LOFTID (Low-Earth Orbit Flight Test of an Inflatable Decelerator) PASS (Payload Adapter Separation System) Design & Qualification

Sean M. Hancock[1] and Jacob P. Montgomery[2]
STC at NASA Langley Research Center, Hampton, VA, 23666

Joe A. Del Corso[3] and Ben J. Nickless[4]
NASA Langley Research Center, Hampton, VA, 23681

Matt B. Realsen[5]
United Launch Alliance, Centennial, CO, 80112

On November 10, 2022, NASA, in partnership with United Launch Alliance (ULA), launched Low-earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) as a secondary payload on an Atlas V Centaur out of the Vandenburg Space Force Base (VSFB). After successfully delivering the primary payload, Joint Polar Satellite System-2 (JPSS-2), to a sun synchronous trajectory, the Centaur upper stage reoriented LOFTID onto the desired reentry trajectory. After conducting a de-orbit burn to enter the atmosphere the Payload Adaptor was ejected to expose the packed LOFTID vehicle. The LOFTID Hypersonic Inflatable Aerodynamic Decelerator (HIAD) was deployed and inflated. The Centaur pointed LOFTID to the desired entry attitude and spun the vehicle up to roughly three rpm before separating the reentry vehicle over the Middle East. The LOFTID vehicle flew freely before reentering the atmosphere over Alaska at >8km/sec and decelerating as designed. LOFTID demonstrated stable flight from hypersonic entry through subsonic parachute deployment. LOFTID was enabled by a mission-unique Payload Adapter Separation System (PASS) which separated the Payload Adapter prior to the start of the LOFTID flight demonstration, allowing the launch vehicle to accommodate a superstack of two independent, similarly sized payloads. This paper will discuss the design, development, and qualification effort of the LOFTID PASS.

I. Introduction

In November 2022, engineers at NASA Langley Research Center, in partnership with United Launch Alliance (ULA), validated Hypersonic Inflatable Aerodynamic Decelerator (HIAD) technology with the successful Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) technology demonstration mission. LOFTID successfully demonstrated deployment, reentry, splashdown and recovery of a 6 meter HIAD [1]. HIAD is an enabling technology that facilitates atmospheric entry of heavy payloads to bodies with atmospheres. Utilizing a deployable aeroshell eliminates the size constraints imposed on current rigid aeroshell entry systems by the launch vehicle (LV) Payload

[1] LOFTID Payload Adapter Lead, Engineering Integration Branch, AIAA Senior Member.
[2] LOFTID Payload Adapter Engineer, Mechanical Systems Branch.
[3] LOFTID Project Manager, Space Technology and Exploration.
[4] LOFTID Mechanism/Motion Analyst, Mechanical Systems Branch.
[5] Payload Accommodations System CRE.

Fairing (PLF). This enables use of larger aeroshells resulting in lower ballistic coefficients and increased entry system performance (e.g., higher payload mass and/or volume, higher landing altitude at Mars) [2].

Taking advantage of excess Atlas V LV capacity, LOFTID flew as a secondary payload to NASA-NOAA's Joint Polar Satellite System-2 (JPSS-2) weather observing satellite, launching from Vandenburg Space Force Base (VSFB). After delivering JPSS-2 to its orbit, the LOFTID payload was reoriented for reentry, the reentry vehicle (RV) was inflated, positioned, and then separated to reenter Earth's atmosphere at a velocity of >8 km/s, ultimately splashing down safely in the Pacific Ocean [3]. To accommodate a superstack of two independent, similarly sized payloads, LOFTID flew in a mission-unique configuration, directly under JPSS-2, inside the Payload Adapter (PLA) that integrated JPSS-2 to the LV. The JPSS-2/LOFTID superstack is shown in Fig. 1 being integrated into the PLF. A mission-unique Payload Adapter Separation System (PASS) was required to separate the PLA from the LV prior to the start of the LOFTID flight demonstration.

Fig. 1 JPSS-2/LOFTID superstack.

The PASS performed flawlessly in flight. This paper provides an overview of the JPSS-2/LOFTID super-stack configuration, the LOFTID PASS design, development challenges, and the testing and modeling campaign to qualify PASS for flight.

II. Rideshare

NASA was approached by United Launch Alliance (ULA) in 2017, with a proposal to use HIAD technology as part of a concept to recover the first stage engines on a launch vehicle. In order for the technology to be considered viable for a recovery application, it was necessary to first demonstrate an orbital entry capability at a relevant scale and conditions. With the intent of demonstrating orbital entry, LOFTID was initiated as a flight demonstration project, in partnership with ULA.

As the LOFTID concept evolved, so did the partnerships within NASA, with government agencies, and with industry. In addition to the NASA-ULA relationship, LOFTID also developed a relationship with the National Oceanic and Atmospheric Administration (NOAA) funded Joint Polar Surveyor Satellite (JPSS-2), and by necessity, the Launch Services Program (LSP). In a NASA Flight Planning Board, conducted in early 2020, it was determined that LOFTID would be manifest as a rideshare on the JPSS-2 launch vehicle. By making use of available up-mass allocation, LOFTID was able to satisfy size and mass requirements necessary to demonstrate an entry condition applicable to future applications.

Initial stacking configurations focused on attempting to side mount the LOFTID reentry vehicle in an ESPA payload configuration. After several iterations, looking at stacking and CubeSat configurations, LOFTID considered encapsulation of the RV within the launch vehicle adapter rings. That decision initiated a study of multiple Payload Adapter configurations. Fig. 2 below shows the evolution of the LOFTID payload as the design matured.

Fig. 2 LOFTID payload evolution.

Once the stacking arrangement of the JPSS-2 (primary) and LOFTID (secondary) payloads was decided, a unique separation mechanism was required to allow for the deployment of the RV. The Payload Adapter Separation System (PASS) was the mechanism developed to deploy the RV after the primary payload was released. To add to the complexity of the mission, LOFTID, including the PASS and all attachment hardware, had to fit within the volume and mass constraints of the PLF, and launch mass capability of the Atlas-V LV.

III. Payload Adapter

The JPSS-2 / LOFTID superstack, shown in Fig. 3, was completely enclosed by the 4m Atlas V Extended Payload Fairing (EPF). The PLA enclosed the lower LOFTID payload and provided structural support for the upper JPSS-2 payload.

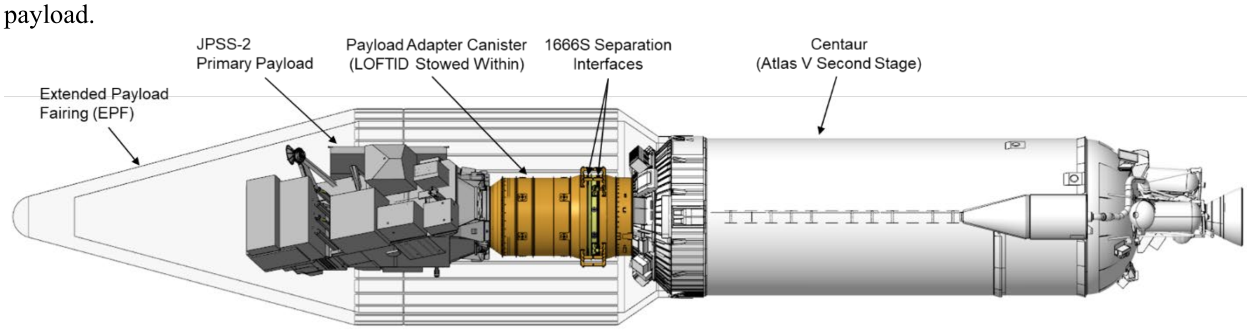

Fig. 3 JPSS-2/LOFTID launch configuration.

