

Aerodynamic Decelerator Systems—Diverse Challenges and Recent Advances

THIS special section of the *Journal of Aircraft* is devoted to recent advances in aerodynamic decelerator systems technology. Parachute systems are often taken for granted. As will be seen in this section, the controlled deceleration of a payload is a vital part of many aerospace missions that involves significant technological challenges and creative engineering solutions. These diverse challenges are highlighted by five papers that cover parafoil systems, computer simulation, guidance and control, design and testing, and aerodynamic modeling.

An overview of the NASA X-38 Crew Return Vehicle (CRV) program is given by Machin et al. The challenge confronting NASA was to develop a robust emergency return vehicle for seven crew members aboard the International Space Station (ISS). Their solution utilizes a three stage decelerator system (pilot, drogue, and parafoil parachutes) as the primary recovery system. A novel parafoil with a span of 121.5 ft. and chord of 45 ft. is used with an autonomous Guidance, Navigation and Control (GNC) system to maneuver and land the 15,000 lb. CRV.

Stein et al. present the state-of-the-art in computer simulation of parachute systems. Here, it is necessary to model the coupled behavior of the parachute system and the surrounding air flow which are both highly transient and nonlinear. To capture this complex behavior, large-scale finite element models are used that are executed on massively parallel computers. The results from these computer simulations provide a predictive capability to understand the complex dynamic behavior of parachute systems and supplement information obtained by full scale drop tests which are expensive and time consuming to perform.

Another major challenge in parachute system design is to accurately and reliably deliver the payload to a specific landing point with limited knowledge of prevailing wind conditions. Dellicker et al. describe a novel approach to accomplish this task. The AGAS

system utilizes four Pneumatic Muscle Actuators (PMAs) as the parachute risers to control the system trajectory. The parachute is maneuvered by changing the lengths of the PMAs which are controlled by a GNC system in response to the current and planned flight trajectories.

The paper by Heindel and Wolf illustrates the stringent mission requirements that are frequently faced by parachute system designers and presents their design solution and results from full scale prototype drop testing. In this mission, a long-duration stable descent is required for an air launched missile system. The design utilizes a cluster of four reefed G12 parachutes with two additional ringslot parachutes for stabilization. Following the initial design, a progressive series of drop tests were performed to evaluate and modify the design.

Finally, in the paper by Potvin et al., the aerodynamics of parachute inflation is addressed using a theoretical approach that is validated with experimental data. The parachute inflation phase is of critical importance in parachute design but is still not well understood. The fundamental work presented here gives a simple yet comprehensive tool to simulate the inflation of parachutes that include "sliders". Sliders are commonly used on the parachute suspension lines to control the opening shock during inflation.

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