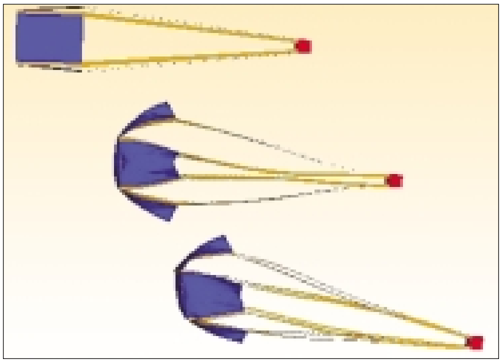
Aerodynamic decelerators

Parachute R&D saw the completion or initiation of several large-scale testing programs supporting space exploration and high-precision delivery of cargo. The number of modeling and simulation projects also increased significantly, adding to our understanding of parachute inflation and flight dynamics.

Major systems developments

Parachute systems destined to decelerate scientific payloads to the Martian surface by year's end underwent final testing. NASA's two Mars Exploration Rover (MER) missions will use a disk-gap-band parachute updated from designs used on past Mars landing missions. Researchers from NASA-Langley, JPL, and Pioneer Aerospace completed the wind tunnel and drop tests required for flight qualification. In another of the year's Mars landing missions, ESA, in collaboration with Astrium and Irvin Aerospace, began and completed the redesign and testing of the main parachute of the Beagle 2 spacecraft in an astonishing five months. This effort was necessary following the reevaluation of the required landing speed for the lander's airbag system. Unlike NASA's MER parachutes, the Beagle 2 parachute has a Ringsail design similar to that of Project Mercury.



This simulation of an inflating cruciform parachute was conducted using fluid-structure interaction.

The Army Natick Soldier Center (NSC) and the USAF Air Mobility Command have begun execution of a new Advanced Concept Technology Demonstration program known as JPADS (Joint Precision Airdrop System). ACTDs are high-visibility programs funded by the Office of the Secretary of Defense. JPADS requirements include the ability to airdrop multiple 10,000-lb payloads from C-17 and C-130 aircraft, from heights of 25,000 ft, up to 30-km offsets, and to a landing within 100-m CEP (circular error probability). To do the job, the JPADS parachutes will use flight control activators to enable autonomous glide to a preprogrammed impact point. These decelerator systems will be linked (wirelessly) to the USAF Precision Airdrop System, an airdrop mission planning and weather-sensing tool, to ensure that the launch from the aircraft is conducted according to the latest meteorological conditions.

The latter point is crucial: Unlike aircraft or ordnance, which can easily penetrate wind, parachutes are quite sensitive to wind variability. The candidate JPADS parachute systems include a low-cost Para-Flite parafoil system and Strong Enterprises' SCREAMER system, consisting of a small and fast parafoil, flown through most of the descent, and a standard Army cargo parachute for landing. Finally, JPADS will be integrated with existing satellite systems, allowing users to wirelessly update the landing point and/or best available meteorological information while en route.

Several feasibility studies of soft landing using retraction were continued this year. The retraction concept involves the sudden pull of a parachute's risers just prior to touchdown to minimize the payload's landing speed. Various Army-funded projects are currently aimed at the successful use of this technology for payloads exceeding 20,000 lb. A retraction concept using gas-powered winches was tested by Warrick and Associates with funding from NSC, to allow rapid rigging and derigging of airdropped vehicles such as Humvees. Another Army-funded soft landing system developed by Vertigo uses pneumatic muscle actuation to execute retraction. In a separate effort, height sensing prior to retraction using high-frequency sound was studied by Kaman Aerospace and NSC.

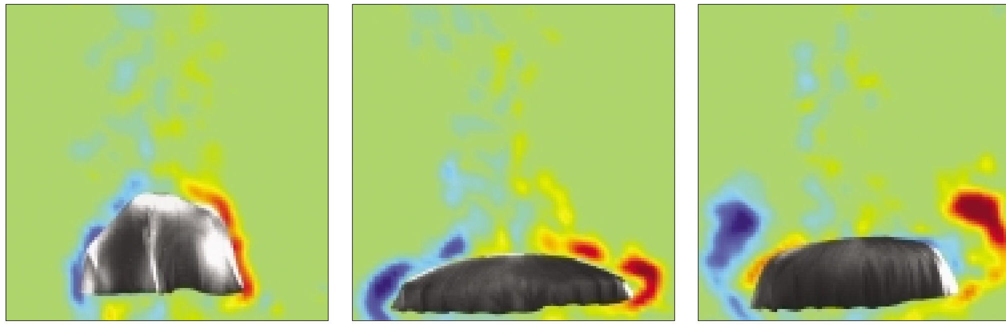
Gliding performance studies

The need for low-cost, autonomous, gliding parachute systems has spurred several glide and turn performance studies of various parachute designs not known for their gliding abilities. A test-drop study of half-scale and full-scale cruciform, conical, and round parachutes was carried out by Saint Louis University. Similar investigations were performed by NSC on parachute clusters using off-the-shelf Army parachutes.

