Engineering Notes

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Parachute Deployment Process Testing Technique

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Introduction

THE problem of observing details during a recovery system deployment process is probably one of the most frustrating tasks associated with recovery system evaluation. It would be difficult to say how many times I encountered such situations before coming across a simple and inexpensive technique for easily observing such details. My purpose for writing this note is to encourage use of this technique as a tool to improve system performance and reduce system costs. I make no claim in development of the technique, only for using it to good advantage and encouraging others to do likewise.

Technique

In general, the technique attempts to dynamically simulate the deployment process as it would occur under natural conditions. Figure 1 illustrates the essential elements of the technqiue (as applied to a lines-first-type deployment process). The main riser is attached to an immovable object through use of an anchor cable. An external force applied to the pack through the drogue or pilot chute attachment bridle accelerates the pack to a predetermined velocity moving away from the fixed anchor point. As the cable draws tight, high-speed cameras are initiated to record the deployment process for subsequent evaluation. If more than one camera is used, some means of film synchronization is required.

Since the canopy velocity is reduced to zero during the test, there is no tendency for it to inflate (other than by prevailing winds), and it can be physically examined for any deployment process-induced damage. Post-test correlation of the film results with physical observations is a relatively easy task.

As with any simulation technique, the value lies in one's recognition and appreciation of its features and limitations as either advantages or disadvantages depending upon the alternatives available. Some of the characteristics of this testing technique which would, in its simplified form, be generally viewed as disadvantages are described below. No attempt is made to counter or prioritize these items or to present the list as being complete.

1) It does not simulate the initial deceleration force environment imposed on the pack, such as would be encountered at force transfer from steady-state drogue descent to main parachute deployment.

2) It does not simulate effects of the actual dynamic pressure environment encountered in the real world. This would include such things as pack oscillation, pack rotation, flagging, or crosswind deployment.

3) It does not duplicate the true separation velocity history as would actually be encountered.

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Some of the characteristics of this testing technique which would, in its simplified form, be generally viewed as advantages are described below. Again, no attempt is made to prioritize these items or to present the list as being complete.

1) Compared to the cost and pace of flight testing, the technique is an inexpensive and rapid way of either increasing confidence in achieving successful system deployment or detecting the cause of deployment problems actually being encountered.

2) It provides a means of evaluating the effects of overcontrol and undercontrol of the deployment process without being overly concerned for flight test instrumentation and payload.

3) It provides a means of identifying system damage induced by the deployment process as distinct from that induced by the inflation process.

4) It provides a means of identifying deployment characteristics indicative of low-probability-type deployment problems.

5) It is more representative of the actual dynamic environment encountered during system deployment than is a bench tear down.

Application

As a near-term alternative to development of an all new recovery system for an RPV, an effort was undertaken to modify available recovery system components. The main canopy portion of this system, titled Multiple Canopy Recovery System (MCRS), was assembled from two 100-ft-nominal-diam triconical canopies.

Because of limited stowage space onboard the RPV, high-density packing was a necessity, and the split-bag-type packing technique was selected. Each canopy was placed in its own compartment under hand-paced densities. The lines and risers were placed in a common compartment, again under hand-packed densities. Diameter of the bag was then reduced by alternate tightening of two longitudinal rows of shoe-string-style lacing and application of up to 48 tons of packing pressure spread over the conical surface of the pack.

The MCRS weighed about 225 lbs, and its deployed length was about 180 ft. To acquire the level of detail information desired, three cameras were mounted on the truck (see Fig. 2) and one comera was stationed along the test path. Two of the truck cameras were mounted to look at the opening end of the pack to provide details on such items as pack opening, line/riser stowage ties, line/riser deployment, canopy

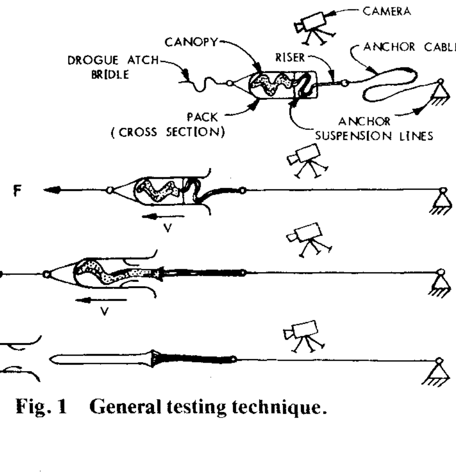

Fig. 1 General testing technique.