The LOFTID PLA configuration is shown in Fig. 4. The PLA stack used a series of three common payload separation systems (CPSS) and the NASA designed PASS system specific to LOFTID. The PLA mates to the Centaur upper stage with a standard ULA C-13 Adapter mounting to the Centaur Forward Adapter (CFA) at the forward end of the LV upper stage. A conical 1666S Payload Separation Ring (PSR) and Reentry Vehicle to Payload Adapter Interface Ring (RVPAIR) mate the LOFTID RV to the PLA. A 1666 Forward Separation Ring (FSR), a second reversed 1666S PSR, a series of ULA C-adapter cylinders, and finally a B1194 Payload Separation Ring make up what was called the PLA Canister. This is the portion of the PLA that separates, exposing the LOFTID payload. The PLA Canister was closed out forward of the LOFTID RV with a Contamination Control Diaphragm. A single pneumatic and eight avionics in-flight disconnects (IFDs) spanned the PLA Canister separation interface. Two additional avionics IFDs spanned the RV separation interface. The forward 1666S Payload Separation Ring separated the PLA Canister from the RV while mated to the Centaur. The aft 1666S Payload Separation Ring separated the RV from the Centaur. The PASS mounted interior to the PLA.

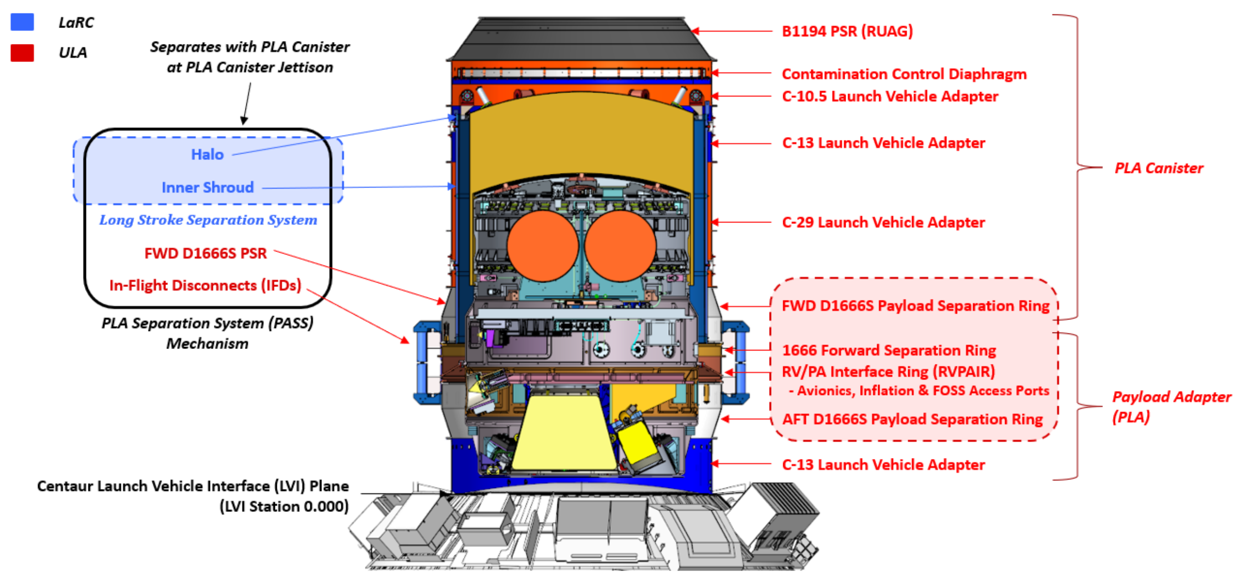

Fig. 4 LOFTID Payload Adapter.

IV. PASS Design

Development of the PASS design was challenging due to a shortened development schedule resulting from the process of determining the rideshare configuration, the iterative nature of PLA development with NASA's partners at ULA, and a need to conform to a fixed JPSS-2 launch date. In order to meet the launch delivery schedule, it was necessary to begin design and fabrication of the PASS before a rideshare decision had been finalized. The initial rideshare configuration included an Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) ring. This ESPA ring included accommodations for up to 1200 lbm of Auxiliary Payloads (APLs) and is shown in Fig. 5 below. In addition to the unknown APL configuration, the PASS design had to accommodate some or all of the APLs failing to separate from the ESPA and having to separate with the PLA Canister. This resulted in a very wide range of mass properties to be considered. In addition to separating the PLA Canister from the RV, the PASS had a requirement to prevent damage to the stowed aeroshell during PLA Canister separation. Some initial concepts were considered to minimize tip-off (rotation about an axis resulting from the separation event), including guide rails, however the uncertainty in separation mass and mass properties eventually led to the design decision to accept that there might be contact between the separating PLA Canister and the stowed aeroshell and to develop a design that would prevent damage to the stowed aeroshell. Eventually, a rideshare configuration was settled on that eliminated the ESPA an all APLs, eliminating ~1400 lbm (ESPA: ~200lbm, APLs: ~1200lbm). The PASS design was capable of accommodating the PLA configuration change with minimal impact.

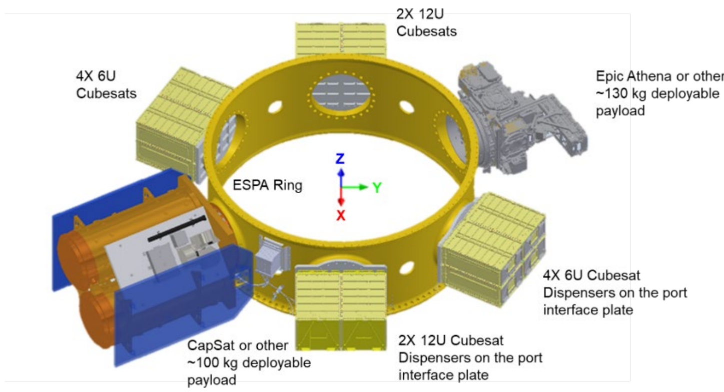

Fig. 5 LOFTID Potential Rideshare Payloads.

The PASS design was a collaborative effort between ULA and NASA. It consisted of an inverted ULA provided 1666S PSR and a NASA provided Long Stroke Separation System (LSSS). The 1666S PSR provided the initial kick-off motive force to overcome any stiction and overcome IFDs. The LSSS ensured the separation force margin was greater than zero for the duration of the separation while also ensuring that the separating PLA Canister would not damage the stowed LOFTID aeroshell.

