PIA Technical Report TR-401
Parachute Industry Association Publications
August 18, 2016

PIA TECHNICAL COMMITTEE
LOW RESERVE OPENING
INVESTIGATION REPORT

Background

This report covers the investigation performed by the Technical Committee of the Parachute Industry Association (PIA) regarding the issue commonly known as a Low Reserve Opening (LRO). A Low Reserve Opening event is one in which the reserve canopy is activated by an Automatic Activation Device (AAD) and where impact occurs while the reserve canopy is in the deployment or inflation process. USPA brought the Low Reserve Opening (LRO) issue to the PIA Technical Committee during the Feb 2010 regular meeting in Lexington, KY. This was directly following the FAA Washington AAD Summit, which had a focus on the 2008 Perris fatality that appeared to meet the criteria of what seemed to be a Low Reserve Opening scenario. A conference call with the president of PIA and USPA was held on March 18, 2010. The discussion included the PIA Technical Committee investigation goals as well as the goals of the joint USPA/PIA Skydiver Advisory.

PIA Technical Committee Goals to Address the USPA Request for Investigation

a. *Technical Committee review of the fatality reports in total, as part of the initial discovery phase. (Deliverable: Committee member individual review, committee discussion, vote to proceed)*
b. *Review and discuss root cause analysis of fatalities. (Deliverable: Committee discussion, review and possible problem identification)*
c. *Determine applicable testing specifics based on potential root causes (Deliverable: draft test program, committee review, vote)*
d. *Conduct initial testing to validate test protocol and result specifics. (Deliverable: report back to committee after initial testing is completed)*
e. *Perform full test program as guided by root cause analysis and committee consensus. (Deliverable: PIA Technical committee presentation, formal report back to PIA and USPA, findings of any testing)*

USPA / PIA - Skydiver Advisory Goals

The goals of the jointly issued Skydiver Advisory, issued March 31, 2010 (see Appendix – B), were the same for USPA as they were for PIA. It described skydiving safety in terms of statistics and historical significance. The advisory then explained the collaboration between USPA and PIA to investigate unexplained fatalities, such as low reserve deployments. "PIA has tasked its Technical Committee to collect and review relevant data, to work within the industry in order to identify any trends or specific causes and to make any relevant recommendations." The advisory then enumerated three actions for skydivers and riggers. In closing, the advisory recommended, "…component or deployment anomalies should be thoroughly documented and reported to the equipment manufacturers and PIA's Technical Committee." In addition, a form was generated so that all parachute riggers could submit information related to any equipment issues found in the field.

Primary Root Cause Analysis Possible Causes

A. AAD and Harness/Container interface may be causing a delay.
B. AAD initiated deployment sequence is somehow different than a manually activated deployment sequence.
C. AAD activation altitude is not sufficient.
D. Reserve container restrictive forces are too high due to:
   1. Reserve canopy pack volume compared to container volume.
   2. Reserve container design creates unforeseen restrictions.
E. Reserve pilot chute drag forces are not sufficient to withdraw the packed reserve parachute/freebag, from the reserve container, causing delay.
F. Low pressure area (burble) creates an uncontrollable variable with regards to initial reserve pilot chute deployment and inflation.

Investigative Results

Primary Root Cause A and B

TS112 Harness/Container – AAD Installation Test Protocol

This testing standard was developed, validated, adopted by the PIA Technical Committee and published. (see the link below)

Test Scope:

This test protocol was developed to provide a basic "first look" bench test to evaluate AAD cutter performance and harness/container compatibility.

http://www.pia.com/piapubs/TSDocuments/TS-112.pdf

Primary Root Cause C

Discussions and general concurrence regarding the raising of AAD firing altitudes was a logical step to provide an extra margin of safety to offset the unplanned variables that might cause a delay in immediate reserve deployment.

The PIA Risk Management Committee presented data numerous times to the USPA Board of Directors requesting adjustments to the minimum container opening altitude. After multiple presentations and repeated requests, BSR Section 2-1 H became effective with the printing of the 2014/15 SIM. Changing the long standing minimum container opening altitude of 2000' AGL to "…..2,500 feet AGL (waiver-able to no lower than 2,000 feet AGL)"

Primary Root Cause D

Reserve Pilot chute launch and Freebag extraction force test was developed and a test protocol was discussed by the committee.

Test Scope:

A proposed bench test matrix was developed to isolate the freebag extraction forces using an inline-mounted pulley and force gauge. Applying various body attitudes attainable in freefall in order to induce extraordinary freebag extraction scenarios. The test matrix was evaluated by committee member harness/container manufacturer committee members. However, the bench/ground testing with pulleys was never officially adopted, nor published. This testing program was abandoned when the committee decided to do live jump testing to evaluate configuration specific, pilot chute/freebag extraction forces.

