

# ADVANCED LIGHTBAND

User's Manual | 2003336F

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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 PSC  
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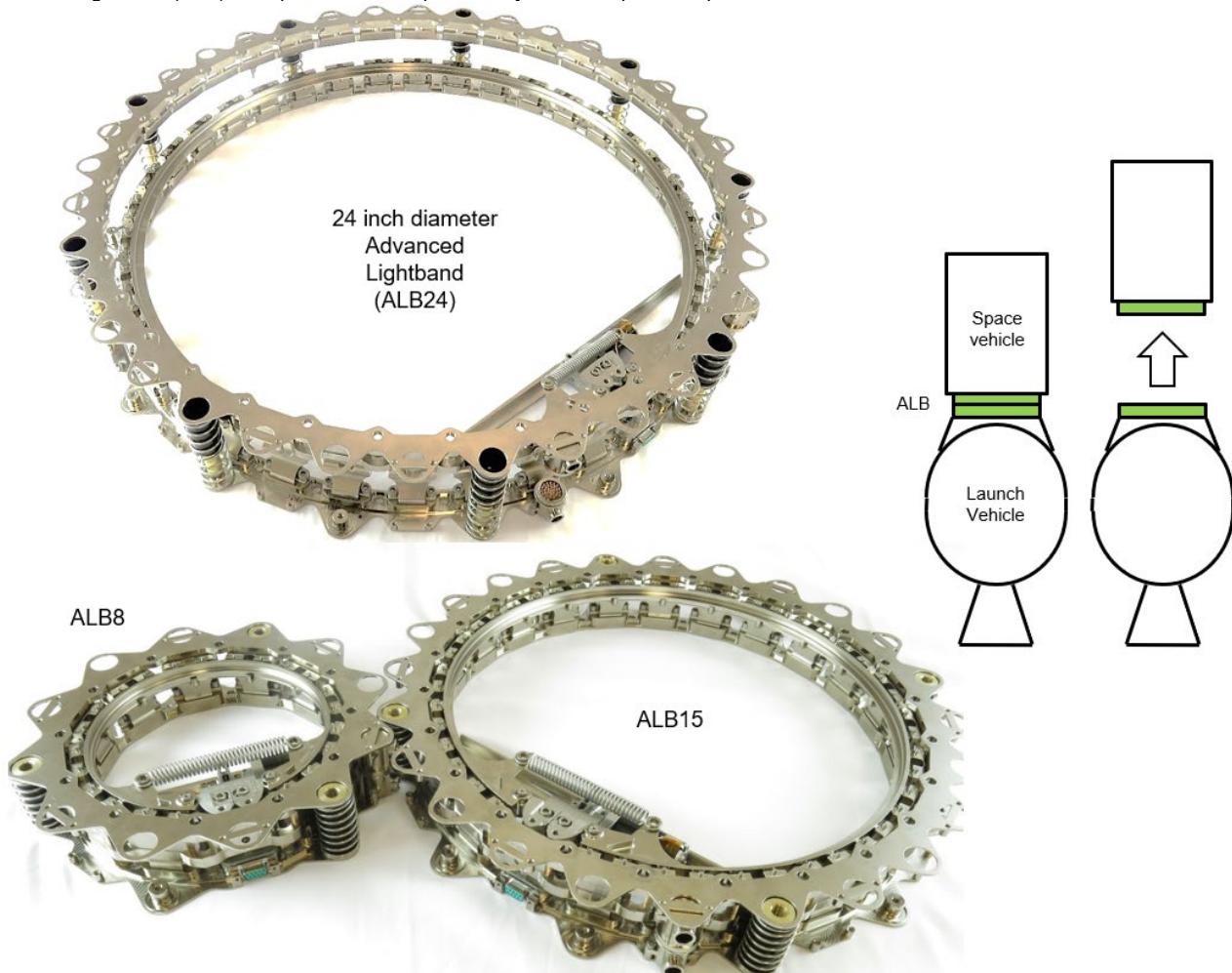
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# 1. Revision History

Rev.	Issued	Written By	Released By	Change Description
- to D	See previous revisions			
E	22Aug24	BB/DJ	RJB	<p>Updates per ECN131 as follows:</p> <ul style="list-style-type: none"> <li>○ Table 3-1: Updated Ts and To to reflect new temps. Operating T now -24 to +69, survival T now -44 to +89</li> <li>○ Section 3.1: Updated section 3.1 to say "Only Rev E ALBs and later are to be operated below 24V."</li> <li>○ Section 4.15: Updated to reflect new Lifecycle parameters</li> <li>○ Table 7-2 Updated: <ul style="list-style-type: none"> <li>▪ Build Verification: Removed <math>\geq</math> signs since it is stated that values may be exceeded.</li> <li>▪ Random Vibration: Added row below Duration to show Excitation axes as X, Y, Z for Qualification, Prototest, and Flight (acceptance) tests.</li> <li>▪ TVAC: <ul style="list-style-type: none"> <li>• Updated Ts and To to reflect new temperatures. Operating now -24 to +69. Survival now -44 to +89.</li> <li>• Add a row below Temperature for Pressure as &lt;1.0E-4 Torr for Qualification, Prototest, and Flight (acceptance).</li> </ul> </li> <li>▪ Shock: Reference Section 7.5, not Figure 7-3:</li> <li>▪ Separation: <ul style="list-style-type: none"> <li>• Renamed section to "Benchtop Separations".</li> <li>• Removed min in parameter column.</li> </ul> </li> <li>▪ Separation Reliability: <ul style="list-style-type: none"> <li>• Added row for separation reliability testing.</li> <li>• Added separations parameter as "Not Performed" for Qualification, Prototest, Flight (Acceptance) and EDU.</li> </ul> </li> <li>▪ Fatigue: References Section 7.9 not Figure 7-7.</li> </ul> </li> <li>○ Sections 7.2 thru 7.8 <ul style="list-style-type: none"> <li>▪ Removed all tables redundant to Table 7-2</li> <li>▪ Figure 7-2: Removed vertical temperature axis values.</li> </ul> </li> <li>○ Section 7.5: Updated Figure 7-3 Qual Shock values per 2004772 ALB 17V Qualification Shock Test and new shock fixture.</li> <li>○ Section 7.7: <ul style="list-style-type: none"> <li>▪ Renamed to "Separation Reliability Testing (Custom Test)</li> <li>▪ Updated description to remove references to benchtop separations</li> </ul> </li> <li>○ Section 7.6: <ul style="list-style-type: none"> <li>▪ Added and named section "Benchtop Separation Testing"</li> <li>▪ Added benchtop testing description and added Figure 7-4</li> </ul> </li> <li>○ Removed note in Figure 4-5 schematic that stated "DC Motor polarity does not matter"</li> </ul>
F	30Oct24	RJB	DJ	<ul style="list-style-type: none"> <li>• Revised Table 7-2: <ul style="list-style-type: none"> <li>○ TVAC qualification temperatures from -44 to +89 to -34 to +79 to reflect cycling temperature range</li> <li>○ Removed Prototest column</li> <li>○ Changed Benchtop Separations to Benchtop Operations</li> <li>○ Updated TVAC qualification temperature cycles min from 10 to 12</li> </ul> </li> <li>• Removed Prototest information from sections 7.3 &amp; 7.5</li> <li>• Section 9.2: Updated lead time language</li> <li>• Section 7.3: Updated qual level in Figure 7-1</li> <li>• Section 7.5: Updated labelling in Figure 7-3</li> <li>• Section 9.3: Added copies of as-run test reports to deliverables</li> <li>• Table 3-1: Corrected Table 4-4 reference</li> </ul>

## 2. Introduction

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



**Figure 2-1: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 Planetary Systems Corp by Rocket Lab (PSC-RL) 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 1<sup>st</sup> modes and reduces deflection.
4. **All-inclusive product** The ALB can accommodate 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. and larger springs produce more separating velocity.
13. **Backwards compatible and pyro-pulse compatible** Accepts same connector and electrical pulse as MLB.



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



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

### 3. 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	
		C	5.410	9.142	10.410	12.410	15.660	17.258	20.660	21.410	min	
		E	0.239	2.130	2.766	3.770	5.383	6.123	7.780	8.151	max	
		H									max	
	Latch-up distance [in]			ds	.475 to -.090	.475 to -.090	.475 to -.090	.475 to -.090	.075 to -.135	.075 to -.165	.075 to -.175	
Mass Properties (Does not include accessories)	Mass [lb <sub>m</sub> ]	Upper Assembly	1.24	1.78	1.96	2.20	2.71	3.00	3.52	3.55		
		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	± 5%	
	Center of Mass [in]	X <sub>LB</sub>	1.03	1.04	1.05	1.04	1.05	1.07	1.07	1.07		
		Y <sub>LB</sub>	0.58	0.85	0.92	1.00	1.12	1.19	1.28	1.26		
		Z <sub>LB</sub>	0.11	0.08	0.08	0.07	0.06	0.06	0.05	0.05		
		X <sub>LB</sub> , Upper Assembly	1.60	1.61	1.61	1.61	1.61	1.61	1.60	1.61		
	Mass Properties (Does not include accessories)	Y <sub>LB</sub> , Upper Assembly	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
		Z <sub>LB</sub> , Upper Assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
		X <sub>LB</sub> , Lower Assembly	0.82	0.81	0.81	0.81	0.81	0.80	0.80	0.80	0.80	
	Inertia [lb <sub>m</sub> ·in <sup>2</sup> ] (Measured about CM in stowed state)	Y <sub>LB</sub> , Lower Assembly	0.80	1.20	1.31	1.41	1.62	1.77	1.93	1.86		
		Z <sub>LB</sub> , Lower Assembly	0.15	0.12	0.11	0.10	0.08	0.08	0.07	0.07	0.07	
		I <sub>xx</sub>	58	184	250	386	682	852	1,350	1,522		
	Inertia [lb <sub>m</sub> ·in <sup>2</sup> ] (Measured about CM in stowed state)	I <sub>yy</sub>	29	87	117	179	316	393	624	705		
		I <sub>zz</sub>	33	102	138	212	373	466	735	826		
		I <sub>xx</sub> , Upper Assembly	22	66	89	133	238	311	497	533		
	Inertia [lb <sub>m</sub> ·in <sup>2</sup> ] (Measured about CM in stowed state)	I <sub>yy</sub> , Upper Assembly	11	33	45	67	120	156	249	267		
		I <sub>zz</sub> , Upper Assembly	11	33	45	67	120	156	249	267		
		I <sub>xx</sub> , Lower Assembly	35	116	158	250	438	534	844	980		
	Inertia [lb <sub>m</sub> ·in <sup>2</sup> ] (Measured about CM in stowed state)	I <sub>yy</sub> , Lower Assembly	17	53	71	112	195	236	374	437		
		I <sub>zz</sub> , Lower Assembly	20	66	90	142	248	302	476	549		
		X <sub>LB</sub> (Axial) [lb/bolt]	P <sub>eq</sub>	1,720								
Loading & Boundaries	Line Loads	Y <sub>LB</sub> or Z <sub>LB</sub> (Shear) [lb/bolt]	Q	646								
	Stiffness about X <sub>LB</sub> [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 <sub>LB</sub> or Z <sub>LB</sub> [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 4-4)			0.004	0.007	0.008	0.008	0.009	0.011	0.013	0.013	
Electrical Initiation	Required flatness of adjoining structure if adjoining structure is "stiff" [in] (see table 4-4)			0.003	0.005	0.006	0.006	0.007	0.008	0.010	0.010	
	Voltage, Pn 1-4) [V]		V	See table 3-2								
	Motor terminal resistance [Ohm]		R <sub>w</sub>	5.9 to 11.4								
	Motor terminal inductance [mH]		H <sub>m</sub>	0.746								
	Peak current [A]		I <sub>p</sub>	5.4								
	Minimum supplied current to the ALB [A]		I <sub>min</sub>	3.3								
	Time to apply power [s]		T <sub>p</sub>	0.1 to 1								
	Time to Initiate [s]		T <sub>i</sub>	0.005 to 0.035								
	Time to spin down [s]		T <sub>sd</sub>	>0.3								
	Free running current, maximum [A]		I <sub>frm</sub>	<0.2								
Thermal-vacuum	No Fire Current [A]		NFC	0.02								
	Max resistance, through Lightband [Ohm]		R <sub>th</sub>	<0.01								
	Thermal resistance, X direction [°C/W]		K <sub>x</sub>	0.392	0.267	0.241	0.209	0.172	0.158	0.135	0.130	
	Survival Temperature[°C]		T <sub>s</sub>	-44 to +89								
	Operating Temperature[°C]		T <sub>o</sub>	-24 to +69								
Accessories	Pressure [Torr]		P <sub>atm</sub>	<10 <sup>-4</sup>								
	Separation Springs	Spring Radius [in]		R <sub>s</sub>	4.788	6.701	7.344	8.360	9.992	10.786	12.493	12.878
		Energy per spring [J]		e	± 0.005							
		Spring Constant [lbf/in]		K <sub>s</sub>	5.85							
		Force per spring, stowed [lbf]		F <sub>ss</sub>	19.9							
		Force per spring, deployed [lbf]		F <sub>sd</sub>	8.8							
		Stroke [in]		delta <sub>s</sub>	1.890							
		Weight Supported per Spring when stowing [lb]		F <sub>ws</sub>	50.0							
Accessories	Spring assembly + fastener [lbm]		S <sub>max</sub>	0.087								
	Standard Qty. of Separation Springs [-]		3	3	4	3	4	4	4	3		
	Maximum Qty. of Separation Springs [-]		6	9	10	12	14	14	16	18		
	X		X <sub>0</sub>	0.0003	0.0023	0.0023	0.0023	0.0008	0.0008	0.0008	0.0008	
	Y		Y <sub>0</sub>	0.0002	0.0010	0.0011	0.0011	0.0024	0.0024	0.0024	0.0024	
	Z		Z <sub>0</sub>	0.0092	0.0008	0.0028	0.0028	0.0061	0.0061	0.0061	0.0061	
	Connector and Switch Radius [in]		R <sub>c</sub>	4.724	6.637	7.280	8.296	9.928	10.722	12.429	12.814	
	Max. sum of Sep. Connector and Sw itch Qty. [-]		5	8	9	11	13	13	15	17		
	Energy per separation connector [J]		K <sub>ec</sub>	0.001								
	Spring Constant [lbf/in]		K <sub>s</sub>	38								
Separation Connector	Force per connector, stowed [lbf]		F <sub>sc</sub>	5.1								
	Force per connector, deployed [lbf]		F <sub>dc</sub>	1.9								
	Stroke [in]		d <sub>sc</sub>	0.110								
	Current, each pin, steady state, vacuum [A]		I <sub>scv</sub>	3.00								
	Current, each pin, steady state, STP [A]		I <sub>scsa</sub>	5.00								
	Pulsed current through pin [A]		I <sub>pv</sub>	5.00								
	Mated pin-pair contact resistance [Ohm]		R <sub>sc</sub>	0.04								
Separation Switch	Mated pair mass + fasteners [lbm]		M <sub>sc</sub>	0.099								
	Energy per separation switch [J]		K <sub>es</sub>	0.02								
	Spring Constant [lbf/in]		K <sub>s</sub>	14.0								
	Force per switch, stowed [lbf]		F <sub>sw</sub>	3.7								
	Force per switch, deployed [lbf]		F <sub>ds</sub>	0.9								
	Stroke [in]		d <sub>sw</sub>	0.21								
	Current, steady state, vacuum [A]		I <sub>scv</sub>	5.0								
Life	Contact resistance [Ohm]		R <sub>sw</sub>	<0.025								
	Mass + fasteners [lbm]		M <sub>sc</sub>	0.058								
	EDU Post-SHIP Deployments [-]		N <sub>eds</sub>	50								
	Flight Post-SHIP Deployments [-]		N <sub>fps</sub>	10								
	Storage (Stowed or Deployed) [year]		T <sub>storage</sub>	3								