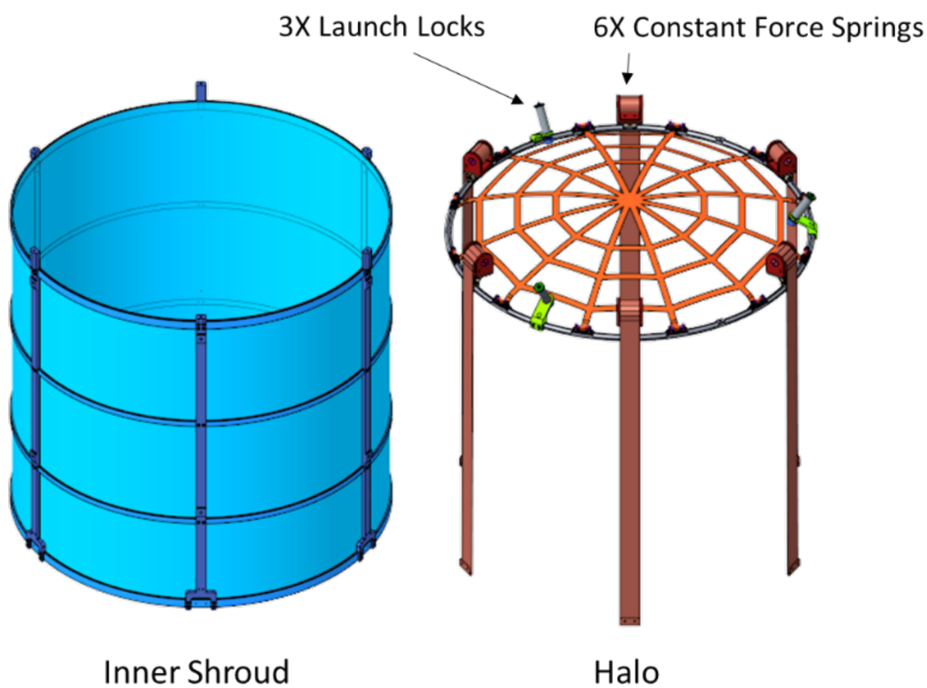

Fig. 6 PASS Long Stroke Separation System.

The LSSS consisted of two primary sub-components – an Inner Shroud and a Halo. These are shown in Fig. 6 above. The Inner Shroud consisted of a smooth aluminum liner bonded to an aluminum frame. The inner surface, facing the stowed aeroshell, was coated with a Teflon impregnated hardcoat anodized coating that provided a low friction surface to protect the stowed aeroshell during PLA Canister separation. The Inner Shroud attached to the PLA Canister at twelve locations – upper and lower mounts clocked in 60 degree increments. The Inner Shroud alone was not a stiff structure, however bolting it to the interior of the PLA Canister gave it considerable stiffness. The Halo was an aluminum ring that hosted a set of six constant force (CF) springs, three launch locks, and custom webbing that provided the interface with the stowed aeroshell. Like the interior of the Inner Shroud, the Halo was coated with a Teflon impregnated hardcoat anodized coating. The six constant force springs ensured the separation force margin was greater than zero for the duration of the separation event. The constant force springs, shown in Fig. 7, were prestressed flat strips of spring material formed into a constant radius coil around a drum. When extended, the inherent stress resists the loading force at a nearly constant (zero) rate. The springs offer high force output with minimal space requirements, provide long strokes, and store power indefinitely when extended. The springs clocked 60 degrees apart and matched to minimize tip-off. Because the OML (outer mold line) of the stowed aeroshell changed each time it was packed, the PASS interface had to accommodate a range of shapes. The Halo webbing provided a conformal interface between the PASS and the stowed aeroshell. Halo launch locks were included to ensure the Halo remained centered over the stowed aeroshell for the duration of launch.

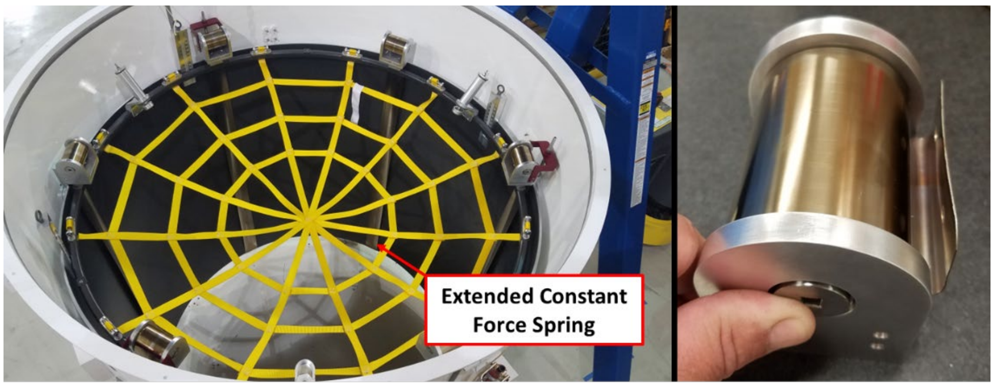

Fig. 7 PASS Constant Force Spring.

Following the KISS (Keep It Simple, Stupid) principle, the PASS was neither elegant nor complex. It performed much like a sling shot, except that the sling shot ended up with velocity imparted to it and the "projectile", the LOFITD RV, remained stationary. Upon command from the ULA Centaur, the 1666S clamp band released. The short stroke 1666S compressed springs provided an initial kick-off force initiating separation and overcoming the retaining force in the eight avionics in-flight disconnects (IFDs) that spanned the PLA Canister separation interface. The six constant force springs, mounted to the Halo, retracted The spring free ends, mounted to the base of the Inner Shroud, pulled the Inner Shroud and PLA Canister up, while pulling down on the Halo with the webbing reacting the separation force against the stowed aeroshell until the PLA Canister was eventually thrown off the RV. Fig. 8 below shows this sequence.

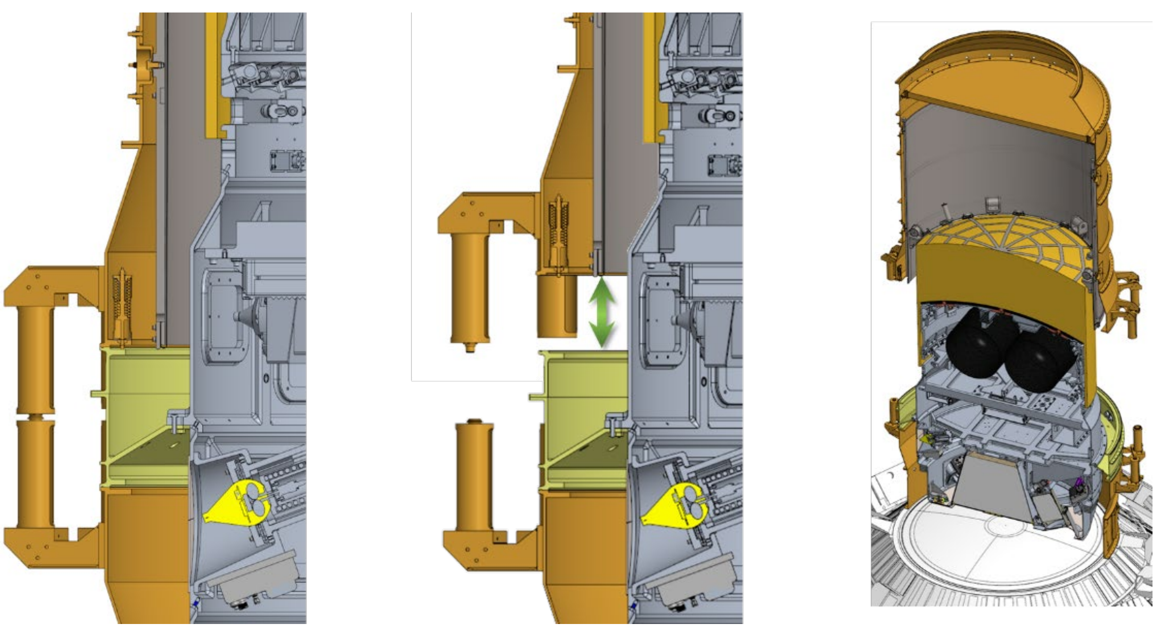

Fig. 8 PASS Separation.

