AIAA 81-1930R

Air-Launched Balloon System Phase II Test Results

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Introduction

THE air-launched balloon system (ALBS) development program is an Air Force in-house effort, the aim of which has been to develop techniques applicable to the midair deployment and inflation of large balloons. The balloons so launched would serve as high altitude sensor or communications relay platforms.

The ALBS package, which weighs approximately 2275 lb, is extracted from a C-130 aircraft at 25,000 ft. After the 158,000-ft^3 balloon is deployed and inflated, it rises with its 200-lb payload to a float altitude of 70,000 ft. The inflation equipment is recovered separately.

The first phase of the program was described at the AIAA 6th Aerodynamic Decelerator and Balloon Technology Conference.[1] This Note will describe system design modifications accomplished subsequently and full-scale flight tests carried out to demonstrate ALBS performance.

Establishment of the Phase II System Configuration

The ALBS subsystem for preflight storage and in-flight transfer of helium to the balloon is called the "cryogenic unit." It consists of a liquid helium (LHe) dewar, a pressurization system to expel and vaporize the helium, and a packed-bed heat exchanger to warm the gas to approximately 270 K. Helium transfer is controlled by timer-activated solenoid valves. The system terminates in a pipe to which the balloon's inflation tubing is secured (see Fig. 1).

Except for the dewar, the cryogenic unit components left over from Phase I of the ALBS development program were all reusable. Thus the Phase II configuration was keyed to the design of a replacement dewar. The primary metal used in the new dewar was an aluminum alloy (vs the titanium used in Phase I). Since the maximum operating pressure is only 75 psia, the aluminum construction did not impose severe weight penalties, and the finished dewar weighs 218 lb, empty. It holds 377 liters (103.79 lb) of LHe, with 10% ullage. Spherical in shape, to minimize surface area and boil-off losses, and of insulated double-wall construction, it has an outside diameter of 40 in. It is anchored in a novel and effective way: Rejecting the usual trunnion mount, the contractor cradled it in low-stretch polyester straps, a design which easily tolerates the 5.4-*g* shock forces encountered during midair deployment.

From the standpoint of ease of fabrication, handling, extraction, deployment, and recovery, the most desirable overall ALBS system configuration is a long rectangular box of uniform cross section. The new LHe dewar required that the interior of the box have a 43×43-in. cross section. The box wall thicknesses brought the outside cross-section dimensions up to 47×47 in.

The module has two sections of equal length (5.5 ft), joined one above the other, when viewed in the vertical orientation (see Fig. 1). The upper section is sheathed in plywood, while the lower, cryogenic section is of open frame construction. The sections are joined and loaded aboard the C-130 horizontally. After extraction from the aircraft, the module repositions itself vertically. The balloon and main parachute are then withdrawn from the upper section for midair deployment. Following inflation and release of the balloon, the empty upper section and the cryogenic unit, still joined, descend on their own 100-ft recovery parachute.

Parachute Balloon Interface Redesign and Other Changes

The ALBS midair deployment scheme puts the balloon above the 42-ft ring sail main parachute (see Fig. 2). A long external inflation tube of 4-mil cross-laminated polyethylene film extends from the base of the balloon down through the main parachute to the cryogenic gas supply underneath. Unlike ordinary balloons, which are filled through external inflation ducts attached to the gores, the ALBS balloon is filled through its base. Once inside the balloon, the gas is conveyed to the balloon's apex via an internal inflation tube. Thus the balloon's bottom end fitting serves both as a load attachment point and as a gas inlet port. This leads to a complicated interface between the base of the balloon and the apex of the main parachute.

In the current configuration, a special dual ring fitting was integrated into the main parachute apex, together with a companion single ring located at the parachute base, to isolate the inflation tubing and the balloon from deployment shock forces. The inflation tubing floats inside of these fittings. They carry the force loads and provide attachment points both for the parachute's four center lines and for the lines extending above and below the parachute. With this design, the 10,000-lbf main parachute deployment shock forces travel

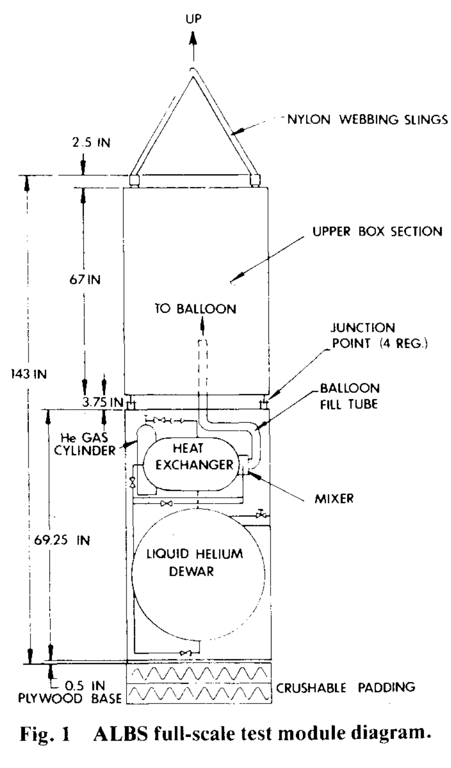

Fig. 1 ALBS full-scale test module diagram.

Received Oct. 14, 1981; presented as Paper 81-1930 at the AIAA 7th Aerodynamic Decelerator and Balloon Technology Conference, San Diego, Calif., Oct. 21-23, 1981; revision received April 26, 1982.

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safely up the 4-piece centerline assembly to the dual ring and thence around the base of the packed balloon on three extension lines, spaced 120 deg apart and connected to the drogue parachute.

