APPENDIX A: STATIC LOAD VERIFICATION VIA RANDOM VIBRATION TEST

An acceptable deviation from testing exists for the static load requirements defined in Section 3.3.1 of the Rideshare Payload User's Guide (RPUG). For this deviation, the Customer must show that **the achieved equivalent quasi-static load during random vibration testing is enveloping of the static load requirement for each axis**. This approach may be used to satisfy static load qualification via random vibration qualification testing and/or to satisfy static load acceptance via random vibration acceptance testing. Additional documentation is required to justify that the vibration test fully envelopes the static requirement in each axis.

SpaceX approval will be conditional upon correct analysis and setup, successful testing, and completeness of the additional required documentation.

APPROACH

Prior to beginning testing, **the Customer is responsible for choosing an input Power Spectral Density (PSD) that will achieve a sufficient equivalent quasi-static load** during random vibration testing. As-written, the required random vibration test levels in Section 3.3.5 of the RPUG are not guaranteed to envelope the static load requirements with this approach, and input levels may need to be raised in the frequency band of the spacecraft's dominating mode.

SpaceX discourages the use of notching when following this approach. If equivalent loads for the fundamental frequencies far exceed the requirements, it is possible that this approach could be satisfied with the inclusion of notches. However, notching the dominant mode may result in insufficient accumulated g-RMS to cover the static load requirement, and is generally counterproductive to the intent of testing for quasi-static load.

OPTION 1: ACCELERATION RESPONSE MEASUREMENTS

During testing, the acceleration response shall be measured as near as possible to the center of gravity (CoG) of the test specimen, or shall be measured at other locations on the specimen which can derive the CoG response.

Upon completion of testing, the accumulated g-RMS shall be calculated up to and including the dominant mode. The dominant mode (f1) is defined as the mode having the highest effective mass participation and consequently creating the highest interface force. More of the acceleration response may be used at higher frequencies, if justification can be provided for why the higher frequency responses still contribute to the interface force.

The resulting accumulated g-RMS may be multiplied by 3 to take advantage of 3-sigma statistical variation during testing. This final value must be greater than the static load requirement.

$$g_{RMS} = \sqrt{\int_{f0}^{f1} S_{accel}(f)df}$$

OPTION 2: DIRECT FORCE MEASUREMENTS

Alternatively, the interface force may be measured between the payload and the test fixture with dedicated hardware, e.g. load cells or strain gauges. This option is preferred when possible.

For direct force measurements, accumulated F-RMS may be calculated for the full frequency spectrum of the test, per Equation 3. Then, the accumulated F-RMS may be multiplied by 3 to take advantage of 3-sigma statistical variation during testing. When converted to acceleration using the spacecraft mass, the final value must be greater than the static load requirement.

$$F_{rms} = \sqrt{\int_{f0}^{f_\infty} S_{force}(f)df}$$

DELIVERABLES

After testing, the Customer must provide the following results to clearly identify the achieved equivalent quasi-static load. SpaceX requires the customer documentation to include:

- A graph of the as-tested Acceleration Spectral Density (ASD) or Force Spectral Density (FSD) with input and response curves for each axis
- A graph of the as-tested accumulated g-RMS or F-RMS for each axis
- A table comparing the derived g-RMS or F-RMS against the static load requirement for each axis

Example (using Option 1):