V. Development and Qualification Testing

Development of the PASS system followed the traditional NASA prototype development process, with the fabrication and testing of a qualification unit (Engineering Development Unit (EDU)) and then of a flight unit. NASA-STD-5017A Design and Development Requirements for Mechanisms [4] was tailored to maintain sufficient technical rigor yet align with the project's schedule, budget, and risk posture. Prior to assembling the PASS EDU, the CF springs underwent component level sine vibration testing, characterization testing, run-in testing, and life cycle testing. The PASS Halo assembly was static load tested. Once assembled, the EDU was subjected to mechanism testing that included run-in testing, pre-random vibration performance testing, random vibration performance testing, post-random vibration performance testing, and life cycle testing. The Qualification Test Matrix is provided in Table 1 below.

Table 1: LOFTID PASS Qualification Test Matrix

Test	Recommended Qual Unit Testing	LOFTID PASS EDU Testing	Comments
Run-In	(1)	Nominal Actuation	Minimum of 3 Cycles at Assembly Level
Performance	Envelopes	Nominal Actuation	
Leak	X	N/A	
Shock	X	No	Analysis Only
Transportation from LaRC to GSFC			
Random Vibration	Qual Level	Qual Level	Post-Test Visual Inspection
Acoustic Vibration	Qual Level	No	Covered by Random Environments
Sinusoidal Vibration	Qual Level	No	Not Required
Transportation from GSFC to LaRC			
Thermal Cycle/Thermal Vacuum	X	No	Thermal characterization of spring sets
Thermal Gradient	X	N/A	
Depressurization/Repressurization	X	N/A	
Climactic	X	N/A	
Electromagnetic Compatibility	X	N/A	
Life	X	Nominal Actuation	Minimum of 5 Cycles
Statis Loads	X	No	Analysis Only
Performance	Envelopes	Nominal Actuation, Envelopes, Off-Nominal	Envelope – Maximum linear acceleration, Minimum linear acceleration Off Nominal – 1666S Spring-out, CF Spring-out, Halo Misalignment

(1) Run-in testing is not listed in the qualification sequence because it is a workmanship test, and it is assumed that the qualification unit undergoes acceptance testing prior to qualification testing. However, if for some reason acceptance testing is not performed on the qualification unit, the qualification unit should still be run-in prior to qualification testing.

The CF Spring sine vibration test provided insight into the response of a CF spring, in a flight configuration, to the launch environment acceleration input. It also provided a qualitative understanding of the interaction between the spring tape and the inner shroud liner. For this testing, a fixture was fabricated to mount the spring fully extended against a liner surrogate, with the appropriate clearances between the spring tape and the Inner Shroud liner that would be seen in the PASS assembly. Testing was conducted in all three axes.

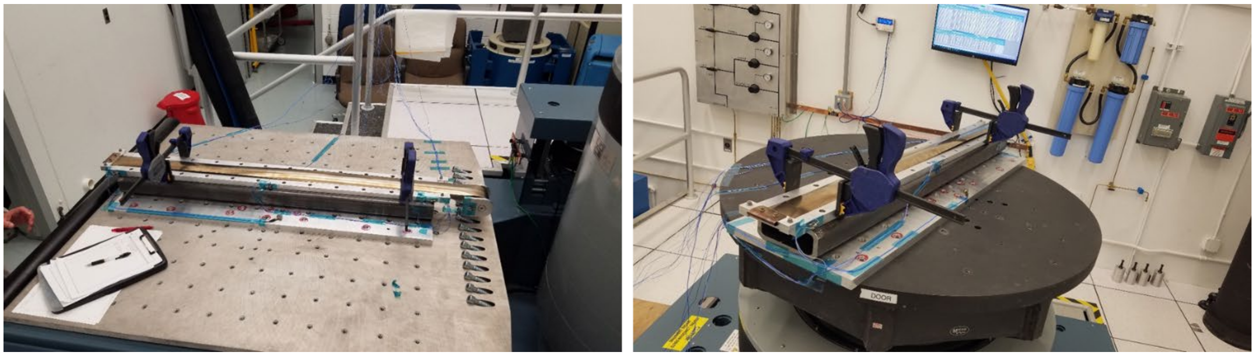

Fig. 9 CF Spring Sine Vibe Testing – x and z axis (left), y axis (right).

For qualification testing, twelve constant springs were procured. The spring used for sine vibration testing was not used further. The remaining eleven springs were subjected to characterization testing. After which, a matched set of six springs was selected. Spring characterization testing utilized an MTS testing frame with an integral thermal chamber to measure the spring pull force over is full range of travel. The testing also measured thermal sensitivity of the spring force to temperature by testing a hot case and a cold case for each spring. Fig. 10 shows the CF Spring characterization test set up.

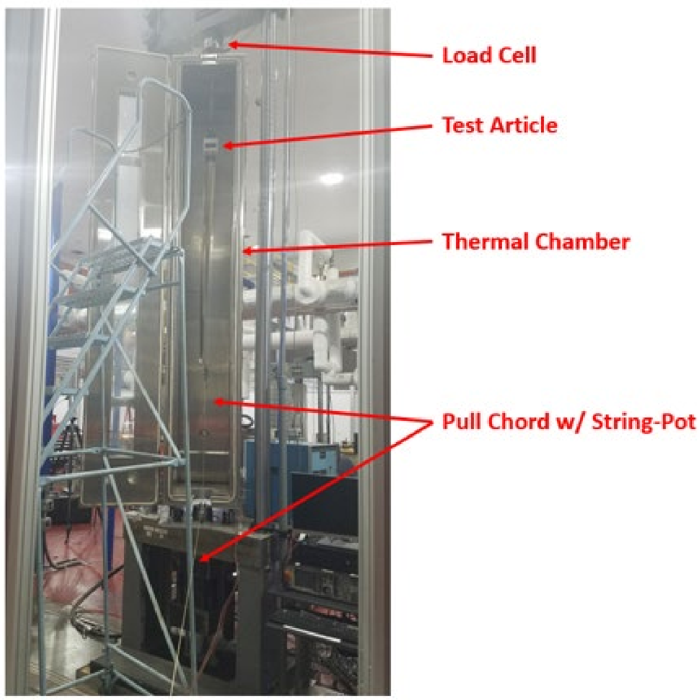

Fig. 10   CF Spring characterization test setup.

