National Aeronautics and Space Administration

Additive Design and Manufacturing of SmallSat Structures (ADAMSS)

Principal Investigator: Bryan McEnerney (353); Co-Investigators: Ryan Watkins (357), Matthew Jadusingh (355), Adam Duran (355), Theresa Juarez (353), Molly Hwang (353), Hector Ramirez (357), John Paul Borgonia (357), Abigail Reigner (353)

Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Additively Designed and Manufactured Small Sat Structures - Strategic Initiative Leader: Timothy P O'Donnell

Objectives:

The objective of ADAMSS was to create multi-functional hardware for the Cupid's Arrow reference mission utilizing additive manufacturing and topological optimzation. The specific project objectives, over three years, were to demonstrate cost, mass, and schedule savings of 25% versus the conventional state of the art. In this year, due to the evolding needs of the Cupid's Boomerang mission, objectives were changed from designing a 11.1 liter hydrazine tank to fabricating an entire 55 liter bi-propellant propulsion module that included mass simulators for star trackers, sample electronics boxes, and a Stardust-sized sample capture and return module. Additionally, the overarching objective of this task was to mature the relevant technologies to a TRL 5 at the end of the 3 year effort.

Background:

Multi-functional structures offer a significant benefit for more efficient use of spacecraft mass, by combining multiple roles into a single piece of hardware. The FY22 ADAMSS hardware was conceived to serve multiple roles for a Venus atmosphere sample capture and return mission: 10 act as the 55 liter bi-propellant tanks (monomethyl hydrazine and nitrogen tetroxide) for primary propulsion, 2) function as the primary structure of the propulsion module, and 3) use the tankage and propellants as radiation shielding for in-board electronics boxes, to minimize the need for parasitic radiation shielding mass (e.g. single-use material). The approach aimed to demonstrate radical new geometries creating high-efficient structures with reduced part counts, multi-functional uses, and scalability. For the purposes of this effort, flight-like design, analysis, and testing methodologies were employed, in order to ensure that the maturation effort could seamlessly mesh into any proposal efforts, and that all techniques were consistent with the eventual flight needs.

Approach and Results:

The design approach leveraged laser powder bed fusion to create a nested tank architecture mated to a Stardust-class return capsule, Figure 1. The nested tanks, Figure 2, allow for ready non-destructive examination, as well as effective integration and packing, with external star tracker mounts grown into the exterior tank. The entire assembly, Figure 3, which includes mass simulators for the star trackers, also additively manufactured, as well as center of gravity and mass simulators for the capsule, was assembled and subjected to flight-like random vibration and sine bust testing. The test plans were generated by JPL's Flight Dynamics group and the final hardware was 60% scale of the reference mission; cost and schedule concerns prohibited full-scale hardware on the R&TD budget, but would not be prohibitive for a flight mission.

Significance/Benefits to JPL and NASA:

The design, fabrication, and testing of the hardware followed flight-like practices and demonstrated that it is viable to create SmallSat architectures that are multi-functional structures (e.g. propellant tanks as primary structures, integrated startracker mounts, center-bore electronics box mounting, and efficiently mounting of the return structure. The key to this work is that it's a design methodology, enabled by topological optimization and additive manufacturing, that is extensible to a wide range of architectures, missions, and destinations. The design can be easily modified from an orbital system to become a lightweight, cost-effective lander for a wide range of destinations.

NASA and JPL require cost-effective solutions for distributed science (e.g. swarm) architectures, or for being able to examine outer planets with more than one landed mass. By creating multi-functional structures that enable multiple packages to be landed, the science return can be increased dramatically, and furthermore, will fit into cost-capped mission profiles.