Table 3-1: Parameters

### 3.1 Launch Vehicle Supply Voltage to ALB

ALB Rev	Sym.	Value
D & Earlier	V	24-32
E & Later		17-36

Table 3-2: ALB Supply Voltage Ranges

Supply voltage from launch vehicle is as measured at DE-9 connector pins. Only Rev E and later ALBs are to be operated below 24V. Recommended minimum voltage is 24V to optimize torque margin. 36V is permissible for flight but not recommended for ground operations. See Figure 4-1 for ALB Assembly Rev marking.

Increasing the pulse length for motor activation on initiation is not detrimental to the ALB but is also not value adding for deployment.

## 4. ALB Description

### 4.1 Part Marking

Each ALB is marked with its assembly number, revision, and serial number in the vicinity of the DE-9 connector on the Upper Ring and on the  $-Z_{LB}$  or  $+Z_{LB}$  side of the motor on the Lower Ring (See Figure 4-1). The Upper and Lower Rings are matched pairs, the serial numbers shall match.

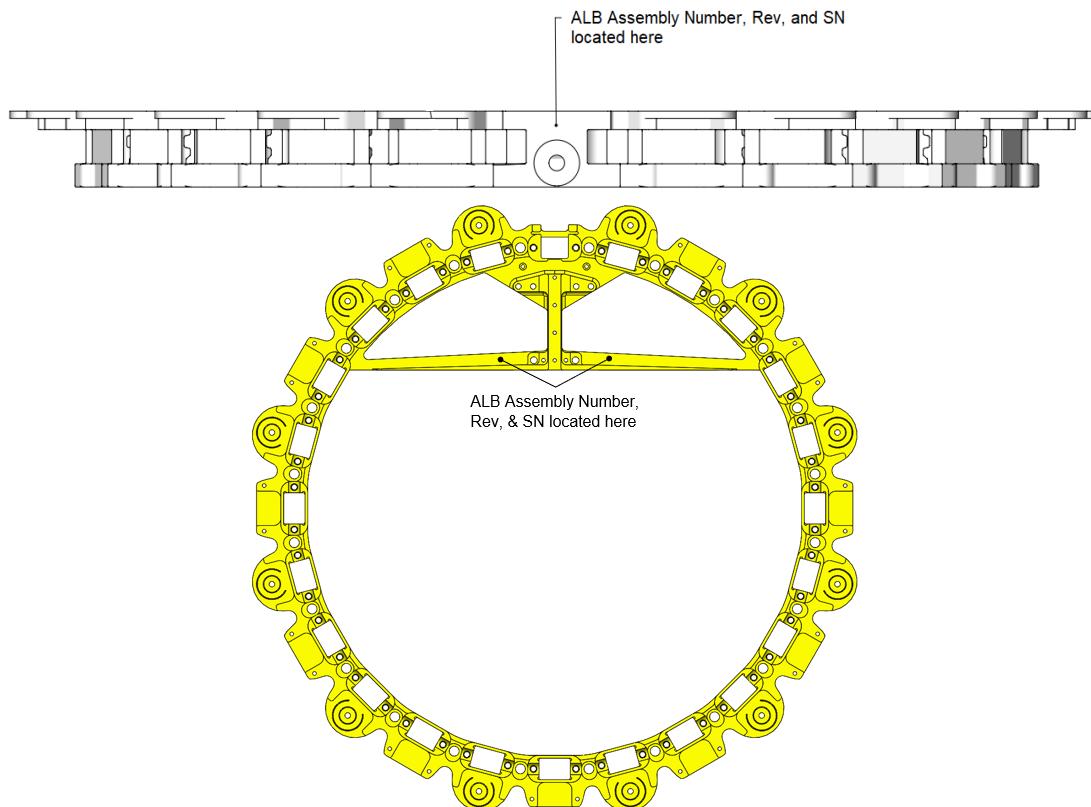


Figure 4-1: ALB Part Marking Location

### 4.2 Tolerance on Dimensions

Precision	Tolerance [unit]
X.XXX	$\pm 0.005$
X.XX	$\pm 0.010$
X.X	$\pm 0.030$
X	$\pm 1.000$