Another Natick study focused on the performance of Twin Keel Parawings, a design developed in the 1960s by NASA. This study also considered a "single skin" rectangular planform canopy that is a cross between the well-known Sailwing and Volplane. All these investigations involved the use of GPS for trajectory measurement, and simultaneous drop of a nongliding GPS-equipped parachute to gather data needed for wind-effect subtraction.

by **Jean Potvin**

Modeling and simulation



In these video frames of a parachute opening in a water tunnel, a time stamp was synchronized with the particle image velocimetry measurements. These measurements yield the colored vorticity data. The picture shows a ring vortex attached around the canopy, and its separation from the canopy during the times of maximum inflation forces.

Although used for centuries and "easy" to build, parachutes represent a class of aerospace system that is still very difficult to simulate from first principles. Unlike solid vehicles, parachutes are highly flexible structures. To make matters worse, they typically evolve in an unsteady turbulent airflow. Because of this complexity, most of the modeling used in designing them is still based on semiempirical formulations.

Researchers at NASA-Langley and Irvin Aerospace used various models to study the inflation characteristics of the disk-gap-band and Ringsail parachutes accompanying the current Mars missions. Elsewhere, investigators at Saint Louis University proposed a new model for the unsteady drag force sustained by decelerating bluff shapes such as cargo containers or fully opened parachutes. Collaborative work between NASA-Johnson and NSC has also yielded new models for the fall and tumble dynamics of cargo containers prior to parachute inflation. These studies complement earlier work performed at Sandia National Laboratories on suspension line twists. Meanwhile, a biomechanical study of a parachutist's landing has continued, with participation from Foster-Miller, NSC, and the University of Massachusetts. Consisting of both modeling and experimental components, the study aims at understanding the ways in which the human body impacts the ground after parachute flight.

Several flight and turn modeling projects have either continued or begun. These include new computer simulations of parafoil flight by the Naval Postgraduate School (NPS), Army Yuma Proving Ground, Draper Laboratory, JM Technologies, DLR (German Aerospace Center), and the Institute of Flight Mechanics and Flight Control in Munich, Germany. Results of simulations of gliding hemispherical parachutes were also published recently by NPS investigators.

Research in the field of coupled fluid-structure interaction (FSI) simulations continues unabated. Simulations of inflated round and cruciform parachutes undergoing canopy deformations caused by suspension line pulls or releases were reported by investigators from Irvin Aerospace and by a team from Bethel College, Rice University, and NSC. These simulations correlated the flow evolution past asymmetrical parachutes with the corresponding changes in the canopy inflated shape.

Although such FSI simulations will need additional work to handle the complex problem of parachute inflation, progress has nevertheless been significant. In particular, new algorithms have been developed by investigators from the University of Connecticut and NSC to predict contact between canopies in a parachute cluster and to model slider reefing during parachute inflation. Full FSI simulations of an inflating cruciform parachute were also reported by a team from Sandia and Northern Arizona University, using a model released from a partially opened configuration that entailed little flutter. These results are notable because the simulated fluid flow completely dictated the inflation rate and vice versa, thereby bypassing the need for artificially prescribing a rate of canopy area increase.

Finally, a series of water tunnel experiments conducted at Worcester Polytechnic Institute yielded interesting insight on the fluid dynamics of inflation. Using particle image velocimetry, connections between the flow field and the forces sustained by an opening parachute were demonstrated for the first time.

Exit X-38

Unfortunately, this year marked the shutdown of the X-38 Crew Return Vehicle effort, a very important and successful parachute development program. Although some skepticism had been voiced about the name's "X" prefix, the parachute community never doubted its appropriateness. The project was one of superlatives, as the X-38 reentry vehicle boilerplate flew with a 7,500-ft^2 parafoil, the largest ever built. This parachute also carried the second-heaviest load for a parafoil system (24,000 lb, vs. 36,000 lb flown by NSC in 1996), and featured the largest drogue parachute ever built (100 ft in diameter). Such sizes and loadings gave rise to inflation dynamics never encountered before, and new design challenges were met thanks to the hard work of NASA-Johnson, Pioneer Aerospace engineers, and several subcontractors. As with the other great NASA and NACA X projects of the past, the experience and data gained are being passed to other large-scale aerospace programs now planned.