Each spring was cycled a minimum of 15 cycles for component run-in testing. Some inconsistencies from one cycle to the next was allowed during run-in testing. At a minimum, the average force for each of the last five cycles was required to not deviate more than +/- 10% from the mean of the last five cycles. In the case where one of the last five cycles were not within +/- 10% of the mean, spring cycling was continued until five cycles occurred that were within +/- 10%. Fig. 11 below shows a typical measured spring force profile. It should be noted that the unsmooth nature of the curve was due to twisting of the spring in the load frame as the spring was extended or retracted, however the resolution of measurements was such that this impact was negligible. It should also be noted that the measured force on the spring extension was higher than that for retraction. This was the case for every cycle measurement. Because the pass springs were to retract in flight, the retraction measurements were used for PASS analysis. After run-in testing, springs were subjected to additional cycles until each spring had been cycled 48 times.

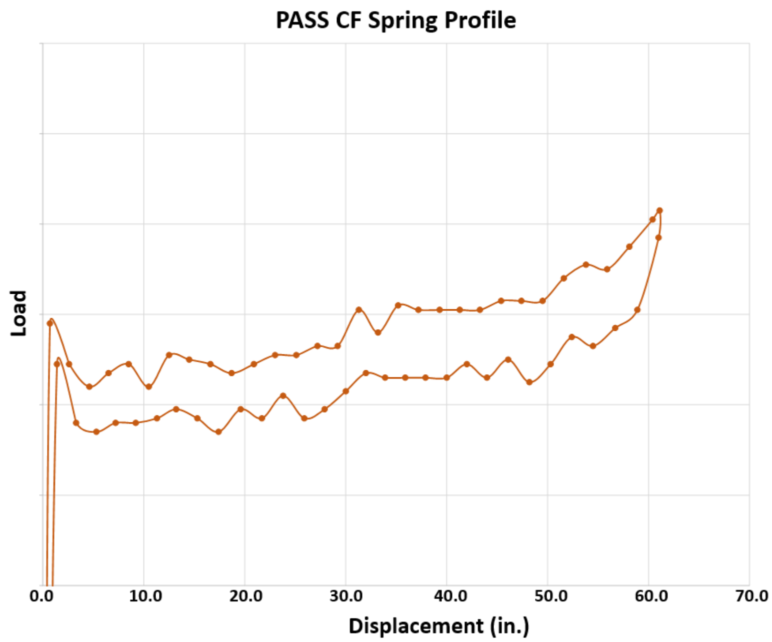

Fig. 11 Typical measured CF Spring force profile.

Prior to integration of the Halo to the Inner Shroud, the Halo, with webbing installed, was static load tested to 125% of its design load. This test was conducted in a flight-like configuration with the test weights mounted to the CF Spring mounts and the weight pulling the webbing down against a mock-up of the stowed aeroshell. Fig. 12 shows Halo static load testing.

Fig. 12 PASS Halo static load testing.

The PASS mechanism was tested using a planar air bearing test which allowed for 3 degrees of freedom in a 1-g environment – 2 translational and 1 rotational. The test allowed freedom in the yaw direction. Because of the 1-g testing constraints, the mechanism was tested in two planes (two separate tests for each condition), using superposition to qualify the operation in a zero-g environment. The mechanism test configuration is shown below in Fig. 13.

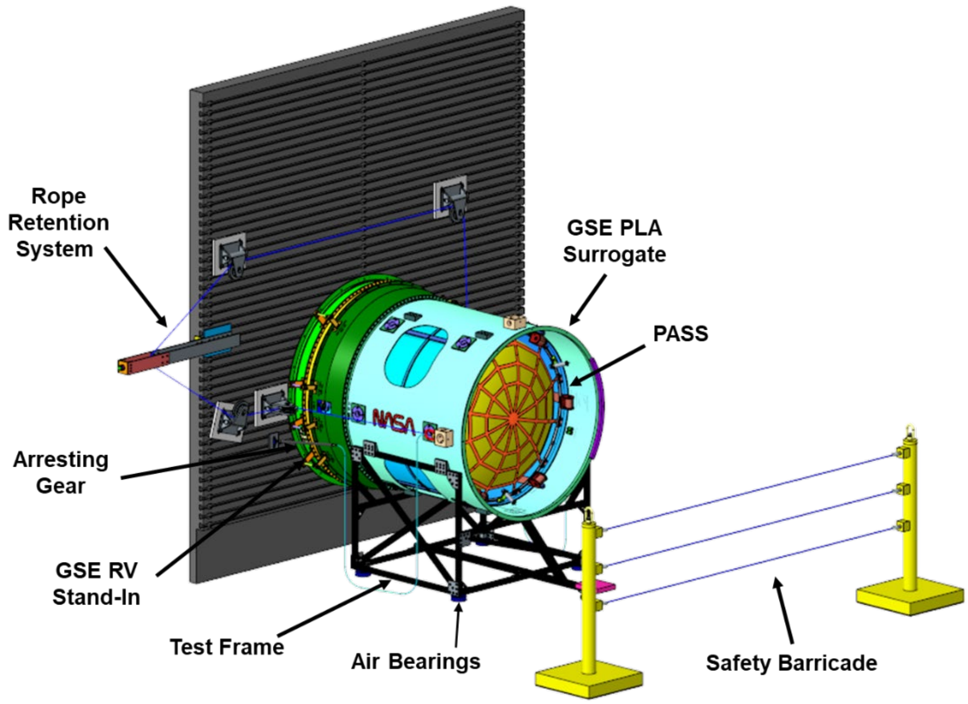

Fig. 13 PASS mechanism test setup.

An RV Stand-in was mounted to a rigid backstop. The PASS EDU was mounted to a PLA Canister Surrogate which was then mounted on a frame supported by air bearings. In lieu of a clamp band at the FWD 1666S separation interface, the PLA Canister Surrogate was secured to the RV Stand-In using a series of ropes and pulleys that could be tensioned – clamp bands do not perform well in a horizontal 1-g environment. When it was time to test separation, the rope was cut, and the PLA Canister, with the PASS EDU installed, could separate freely on air bearings. A set of dampers secured to the backstop and the PLA Canister slowed and then stopped the PLA Canister after separation was complete. A second safety barricade was added in-case the damper system failed to stop the PLA Canister. Photogrammetry and high speed cameras were used to measure the PLA canister separation and tip-off rates and to qualitatively inspect PASS performance during separation. Mechanism test criteria required that the mean separation velocity of an individual test fall within +/- 10% of the overall mean from all tests for all tests for a given configuration. Failure of the PASS/PLA Canister to fully separate or cause damage to the aeroshell restraint bag would also constitute a test failure.

Qualification mechanism testing included three run-in cycles, a single performance cycle, and fifteen life-cycle cycles for a total of 18 individual tests, all demonstrating repeatable performance. Two envelope tests were conducted in a single plane. These tests were maximum and minimum linear acceleration. Lastly, three off-nominal cases were evaluated, again in a single plane. The off-nominal cases included a ULA kick-off spring-out case, a CF spring-out case, and a case that simulated the Halo shifting all the way to one side during launch. The PASS separated the PLA Canister Surrogate cleanly during each of the off-nominal cases.