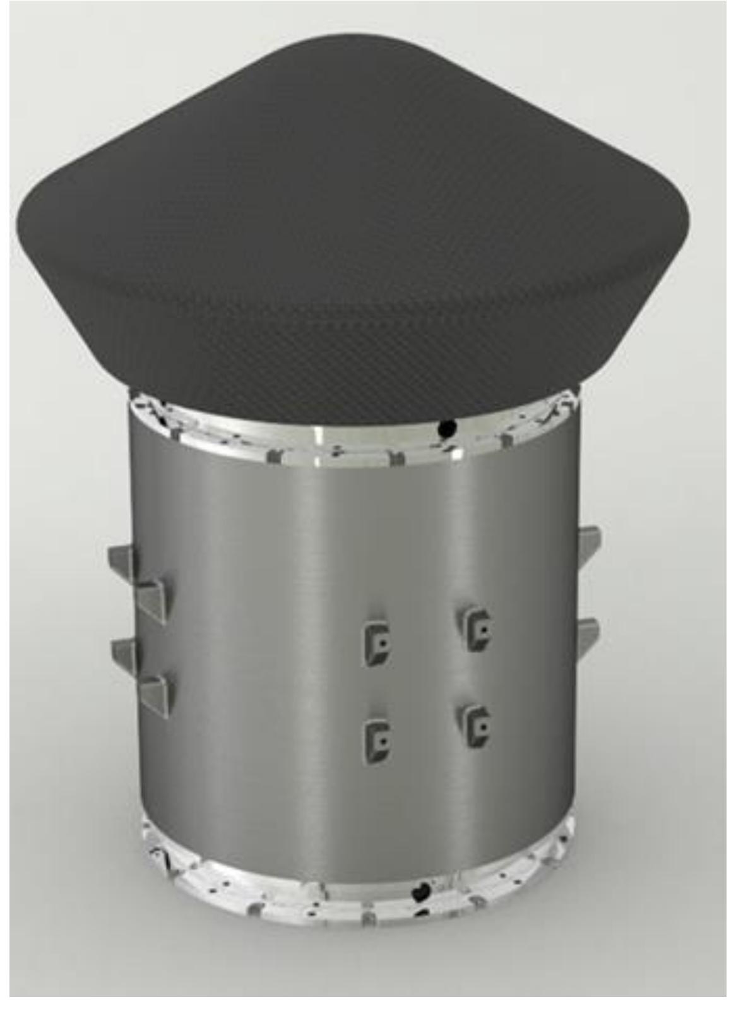

Figure 1: Conceptual flight design, integrated.