Table 4-1: PSC-RL distance tolerances

### 4.3 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.

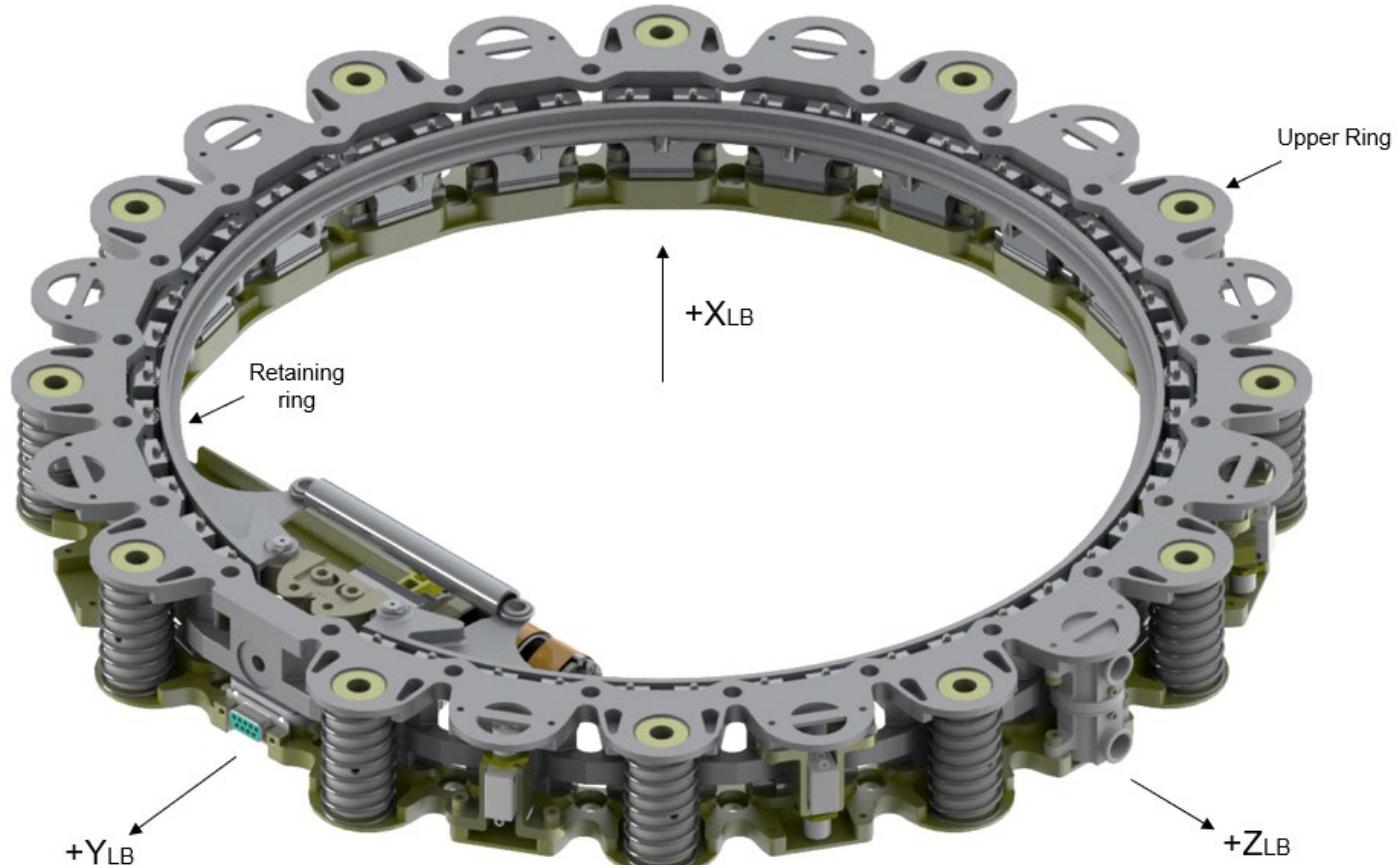


Figure 4-2: Stowed ALB

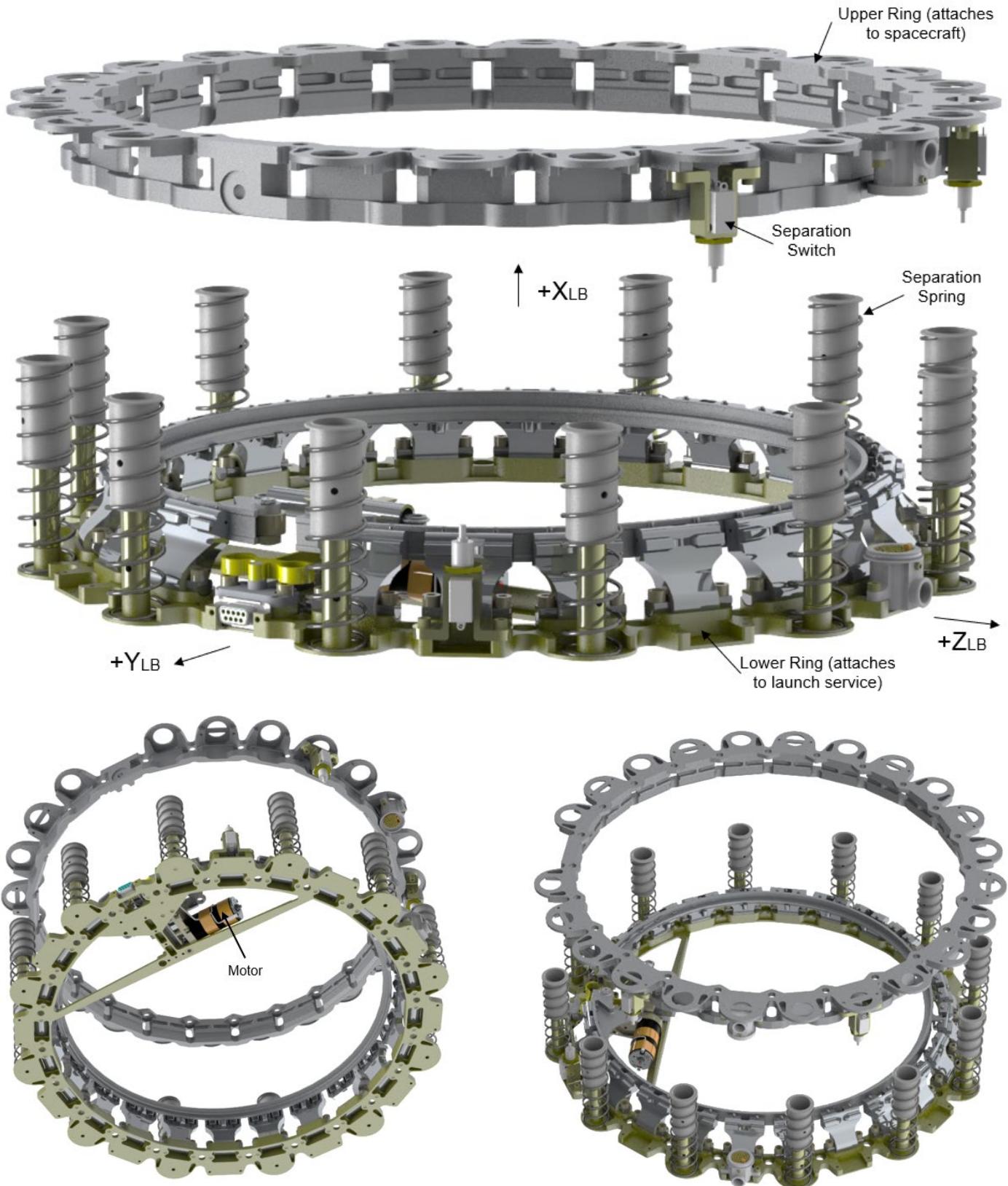


Figure 4-3: Separated ALB

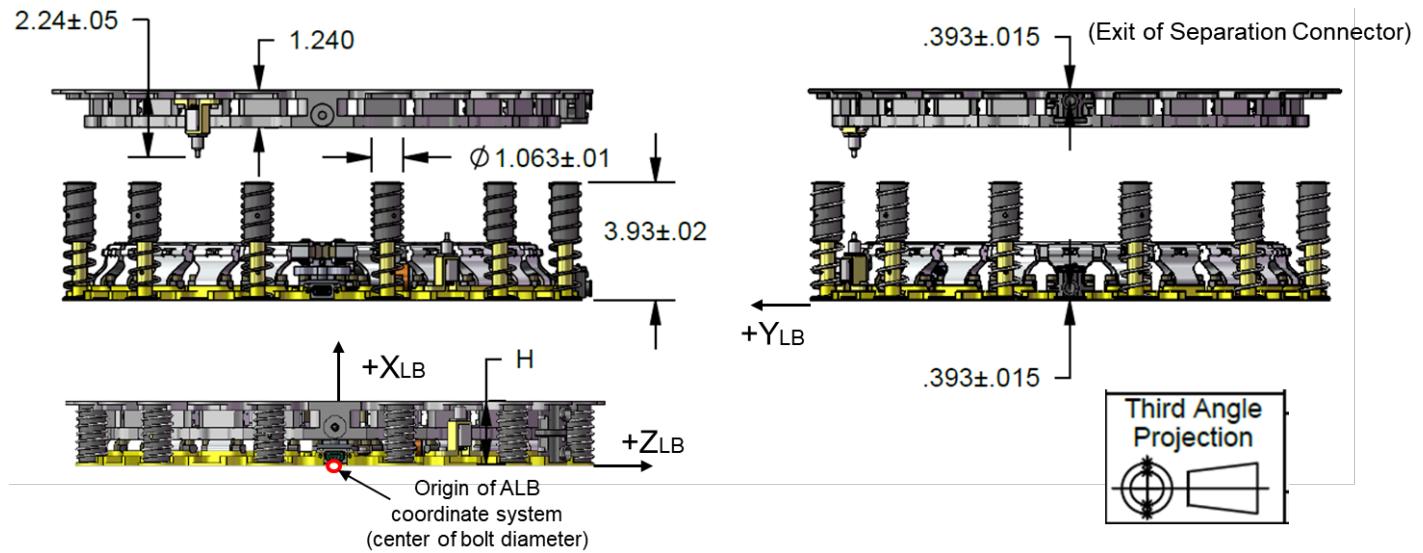


Figure 4-4: Origin, Deployed and Stowed Dimensions

#### 4.4 Electrical Interface

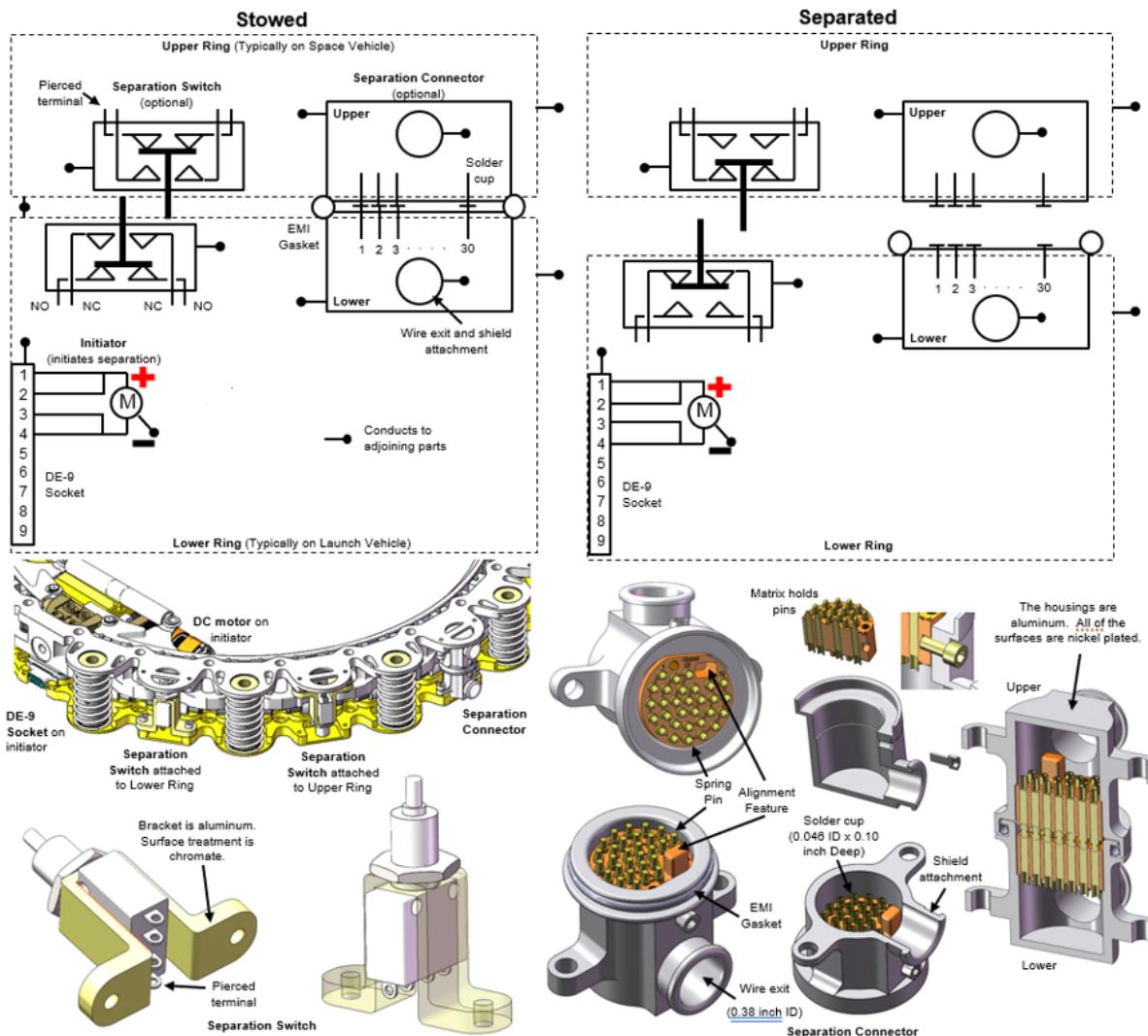


Figure 4-5: Schematic

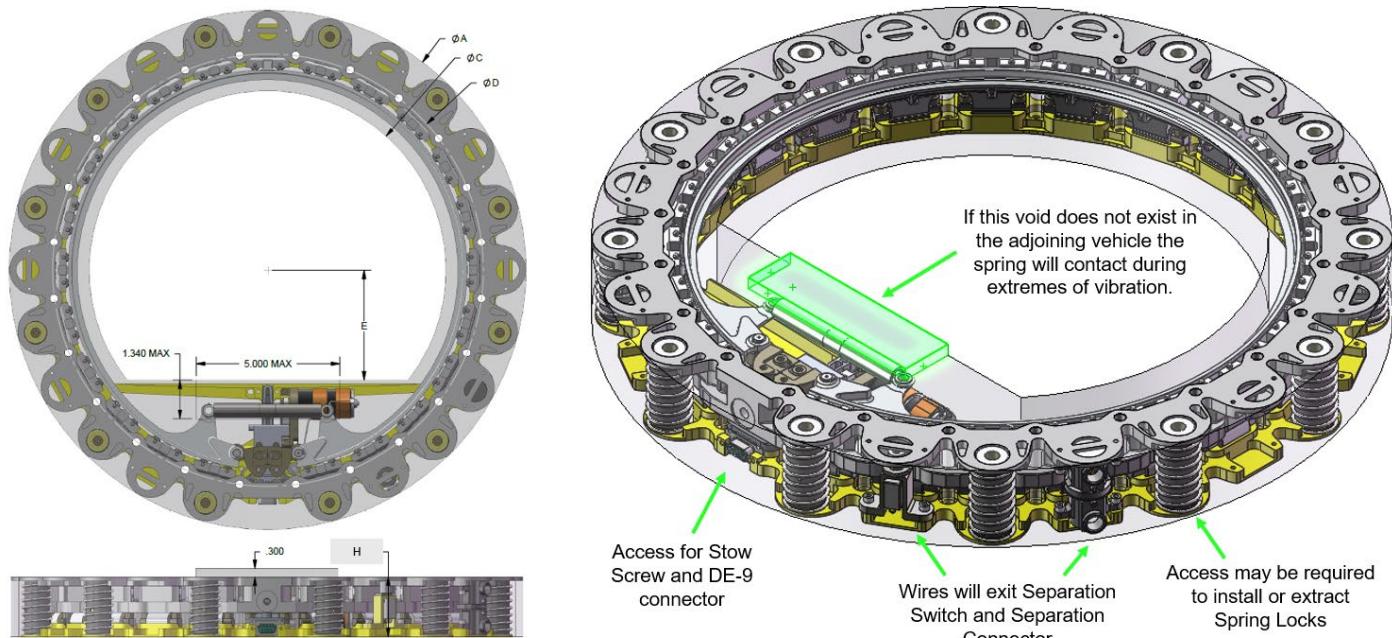
## 4.5 Motor Polarity

Successful initiation of the ALB requires the Motor to be wired for a specific polarity. The required wiring orientation is: Motor positive lead connected to Pins 1 & 2 and Motor negative lead connected to Pins 3 & 4 of DE-9 connector.

## 4.6 Separation Switch

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.

## 4.7 Accessibility and Stay-out Zones



**Figure 4-6: 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 3-1 for stay-out zone dimensions.

## 4.8 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 4-2: Materials and Surface Treatments

## 4.9 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 3-1. Higher fidelity stiffness estimations of the ALB can be determined via FEM.

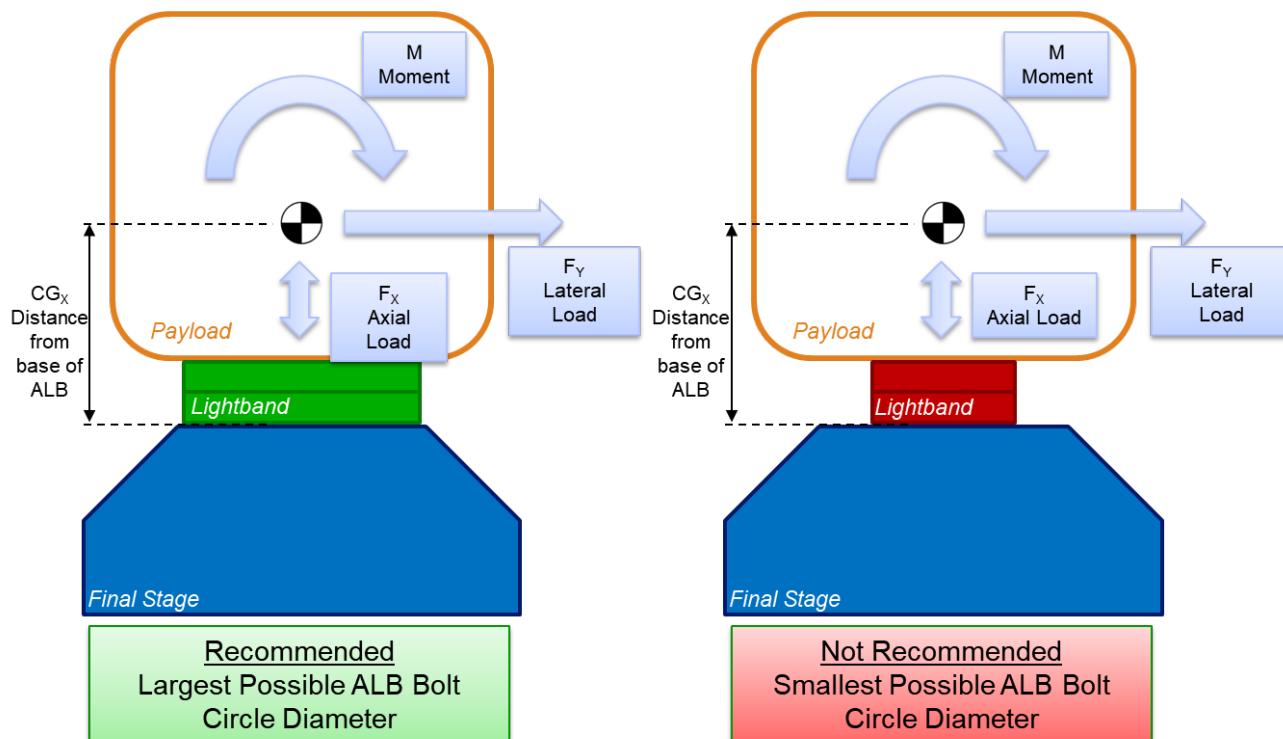


Figure 4-7: Larger diameter ALBs are stiffer and stronger than smaller diameters

## 4.10 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 4-3 shows, thick flanges, small moment arms, and chamfers (or large radii) create much stiffer and lighter structures.

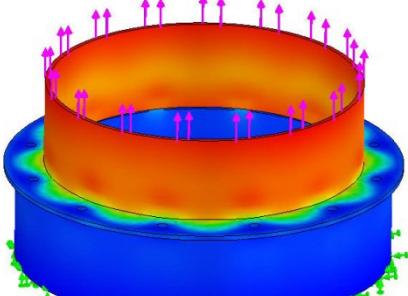
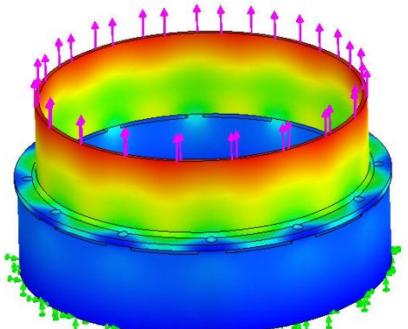
Design	Deflection Plot	Design Notes	Max Deflection Value [in]
	 URES (in) 0.0005 0.0004 0.0003 0.0002 0.0001 0.0000	<ul style="list-style-type: none"> <li>•Flanges too thin</li> <li>•Moment arms too large</li> <li>•No chamfer or fillet</li> </ul>	0.0005
	 URES (in) 0.0002 0.0001 0.0000	<ul style="list-style-type: none"> <li>•Thicker flanges</li> <li>•Smaller moment arms, but fits fasteners</li> <li>•Chamfer added for stiffness</li> <li>•No significant increase in mass</li> </ul>	0.0002

Table 4-3: Features of adjoining structure<sup>1</sup>

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.