In order to ensure flight like interfaces between the PASS and the RV, an RV Stand-In was fabricated to duplicate the OML of the RV from the RVPAIR ring forward to the stowed aeroshell. The RV Stand-In incorporated all external features that the PASS would potentially interact with. Fig. 14 below compares the RV Stand-In with the flight RV and shows the external features incorporated, including access panel fasteners, bulkhead connectors on the RVPAIR, a Fiber Optic Sensing System (FOSS) [5] cover with fasteners, and the packing restraint bag cord cutter blocks and retention groove. Because the stowed aeroshell reacts the load of the PASS CF Springs and the Halo webbing had to be conformal to the stowed aeroshell OML, the RV Stand-In included a surrogate for the stowed aeroshell, shown in Fig. 15. The stowed aeroshell surrogate was fabricated from model foam of the same density as the packed HIAD. The OML was machined to match a simple revolution of a section from a laser scan of stowed aeroshell EDU. The stowed aeroshell surrogate was then covered with the packing restraint EDU, providing a completely flight like interface between the PASS and the RV.

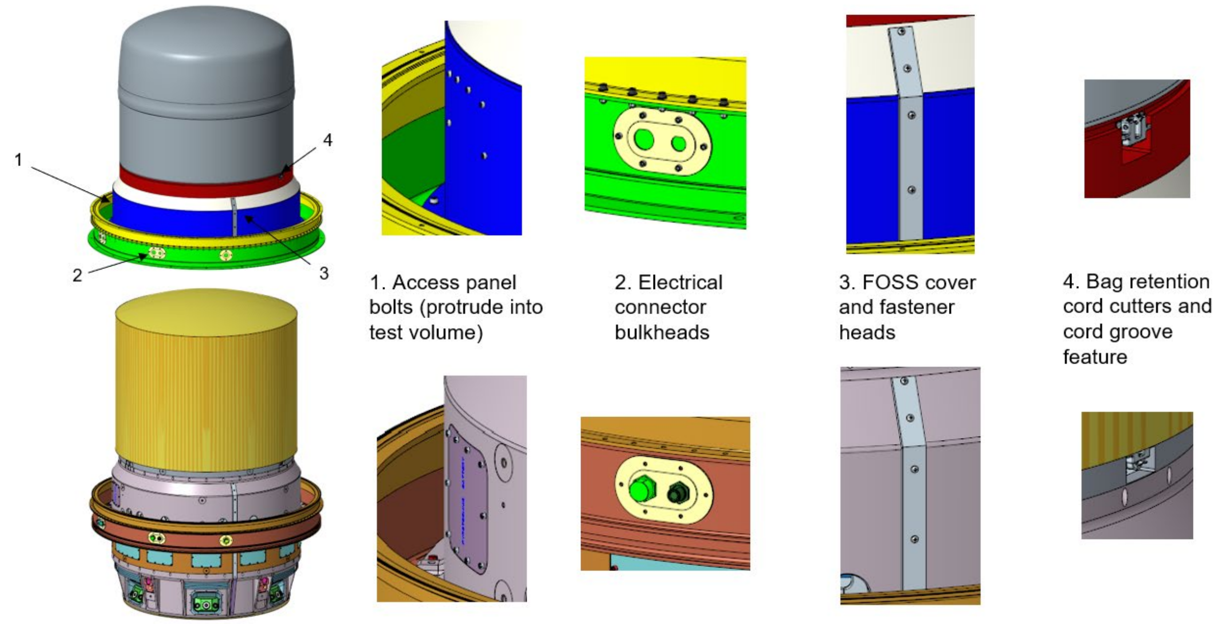

Fig. 14 RV Stand-In (top) compared to the RV (bottom) including external features.

Fig. 15 RV Stand-In stowed aeroshell surrogate (left) with packing restraint EDU being installed (right).

To ensure flight like interfaces between the PASS and the PLA Canister, a PLA Canister Surrogate was fabricated. The PLA Canister Surrogate incorporated all of the separation mechanism features of the ULA 1666S PSR with the exception of a clamp band which would not perform as intended in the PASS mechanism test configuration as explained earlier. ULA provided a set of kick-off compression springs and the separation surface between the 1666S PSR and 1666 FSR was duplicated. IFD surrogates were fabricated and installed in the correct location to simulate the JPSS-2 IFDs spanning the PLA Canister separation plane. The IFD surrogates were sized to match the nominal pull force for the flight IFDs. Pull testing was conducted on each of the IFD surrogates to verify the pull force. This would later be used as an input to the dynamic model developed to simulate/predict PASS flight performance. The PLA Canister Surrogate also included the each of the twelve PASS to PLA Canister interfaces, fabricated to the tolerances specified in the Mechanical Interface Control Drawing so that mating of the PASS to the PLA Canister Surrogate could serve as an early verification of fit between the two pieces of hardware. Fig. 16 below compares the PLA Canister Surrogate with the flight PLA Canister and shows the features incorporated.

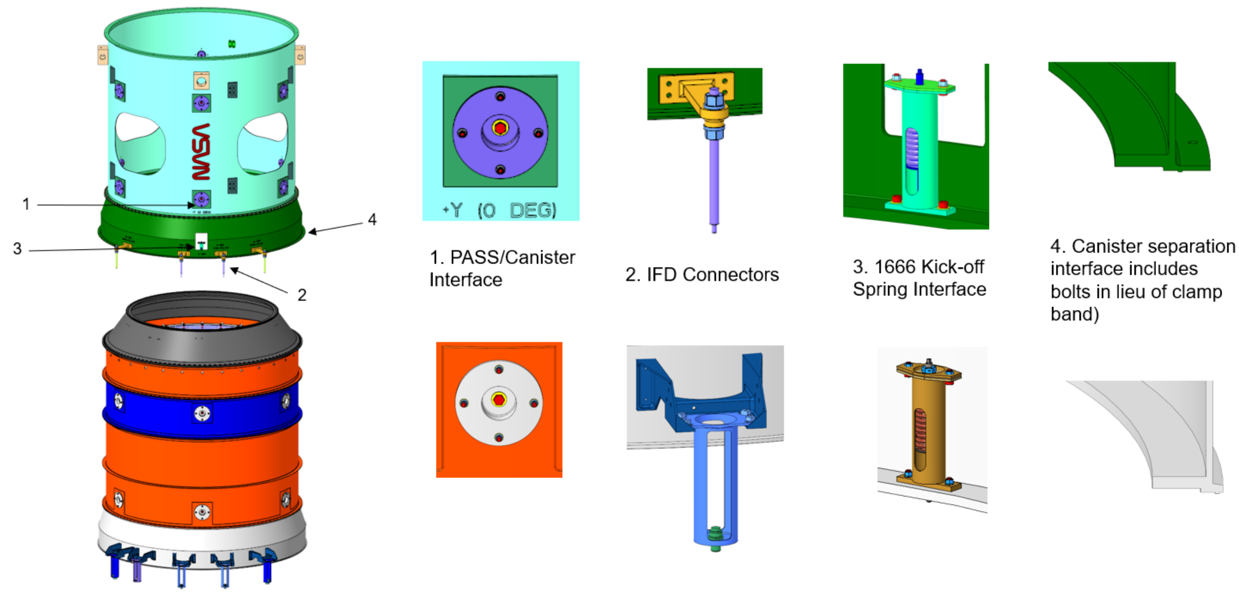

Fig. 16 PLA Canister Surrogate (top) compared to the PLA Canister (bottom) including features.

