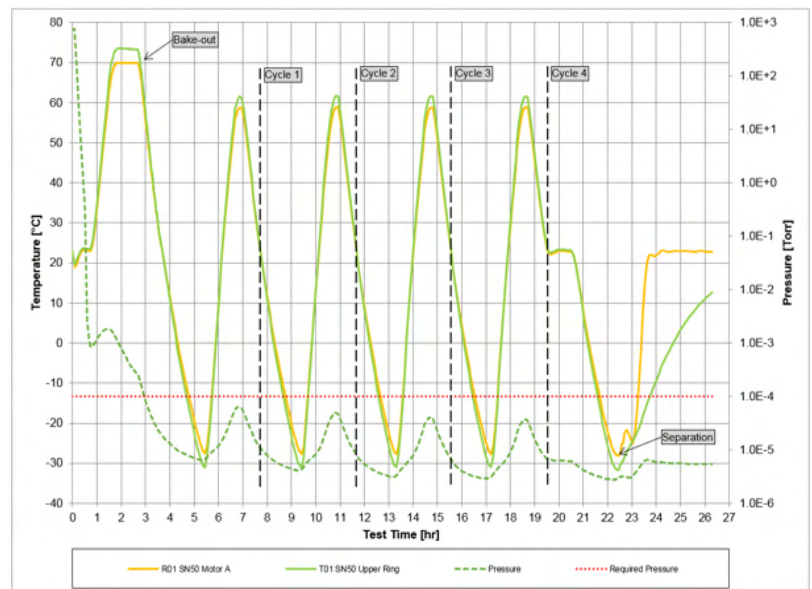
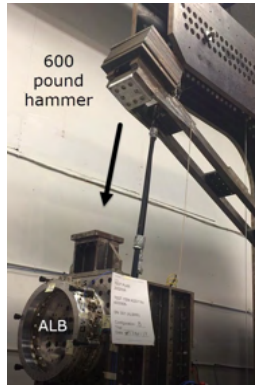


Figure 6-3: TVAC Testing

6.5 Shock (Custom Test)

The ALB is exposed to simulated flight shock.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Shock	Level [g]	See following figure		Not Performed	Not Performed



Frequency [Hz]	Acceleration [g]	
	Qual	Protoflight
100	60	42
2,150	1280	906
10,000	1280	906
% over Nominal	50%	
Q	10	

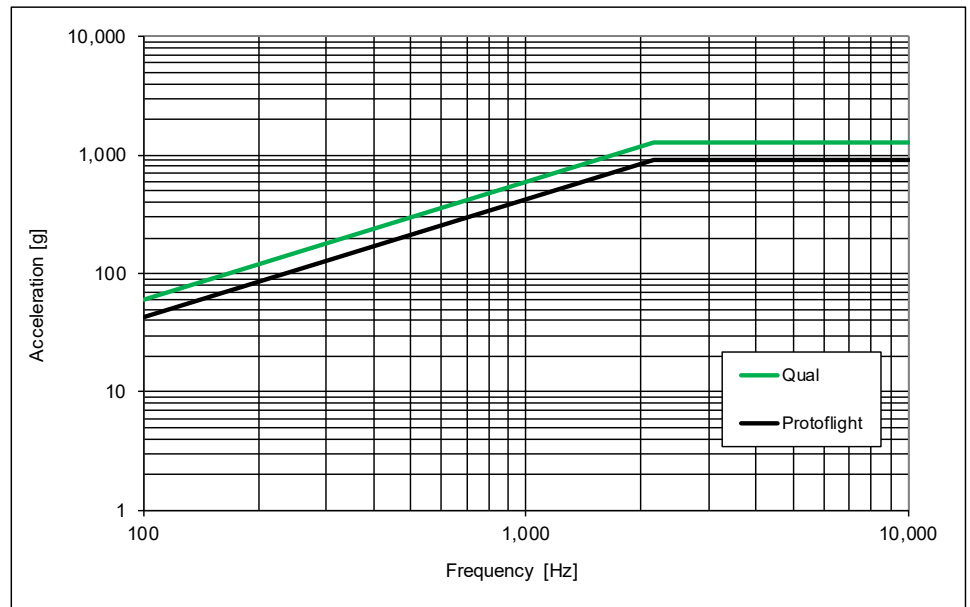


Figure 6-4: Shock Testing

6.6 Separation Testing (Custom Test)

The ALB is separated repeatedly to monitor nominal operation. This may be performed as a benchtop test or on the PSC Separation Reliability fixture, a 5 degree of freedom air bearing table. During Separation Reliability, tip-off rates and separation energy are measured and recorded.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Separation Testing	Operations [-]	100	5	Not Performed	Not Performed

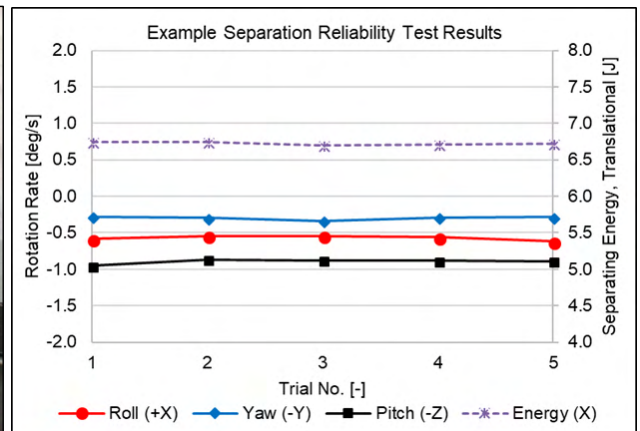
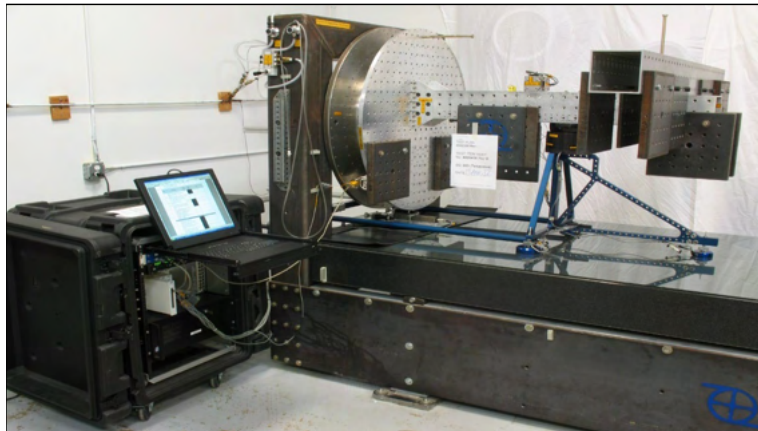


Figure 6-5: Separation Reliability Testing

6.7 Strength (Custom Test)

The ALB is exposed to line loading at the specified limits. Reactions in the ALB may be produced with sine-burst testing or with hydraulic rams. Sine-burst testing requires a PSC supplied mass simulator.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Strength (sine burst or static)	Axial Line Load (Peq) [lbf/bolt]	2064	Not Performed	Not Performed	Not Performed
	Shear line load (Q) [Lbf]	775			