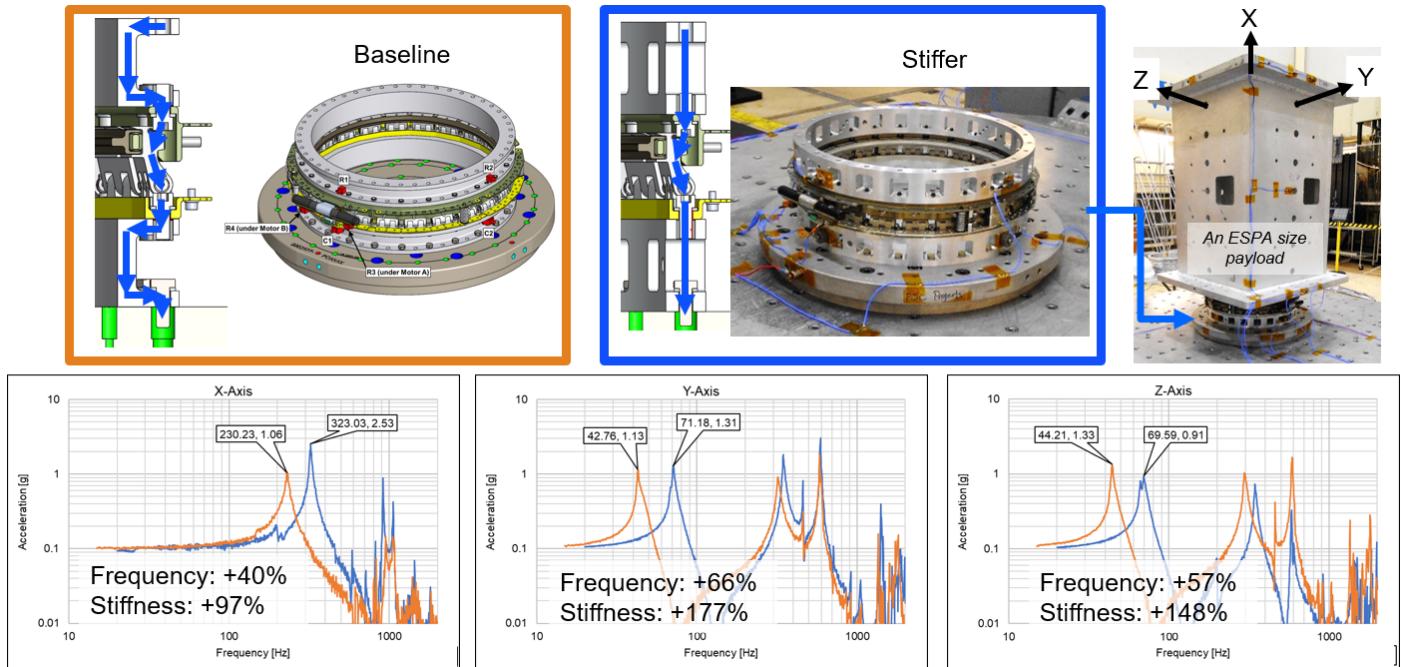
The stiffness increase associated with straight load-paths is illustrated below. A straight load path can double the stiffness and increase lateral frequencies by 40%.

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.

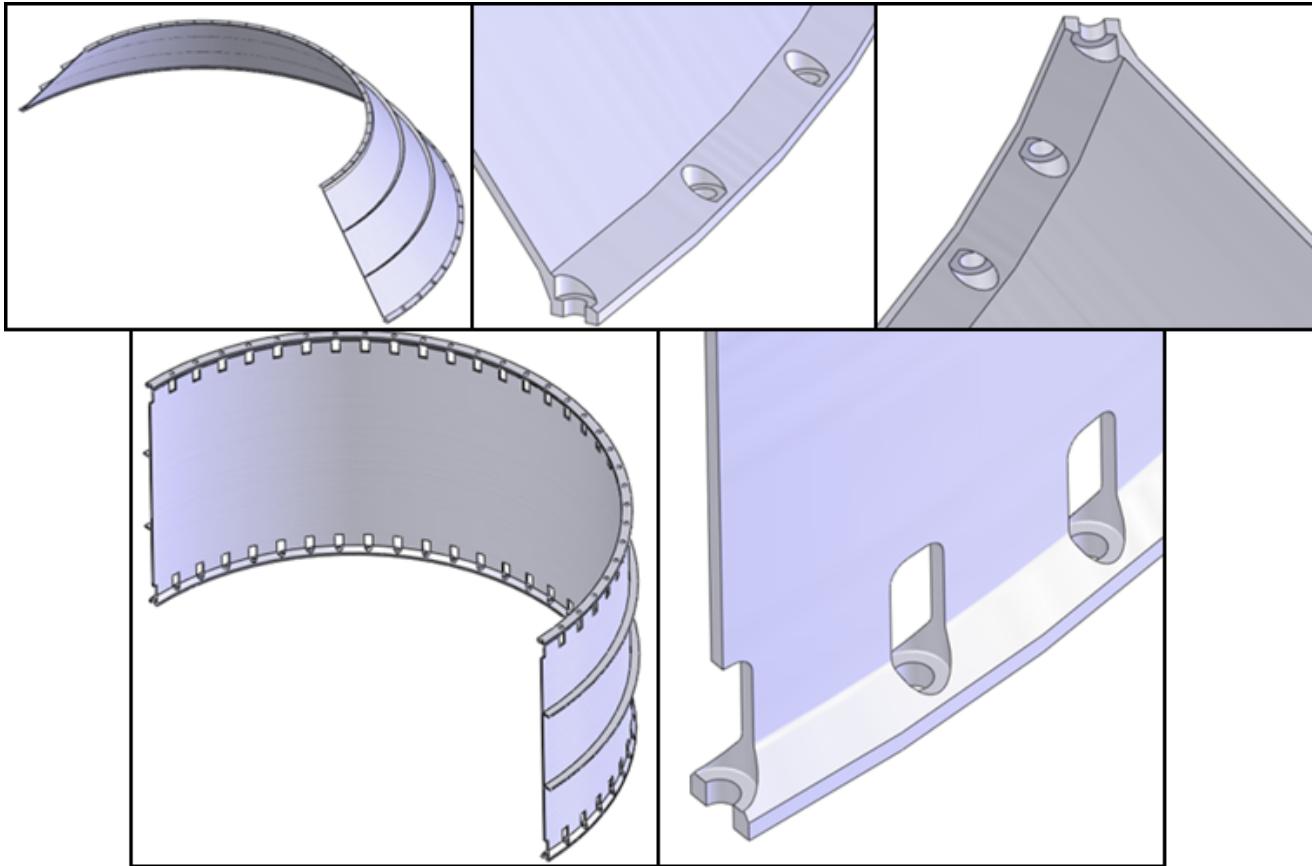
The thermal extremes of the bolted joint often drive the selection of fasteners. Users anticipating temperatures beyond +10 to +50°C should examine the preload changes associated with coefficient of thermal expansion (CTE) mismatch. In the past, missions on the Space Shuttle have driven bolted joint 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.

<sup>1</sup> 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 4-8: Straight load-paths from adjoining structures substantially increase stiffness**



**Figure 4-9: Structures with stiffest flange design. Moment arms in the flange are minimal, maximizing stiffness and strength**

As noted in Table 3-1, 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 influence 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 Table 4-4.

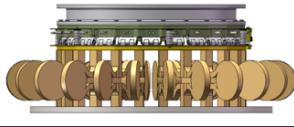
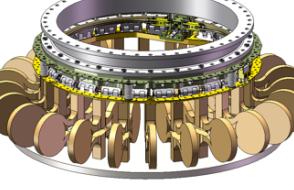
	Lightband Adjoined to...		
	Stiff Weldment, Ring, or Plate	Transition Rings	Isolation System
Typically Characterized As (See Table 3-1)	Stiff	Flexible	Flexible
Most Similar Type of Flight Adjoining Structure	Adapter plate or base plate	Adapter cone or ring	Isolation system
Flatness	Often difficult to 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 4-4: Comparison of ALB adjoining structures

## 4.11 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.

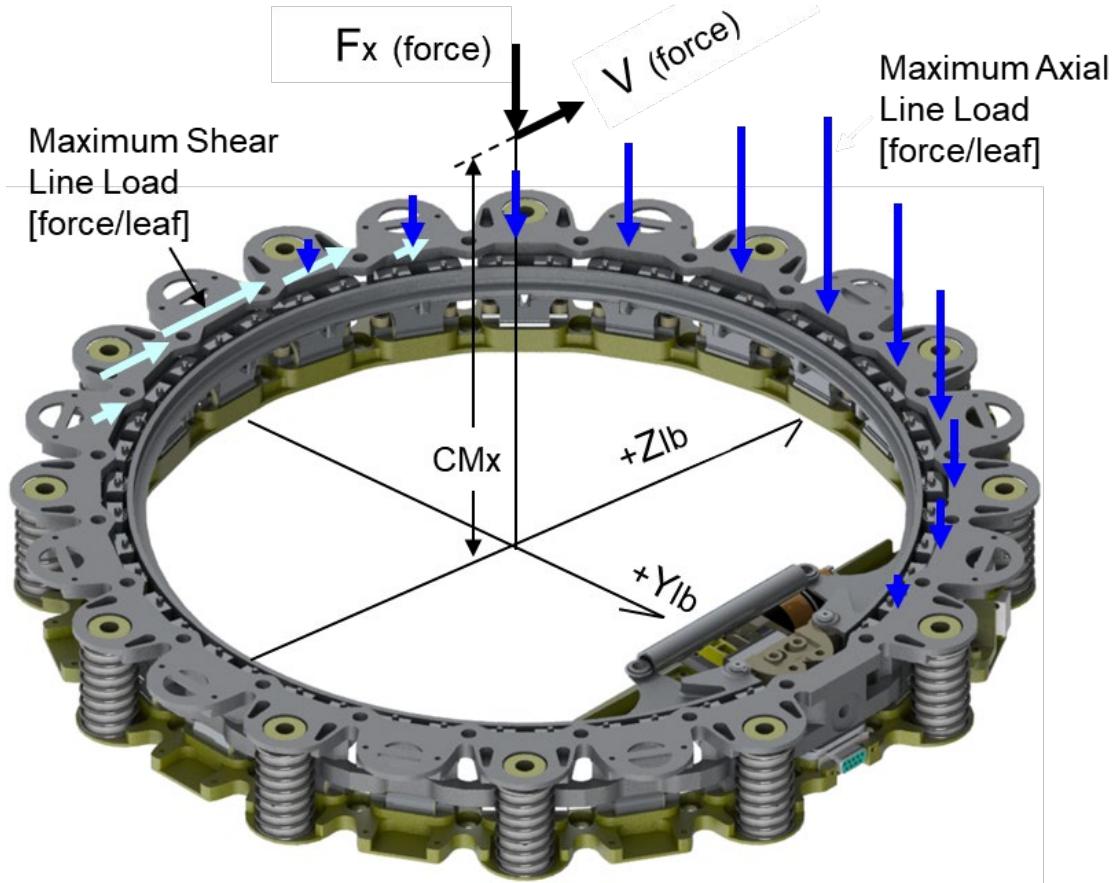


Figure 4-10: Line loading forces

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-RL analysis and tests have shown that the as-designed fastener hole size and spacing is optimum for ALB operation. All testing at PSC-RL is performed with 0.25-inch fasteners because PSC-RL 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-RL strength testing reflects this fact.

Note: PSC-RL 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-RL qualification testing. Thus, the terms force/Leaf and force/bolt are interchangeable.

The equations below provide an approximation of the line loading for initial sizing purposes. They will not however account for peaking due to stiffness variation of adjoining structures (e.g. base plate stiffening ribs, access cutouts, walls, etc.). They also do not account for non-uniform load distribution resulting from significant lateral CG offsets. Customers should incorporate the ALB finite element model in their flight stack to determine the actual load distribution around the ALB. This will expose peaking and inform any derating. Naturally customers should avoid structural discontinuities to retain high line load margin.

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<sub>x</sub>** 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 3-1 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 3-1. 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).