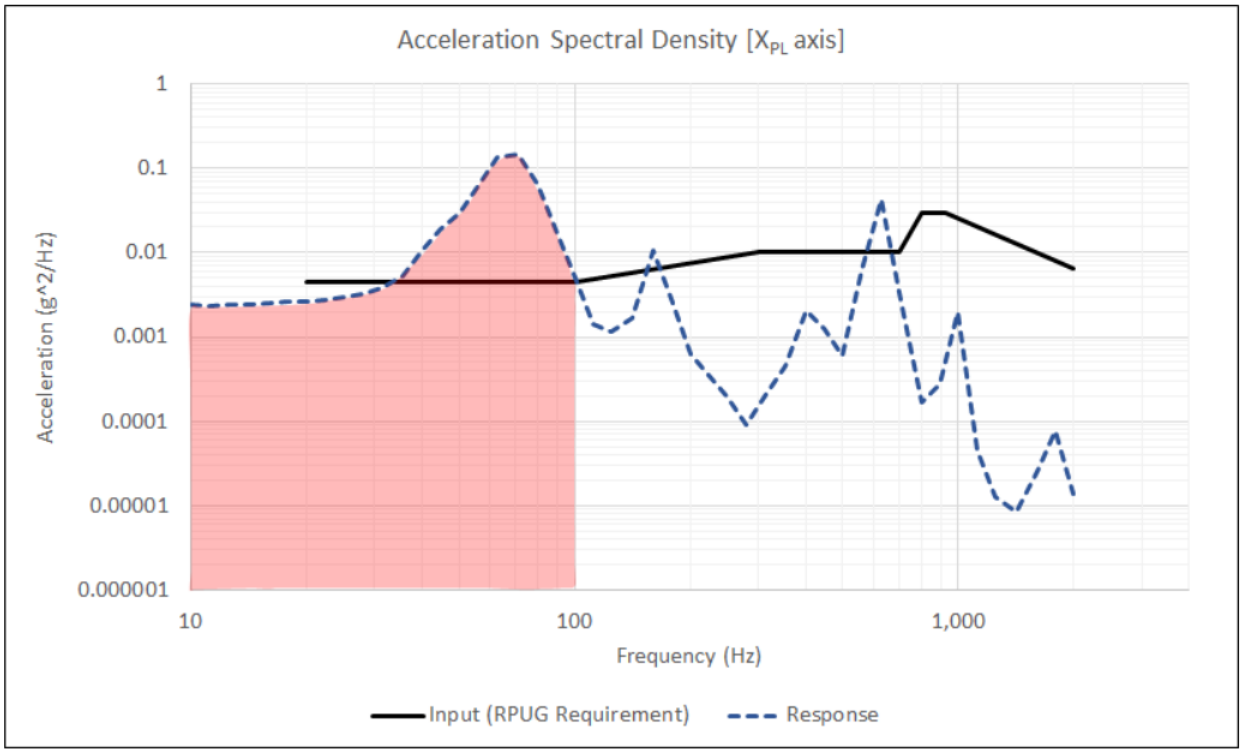

Figure 1: Example Acceleration Spectral Density (ASD)

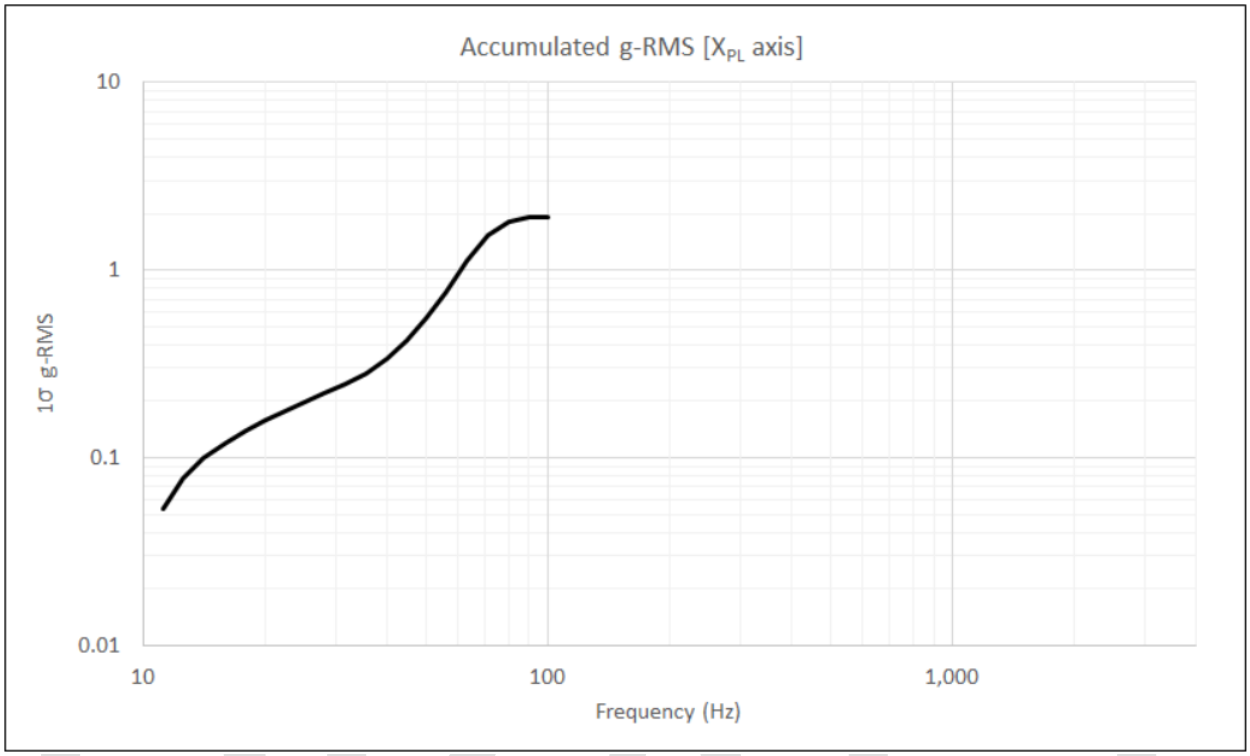

Figure 2: Example accumulated g-RMS profile

Table 1: Example comparison to static load requirement

Frequency Range (Hz)	X-axis Static Load Requirement (g)	Accumulated Response at Spacecraft CoG (g-RMS)	
		1 σ	3 σ
Up to dominant mode (100Hz)	5.5g	1.9	5.8

REFERENCES

1. NASA Handbook 7005, Dynamic Environmental Criteria, NASA Technical Handbook, March 13 2001
2. ECSS-E-HB-32-26A, Space Engineering: Spacecraft mechanical loads analysis handbook, February 19 2013
3. NASA Handbook 7004C, Force Limited Vibration Testing, NASA Technical Handbook, November 30 2012