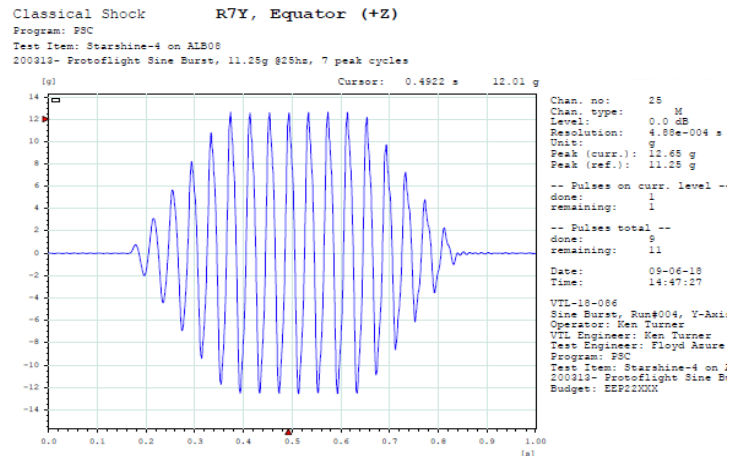
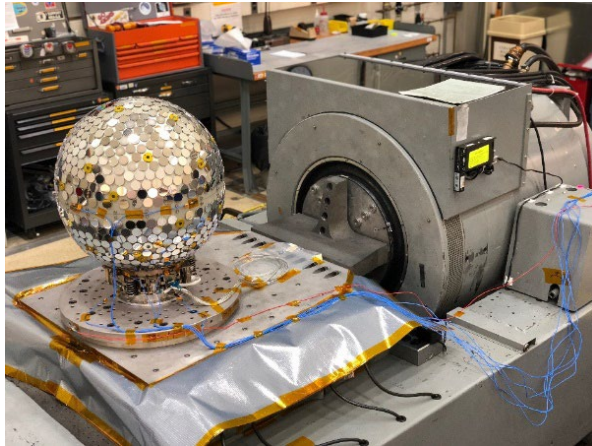
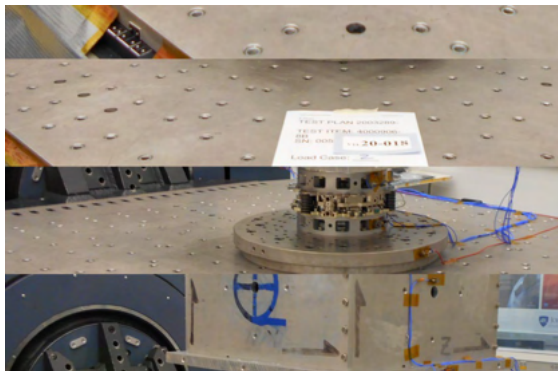


Figure 6-6: Strength Testing

6.8 Fatigue (Custom Test)

The ALB is cyclically loaded. Reaction forces are excited through dynamic loads, reaching a prescribed line load to a required number of cycles. A PSC supplied mass simulator is required.

Test	Parameter	Use			
		Qualification	Proto-Flight	Acceptance (Flight)	EDU
Fatigue (sine burst or sine dwell)	Axial Line Load [lbf/bolt]	1188 893 670	Not Performed	Not Performed	Not Performed
	Cycles [-]	100 800 10000			



Load Case	Cycles	Axial Line Load
1	100	1170-1188
2	800	893
3	10000	670

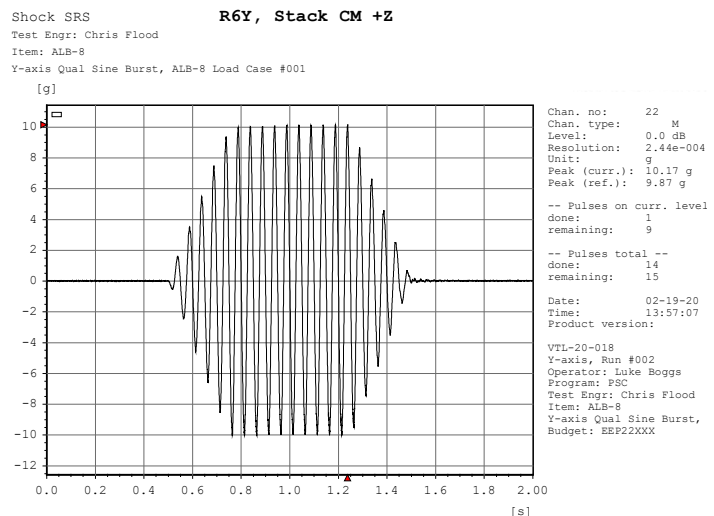


Figure 6-7: Fatigue Testing

7. Specifying an ALB

7.1 Determine stiffness requirements

The biggest driver in ALB diameter selection should be payload stiffness requirements. From dynamic envelope mission requirements, determine the required axial and lateral stiffness of the payload stack. The minimum ALB diameter can then be selected from Table 2-1. However, it is prudent to choose an ALB diameter larger than necessary to provide additional stiffness margin at less than an equivalent increase in weight. For example, a 15-inch diameter ALB is about 6.6 times stiffer than an 8-inch diameter ALB but weighs less than twice as much.

7.2 Determine strength requirements

From your expected mission loads on the payload, calculate maximum line load. Verify that mission loads required to attain those line loads are less than maximum ALB loads shown in Table 2-1. If not, increase the chosen ALB diameter until allowable line load is achieved. PSC will request mass of payload, center of mass location (in ALB coordinate system), and quasistatic load factors at Kick-off to verify adherence to strength requirements.

7.3 Select ALB Bolt Circle diameter

Choose an appropriate ALB diameter from Table 2-1 based on stiffness and strength.

7.4 Complete virtual fit check and plan logistics

Integrate both the ALB stay-out zone model and a CAD model of the ALB (download from www.planetarysystemscorp.com or contact PSC) with a model of your payload and verify your fit requirements. Pay close attention to all stay-out zones per Table 2-1 as the CAD model may not represent the maximum travel of all components. Remember to include your wiring harness. Also determine how you will fasten and operate the ALB for shipment, testing and final integration procedures. Determine the electrical and mechanical ground support equipment (GSE) needed.

7.5 Separation Switch quantity (SW)

The greater the quantity of Separation Switches, the more complex and heavier the harness. See Table 2-1 to ensure the total quantity of Separation Switches and Separation Connectors does not exceed the maximum allowable.

7.6 Separation Connector quantity (SC)

As with Separation Switches, fewer Separation Connectors allow for a simpler harness. Connectors are specified as pairs, so one Connector consists of both the Lower and Upper halves. See Table 2-1 to ensure the total quantity of Separation Switches and Separation Connectors does not exceed the maximum allowable.

7.7 End Use (FLT or EDU)

Engineering Development Unit (EDU) ALBs receive only a bench-top separation test. They do not receive acceptance testing and shall not be used for flight. As such, EDUs are indelibly marked "**NOT FOR FLIGHT**."

Flight Units (FLT) receive testing per Section 6 prior to shipment. If special testing is required (shock, strength, separation reliability, off-set center of mass separation reliability, etc.) additional schedule and cost is typically incurred.

EDU and FLT ALBs are built using the same materials and processes. Customers often purchase an EDU in addition to a FLT for fit checks and ground testing.

7.8 Separation Springs

Use Equation (5) to specify the number of Separation Springs that creates the desired separating velocity or separating energy. A standard ALB comes with 3 Separation Springs (~7.4 J). More than n/4 or less than 3 Separation Springs is a custom unit.

7.9 Specifying ALB

Use the following convention to specify the ALB: ALBXX-SW-SC-FLT-XX

Required Prefix	Bolt Circle Diameter (rounded down)	Separation Switch Qty.	Separation Connector Qty. [pairs]	End Use (Flight or EDU)	Separation Springs [-]
ALB	XX	SW	SC	FLT	XX

Table 7-1: ALB specification convention

For example, **ALB11-1-2-FLT-3** specifies

- ALB – Advanced Lightband
- 11 – 11.732-inch bolt circle diameter
- 1 – Separation Switch
- 2 – Separation Connector pairs (2 Lower and 2 Upper)
- FLT – Be used for space flight and thus receive testing
- 3 – Separation Springs, separating kinetic energy of ~7.4 J

8. Purchasing, Deliverables, & Schedule

8.1 Purchasing an ALB

Contact PSC directly to receive the most up-to-date ALB prices. The standard payment schedule is shown below.

Event	Payment [%]
After Kick-off Meeting	35
Build complete review (BCR) completion	45
Shipment	20

Table 8-1: Standard ALB schedule

8.2 Standard Delivery Schedule

Standard ALBs are typically delivered in 30 weeks ARO. Expedited delivery is available at an additional cost. Custom or Special testing (e.g. shock, strength, separation reliability, CM off-set separation reliability, etc.) increases schedule and cost.

