Fusion of Test and Analysis: Artemis I Booster to Mobile Launcher Interface Validation

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ABSTRACT
NASA is in the midst of bold and exciting next steps in human exploration and spaceflight. The designs of the new Space Launch System (SLS), the Orion spacecraft and the Exploration Ground Systems (EGS) for vehicle processing and launch are essentially complete and there has been significant progress in manufacturing and assembly of specific hardware for the Artemis I and Artemis II missions. Equally as important, the program level and integrated system level testing and analyses are also well underway to support integrated verification, validation, and Certificate of Flight Readiness (CoFR) for Artemis I. Testing and analysis are key to addressing technical challenges faced by the Artemis missions. Building block approaches are required that provide the right balance between component, element, and/or system level testing that satisfies verification and validation objectives where uncertainties are quantified and minimized. Artemis I is a system of systems that requires a fusion of test and analysis that adeptly characterizes critical interfaces between major program elements. An example of this fusion involves characterizing the interface between the SLS booster and the Mobile Launcher (ML) Vertical Support Post (VSP) interfaces. Proper characterization of this interface represents a number of challenges beginning with the fact that it is a mating of ground support structure in the form of a civil structure to flight hardware. Both sides of the interface are built to different construction standards, but are governed by interface requirements to ensure compatibility when mated. From past program experience, the flexibility at the booster to ML interface is critical in developing accurate prelaunch stacking and cryogenic preloads, squat loads, and pad separation release of preloads and squat loads. This same premise holds for Artemis I. To characterize the asymmetric characteristics at this interface, careful consideration of static forces due to gravity loading with the commensurate effects due to leveling during booster stacking (i.e., spacing and shimming) and nonlinear geometric forces are necessary for inclusion in pre-test assessments. This paper will look at these issues for the upcoming Booster Pull Test in which two boosters will be installed on the ML and one of these boosters will undergo static lateral loading followed afterwards with dynamic excitation into resonance and free-decay. This paper evaluates the booster to ML interface characteristics by characterizing the interface flexibility between the booster aft skirt and the ML VSP interfaces. Furthermore, this paper methodically evaluates the effect of the following on the test outcome: gravitational effects on the booster and ML, the effects of VSP leveling, spacing, and shimming under gravitational loading during booster stacking, the effect of geometric nonlinear follower force due to cg offset as booster is laterally displaced, and the system coupling between the booster under test, ML, and the second booster. Simulated results for a static load pull and dynamic excitation provide insight into the differences in measurement responses when boundary conditions and geometric conditions are included and not included.

Keywords: Artemis, Booster, Booster Pull, Building Block Approach, Certificate of Flight Readiness, Exploration Ground Systems, Free-Decay, Interface Flexibility, Mobile Launcher, Gravitational Effects, Nonlinear Geometric Forces, Orion, Space Launch System, Static Loading, Vehicle Support Post, Verification and Validation