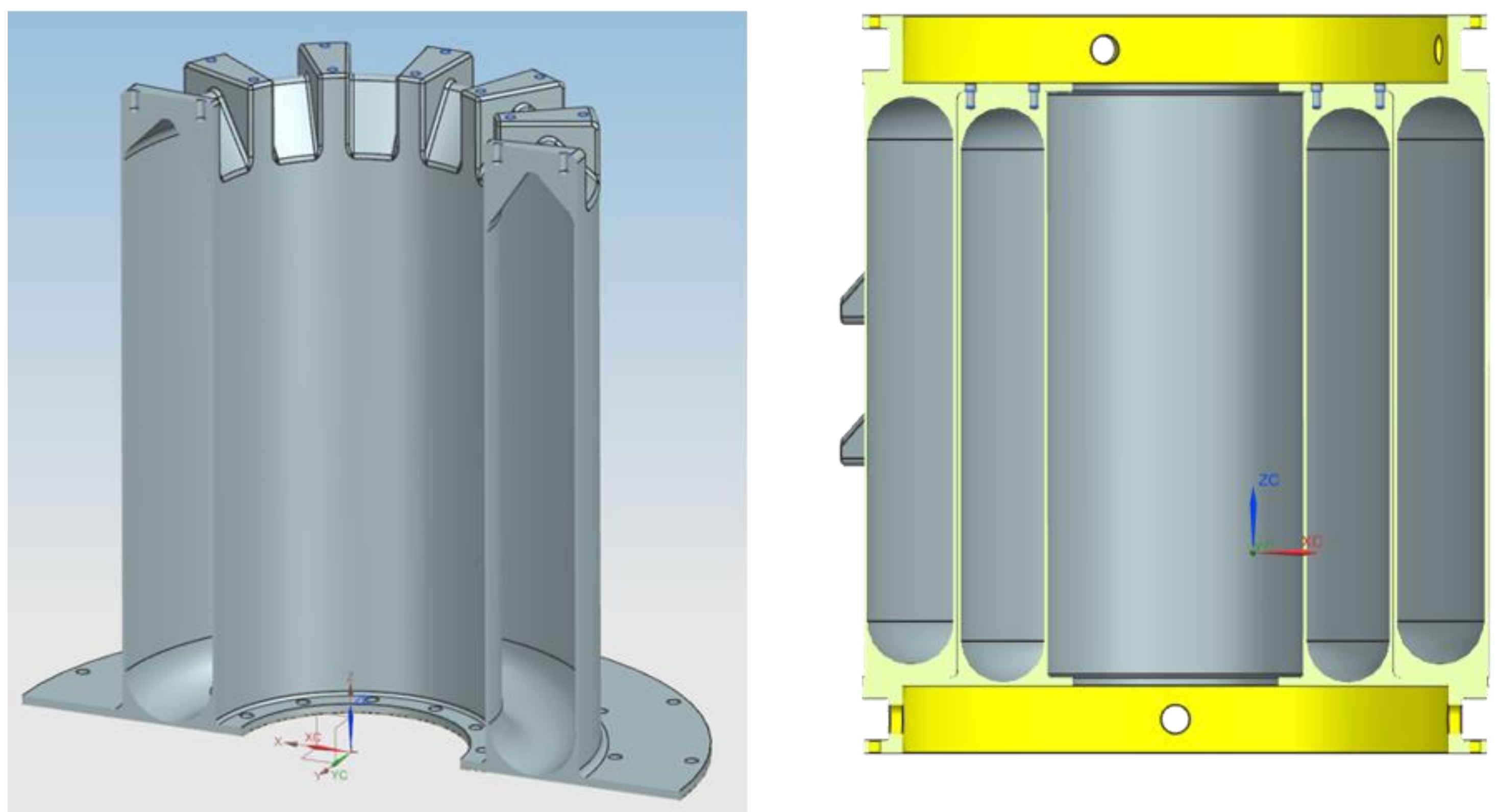

Figure 2: Cross-sectional design of a tank (left0, with the integrated structure (right)

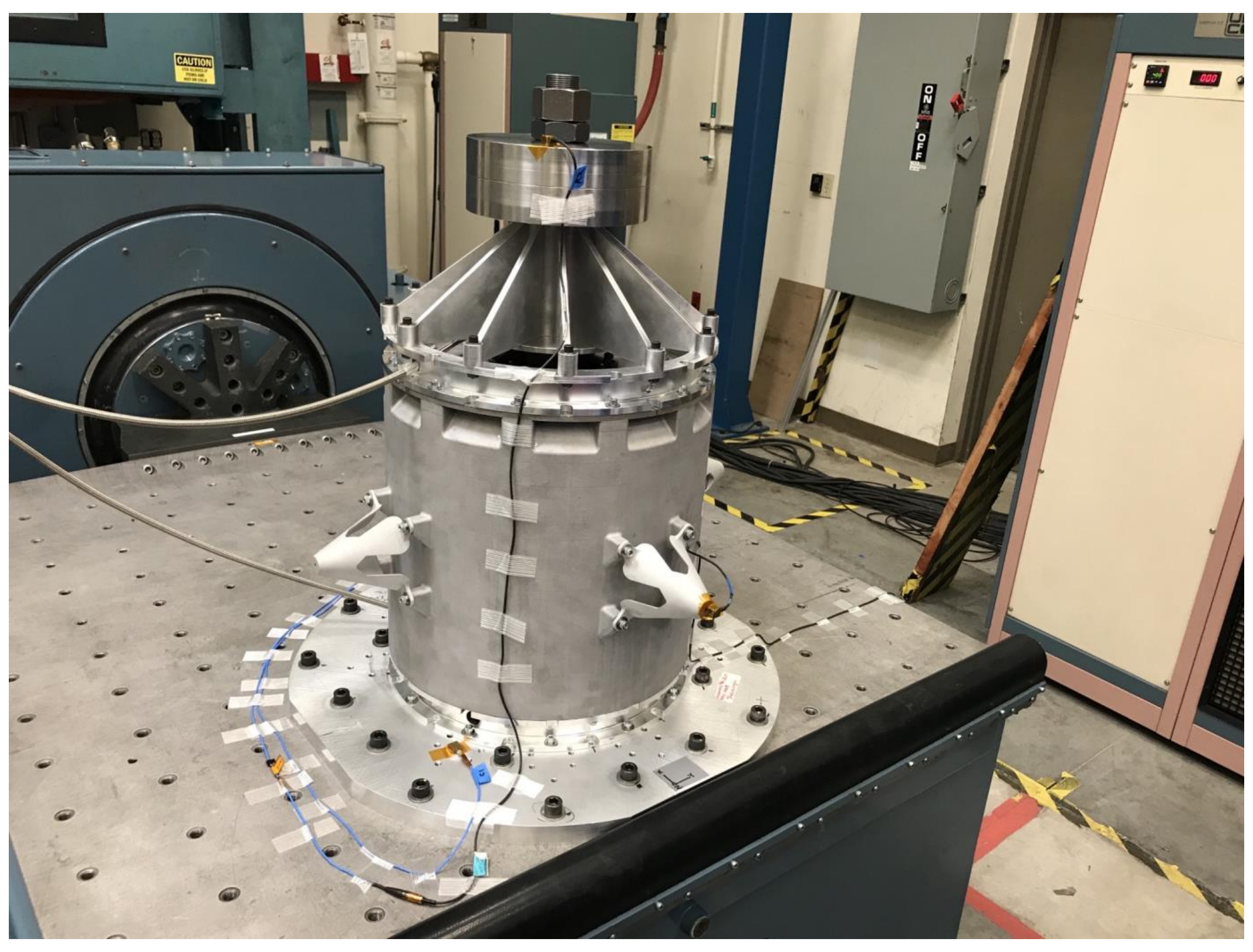

Figure 3: Assembled structure with mass and Cg simulators during vibration testing

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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PI/Task Mgr. Contact Information:
Email: Bryan.Mcenerney@jpl.nasa.gov

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