8.3 ALB Deliverables

The items included in the price of an ALB and delivered to the customer are:

1. The ALB(s)
2. Certificate(s) of conformance

8.4 ALB STEP Files

STEP files of simplified ALB assemblies are available to prospective users and customers. Users may request a STEP model at www.planetarysystemscorp.com.

Note: ALB STEP models do not show all components or their full extent of travel. Users shall not use simplified ALB STEP models to verify clearance. Instead use the stay-out zone CAD models for clearance verification.

8.5 ALB Finite Element Models

PSC has test-verified finite element models (FEM) of ALBs available for customers. To accurately predict line loading through the ALB, customers should incorporate the FEM into their flight stack model. Contact PSC for further information. FEMs may incur an additional cost. This item is subject to US Export Control regulation.

8.6 Custom Units

ALB is a COTS separation system. Any customization (testing, configuration, program management, additional customer requirements, accelerated schedule, etc.) will incur additional cost and schedule. Figure 8-1 has a summary checklist to compare standard vs custom ALBs, the custom list is not all-encompassing (there may be additional unlisted items which necessitate a custom unit).

Standard Lightband	Custom Lightband
<ul style="list-style-type: none"> •No deviation from current Lightband design •3 Separation Springs •Random vibration test •Thermal vacuum test •Entire ALB specification is this User Manual 	<ul style="list-style-type: none"> •Any tests not in standard regimen (shock, strength, separation reliability, CM off-set separation reliability) •Any deviation from standard test requirements •Any requirement or contractual obligation not in this User Manual, including status meetings. •Accelerated schedule •0-2 or n/4+ Separation Springs

Figure 8-1: Standard vs. Custom Lightband

8.7 Accessories

Separation Switches, Separation Connectors, and Separation Springs, may be delivered earlier than the ALB. Accessories delivered not attached to a flight ALB will not receive testing. PSC does not install spare accessories for testing as a standard service. Accessories may be installed at any step through build and test. Separation Connectors and Separation Switches may not receive the full suite of testing. All Accessories should be listed as individual line items on the PO/contract. All PSC paperwork will list parts as individual line items.

8.7.1 Separation Connectors

Separation Connectors are sold in pairs (an -Upper and -Lower half). Each half will be listed as an individual line item.

- 4000932-Upper, ALB Separation Connector Assembly Upper
- 4000932-Lower, ALB Separation Connector Assembly Lower

Note: Quantity 2 (per half, 4 per pair), NAS1352N06-7, .138-32 x .438 SHC Screws, are required to attach the ALB Separation Connector to the ALB Upper/Lower Ring. PSC does not sell fasteners and does not include loose fasteners when accessories are not attached to the ALB.

8.7.2 Separation Switches

Two parts are typically ordered for each Separation Switch (if procuring flight spares, only the Switch needs to be procured):

- 4000952 Separation Switch (includes a .375-32 x .625 x .094 thin hex nut) - this is the actual switch.
- 4000922 ALB Switch Bracket – this bracket is required to attach the switch to the ALB.

Note: Quantity 2, NAS1352N06-7, .138-32 x .438 SHC Screws, are required to attach the ALB Switch Bracket to the ALB Upper/Lower Ring. PSC does not sell fasteners and does not include loose fasteners when accessories are not attached to the ALB.

8.7.3 Separation Springs

Three parts make up a single Separation Spring

- 4000920 ALB Spring Stop
- 4000921 ALB Spring Guide
- Separation Spring, 1.06 x .79 x 53.2 Compression Spring

Note: Quantity 1, NAS1352N3-10, .190-32 x .625 SHC Screw, is required to attach spring parts to an ALB Lower Ring. PSC does not sell fasteners and does not include loose fasteners when accessories are not attached to the ALB.

To stow the Spring an ALB Spring Lock is required. See Section 11.

9. Manufacturing Process

Employees at PSC design, assemble, and test separation systems. PSC is an AS 9100-compliant organization. All of the machining and fabrication is completed by vendors qualified to PSC's standards. PSC maintains documentation of all tasks associated with flight hardware procurement, inspection, storage, assembly, test, and shipment. All of these are enveloped by PSC's quality management program. Procuring, manufacturing, and stocking are controlled by inventory management software. ALBs and their subsystems are tracked and completely traceable using their purchase order, serial number, or lot number. Just like in testing at PSC, manufacturing is done in teams. Two employees typically sign-off on steps in manufacturing procedures (one acts as the technician, the other as quality assurance) and execute a Build Complete Review (BCR) as the final step in the completion of the manufacturing procedures. PSC writes, executes and approves manufacturing procedures. PSC also takes any corrective action if anomalies arise. The customer-furnished wiring harness is not included in the manufacturing of an ALB.

10. ALB Testing and Procedures Performed by Customer

Customers often complete some of these tests and procedures after receiving the ALB.

Test or procedure	Objective	Remarks and cautions
ALB training	Learn how to operate ALB and uncover unexpected potential integration difficulties	Verify operators are trained to operate the ALB
Fit check to adjoining structures	Verify bolt patterns and clocking	Is the electrical wiring harness attached during this procedure?
System-level vibration test	Verify workmanship and modes	Will the ALB be overloaded at resonance? Are notching or force limiting methods employed? EDU ALBs are great for this test.
Electrical initiation test	Verify the initiation circuit and power system from the launch vehicle will initiate the ALB within specification. Verify adjoining vehicles will receive the proper signal upon separation.	Ensure ALB operation procedures are being followed.


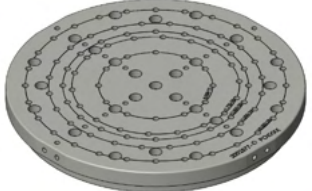
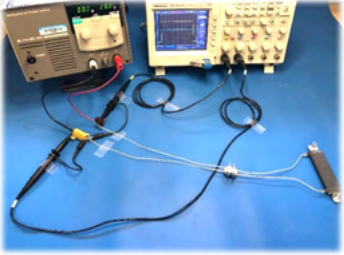
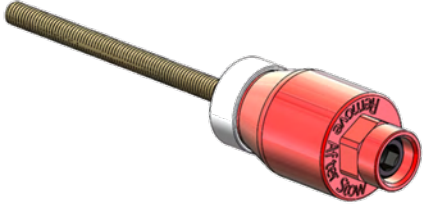

Table 10-1: Testing and other procedures



Figure 10-1: Electro-mechanical fit check and a separation test

11. Ground Support Equipment (GSE)

For program planning, several pieces of GSE are listed below that have been useful to customers in the past.

Item	Description	Graphic
Transition Ring NOT SUPPLIED NOR SOLD BY PSC	Fastens to the Upper or Lower Ring. Useful to attenuate flatness issues of adjoining structures, allow access to fasteners, simulate stiffness of adjoining structure	
Vibration Adapter Plate NOT SUPPLIED NOR SOLD BY PSC	The interface between an electro-dynamic exciter and the ALB or a Transition Ring.	
Oscilloscope, probes, power supply, 1.0Ω (10W) and 8.0 Ω (150W) resistors, 2x DE-9 breakout cables and various banana jack cables NOT SUPPLIED NOR SOLD BY PSC	Used to deploy, initiate, and record V and I	
Stow Screw ONE SUPPLIED WITH EACH ALB	Used to Stow ALB	
Spring Lock ONE SUPPLIED WITH EACH SPRING	Used to hold Separation Spring in stowed state	




Item	Description	Graphic
Crane Compliance Sling NOT SUPPLIED NOR SOLD BY PSC	Allows for compliance when mating adjoining vehicles with the ALB	
Turned-down flat head screws NOT SUPPLIED NOR SOLD BY PSC	Align an Upper or Lower ring to an adjoining structure	
1.0 inch long, #2-56 screw Typically SUPPLIED BY PSC	Aids in Separation Connector assembly	

Table 11-1: Ground support equipment

12. Packing, Unpacking, Transport, Storage and Handling

The ALB comes in a re-usable shipping container capable of holding several ALBs at once. Ship the ALB in the stowed condition. Remove any Spring Locks or Stow Screws. Encapsulate the stowed ALB in a plastic bag and seal the bag closed. Verify the ALB will be 100% surrounded by at least 1.0 inch of closed cell-foam. Label and transport the shipping container according to its value. Store inside in a temperature and humidity-controlled environment. To verify operability after an extended storage, operate the ALB to test verify in-spec initiation, separation and stowing. To reduce waste, return the empty shipping container to PSC.

