# True Commercial Method to Test Combined Environments on Spacecraft Launch Systems and Payloads to Reduce Mass, Cost and Mission Risk

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**Abstract**

Simultaneous sustained (G) acceleration and vibration loads experienced by space launch vehicles and payloads during ascent can cause nonlinear structural responses to the systems, including shifts in natural frequencies, changes in mode shapes, and changes in the components that are excited. These responses cannot be tested using individual, sequential traditional qualification methods and suggest an alternative approach. A recent study using a Combined Environments test method showed a way to accurately replicate the launch environment and vibration load levels using a joint centrifuge and vibration system. Further investigation into the use of Combined Environments may offer a viable true commercial alternative to test government, commercial, and university payloads by reducing mass, saving time and cost, and lowering overall system risk through improved design margins.

**Traditional Qualification Methods**

Current NASA GSFC-STD-7000 and NASA-STD-7001 specifications and qualification processes dictate use of sequential, discrete tests to apply loads individually with iterative analyses. Testing is applied at the component level first, then at the subsystem level and finally at the system level for payloads, satellites, and space craft systems[1]. Test load levels are commonly provided by the launch provider, however in the case of early test and design, or unknown launch provider, the use of traditional testing standards (NASA GSFC-STD-7000 and NASA-STD-7001) are referenced as the environmental test qualification standard.

**Combined Environments**

A NASA Phase 1 STTR study by Drexel University, American Aerospace Advisors, and The NASTAR Center developed and demonstrated an early stage Combined Environments capability which delivered simultaneous sustained (G) acceleration and vibration loads to space launch hardware using an electromagnetic vibration table and counterbalance system integrated onto a state-of-the-art centrifuge.

**Test Method**

A 1U CubeSat (the Drexel University DragonSat-1) was selected as the Device under Test (DUT) and subjected to 23 test cycles up to 9Gs using standard random vibration profiles NASA-STD-7001 and NASA GSFC-STD-7000 as a baseline. Testing results showed that shifts in natural frequencies, changes in mode shapes, and changes in the excited components do occur and can be discovered through the use of Combined Environments testing methods.

**NASA & Commercial Applications**

Combined Environments may be beneficial for both NASA and non-NASA commercial applications including launch vehicles and spacecraft, small satellite, payloads, and system and subsystem applications for GNC, flight separation, flight termination, fluid systems, structural components, and mechanical and electromechanical devices. It may offer a true commercial approach to reduce mass, save time and cost, and lower overall system risk through newly improved design margins.

**Conclusion**

If testing in environments that more accurately reflect real world conditions enables a reduction in design load levels, use of Combined Environments may significantly reduce risk, launch costs, and increase performance and the number of launch opportunities available for both NASA and non-NASA systems.