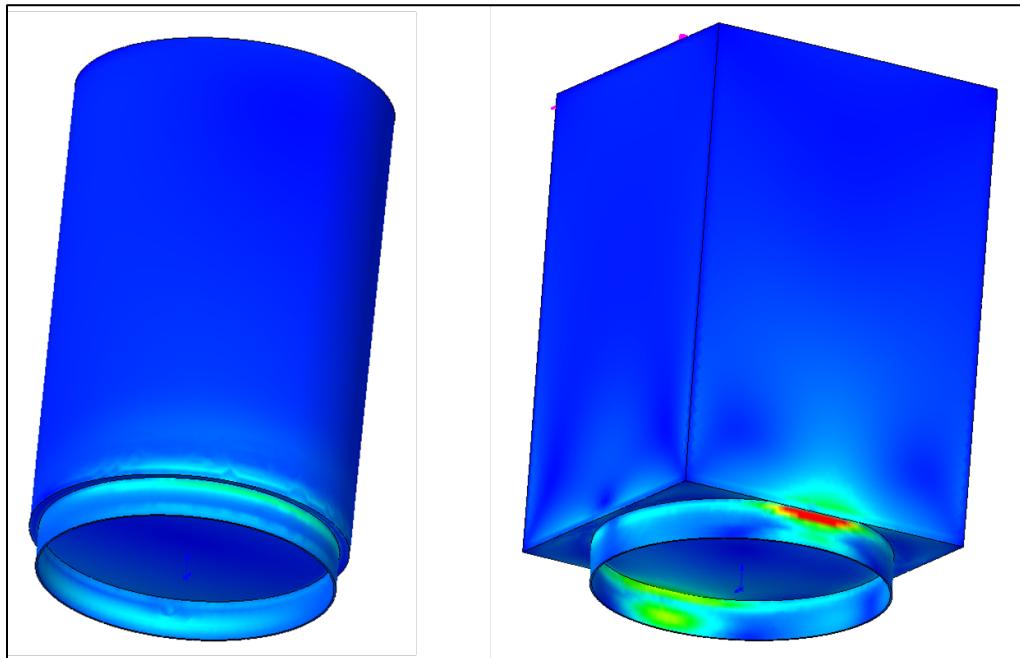


Figure 4-11: A round separation system and a square satellite can create high line loading

## 4.12 Fatigue Limits & Mass-Loaded Vibration

Fatigue failure is generally defined as failure due to cyclic loading. Fatigue failure is typically manifested in a flight stack as a loss of preload in fasteners, a breakdown of surface treatments at separable interfaces, or cracking of materials. Fatigue can be induced by static, dynamic and thermal environmental loads. Loading can be locally amplified when dissimilar structures (ex. round to square) are joined to the ALB. The ALB's load limits are based on quasi-static strength testing.

When derating the ALB's maximum load capability from Table 3-1 consider all loading events including mass loaded random vibration, sine sweep, sine burst and shock testing as well as flight environments. The customer shall use an equivalent fatigue damage approach to properly account for the combined effects of all loading. See section 7.9 for qualification fatigue testing performed on the ALB. The line loads shown are axial.

Mass-loaded vibration will generate cyclic loading on the ALB dependent on the adjoining structure and payload stiffness and damping. This will often result in loads far greater than those calculated in Section 4.11 using quasi-static load factors. Flight ALBs should not be used for mass-loaded vibration testing. If mass-loaded vibration testing is required by the launch provider a waiver should be requested given the ALB's qualification or an EDU ALB shall be used. Further, all test and flight environments shall be accurately predicted using a finite element model of the ALB and payload. During testing, the test results shall be continually compared to analytical predictions for sufficient agreement.

## 4.13 Flatness and Parallelism

Prior to joining, the surfaces adjoining the ALB should be flat to the specification defined in Table 3-1.



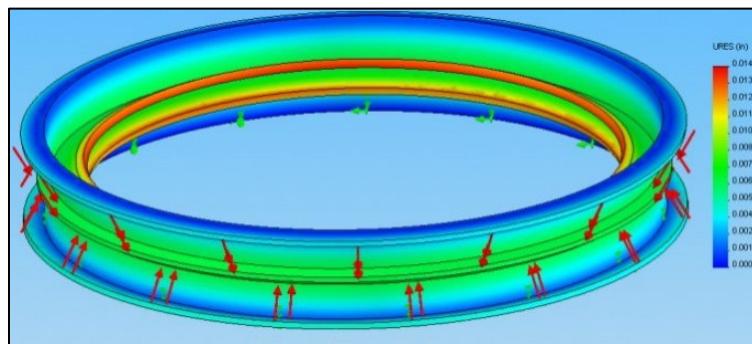
**Figure 4-12: An ALB attached to a launch vehicle cone and CAD model showing resulting stress peaking that occurs when adjoining two warped surfaces**

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.

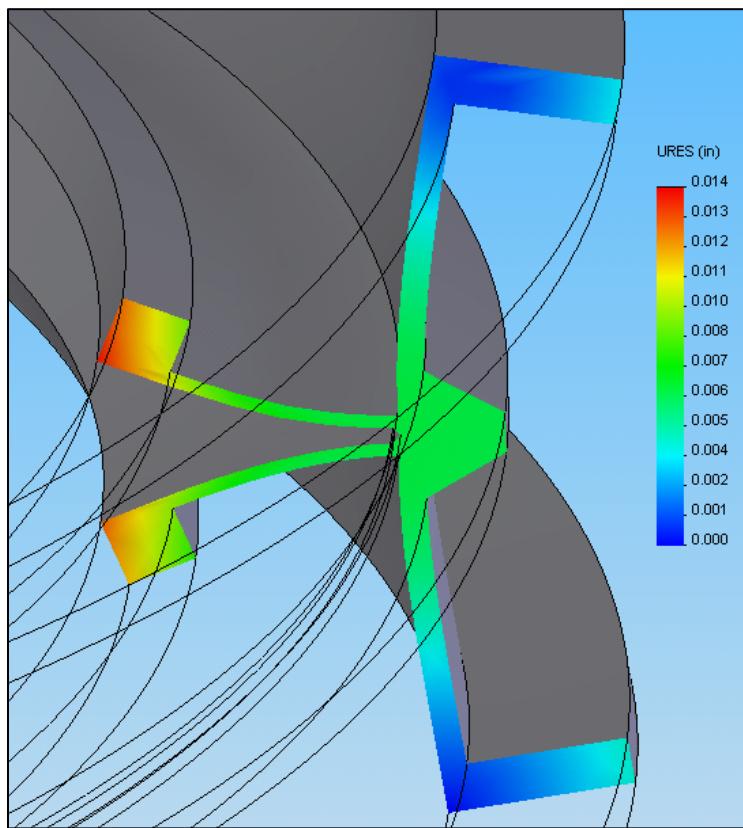
It may be tempting to design flexible features to attenuate stress exhibited in the warped structures that are joined. However, this can lead to an unacceptably low stiffness and first mode frequency of the entire system. To achieve both a low stress and high stiffness system, flatness of the adjoining 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 4-13: FEM simulates a clamp band separation system via radially inward preload from band tension. Warping can result**



**Figure 4-14: 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-RL 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.

## 4.14 SoftRide and ALB

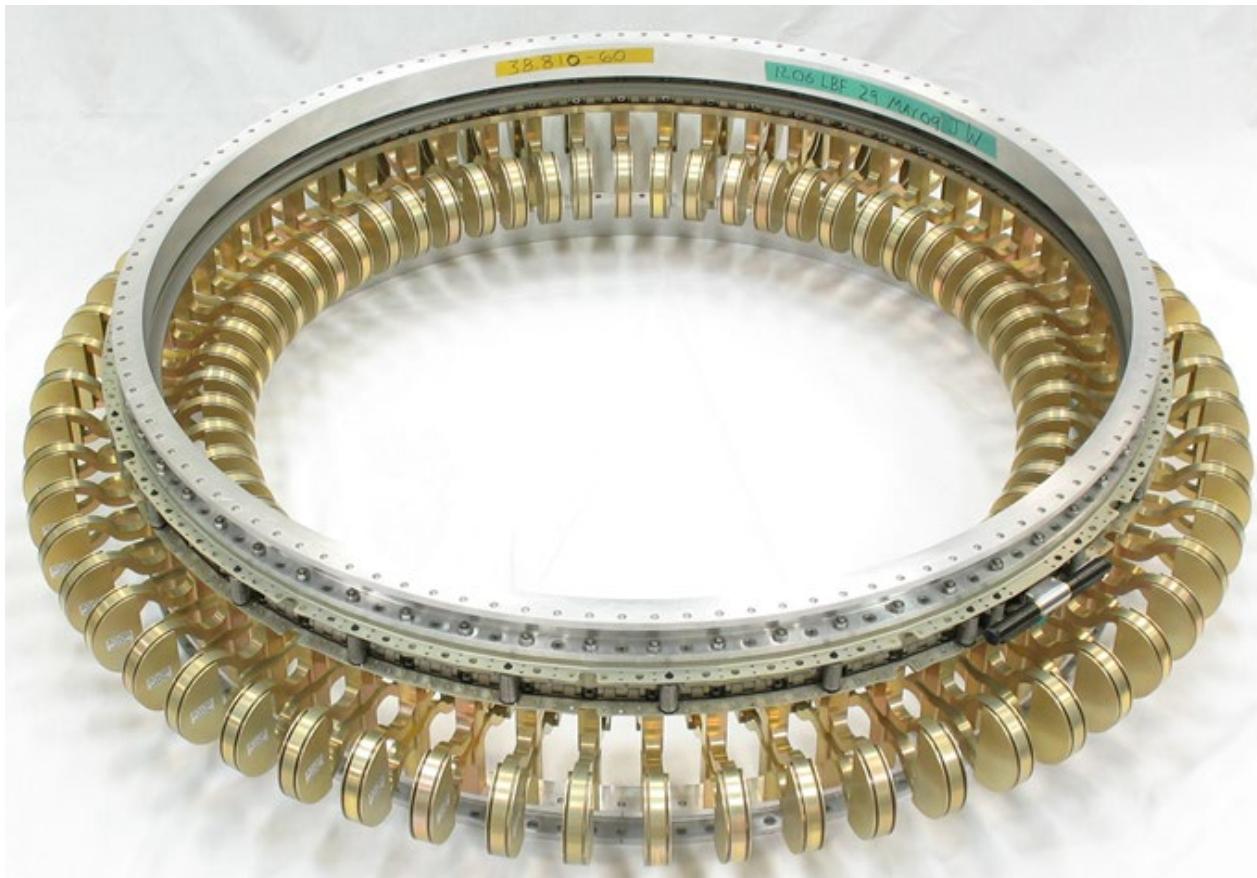
The SoftRide Isolation System is a spacecraft vibration and shock isolation system designed to reduce launch vehicle-induced loading on the spacecraft. SoftRide is a patented product of Moog CSA Engineering ([www.csaengineering.com](http://www.csaengineering.com)). It has been flown successfully many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

Bicycle	Car	Aircraft	Spacecraft

**Table 4-5: 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 4-15: 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.

## 4.15 Lifecycle

An ALB cycle is defined as one stow and one separation. Refer to Table 3-1 for max number of cycles (Noted as Life | *EDU Deployments* or *Flight Deployments*). If cycles equal or exceed the allowable, the unit must be returned to PSC-RL for inspection and possible refurbishment. Contact PSC-RL for pricing and schedule.

## 4.16 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 because 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.

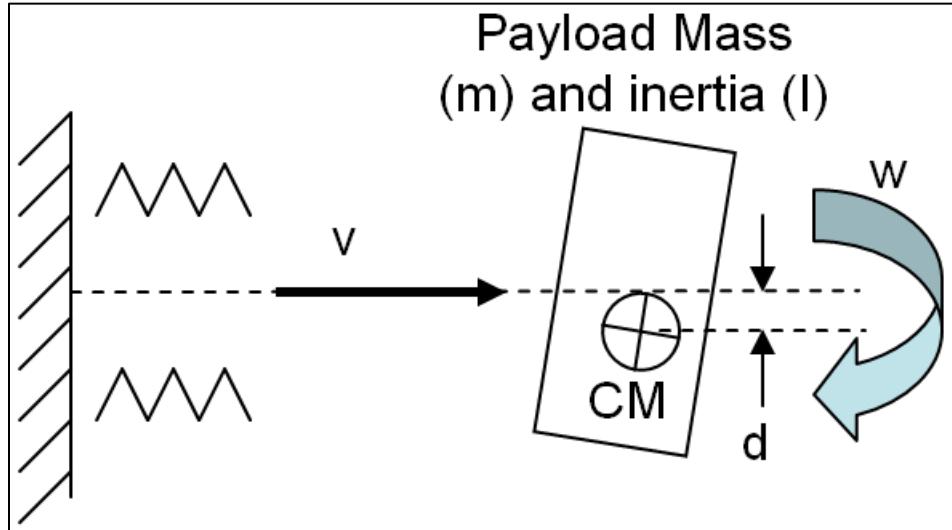


Figure 4-16: CM offset and rotation rate

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

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·length<sup>2</sup>]

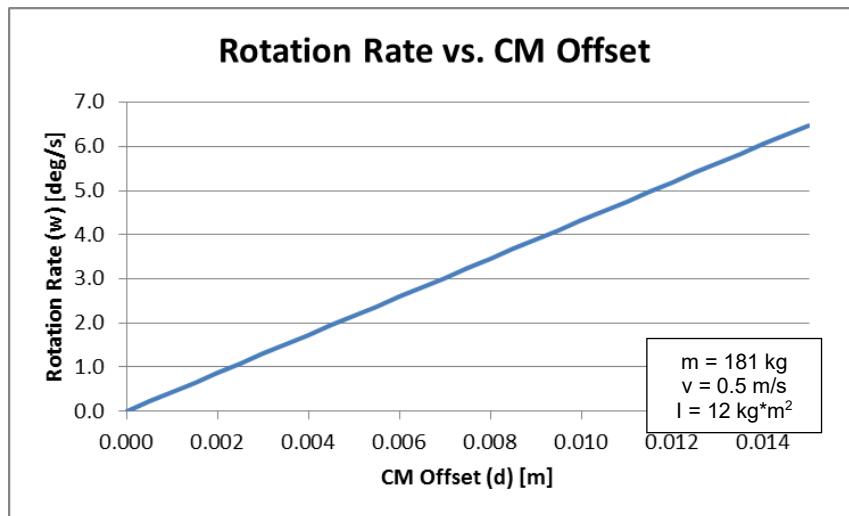


Figure 4-17: An illustration of Equation 4

The Separation Spring configuration may be adjusted on the ALB so the Springs, as a sum, act through the CM. Table 3-1 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  $d = 0.0\pm.01$  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?

#### 4.17 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] ( $\Delta V$  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 3-1 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

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

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.