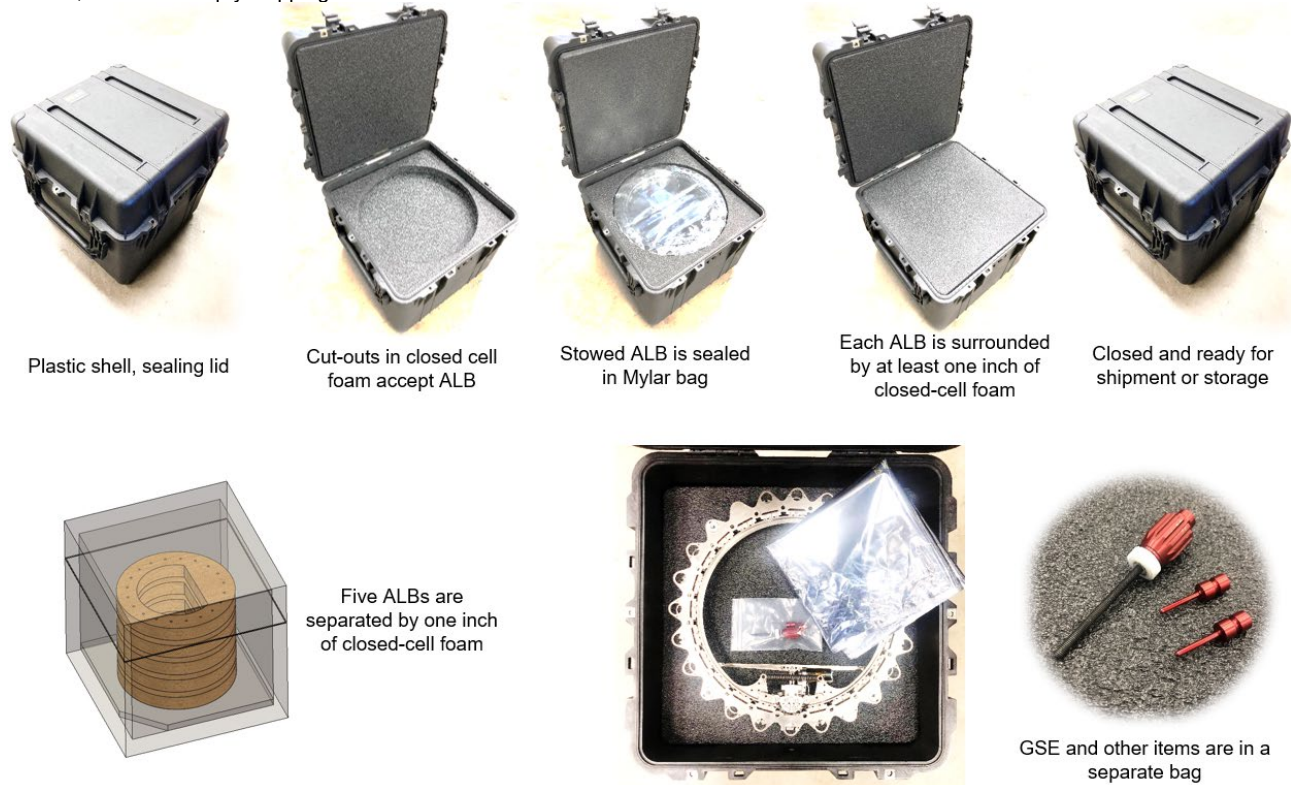


Figure 12-1: ALB Shipping

Users shall store and operate the ALB in a visibly clean environment. The Separation Connectors can collect debris when the ALB is in a deployed state. This can lead to inadvertent intermittencies. PSC recommends that the exposed Separation Connector pins be covered when in the deployed state for extended durations. Always verify mating connectors (from launch vehicle or GSE) are clean and free of FOD.

Lubricant (Braycote 601 and molybdenum disulfide mixture) is applied in several locations and shall not be removed by cleaning processes. Lubricant should be assumed to be in any rotating part or mechanism interface. The Upper Ring and the accepting Leaf Lip have no lubricant. All non-greased surfaces may be wiped (with lint-free wipes) down with isopropanol provided technicians do not allow any IPA to soak into any rotating junction.

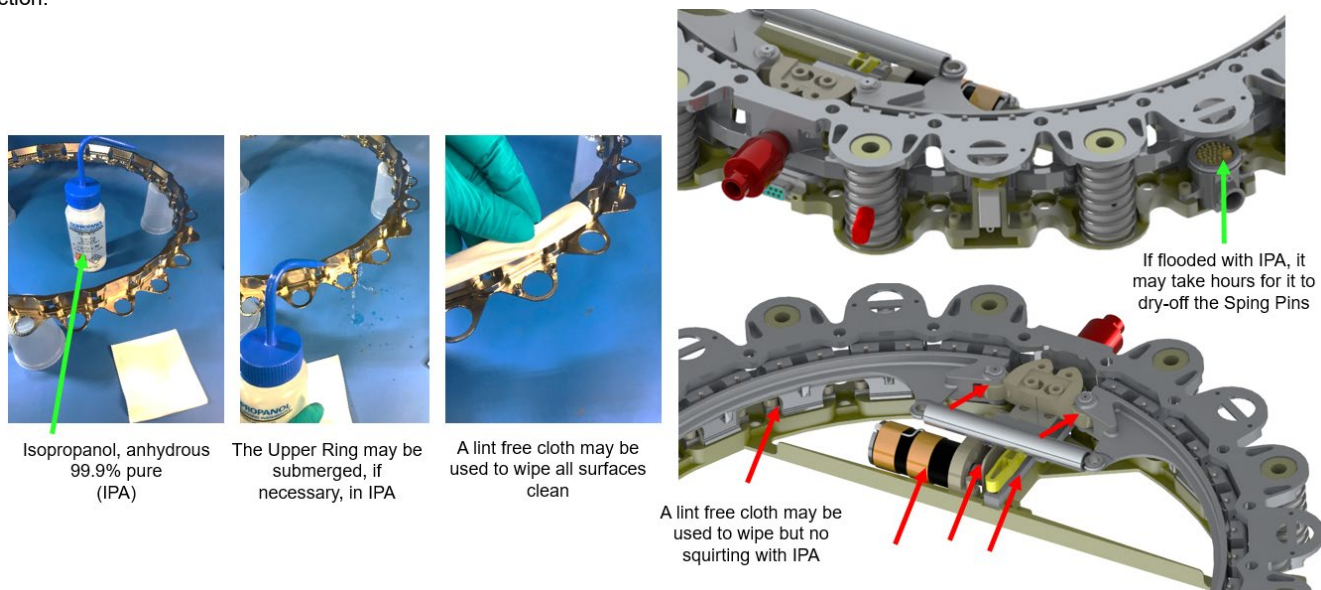


Figure 12-2: Cleaning the ALB

The ALB shall be covered when not in use. The ALB may be handled without gloves.

13. Warranty, Glossary, Revision History

13.1 Warranty

The ALB warranty is defined in *PSC Document 1001015 Warranty MLB*.

