ATK-Goleta Deployables Technical Papers

Guy, L., Foster, M., McEachen, M., Pellicciotti, J., and Kubitschek, M., "Design, Development And Testing Of The GMI Reflector Deployment Assembly", *14th European Space Mechanisms and Tribology Symposium,* Constance, Germany, September 28-30, 2011.

> **ABSTRACT**: The GMI Reflector Deployment Assembly (RDA) is an articulating structure that accurately positions and supports the main reflector of the Global Microwave Imager (GMI) throughout the 3 year mission life. The GMI instrument will fly on the core Global Precipitation Measurement (GPM) spacecraft and will be used to make calibrated radiometric measurements at multiple microwave frequencies and polarizations. The GPM mission is an international effort managed by the National Aeronautics and Space Administration (NASA) to improve climate, weather, and hydro-meteorological predictions through more accurate and frequent precipitation measurements1. Ball Aerospace and Technologies Corporation (BATC) was selected by NASA Goddard to design, build, and test the GMI instrument. The RDA was designed and manufactured by ATK Aerospace Systems Group to meet a number of challenging packaging and performance requirements. ATK developed a flight-like engineering development unit (EDU) and two flight mechanisms that have been delivered to BATC. This paper will focus on driving GMI instrument system requirements, the RDA design, development, and test activities performed to demonstrate that requirements have been met.

McEachen, M., "Development of the GEMS Telescope Optical Boom", AIAA-2011-2021, *52nd AIAA Structures, Structural Dynamics, & Materials Conference, 12th Gossamer Systems Forum*, Denver, CO., Apr. 4-7, 2011.

> **ABSTRACT**: A deployable Telescope Optical Boom (TOB), derived from the venerable Coilable boom, has been developed for the Gravity and Extreme Magnetism SMEX (GEMS) X-ray polarimetry mission led by the NASA-Goddard Space Flight Center (GSFC). The driving requirements for the TOB are precision deployment repeatability and thermal stability, as well as deployed stiffness. Achieving these requirements would be challenging with any deployable structure, but GEMS adds the constraint that the boom fit around the optical fields of view while staying within the very limited Pegasus-class launch vehicle shroud volume and mass allocation. Given these challenges, the GEMS project has funded the development of the 0.85 m diameter, 4 m long, carbon fiber Coilable TOB, through several iterations of engineering and test hardware. This development effort has succeeded in validating the performance requirements for GEMS.

McEachen, M., "Validation of SAILMAST Technology and Modeling by Ground Testing of a Full-Scale Flight Article", AIAA-2010-1491, *48th AIAA Aerospace Sciences Meeting,* Orlando, FL, Jan 4-7, 2010.

> **ABSTRACT**: This paper describes the comprehensive ground testing program and modeling validation that was performed to achieve Technology Readiness Level (TRL) 6 for ATK's lightweight graphite Coilable SAILMAST technology as part of the NASA New Millennium ST8 project. The SAILMAST deployable boom architecture is closely derived from heritage fiberglass Coilable booms. By incorporating high-modulus graphite fiber in lieu of the heritage glass fiber, SAILMAST provides a significant reduction in mass for equivalent stiffness, as well as greatly improved thermal stability. Manufacturing techniques and materials were developed to allow the construction of flight-quality, ultra-light truss booms, and a full-scale flight article was constructed. The testing performed on this article has validated, with close correlation, new nonlinear coupled mechanics models, both numerical and closed-form, to predict the behavior of long slender truss structures subjected to combined axial and bending loads. These models were validated by hardware testing at various effective lengths and conditions, allowing application of the models across a wide range of scaling. The current work provides the basis for low-risk, mass-optimized designs to be applied to new flight missions, including the infusion of SAILMAST technology aboard AFRL's DSX spacecraft, among others.

Trautt, T., and McEachen, M., "Confirmation of Non-Dimensionalized (Scalable) Closed-Form Analytics for Modeling Slender Truss Behavior under Combined Loading", AIAA-2010-1492, *48th AIAA Aerospace Sciences Meeting*, Orlando, FL, Jan 4-7, 2010.

ABSTRACT: A comprehensive program of model development and validation by hardware testing was performed to achieve Technology Readiness Level (TRL) 6 for ATK's lightweight graphite Coilable SAILMAST technology as part of the NASA New Millennium ST8 project. The testing performed for the current work has validated, with close correlation, new nonlinear coupled mechanics models, both numerical (finite element) and closed-form, to predict the behavior of long slender truss structures subjected to combined axial and bending loads. These models were validated by hardware testing at various effective lengths and conditions, allowing application of the models across a wide range of scaling. These models account for both initial shape and loading (external loads and internal preloads). Despite their relative simplicity, the closed-form models were found to be extremely accurate (within a few percent) for calculating the slender truss behavior. Finally, these equations were reworked into non-dimensional forms, generalizing and expanding the results of the TRL 6 test and correlation effort to apply well beyond the range of sizes, lengths, and strengths of trusses envisioned for future gossamer spacecraft systems.

Murphy, D., Wilkie, W., Bradfordz, S., Tanimotoz, R., and Barberz, D. "Deployment Demonstration and Validation of SABUR: A Stable Articulating Backbone for Ultra-long Radar", AIAA 2007-9918, *AIAA Space 2007 Conference*, Long Beach, CA, Sept. 18-20, 2007.