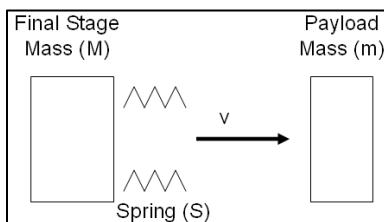
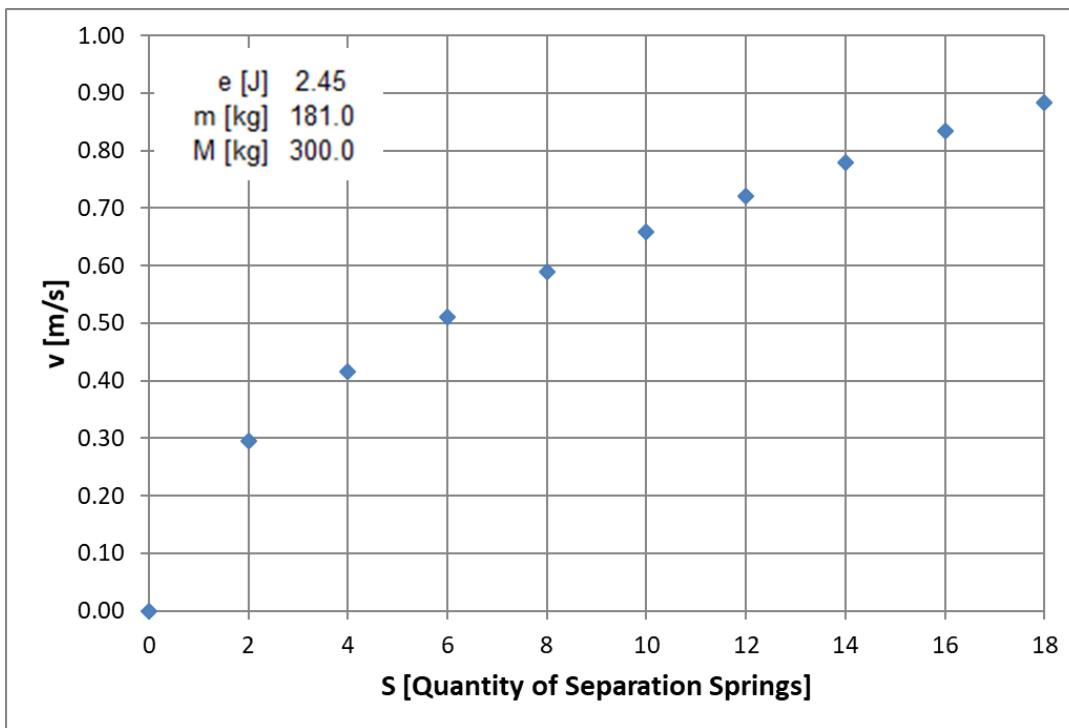


Figure 4-18: The relative velocity (**v**) is created by the Separation Springs (**S**)

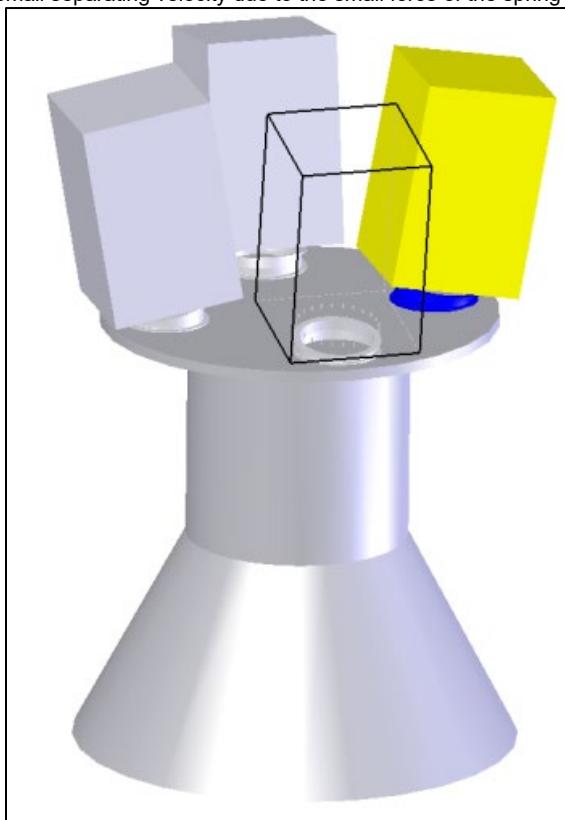


**Figure 4-19: Spring quantity required increases with the square of velocity (springs are lousy rocket engines)**

The location of Separation Springs, Separation Connectors, and Separation Switches need not be symmetric to minimize rotation rates. Sometimes PSC-RL 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 4-20: Spacecraft oriented so they reduce the moment arms between center of force and center of mass**

## 5. 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>	 <p>Spring – damper of isolation system</p> <p>Upper Ring</p> <p>Lower Ring</p>	 <p>Spring compliance system</p> <p>Space vehicle</p> <p>Final stage of launch vehicle</p>

Figure 5-1: 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 5-2: Horizontal and vertical integration**

Flatness of the adjoining surfaces should be within the flatness requirement. See Table 3-1. 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.

## 6. 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.

### 6.1 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-RL rework	Procedures, checklists, PSC-RL 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 6-1: Failure Modes, Effects and Preventative Actions

## 7. Testing

PSC-RL completes acceptance testing on standard flight ALBs prior to delivery. EDU ALBs only receive build verification tests. PSC-RL'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-RL writes, executes, and approves all test plans. PSC-RL also takes any corrective action if anomalies arise. PSC-RL may employ a lot testing strategy, at PSC-RL 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
Benchtop Separation Test	Standard
Separation Reliability Test	Special (Custom)
Strength Test	Special (Custom)
Shock Test	Special (Custom)

Table 7-1: Standard vs Custom test summary

### 7.1 Test Summary

These values may be exceeded at PSC-RL's discretion.

Test	Parameter	Qualification	Flight (Acceptance)	EDU	
Build Verification	Preload Tuning [-]	proprietary	proprietary	proprietary	
	Benchtop Operations [-]	7	7	7	
Random Vibration	Level [grms], ± 1 dB	14.1	10	Not Performed	
	Duration [s/axis], +10%/-0%	180	60		
	Excitation Axes [-]	X, Y, Z			
TVAC	Temp [°C], ±3.0 °C	-34 to 79	-24 to +69	Not Performed	
	Pressure [Torr]	<1.0E-4			
	Cycles, min [-]	12	4		
	Separations [-]	2	1		
Shock	Levels	See Section 7.5	Not Performed	Not Performed	
	Impacts/axis	3			
	Strategy	positive & negative			
Benchtop Operations	Operations [-]	80	3	Not Performed	
Strength	Axial Line Load [lbf/bolt]	2064	Not Performed	Not Performed	
	Shear Line Load [lbf/bolt]	775			
Fatigue	Axial Line Load [lbf/bolt]	See Section 7.9	Not Performed	Not Performed	
	Cycles	See Section 7.9			
Separation Reliability	Separations	Not Performed	Not Performed	Not Performed	

Table 7-2: Test Summary

### 7.2 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.

### 7.3 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 and flight vibration.



Frequency [Hz]	ASD [g <sup>2</sup> /Hz]	
	Qual	Acceptance
20	0.040	0.013
50	0.160	0.080
800	0.160	0.080
2000	0.026	0.013

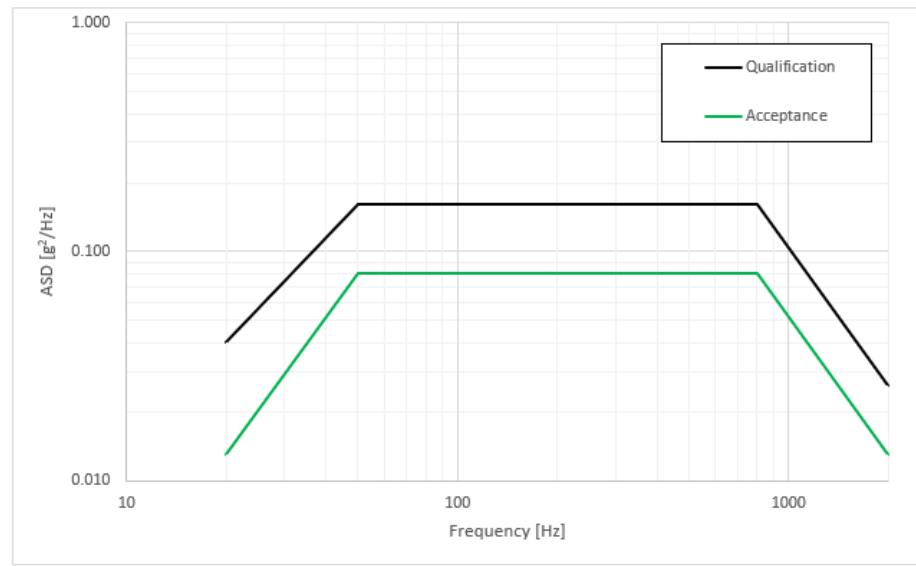


Figure 7-1: Random Vibration Testing

### 7.4 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. Temperature data provided by control sensor located on ALB Lower Ring (Note – this does not provide motor-specific temperature data). During qualification testing the unit is thermally cycled to the full survival temperature range ( $T_s$  as specified in **Table 3-1**), however the ALB is only to be separated between the operating temperature range ( $T_o$ ).

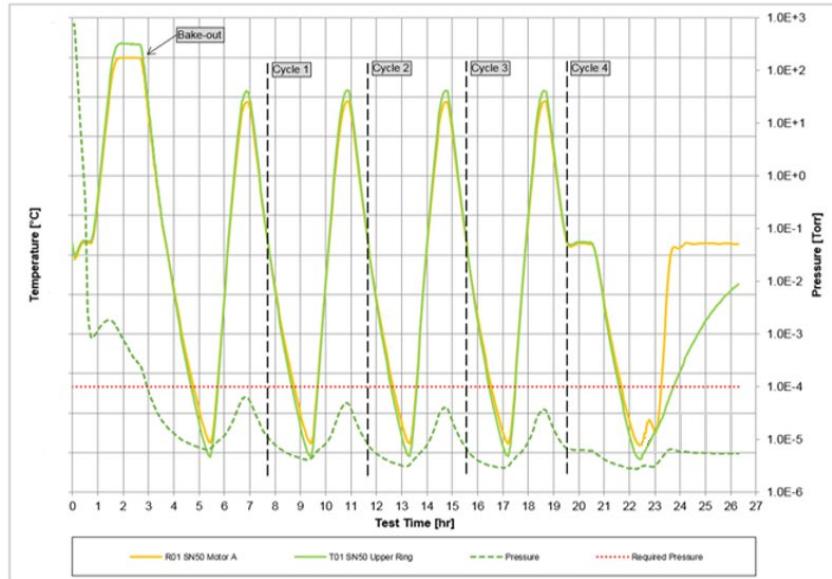
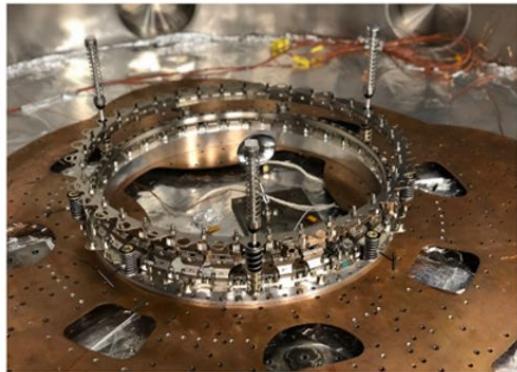
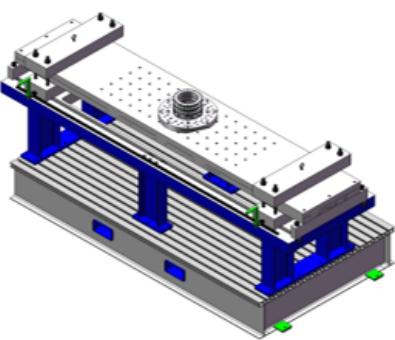


Figure 7-2: TVAC Testing

## 7.5 Shock (Custom Test)

The ALB is exposed to simulated flight shock.



SRS Profile	
Natural Frequency [Hz]	Acceleration [g]
100	60
1,000	1,995
10,000	1,995
% over nominal	50%
Q	10

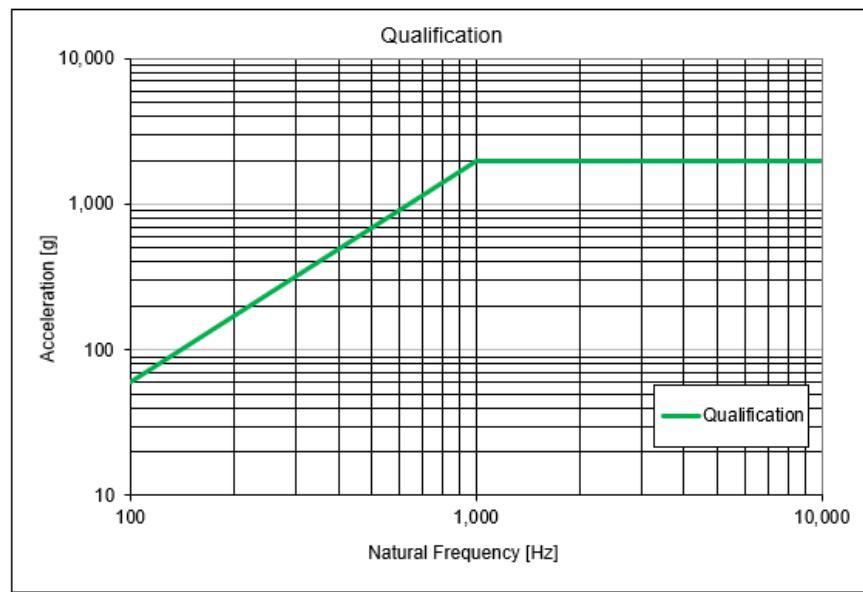


Figure 7-3: Shock Testing

## 7.6 Benchtop Separation Testing

The ALB is separated repeatedly on a benchtop to monitor nominal operation. Transition Rings are fastened to the ALB to produce flight like structural boundary conditions. For each operation, the Lightband electrical data (voltage, current, time to initiate) are recorded. Upon completion, the Lightband is formally inspected.