13.2 Glossary

- **ALB:** Advanced Lightband
- **ARO:** After receiving order
- **Bench-top testing:** A separation test of the ALB on a bench top. Rate and velocity information are not recovered.
- **Build Complete Review (BCR):** Verify product assembly is complete (and hence ready for test). This includes bench-top separation.
- **CAD:** Computer Aided Design
- **CCW:** Counterclockwise
- **CM:** Center of mass (also known by center of gravity, CG)
- **CRES:** Corrosion Resistant Steel
- **CTE:** Coefficient of thermal expansion
- **CVCM:** Collected volatile condensable material
- **CW:** Clockwise
- **Engineering development unit (EDU):** An ALB designated for use on the ground to allow engineers to use flight like hardware. EDU are not exposed to testing, they only receive several bench-top separation tests prior to delivery
- **EMF:** Electromotive Force
- **FEA:** Finite element analysis
- **Flight Unit:** An ALB designated for use as a hardware that will fly into space. Flight units are exposed to acceptance testing prior to delivery
- **FMEA:** Failure modes and effects analysis
- **FOD:** Foreign object debris, any article or substance, alien to a space vehicle or system, which could potentially cause damage
- **GSE:** Ground support equipment
- **IAW:** In accordance with
- **Inch (in):** English unit of distance
- **Initiation:** The Upper and Lower halves of the ALB unlock
- **IPA:** Isopropanol (Alcohol)
- **LV:** Launch vehicle
- **MLB:** Motorized Lightband (version preceding the ALB)
- **MOI:** Moment of inertia
- **Nominal Operation:** Separation of the ALB at $23 \pm 10^\circ\text{C}$, initiated within limits of Table 2-1
- **Payload:** Spacecraft or space vehicle (used interchangeably)
- **Pound (lb):** English unit of weight
- **Quality Management System (QMS):** Policies, processes and procedures required for planning and executing business
- **Separation:** The Upper and Lower halves of the ALB unlock, and the Separation Springs elongate to end of travel
- **SHC:** Socket Head Cap Screw
- **Spacecraft or Space vehicle:** payload (used interchangeably)
- **SRS:** Shock response spectrum
- **Standard for the Exchange of Product model data (STEP):** A file format used to share CAD files governed by ISO10303-21
- **Stow:** To mechanically join the Upper and Lower halves of the ALB
- **TML:** Total mass loss
- **Transition Ring:** custom aluminum interface rings attached to the ALB. Used to emulate flight boundary conditions and ease bolt attachment.
- **WRT:** With respect to

13.3 Revision History

Rev.	Issued	Written By	Released By	Change Description
-	31 July 2019	WH	CF	Initial revision. This revision is applicable to 4000906- A ALB Assembly.
A	17Sep21	CF	MT	<ul style="list-style-type: none"> Updated Table 2-1, major changes Moved Operation and Integration out of Section 3 into standalone Section 4. Section 3.1, added serial number matching requirement. Section 3.4 updated electrical schematic to include 4 wire redundant path. Section 3.5 added reference to Table 2-1. Section 3.6 added hydrazine compatibility. Section 3.14 updated with refined spring energy Section 4 updated with lessons learned and 4 wire redundant path.110 Section 5.1 updated wording, added over stow failure mode. Section 5.2 added support@planetarysystemscopr.com email Section 6 updated wording, add lot testing Section 6.1 added test summary section Section 6.2 updated name and levels Section 6.3 updated levels Section 6.4 updated levels Section 6.5 updated levels Section 6.6 updated name and levels Section 6.7 updated levels Section 6.8 added section Section 7.6 added reference to Table 2-1 Section 7.7 added reference to Section 6 and additional schedule Section 7.8 updated wording for custom springs Section 7.9 updated example Section 8.2 added additional costing Sections 8.6 and 8.7 added. Section 9 updated grammar Section on ALB Inspection removed, this is now covered in Section 14 Training and Checklist Section 11 updated Section 12 updated language Section 14 added Section 15 Appendix A added
B	07Jun22	ML	CF	<ul style="list-style-type: none"> Updated cover page with updated logo and graphic Typo fixes and grammatical changes throughout document Table 2-1: updated dim E stay out zone and latch up distance range, updated wording and symbol Fws for clarity. Figure 4-25, Figure 4-26: clarified stow screw torque at 'ping' for ALB24, increased first peak torque to 22 in lb Section 7.2: added details PSC will request from customer to ensure strength requirement compliance Section 7.8: reduced maximum number of springs for standard ALB to n/4 Section 8.1: updated payment milestones Section 8.2: updated standard lead time Figure 8-1: updated number of springs for custom Lightband Section 14: updated checklist typos Table 15-3: updated wording and symbol Fws for clarity.

14. Training and Checklist

Training is always required to operate the ALB. This may occur in person or remotely (likely in the future). Once a trainee has completed the following checklist at least three times successfully under supervision of a PSC employee, the trainee shall be considered trained. Deviation from the checklist may only occur with PSC concurrence. The checklist is the same for all hardware to facilitate the saying "Train like you fight, fight like you train". The most efficient means to retire risk associated with procedure is to follow the checklist.

Step	Section, Figure, or Table	Description	Result		Date and Time	Initials		Remark
			Value	Within Limits of Table 2-1?		Tech	QA	
Removing from Shipping container								
1	1	12	Remove the bagged, stowed ALB from the shipping container					
1	2	12	Verify all items in packing list are included					
1	3	12	Return shipping container to PSC					
	4		To Separate the ALB, use 'Operation and Integration' section					
Adding to shipping container								
2	1	12	Verify ALB is in Stow ed state					
2	2	12	Remove any Spring Locks or Stow screw s					
2	3	12	Encapsulate the stow ed ALB in a plastic bag and seal the bag closed					
2	4	12	Place in shipping container, so the ALB is bounded by foam at least one inch from maximum stayout dimensions					
2	5	12	Separately bag Stow Screw , Spring Locks, and Matrix Extraction Screw s (used in the assembly of Separation Connector)					
2	6	12	Add sufficient foam to slightly preload the foam/ALB assembly and close lid					
General								
3	1	14	Trained = individual has completed this procedure successfully three times w hile a PSC engineer has acted as QA within the past 24 months.					
3	2	-	Read and understand this manual					
3	3	-	Are Tech and QA trained?					
3	4	Figure 3-1	Record ALB Diameter [in]					
3	5	Figure 3-1	Record ALB serial number [-]					
3	6	Figure 3-1	Are serial numbers of Upper and Low er Ring identical?					
3	7	-	Record organization name					
3	8	-	Record location					
3	9	11	Gather all tools, fasteners, and other ground support equipment					
3	10	-	Verify calibration of tools and instruments					
3	11	-	At any time, if any of the items under the heading " Value" or "Within Limits of Table 2-1" are "NO", stop and proceed to 'Anomaly Reporting to PSC' below					
3	12	4.6	Required fasteners and torques are show n in Figure 4-17					
3	13	3.1	The ALB may be Stow ed or Deployed with or without adjoining structures attached					
Attaching subsystems								
4	1	3.1, 4.5	Separation Connectors and Springs may only be attached in the Deployed condition. Separation Sw itches may be attached in Stow ed or Deployed.					
4	2	4.5	Required fasteners and torques are show n in Figure 4-11					
4	3	4.5.1	Attach Separation Springs to Low er Ring					
4	4	4.5.2	Attach Separation Sw itches					
4	5	4.5.3	Attach Separation Connectors (zero torque, attached in the Separated condition)					
Attaching to Adjoining Structures								
5	1	Table 2-1, 3.8	Record the flatness of adjoining structures. Verify within tolerance for stiffness type.					
5	2	Table 2-1	Record mating bolt circle (D and n). Verify within tolerance					
5	3	4.6, Figure 4-17	(Optionally and temporarily) use turned down flat-head screw s as an alignment feature (but do not torque above 5 inch lbs.)					
5	4	4.6, Figure 4-16	Install and torque all the screw s from Upper or Low er Rings to adjoining structures making sure any temporary alignment screw s are replaced w ith flight fasteners					