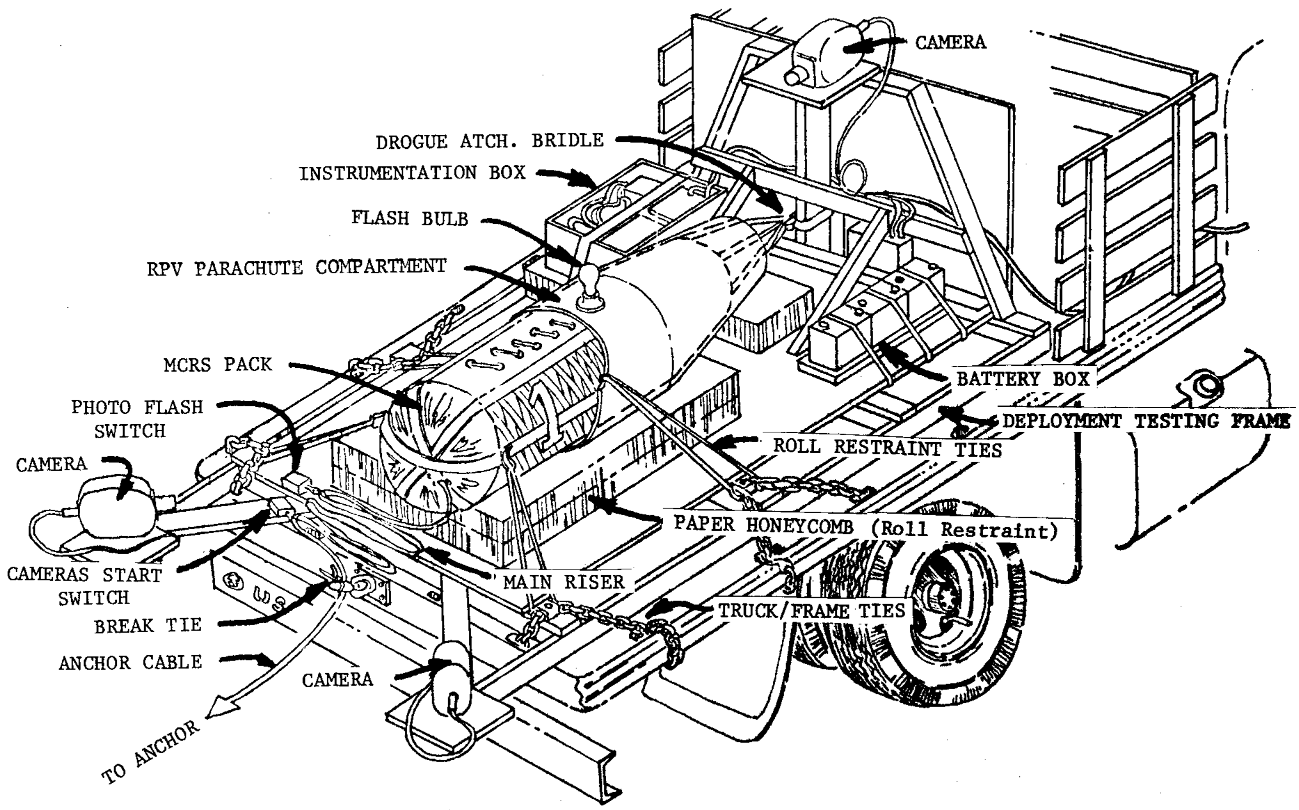

Fig. 2 MCRS deployment test configuration.

compartment opening, skirt attitude at exit, pyro reefing cutter actuation, and canopy deployment. The third truck camera was mounted to look aft observing the dynamics of the cable and the parachute system as it was being pulled from the pack to provide data relative to any excessively tight or loose pack exit conditions. All three truck-mounted cameras were run at 400 frames/sec. The ground-station camera operated at 128 frames/sec. Flood lights mounted with the two aft-truck-mounted cameras would have provided better illumination for documentation of deployment details occurring within the pack.

A 400-ft-long cable to the anchor point enabled the truck speed to stabilize at about 45 mph. As the ⅛-in.-diam cable began to draw tight, it initiated the truck-mounted cameras and then tripped a photo flashbulb visible to all cameras for post-test film synchronization.

Results

A brief description of the deployment process problems detected through use of this technique is indicative of the type and level of detail information acquired.

1) A knife intended for cutting a critical pack opening tie was capable of rotating and severing its pull lanyard. (This potential was known in advance and was believed to have been prevented.)

2) Some line stowage tie anchor loops in the pack were of marginal attachment strength and capable of pulling from the pack structure before the line stowage ties broke. (This problem actually occurred on one flight test where the pack had missed being reworked.)

3) Some of the lines/risers stowage ties were marginal in terms of providing positive control of the deploying suspension system. These were in such areas where the mass per unit length would suddently change, such as at a grouping of connector links.

4) A particular group of deploying connector links showed potential entanglement with adjacent layers of stowed suspension lines.

5) The canopy compartment was opened by a knife attached to one suspension line of each canopy. Although the elongation of this suspension line had been considered in establishing the knife location, the skirt to knife distance was marginal.

6) The reefing line cutters were armed through a positive tie to the pack. The tie attachment loop on the canopy was loaded in a manner that loaded the stitching in peel. (Initially no changes were made to correct this problem as we intuitively knew there was no way for such loading to be applied. After similar loading patterns were noted on flight-tested items, we changed the design despite our intuition.)

7) The canopy compartment divider was potentially capable of being torn from the pack during the deployment process.

8) The canopy stowage break ties burned the canopy.

9) The final canopy stretch break ties loaded the pack attachment point in a manner that loaded the stitching in peel.

These problems were identified through two deployment tests conducted in less than 1 week's time at a cost comparable to a well-conducted bench tear-down. Subsequent system flight tests of a corrected system design identified no problems other than as mentioned in items 2 and 6 above.

Conclusion

A technique exists for detailed evaluation of a recovery system deployment process occurring under dynamic conditions. The technique is simple, inexpensive, effective, and easily adaptable to a wide variety of system configurations. Application of the technique to a RPV recovery system of a highly nonstandard packed configuration identified deployment problems not normally detected through bench tear-down procedures yet typical of those detected through flight testing. Subsequent flight test of the corrected system configuration revealed no additional problems.

Additional details on general application of this technique, our specific application, and interpretation of the results are presented in the original version of this paper titled "Parachute Deployment Process Evaluation Using Simple Dynamic Testing Technique."