Figure 7-4: Benchtop Separation Testing

## 7.7 Separation Reliability Testing (Custom Test)

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

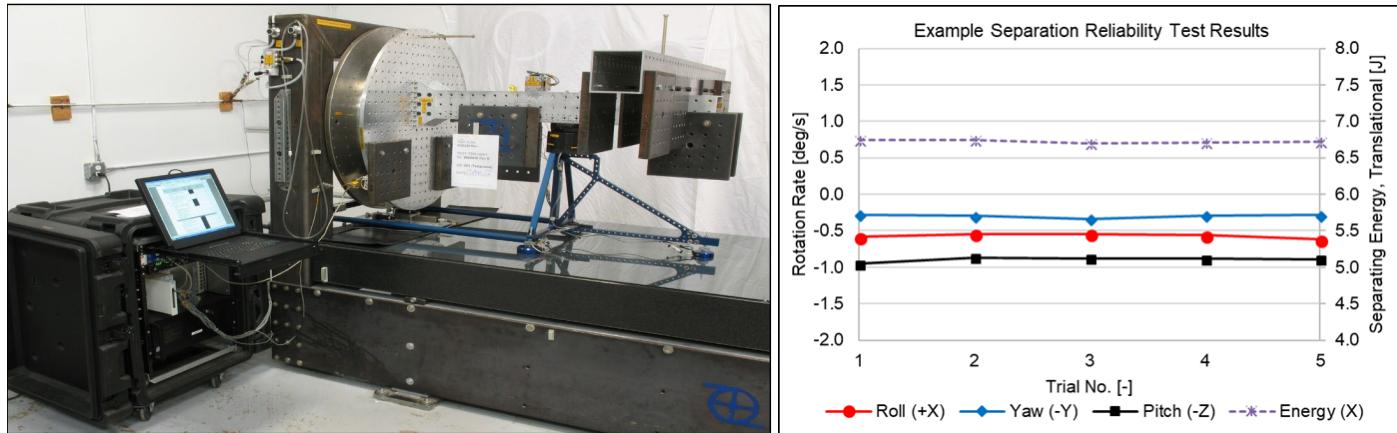


Figure 7-5: Separation Reliability Testing

## 7.8 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-RL supplied mass simulator.

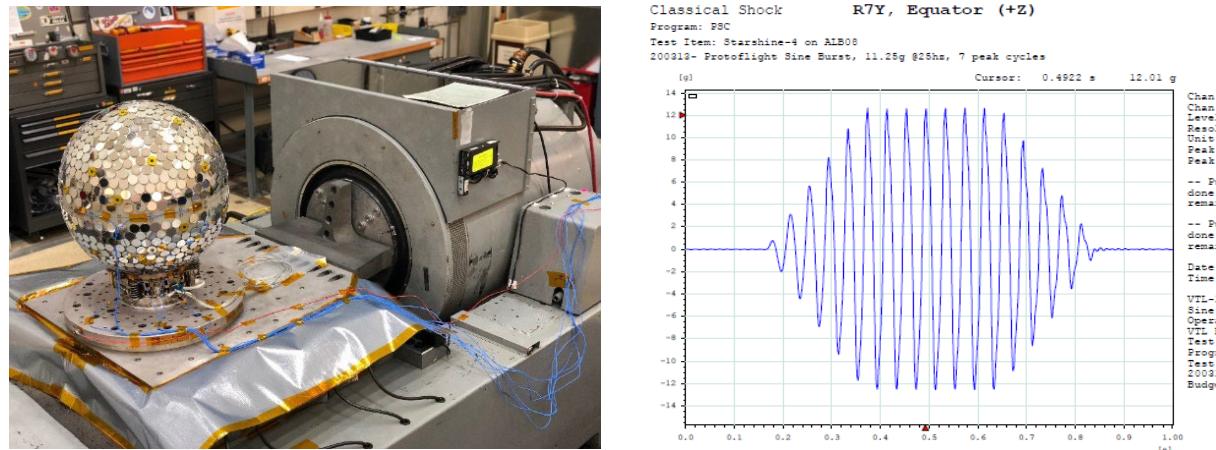
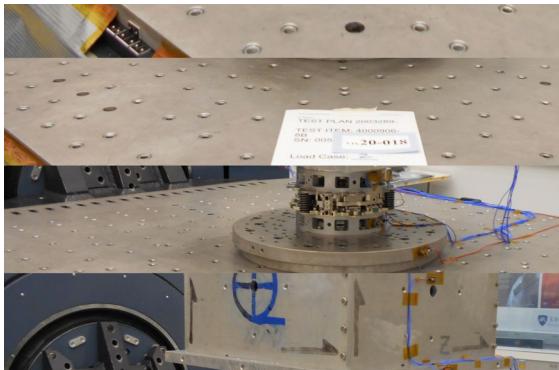


Figure 7-6: Strength Testing

## 7.9 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-RL supplied mass simulator is required.



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

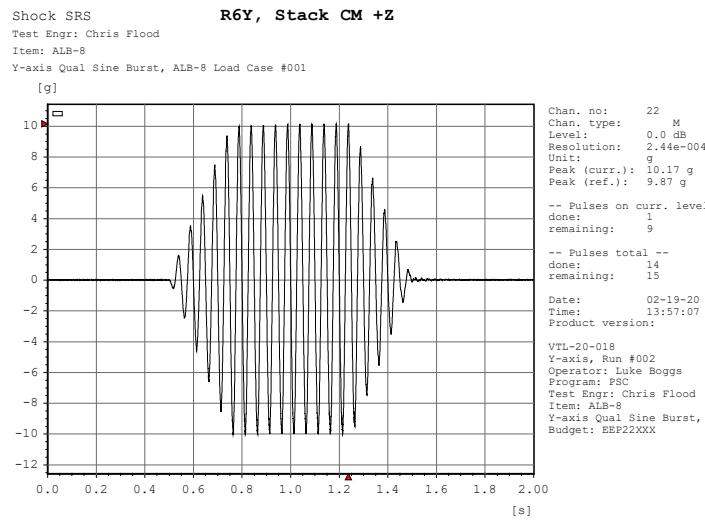


Figure 7-7: Fatigue Testing

## 8. Specifying an ALB

### 8.1 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 3-1. 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.

### 8.2 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 3-1. If not, increase the chosen ALB diameter until allowable line load is achieved. PSC-RL 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.

### 8.3 Select ALB Bolt Circle diameter

Choose an appropriate ALB diameter from Table 3-1 based on stiffness and strength.

### 8.4 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.rocketlabusa.com/space-systems/separation-systems](http://www.rocketlabusa.com/space-systems/separation-systems) or contact PSC-RL) with a model of your payload and verify your fit requirements. Pay close attention to all stay-out zones per Table 3-1 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.

### 8.5 Separation Switch quantity (SW)

The greater the quantity of Separation Switches, the more complex and heavier the harness. See Table 3-1 to ensure the total quantity of Separation Switches and Separation Connectors does not exceed the maximum allowable.

### 8.6 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 3-1 to ensure the total quantity of Separation Switches and Separation Connectors does not exceed the maximum allowable.

### 8.7 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 7 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.

### 8.8 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) or 4 Separation Springs (~9.8 J) depending on the diameter of the Lightband (refer to Table 3-1). Additional Separation Springs can be purchased for customer installation. More than n/4 or less than the standard quantity of Separation Springs is a custom unit.

### 8.9 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 8-1: 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

## 9. Purchasing, Deliverables, & Schedule

### 9.1 Purchasing an ALB

Contact PSC-RL 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 9-1: Standard ALB schedule

### 9.2 Standard Delivery Schedule

Contact PSC-RL directly to receive the most up-to-date ALB lead times.

### 9.3 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
- 3. Copies of all as-run test reports

### 9.4 ALB STEP Files

STEP files of simplified ALB assemblies are available to prospective users and customers. Users may request a STEP model at [www.rocketlabusa.com/space-systems/separation-systems](http://www.rocketlabusa.com/space-systems/separation-systems).

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.

### 9.5 ALB Finite Element Models

PSC-RL 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-RL for further information. FEMs may incur an additional cost. This item is subject to US Export Control regulation.

### 9.6 Custom Units

ALB is a COTS separation system. Any customization (e.g., testing, configuration, program management, additional customer requirements, accelerated schedule, etc.) will incur additional cost and schedule. Figure 9-1 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"> <li>• No deviation from current Lightband design</li> <li>• 3 or 4 Separation Springs depending on Lightband size (see Table 3-1)</li> <li>• Random vibration test</li> <li>• Thermal vacuum test</li> <li>• Entire ALB specification is this User Manual</li> </ul>	<ul style="list-style-type: none"> <li>• Any tests not in standard regimen (shock, strength, separation reliability, CM off-set separation reliability)</li> <li>• Any deviation from standard test requirements</li> <li>• Any requirement or contractual obligation not in this User Manual, including status meetings.</li> <li>• Accelerated schedule</li> <li>• 0-2 or n/4+ Separation Springs</li> </ul>

Figure 9-1: Standard vs. Custom Lightband

### 9.7 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-RL 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-RL paperwork will list parts as individual line items.

#### 9.7.1 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-RL does not sell fasteners and does not include loose fasteners when accessories are not attached to the ALB.

### 9.7.2 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-RL does not sell fasteners and does not include loose fasteners when accessories are not attached to the ALB.

### 9.7.3 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, NAS1351N3-10, .190-32 x .625 SHC Screw, is required to attach spring parts to an ALB Lower Ring. PSC-RL 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 12.

## 10. Manufacturing Process

Employees at PSC-RL design, assemble, and test separation systems. PSC-RL is an AS 9100-compliant organization. All of the machining and fabrication is completed by vendors qualified to PSC-RL's standards. PSC-RL maintains documentation of all tasks associated with flight hardware procurement, inspection, storage, assembly, test, and shipment. All of these are enveloped by PSC-RL'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-RL, 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-RL writes, executes and approves manufacturing procedures. PSC-RL also takes any corrective action if anomalies arise. The customer-furnished wiring harness is not included in the manufacturing of an ALB.

## 11. 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.

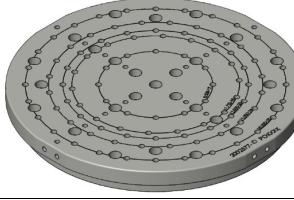
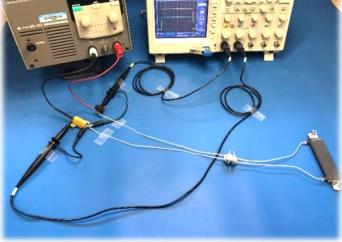
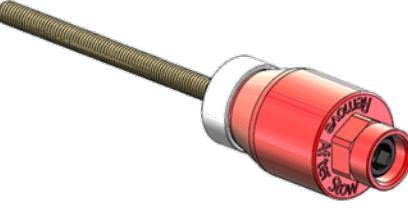
Table 11-1: Testing and other procedures



Figure 11-1: Electro-mechanical fit check and a separation test

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

Table 12-1: Ground support equipment

## 13. Warranty and Glossary

### 13.1 Warranty

The ALB warranty is defined in [Planetary Systems Corporation Commercial Terms and Conditions of Sale \(Doc. 1001112\)](#)

### 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 3-1
- **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

## 14. ALB Training

ALB training at PSC's facility is included in the price of the ALB. This training details the operating procedure for the ALB as outlined in 3000355 ALB Operating Procedure. It can be performed at another location at an additional cost. Operation of the ALB by any customer personnel is prohibited until they have received training. The training session lasts approximately 8 hours. Trained personnel are certified to operate their ALB(s) for 24 months after successfully completing training.

Training sessions are incredibly important and reduce mission risk. In addition to learning how to operate the ALB, customers will be able to discuss their expected integration scenario. PSC's trainers will help uncover potential unforeseen issues during integration and discuss all possible solutions. By having this discussion before customer operations and integration, customers will streamline all processes involving the ALB and prevent expensive program delays.

At a minimum, the following topics will be covered during the training session

- How the ALB works
- Best practices
- Warnings and warranty violation items
- Required materials
- Handling precautions
- Mechanical attachment procedure
- Stowing procedure
- Setting-for-flight procedure
- Deploying procedure
- Preparing the ALB for compression
- Removal from adjoining structure procedure
- Horizontal integration procedure (if applicable)
- Mission assurance verifications
- Customized discussion of mission integration details to improve efficiency
- Any other topics desired by the customer

## 15. Appendix A: ALB Accessories

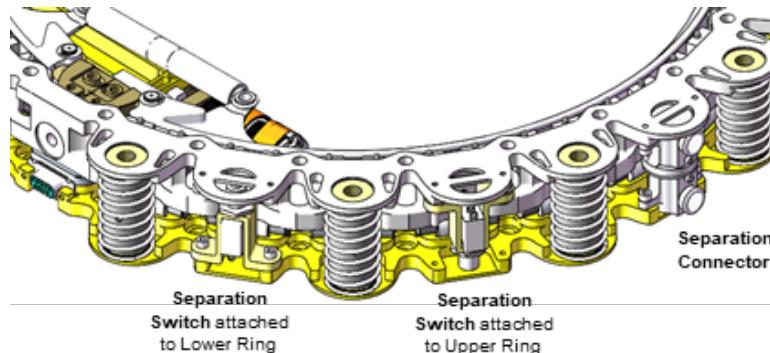


Figure 15-1: ALB Accessories

### 15.1.1 ALB Separation Connector

PSC-RL 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-RL does not sell fasteners.

See Figure 15-2 for overview. See Table 3-1 for parameters, Table 15-1 lists a subset specific to the Separation Connector. See PSL-RL document 3000355 ALB Operating Procedure for attachment. See Section 15.1.4 for wiring details. See Section 9.7.1 for purchasing.