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Stow Procedure									
6	1	4.8.1	Compress Springs and install all Spring Locks						
6	2	4.4	Record ds [in]						
6	3	4.8.3, Figure 4-24	Verify the Stow Screw threads by turning into the Sliding Bracket (from the -YLB side). Remove Stow Screw.						
6	4	4.8.3, Figure 4-23	Record length of threads showing on the Stow Screw. Verify length is 3 +/- .05 inch. If not, thread the screw threads through the screw head until the requirement is met. Jam nuts may be needed to free the threads from the screw head.						
6	5	Table 2-1, 4.8.3	If accessories (Separation Connector or Separation Switch) are attached, use accessory quantity and Fsc and Fsw to calculate required compression force. [lbf]						
6	6	4.7	Record stiffness of member(s) supporting any load. Verify stiffness of member(s) is less than 2,000 lb per inch (Members supporting load include anything supporting the Upper Half and Lower Half: Crane, Table, Cart, etc)						
6	7	4.8.2	Align and join the Upper and Lower Rings						
6	8	Table 2-1, Figure 3-3, Table 11-1	Record and verify H is in tolerance at three equidistant locations around the ALB using a caliper or a telescoping hole gauge			1.			
						2.			
6	9	Figure 4-25 OR Figure 4-26	Record the allowable max turns and max torque. Reference ds measure from step 6.2			3.			
6	10	4.8.3	Install Stow Screw through the radial hole in the Upper Ring						
6	11	4.8.3	Turn the Stow Screw CW until one of the following: a 'ping' is heard, the peak torque is attained, or the maximum number of turns is attained						
6	12	4.8.3	If no 'ping' is heard, then turn the Stow Screw by three turns (CCW) and power the initiator as shown in Figure 3-15 and try above step again						
6	13	Figure 4-25 OR Figure 4-26	Record peak torque and verify it is within limits [in lb]						
6	14	Figure 4-25 OR Figure 4-26	Record number of turns and verify it is within limits [-]						
6	15	Figure 4-30	Remove the Stow Screw from the ALB						
6	16	Figure 4-30	Remove all Spring Locks						
6	17	Figure 4-31 Figure 4-11	Are all Separation Connectors torqued?						
6	18	-	The ALB may now be used in spaceflight or shipping operations						
Verifying Test Circuit									
7	1	4.2	Build circuit of Figure 4-1						
7	2	4.2, Table 2-1	Close switch for duration Tp [sec]						
7	3	4.2, Table 2-1	Record V [Volts]						
7	4	4.2, Figure 4-6	Record I [A]						
7	5	4.2, Table 4-6	Record Tp [sec]						
7	6	4.2, Figure 4-4	Verify V/I = Rw [ohm]						
Initiating Separation									
8	1	Figure 4-30	If Spring Locks are installed, the ALB will not separate (ensure that is your intention)						
8	2	Table 2-1, 4.8.3	If accessories (Separation Connector or Separation Switch) are attached, a force will push apart Rings during separation even if Spring Locks are installed. This could create motion if not properly restrained. See Step 6.5 for force calculation. If weight is used to counteract accessory force, record weight used. [lbf]						
8	3	Figure 4-30	Verify Stow Screw is not attached to ALB or the ALB will not initiate						
8	4	Figure 4-1	Has Test circuit been verified? [Y/N]						
8	5	4.2	Complete circuit of Figure 4-2						
8	6	4.2, Table 2-1	Record command Tp. Close switch for duration Tp [sec]						
8	7	Figure 4-4 Table 2-1	Record actual Ip [A]						
8	8	Figure 4-5 Table 2-1	Record Voltage at the same time instance as Ip [V]						
8	9	Figure 4-4 Table 2-1	Record actual Tp [sec]						
8	10	Figure 4-5 Table 2-1	Record Tsd [sec]						
8	11	Figure 4-10 Table 2-1	Record ds [in]						
8	12	Figure 4-4 Table 2-1	Does V/Ip = Rw						
8	13	4.3	Did the ALB separate? [Y/N] (If Spring Locks were installed, manually separate the Rings to verify Separation)						

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Inspection (in the separated condition)						
9	1	Figure 3-4	Does the Separation Switch Plunger (if attached) have minimum travel of dsw?			
9	2	Figure 3-4	Do the Separation Connector Pins (if attached) have visually uniform free pin heights [-]?			
9	3	Figure 4-11	Are all accessible fasteners in place and can only be loosened with tools [-]?			
9	4	Table 2-1	Is Separation Spring stroke (deltas) within tolerance?			
9	5	Table 2-1, Figure 4-10	Is Latch-up (ds) within tolerance?			
9	6	-	Is the ALB free of any yield or damage that prevents nominal operation?			
Anomaly reporting to PSC						
10	1	-	Stop immediately and maintain the existing configuration (if safe)			
10	2	-	Thoroughly document the state of the ALB with pictures and notes. Verify the quality and focus of every picture prior to sending			
10	3	Figure 4-4 Figure 4-5	Provide the three prior operation's electrical profiles of initiation (if applicable to anomaly) as an Excel file. Ensure all data is properly formatted, titled, graphed and labeled. Sending only the raw oscilloscope .CSV files will increase PSC's response time. Ensure all date labels correspond to the actual event date			
10	4	-	Provide a copy of this as-run checklist			
10	5	-	Provide any relevant operation details including, but not limited to:			
10	6	-	a) Adjoining structures. To what is the Lightband bolted?			
10	7	-	b) How many Lightband operations have been performed?			
10	8	-	c) Reason for operation. Was it an environmental test, avionics verification, integration, etc.? This informs potential failure modes			
10	9	-	d) Are all components accessible? Are there any access restrictions? Is the Lightband in a clean room? Is the ALB in orbit?			
10	10	-	Report all of the above to PSC at psc.support@rocketlabusa.com			
Nominal reporting to PSC						
11	1	-	Following final integration, send this document to psc.support@rocketlabusa.com			
11	2	Figure 4-4 Figure 4-5	Following space-flight, send PSC V and I time histories and rotation rate data as measured in the flight separation to psc.support@rocketlabusa.com			

Figure 14-1: ALB Operations Checklist

15. Appendix A: ALB Accessories

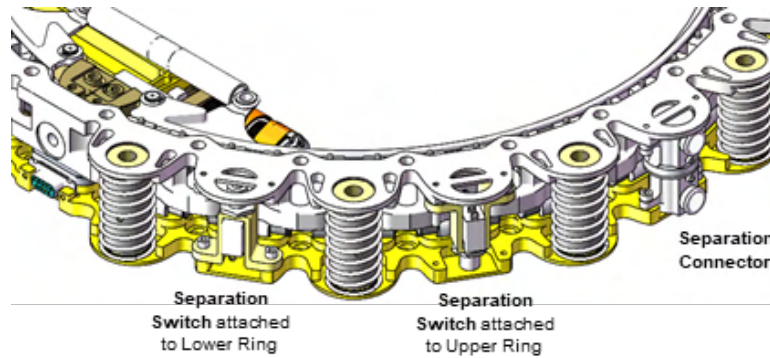


Figure 15-1: ALB Accessories

15.1.1 ALB Separation Connector

PSC has developed a 30 pin Separation Connector for use with the ALB. This connector has been spaceflight qualified alongside the ALB and has flight heritage.

Separation Connectors pairs have two parts: a -Upper and -Lower half.

- 4000932-Upper, ALB Separation Connector Assembly Upper
- 4000932-Lower, ALB Separation Connector Assembly Lower

Note: Quantity 2 (per half, 4 per pair), NAS1352N06-7, .138-32 x .438 SHC Screws, are required to attach the ALB Separation Connector to the ALB Upper/Lower Ring. PSC does not sell fasteners.

See Figure 15-2 for overview. See Table 2-1 for parameters, Table 15-1 lists a subset specific to the Separation Connector. See Figure 4-11 and Sections 4.5 and 4.5.3 for attachment. See Section 15.1.4 for wiring details. See Section 8.7.1 for purchasing.