ABSTRACT: For space-based radar applications requiring a very long linear synthetic aperture, design drivers for the supporting structure are compact packaging for launch, repeatable deployment, and thermal stability. A novel backing structure concept, SABUR, was developed to meet the needs of missions requiring aperture lengths from 50 m to 300 m with compaction for stowage greater than 99%. An 8 m hardware article, representing a ½ scale, and truncated-length, high-fidelity model of a 50 m system, was designed and built to appraise the design. Experimental characterization of the kinematic repeatability and deployed dynamics of the test article was performed at the Jet Propulsion Laboratory. Description of the scalable SABUR design and results of the demonstration and validation testing are presented.

McEachen, M., and Murphy, D., "Advancement In the Utilization of High-Performance Materials in Deployable Trusses: Rollatruss," AIAA-2007-1835, 48th *AIAA Structures, Structural Dynamics, & Materials Conference, 8th Gossamer Spacecraft Forum*, Honolulu, HI, April 23-26, 2007.

ABSTRACT: A novel elastically deployable truss architecture has been developed to make use of the highest specific modulus material currently available: uniaxial, high-modulus graphite fiber reinforced plastic. The subject architecture is compatible with the strain limitations characteristic of such material, while providing extremely compact stowage and self-motivated deployment, both of which are important aspects for space deployables. The concept has been demonstrated with a working prototype model made from commercially-available composite materials. Finite element models have been developed to validate closed-form predictions for the stiffness performance. A discussion comparing this design with other currently-available lightweight deployable structures is also provided.

McEachen, M., Trautt, T., and Murphy, D., "The SAILMAST Flight Validation Experiment", AIAA-2005-1884, *46th AIAA Structures, Structural Dynamics, & Materials Conference, 6th Gossamer Spacecraft Forum*, Austin, TX, April 18-21, 2005

ABSTRACT: The SAILMAST Validation Experiment employs an ultra-light graphite Coilable boom in a Scalable Architecture for the Investigation of the Load Managing Attributes of a Slender Truss. The investigation will validate the strength and stiffness attributes of versatile gossamer boom technology through correlation of inflight measurement with analytical prediction. Successful flight validation of deployable gossamer truss technology is a critical step forward in risk mitigation to make gossamer spacecraft systems a reality, enabling new classes of missions. Propellantless propulsion (solar sailing), large aperture sensors, and applications not yet conceived will be made feasible through the validation of this fundamental building block of gossamer structure. Analysis tools and techniques have been developed, correlated, and scaled to the proposed experiment system in order to predict on-orbit behavior and verify the suitability of measurement range and accuracy to ensure a successful, informative flight validation experiment.

Murphy, D., McEachen, M., Macy, B., and Gaspar, J., "Demonstration of a 20-m Solar Sail System," AIAA 2005-2126, *46th AIAA Structures, Structural Dynamics, & Materials Conference, 6th Gossamer Spacecraft Forum*, AIAA, Washington, DC, 2005.

ABSTRACT: The NASA In-Space Propulsion (ISP) program has been sponsoring system design development and hardware demonstration activities of solar sail technology over the past 27 months. Validation of a 10-m system solar sail system is complete, and efforts to demonstrate and evaluate a 20-m system are underway. Descriptions of the evolution of the design, results of functional testing to date, and analytical model predictions for upcoming shape and dynamic testing are reviewed.

Murphy, D., Trautt, T., McEachen, M., Messner, D., Laue, G., and Gierow, P., "Progress and Plans for System Demonstration of a Scalable Square Solar Sail," AAS 04-105, *14th AAS/AIAA Space Flight Mechanics Meeting*, 2004.

ABSTRACT: In 2003 the NASA In-Space Propulsion (ISP) program began sponsoring extensive development and demonstration activities of solar sail system technology. Significant efforts are underway to design, model, build and test large-scale systems. Progress on system configuration, analysis developments, performance projections, and plans for ground demonstration of a scalable sail system are discussed.

McEachen, M., Trautt, T., Murphy, D., "SALT: Second-order Augmentation of Lattice Trusses," AIAA 2004-1729, 45th *AIAA Structures, Structural Dynamics, & Materials Conference, 5th Gossamer Spacecraft Forum*, Palm Springs, CA, April 19-22, 2004.

ABSTRACT: A novel structural architecture for column elements of a lattice truss has been studied and characterized, substantiating initial performance estimates. The concept substitutes a single-member truss element with a plurality of column elements, mutually braced by deployable spreaders. This new architecture produces an increase in structural hierarchy, by one order, to a second-order lattice. This general configuration has been found to be theoretically ideal for structures of the scale useful on spacecraft. The current work looks at the behavior and performance of a single column element in detail. Test article hardware was built and tested, and finite-element modeling and elasticity-theory based hand calculations were performed. The results were then extrapolated and applied to a candidate structure, the elastically stowed Coilable boom, which benefits in many ways. Primarily, the reduction in stowed strain provided by the smaller individual elements allows the use of higher specific modulus materials. The net result is roughly a 3.5X improvement in stiffness per mass, along with a reduction in stowed volume over state-of-the-art structures of equivalent strength. The increased design space, mostly towards high-strength, diameter-limited applications, brings the venerable flight-proven Coilable boom into the design regime previously accommodated only by comparatively cumbersome articulated structures.