PASS separation performance is a strong function of the mass properties of the PLA Canister. To ensure ground testing was as flight-like as possible, the PLA Canister surrogate was fabricated such that, when sitting on the test stand, the mass of the test hardware was matched within 1% of the predicted mass of the flight hardware and location of the CG in the two directions of lateral freedom of motion were matched to with .10 in of the predicted CG location of the flight hardware. Ballast was used to accomplish this in each test configuration. Fig. 17 shows the CG location for each of the test configurations.

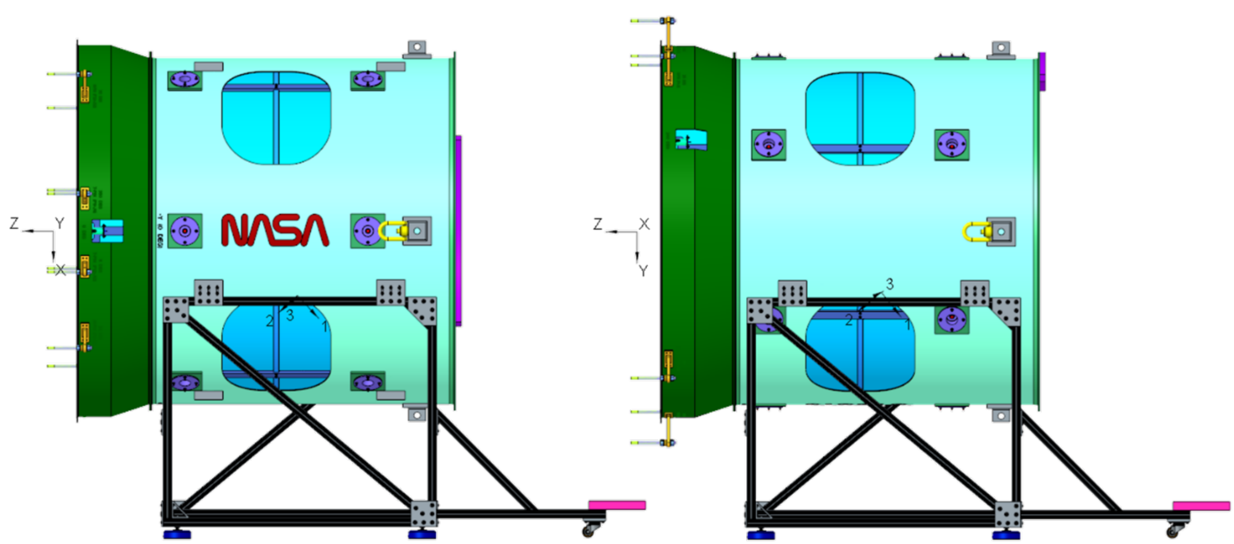

Fig. 17 PLA Canister Surrogate CG locations - y-axis configuration (left) and x-axis configuration (right).

Because of the large size, mass, and required energy levels, the PASS was random vibration tested at Goddard Space Flight Center (GSFC) vibration test facility 409 and 410. The PASS was tested to prototype qualification levels – limit level + 3 dB for a 2 minute duration in each axis. Fig. 18 shows the test configuration. The final run-in mechanism test was used as a pre-random vibration baseline of performance and compared against a post-random vibration mechanism performance test, with no variation in performance.

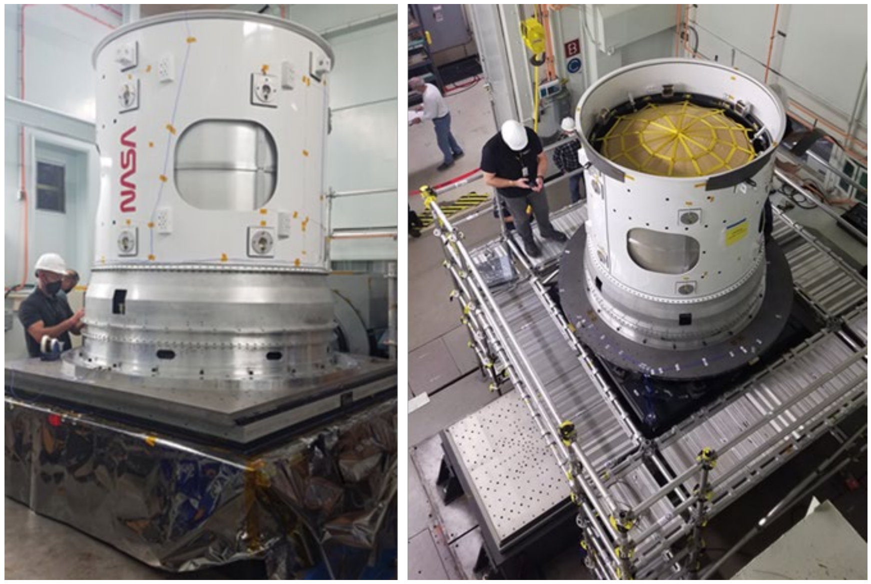

Fig. 18 PASS random vibration testing - latera (left) and axial (right).

VI. Analysis

An ADAMS [6] model of the PASS separation was built to predict the relative motion of the event, and to study the effects of varying some of the inputs previously mentioned. Early in the design cycle, the model was built to represent in-flight behavior, and used to predict min/max separation accelerations and velocities, rotational rates, etc., that were needed to make other design decisions. It was later constrained to represent the ground test, so that ground test data could be leveraged to assess model accuracy and validity. Three separate bodies, and their associated mass properties, were necessary to capture the dynamics of the event: the LOFTID and Launch Vehicle (lumped together), the jettisoned portion of the PASS, and the Halo. Shown in Fig. 19 is the ADAMS model and a ground test configuration CAD model.