The above interface design effort proved to be highly successful. Three other vital system design changes were also accomplished and qualified by flight test in the same period: One was the addition of a 5-ft ribless-guide-surface (RGS) parachute, to prevent recoil in the 200-ft extraction line as the module is pulled out of the C-130 by the system's 28-ft ring slot drogue parachute. This change was in response to an incident which marred the final Phase I test. The second change was the incorporation of an electrically fired 4-point pyrotechnic release subsystem, which drops the module away after balloon inflation. As the final major change, a sophisticated command, control, and telemetry (CCT) subsystem was developed for precise control and monitoring of the inflation process and the subsequent balloon flight.

Human factors were not neglected during the ALBS Phase II redesign effort. For example, the long module is best extracted from the aft edge of the C-130 ramp. This requires potentially hazardous in-flight movement of the module. A technique was developed, therefore, where the module is secured to and launched from a large pallet. This pallet, which stays in the aircraft, is locked to the C-130 side rails and can safely be winched forward and aft in flight. In addition, provisions were made for venting the helium boil-off vapors overboard when the system was being flown on the launch aircraft, and "system start" switches were designed to be activated only upon extraction of the module from the aircraft.

Full-Scale Flight Tests

On March 17, 1981, the assembled module was dropped over the White Sands Missile Range. All components functioned very well and balloon inflation was initiated; however, early in the filling process the balloon's internal inflation tubing ruptured near the base, causing a double bubble. The double bubble led to a bunching of the reefing sleeve and the balloon was torn open by excessive pressure. The test was quickly terminated and all components were recovered safely. The reason for the failure was clear and correctable and a repeat test was planned, using the one remaining ALBS balloon. The extruded polyethylene internal inflation tube of that balloon was replaced by one made of the same material used for the external tubing.

The second air drop was conducted on Sept. 1, 1981. All steps occurred as scheduled. The new inflation tubing inside the balloon easily handled peak gas pressures and a large bubble developed in the balloon (see Fig. 2). Then, about halfway through the inflation cycle, the balloon suddenly tore away. The test was terminated and all systems descended safely.

Films of the test showed that the inflating balloon was subjected to considerable buffeting (peak dynamic pressure was 1.4 psf). The balloon material may have been overstressed locally by peak transient loads; however, a more likely cause of failure was the rough edges found (after the test) along the periphery of the balloon's base casting, instead of the specified smooth radii. It is believed that the buffeting caused the stressed film to move back and forth across the roughness points, weakening it and initiating the failure.

Conclusions

Phase II of the ALBS Development Program showed that the air-launching of large balloons is feasible and can be executed routinely from standard Air Force cargo aircraft. Midair inflation of the balloon from a cryogenic source and recovery of the inflation hardware were also demonstrated successfully. Even though a structural weakness in the balloon prevented realization of the program's final objective of a successful flight following the midair inflation, that goal is not unattainable since the balloon weakness is correctable.

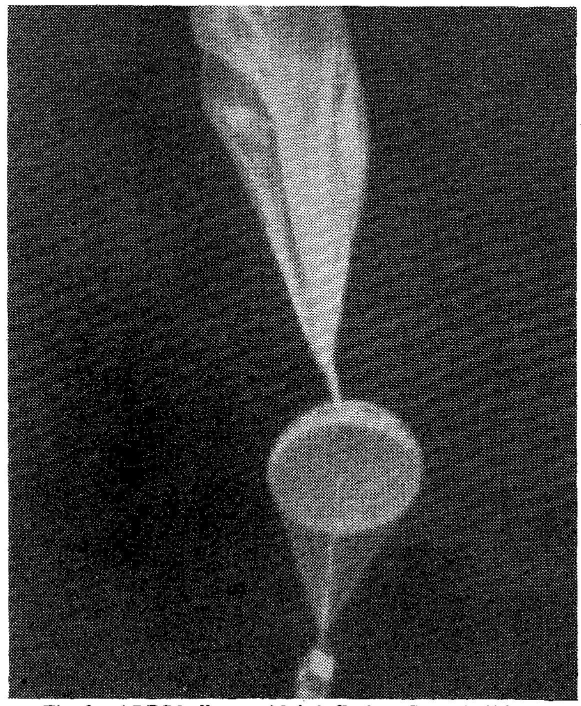

Fig. 2 ALBS balloon midair inflation, Sept. 1, 1981.

Acknowledgments

The authors wish to thank their numerous colleagues at the Air Force Geophysics Laboratory (AFGL) and at the Air Force Flight Test Center (AFFTC) who contributed to the successes achieved on the program. Special thanks are due to Capt. Matthew Raimo, of the 6594th Test Group, Air Force Systems Command, Hickham AFB, Haw., for his dedicated assistance while AFFTC Test Manager, to Ralph Cowie of AFGL for his important contributions, particularly in the development of the command, control and telemetry subsystem, and to Charles Sindt of the National Bureau of Standards for his outstanding efforts in the development of the cryogenic unit. The test support of the White Sands Missile Range and of the 62nd Military Airlift Wing, McChord AFB, Wash., is also acknowledged with thanks.

Reference

[1] Carten, A.S. Jr. and Wuest, M.R., "Parachute Techniques Employed in the Air-Launched Balloon System (ALBS) Development Program," *Journal of Aircraft*, Vol. 17, Feb. 1980, pp. 65-66.

AIAA 82-4201

Estimation of the Peak Count of Actively Controlled Aircraft

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Introduction

THIS Note summarizes an FAA-supported program to estimate the instantaneous air count (IAC) of actively

Received Jan. 4, 1982; revision received May 3, 1982. This paper is declared of work of the U.S. Government and therefore is in the public domain.

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