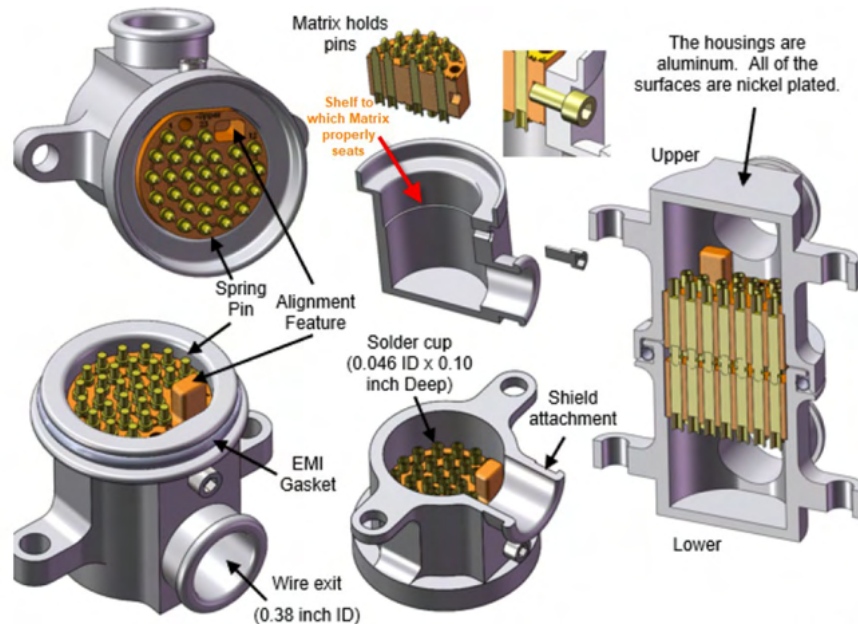


Figure 15-2: ALB Separation Connector Overview

Separation Connector	Energy per separation connector [J]	Kec	0.001	-
	Spring Constant [lbf/in]	Kc	38	-
	Force per connector, stowed [lbf]	Fsc	5.1	-
	Force per connector, deployed [lbf]	Fdc	1.9	-
	Stroke [in]	-	0.110	-
	Current, each pin, steady state, vacuum [A]	Iscv	3.00	-
	Current, each pin, steady state, STP [A]	Iscs	5.00	-
	Pulsed current through pin [A]	Ipv	5.00	-
	Mated pin-pair contact resistance [Ohm]	Rsc	0.04	± 0.02
	Mated pair mass + fasteners [lbm]	-	0.099	± 0.02
	Pin Solder Cup Internal Diameter [inch]	Pid	0.05	-
	Pin Solder Cup Internal Depth [inch]	Pdepth	0.100	-

Table 15-1: ALB Separation Connector Parameters

15.1.2 ALB Separation Switch

PSC has developed a Separation Switch for use with the ALB. This switch has been spaceflight qualified alongside the ALB and has flight heritage.

Two parts make up a Separation Switch:

- 4000952 Separation Switch (includes a .375-32 x .625 x .094 thin hex nut) - this is the actual switch.
- 4000922 ALB Switch Bracket – this bracket is required to attach the switch to the ALB.

Note: Quantity 2, NAS1352N06-7, .138-32 x .438 SHC Screws, are required to attach the ALB Switch Bracket to the ALB Upper/Lower Ring. PSC does not sell fasteners.

See Figure 15-3 for overview. See Table 2-1 for parameters, Table 15-2 lists a subset specific to the Separation Switch. See Figure 4-11 and Sections 4.5 and 4.5.2 for attachment. See Section 15.1.4 for wiring details. See Section 8.7.2 for purchasing.

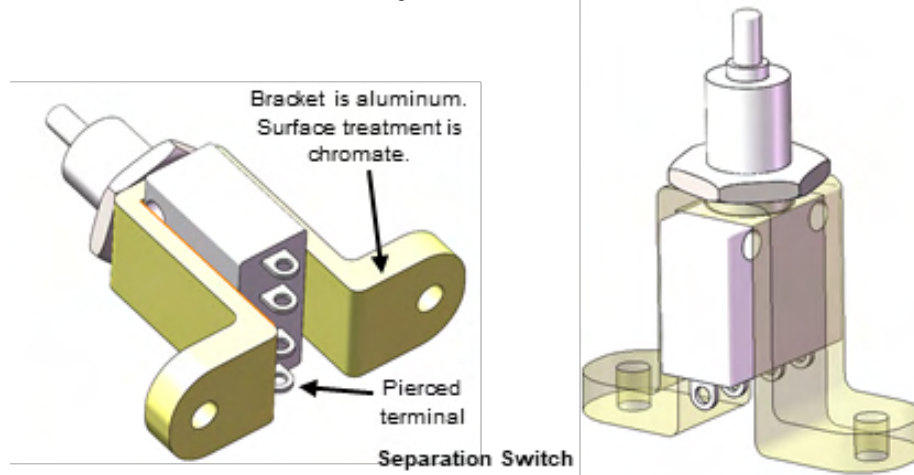


Figure 15-3: ALB Separation Switch Overview

Separation Switch	Energy per separation switch [J]	Kes	0.02	-
	Spring Constant [lbf/in]	Ks	14.0	-
	Force per switch, stowed [lbf]	Fsw	3.7	-
	Force per switch, deployed [lbf]	Fds	0.9	-
	Stroke [in]	dsw	0.21	± 0.05
	Current, steady state, vacuum [A]	Iscv	5.0	-
	Contact resistance [Ohm]	Rsw	<0.025	-
	Mass + fasteners [lbm]	-	0.058	± 0.02

Table 15-2: ALB Separation Switch Parameters

15.1.3 Separation Springs

PSC has developed Separation Springs for use with the ALB. These springs have been spaceflight qualified alongside the ALB and have flight heritage.

Three parts make up a single Separation Spring

- 4000920 ALB Spring Stop
- 4000921 ALB Spring Guide
- Separation Spring, 1.06 x .79 x 53.2 Compression Spring

Note: Quantity 1, NAS1352N3-10, .190-32 x .625 SHC Screw, is required to attach spring parts to an ALB Lower Ring. PSC does not sell fasteners.

To stow the Spring an ALB Spring Lock is required. See Section 11.

See Table 2-1 for parameters,

Table 15-3 lists a subset specific to the Separation Springs. See Figure 4-11 and Sections 4.5 and 4.5.1 for attachment. See Section 8.7.3 for purchasing.

Separation Springs	Energy per spring [J]	e	2.45	-
	Spring Constant [lbf/in]	Ks	5.85	-
	Force per spring, stowed [lbf]	Fss	19.9	-
	Force per spring, deployed [lbf]	Fsd	8.8	-
	Stroke [in]	deltas	1.890	± 0.025
	Weight Supported per Spring when stowing [lb]	Fws	50.0	max
	Spring assembly + fastener [lbm]	-	0.087	-

Table 15-3: ALB Separation Spring Parameters

15.1.4 Wiring Separation Switch and Separation Connector

In the beginning of programs, engineers and program managers often underestimate the cost, mass, and size of wiring harnesses. This is due in part to the difficulty of modeling a harness using CAD software. Harnesses sometimes cost and weigh more than the ALB. Additionally, poorly designed harnesses can obstruct access to the ALB fasteners. If the net shape of the harness is not predetermined, it may not fit and will require extensive re-work. As such it is **absolutely essential** to complete a detailed CAD model of the wiring harness. PSC does not supply harnesses from the ALB or through the ALB. PSC recommends the simplest possible harness design using the smallest quantity of Separation Connectors and Separation Switches.

General Guidance

- 1) Practice this procedure. At PSC all hand soldering is completed IAW NASA-STD 8739.3 with Change 5 or IPC J-STD-001FS (or more recent). All soldering of flight hardware is performed by certified personnel.
- 2) For all soldering, use soldering flux and solder per the most recent revision of IPC-STD-001 Space Applications Addendum.
- 3) Clean flux with 99% pure Isopropanol (IPA).
- 4) Set solder temperature to 315 C, do not exceed three (3) seconds of heating.