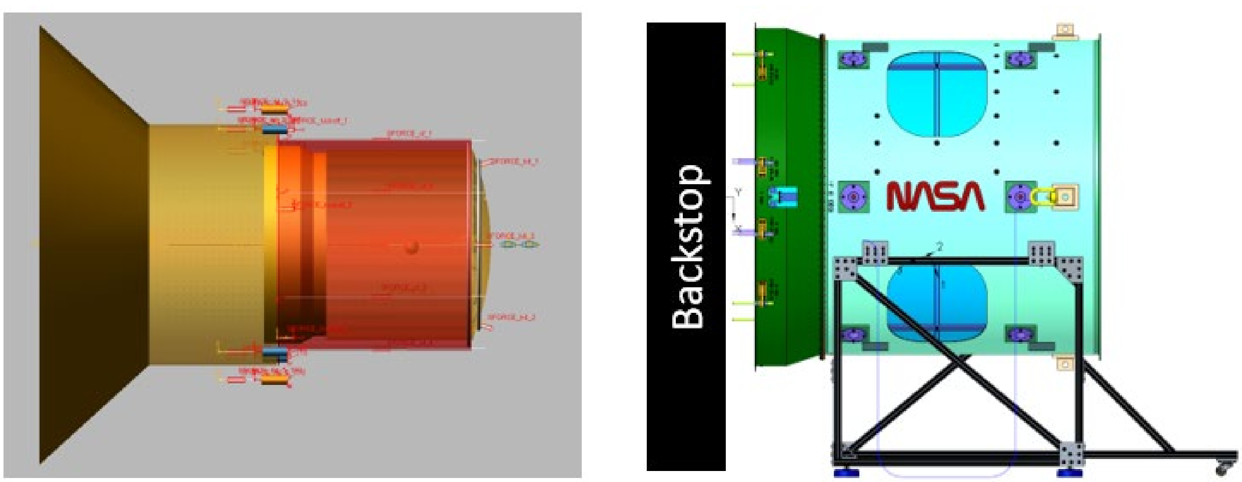

Fig. 19 ADAMS Model compared to Test Configuration

The sets of forces that contributed to the separation event (IFDs, kick-off springs, and CF springs) had their own nominal and tolerance values, used early in the process with the flight model. However, when modeling the ground test, many of the test article components were characterized, including the CF Springs and IFDs. However, not all the components were fully characterized. For those that were, their characterization was done in test fixturing, and not in their test configuration. So, for these and other reasons (data noise, environmental factors, etc.) it was expected the ADAMS model would require some tuning in order to reflect how the components truly behaved in the test, and correlate to the test data. The test data itself was the guide as to how or where to tune. For initial comparison, any component characteristic not explicitly measured was set to its expected nominal value. Shown in Fig. 20 is an example of the model-test correlation for velocity of the X-configuration test, before and after tuning the ADAMS model. It illustrates that, prior to tuning, the general behavior is modeled well, and that only minor changes to component behavior occurred in the test configuration. The following model adjustments were made: decreasing the CF Spring force level, adjustment of the ULA spring hard-stop location, adjustment of IFD force application start and stop points, and increasing IFD force levels . Shown in Fig. 21 is the percent difference of both tests, indicating that after tuning, the requirement of correlation within 10% was met, excepting values below 3X-noise-floor, as evidenced by the high percent difference for the first 20 milliseconds or so.

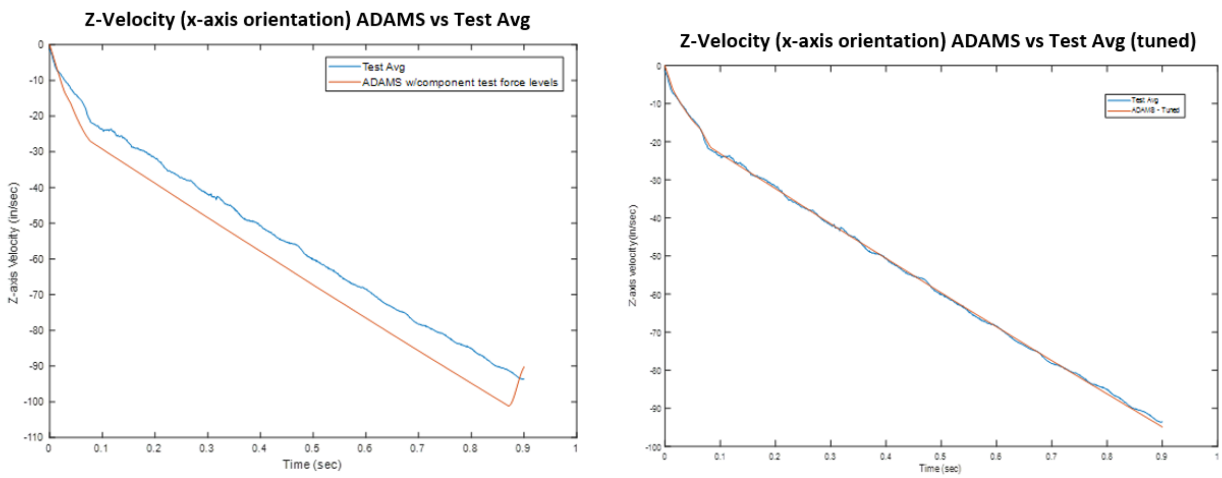

Fig. 20 Sample ADAMS model versus Testing comparison – untuned (left) and tuned (right).

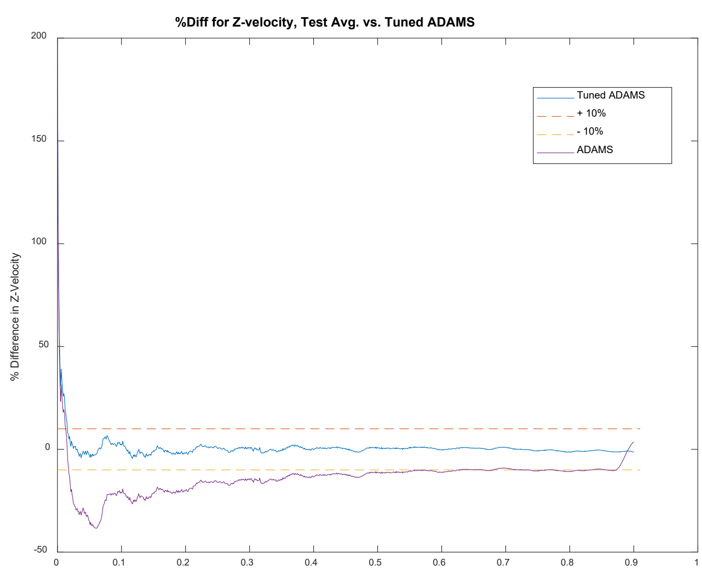

Fig. 21 Model velocity versus Test velocity percent difference (tuned & untuned).

VII. Conclusions

The PASS design completed 31 successful mechanism tests during qualification and acceptance – 24 tests of the EDU, six ground tests of the flight PASS, and, of course, the flight separation. During all separations, the PASS separated the PLA Canister (or Surrogate) cleanly, including 3 off-nominal tests. The PASS performed flawlessly in flight with no noticeable tip-off. A qualitative examination of the flight video shows that the separation velocity was in kind with ground testing and ADAMS model predictions.

References

[1] DiNonno, J., and Cheatwood, N., "Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Mission Overview and Science Return," paper submitted to AIAA SciTech 2024, Orlando.

[2] Cheatwood F.M., et al., "Manufacturing Challenges and Benefits when Scaling the HIAD Stacked-Torus Aeroshell to a 15m-Class System" IEEE Aerospace Conference, 2016
doi: 10.1109/AERO.2016.7500773

[3] Hughes, S.J., Swanson, G., Cheatwood, N., and DiNonno, J., "Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Aeroshell Performance," paper submitted to AIAA SciTech 2024, Orlando.

[4] NASA-STD-5017A, "Design and Development Requirements for Mechanisms." 2015.

[5] Parker, A.R., et al., "Fiber Optics Sensing System (FOSS) deployment on Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)," paper submitted to AIAA SciTech 2024, Orlando.

[6] ADAMS, Automated Dynamic Analysis of Mechanical Systems, Software Package, Ver. 2022.2, Hexagon, Stockholm, Sweden, 2022. https://hexagon.com/products/product-groups/computer-aided-engineering-software/adams.