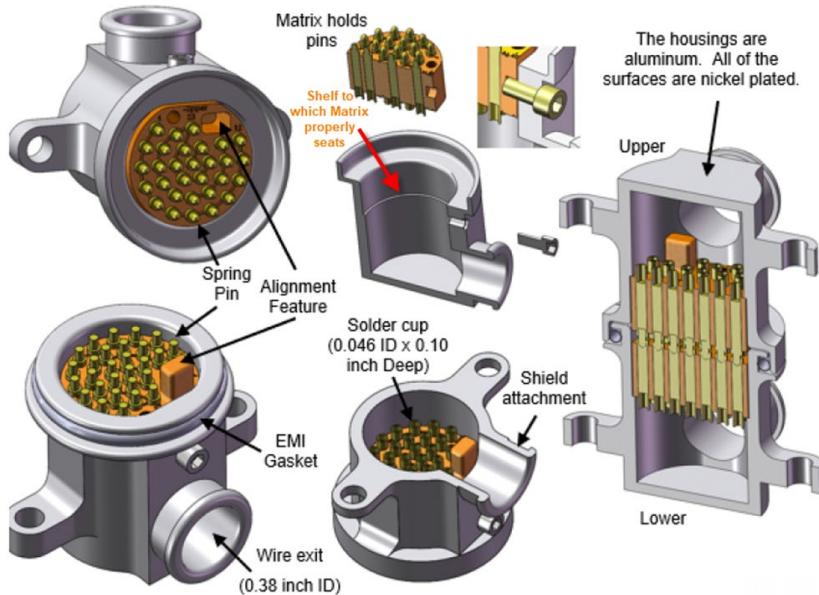


Figure 15-2: ALB Separation Connector Overview

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]	Isca	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-RL 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-RL does not sell fasteners.

See Figure 15-3 for overview. See Table 3-1 for parameters, Table 15-2 lists a subset specific to the Separation Switch. See PSL-RL document 3000355 ALB Operating Procedure for attachment. See Section 15.1.4 for wiring details. See Section 9.7.2 for purchasing.

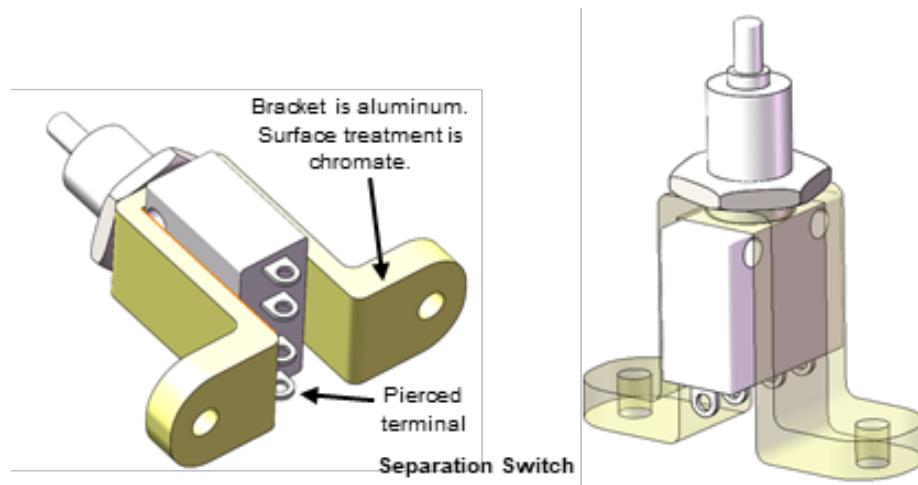


Figure 15-3: ALB Separation Switch Overview

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	$\pm 0.05$
	Current, steady state, vacuum [A]	Iscv	5.0	-
	Contact resistance [Ohm]	Rsw	<0.025	-
	Mass + fasteners [lbm]	-	0.058	$\pm 0.02$

Table 15-2: ALB Separation Switch Parameters

### 15.1.3 Separation Springs

PSC-RL 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-RL does not sell fasteners.

To stow the Spring an ALB Spring Lock is required. See Section 12.

See **Table 3-1** for parameters,

Table 15-3 lists a subset specific to the Separation Springs. See PSL-RL document 3000355 ALB Operating Procedure for attachment. See Section 9.7.3 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	$\pm 0.025$
	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-RL does not supply harnesses from the ALB or through the ALB. PSC-RL recommends the simplest possible harness design using the smallest quantity of Separation Connectors and Separation Switches.

#### General Guidance

- 1) Practice this procedure. At PSC-RL 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.

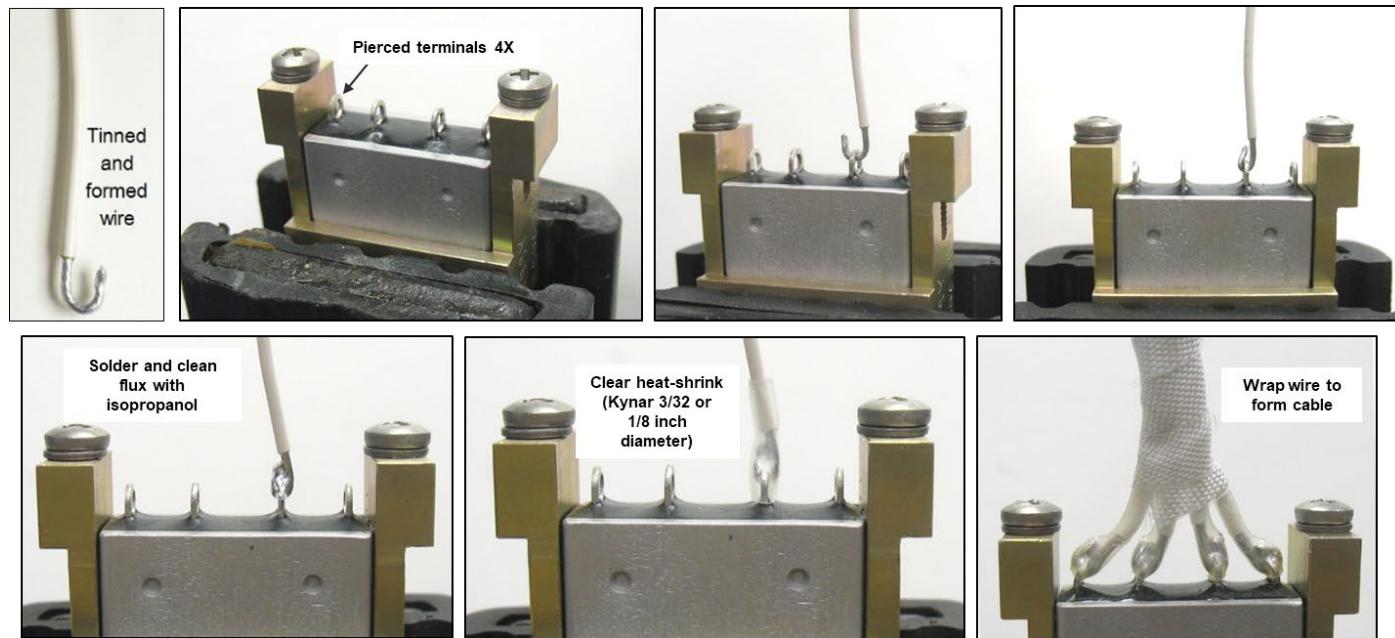


Figure 15-4: Wiring of Separation Switch (MLB switch bracket shown)

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-RL does not have a recommended potting material and process. PSC-RL 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.

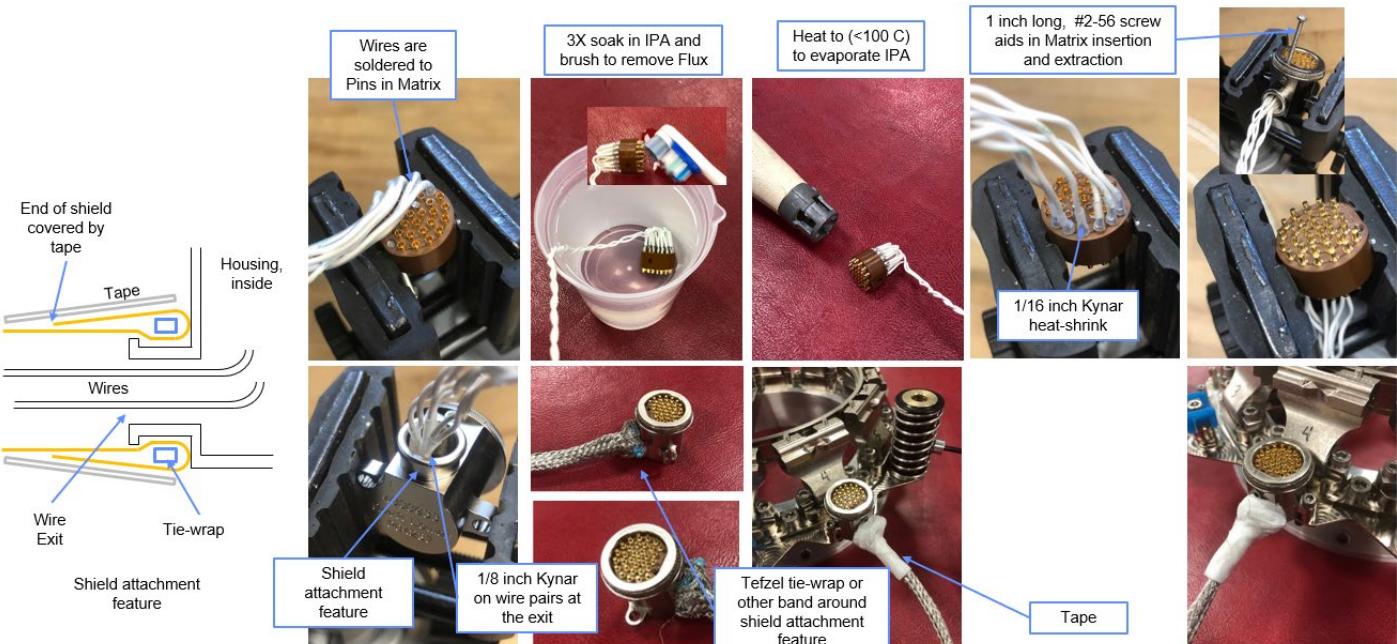


Figure 15-5: Wiring of Separation Connector

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-RL does not have a recommended potting material and process. PSC-RL 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 housing, the .086-56 screw only threads into the housing and retains the matrix from falling out. The two matrices shall be free to self-align 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.

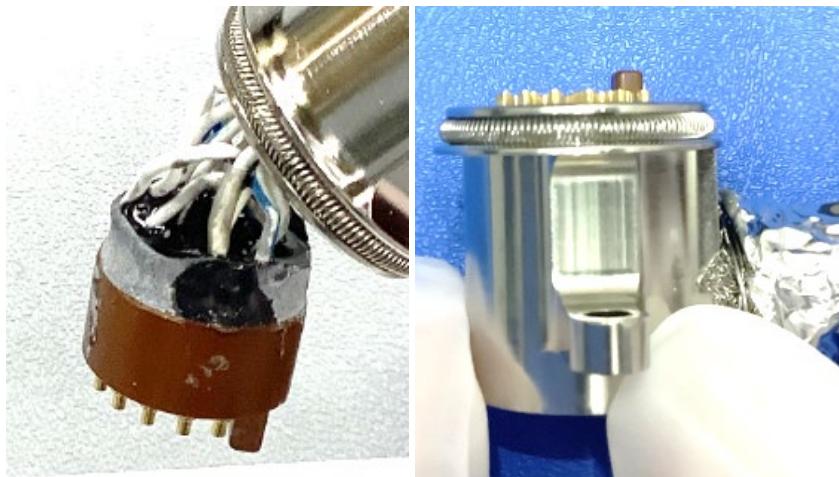


Figure 15-6: Loopbacks too long did not allow for matrix to seat, BAD

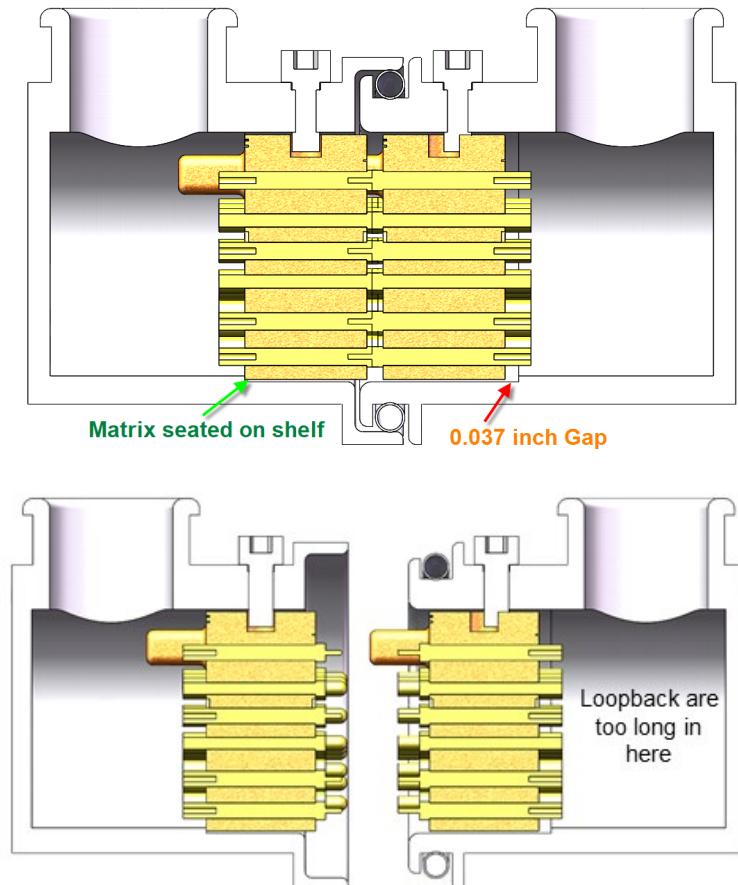


Figure 15-7: The Left Connector shows Matrix properly seated in the Housing, Right Connector is incorrect