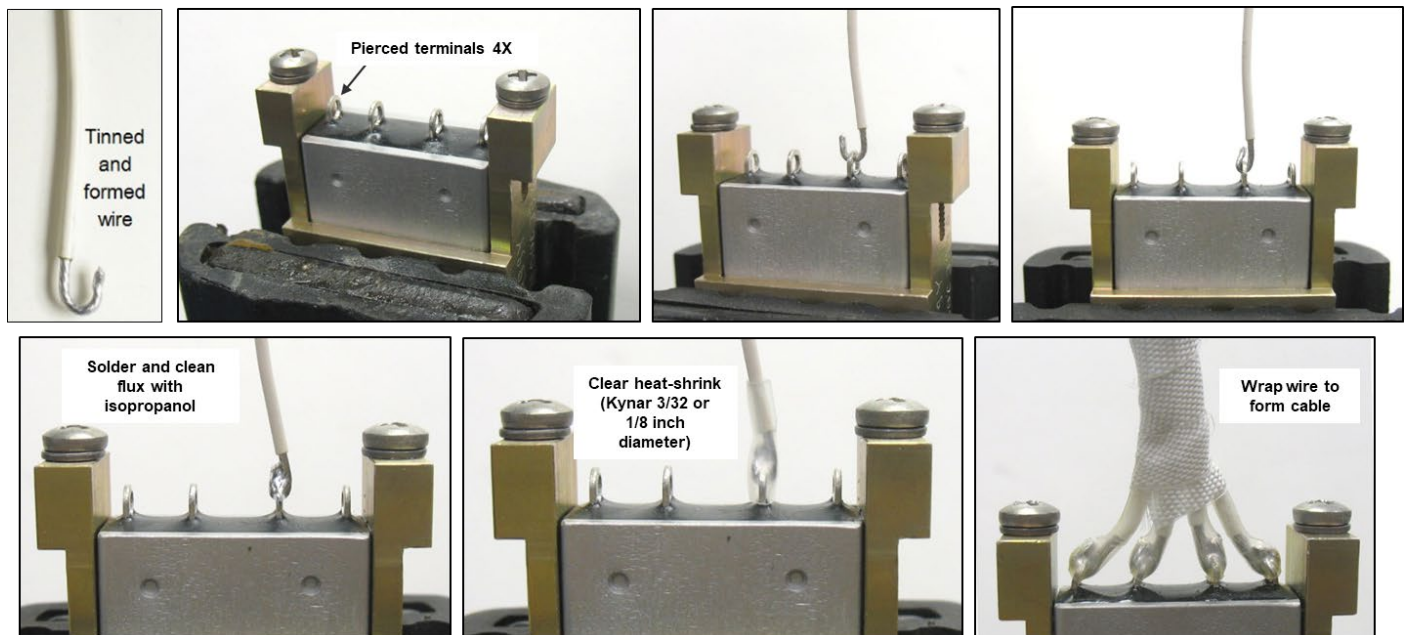


Figure 15-4: Wiring of Separation Switch (MLB switch bracket shown)

Join the Separation Switch to a Switch Bracket on the Upper or Lower Ring using the supplied .38-32 thin hex nut. Or alternatively, keep the Switch Bracket attached to the Switch throughout the wiring procedure, and then use NAS1352N06-7, .138-32 x .438 SHC Screws to attach to the Upper or Lower Ring.

Nothing shall extend below the interface of the Switch Bracket.

Potting of the Separation Switch is not recommended because it is difficult to control where the potting material may migrate to prior to curing. PSC does not have a recommended potting material and process. PSC qualified the Switch without the use of additional potting. If potting is used ensure nothing extends past the Switch body or below the Bracket's interface.



Figure 15-5: Wiring of Separation Connector

Join the Separation Connectors to Upper or Lower Rings. Upper Connector to Upper Ring, Lower Connector to Lower Ring. Loosely attach with provided fasteners. Separation Connectors need to self-align during the first Stow. The fasteners will be torqued during the Stow Procedure.

Potting of the Separation Connector is not recommended because it is difficult to control where the potting material may migrate to prior to curing. Potting may inadvertently be applied to conductors or housing. Similarly, loopbacks may be too long inside the housing, preventing proper seating of Matrix. PSC does not have a recommended potting material and process. PSC qualified the Separation Connector without the use of potting. If potting is used, ensure that the matrix fully seats against housing hard stop. When fully installed the matrix should float within the connector housing. All pins on both Connector halves shall be visibly below the top plane of the Housing.

Ensure that any loop backs inside the housing have sufficient clearance. Nominal dimensions can be determined from supplied STEP models.

The unused features to fasten the Separation Switch or Separation Connector in the Upper Ring and Lower Ring may be used to secure a section of wiring harness. Beware of any possibility that the wiring or harness may move and inhibit ALB operation.

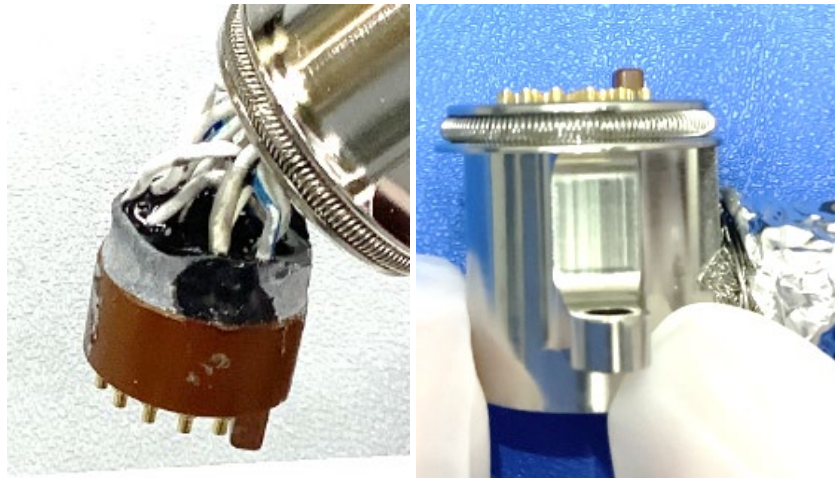


Figure 15-6: Loopbacks too long did not allow for matrix to seat, BAD

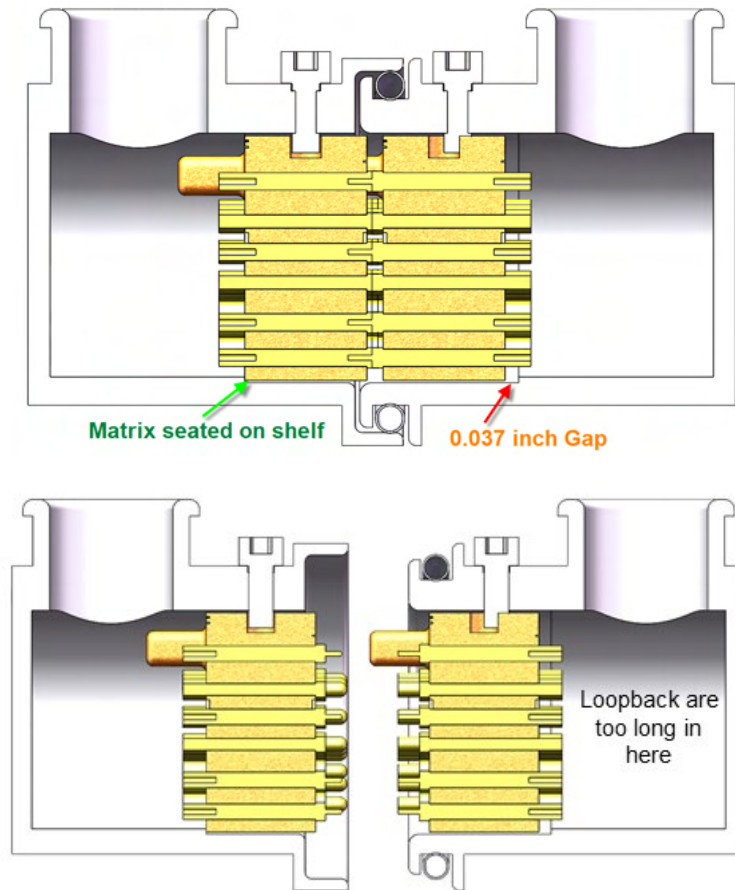


Figure 15-7: The Left Connector shows Matrix properly seated in the Housing, Right Connector is incorrect