Primary Root Cause E and F

In order to determine if sufficient pilot chute drag forces exist and to better understand the effects of the jumper's burble, a live test jump matrix was developed, validated and adopted by the Technical Committee.

The combined efforts of many PIA members found a way to conduct such tests in a manner that provided the most accurate and applicable resultant data, using professional test jumpers, controlled system configurations and testing parameters.

A total of seven (7) test jumps were performed on each of the seven (7) participating harness/container systems. Obtaining a reserve pilot chute drag force measurement was the primary objective. Pilot chute drag forces were recorded/measured using a specially designed load cell, which was mounted on a modified reserve bridle.

Test Plan:

Three (3) test jumps at terminal velocity - total malfunction, manual reserve ripcord deployment, measuring initial onset drag force. Data collection continued while towing the reserve pilot chute for a minimum of ten (10) seconds, measuring sustained drag force.

Three (3) test jumps at sub-terminal velocity (less than 3 second delay)- total malfunction, manual reserve ripcord deployment, towing reserve pilot chute for a minimum of ten (10) seconds, measuring sustained drag force.

One (1) test jump at terminal velocity - total malfunction, AAD activated reserve deployment - validating AAD activation deployment and measuring initial onset drag force.

System specific data was provided to each participating manufacturer of their equipment in the form of a confidential report with graphical representation of the forces recorded along with video overlay. In addition, the data in generic form is PIA property and will be used as part of the ongoing Low Reserve Opening Research Project.

Testing Report

Phase-I testing was conducted over a two (2) year span. Starting in late 2014 and ending in early 2016. All tests were performed in Deland, Florida by employees of Deland Research Corp (DRC) with rigging support provided by United Parachute Technologies (UPT).

Parameters:

A. System specific configuration evaluation of
   i. Terminal velocity - Initial onset of reserve pilot chute drag force.
   ii. Terminal velocity - Sustained reserve pilot chute drag force.
   iii. Sub terminal velocity - Initial onset of reserve pilot chute drag force.
   iv. Sub-terminal velocity - Sustained reserve pilot chute drag force, and
   v. Proof that each system has adequate capacity to operate within the limits of the minimum performance standard to which it is designed and approved.
B. Controls: All jumps were made using the exact same jumper, jumpsuit and testing equipment. Each system was set up with identical instrumentation.
C. Variables: Temperature, humidity and precise deployment altitude.
D. PIA Technical Committee presentation was given during the February 2016 Regular PIA meetings held in Scottsdale, Arizona. Dave Singer presented the test data and sterilized videos to an audience of over sixty (60) people. Video with load cell graphical data was presented.

Interim Conclusions

The test matrix and equipment provided some much needed real life data. The test program allowed for controlled testing of system specific configurations in a live application test. The collected data isolates and captures both *peak onset* and *sustained drag force* values generated by each of the seven (7) systems; as well as *AAD-initiated deployment data points* for comparison.

See *Appendix A* for test data.

All systems tested in Phase-I have shown that they function as designed and are well within the minimum performance requirements set forth in various evolutions of the TSO-C23 test program.

Over the last six (6) years of discussion, committee deliberation, bench testing, development of customized load sensors, live testing and the combined efforts of some of the brightest contributors to our industry in modern times, the Committee Members have yet to locate evidence that supports or indicates a systemic or specific equipment design issue.

The lack of this evidence indicates the presence of other scientific components of freefall that affect the timely deployment of a parachute. Specifically, the variable of the low pressure area produced by a body in freefall and the reactions of drag-producing devices within the dynamic area surrounding a jumper have a potential contributing effect.

Based on these controlled tests designed to isolate and present deployment delays, the Committee Members have not been able to determine a definite cause for the LRO issue directly related to the FAA TSO-C23x parachute harness/container system designs commonly in use.

Suggestions/Recommendations:

For years, spring-loaded pilot chutes have been accepted devices to actuate the main parachute deployment sequence. Training to use this main deployment device typically requires the jumper to “Look, Reach, Pull (the Ripcord) and then perform a “Check Left, Check Right” movement of looking over each shoulder to break the airflow over their back, in order to clear the burble or generate a fluid disturbance, thus allowing the spring-loaded pilot chute to cleanly escape the low pressure area and continue the deployment sequence.

This instruction and guidance is provided in the USPA-SIM, section 5e paragraph 5c. However, it may be advisable to bring closer attention to this procedure in current training programs. Special attention should be given to the critical nature of this action as it specifically applies to spring-loaded pilot chutes, which are common to all harness/containers in use today.

Additionally, all jumpers need to be aware of factors that are known to influence a timely reserve deployment:

- Ideal Body Position
  - Head High and stable is preferable to flat and stable.
  - Head High diminishes the size of the burble.
  - Flat and Stable increases the size of the burble.
- Instability during deployment will increase the chance of snag potential.
- Ensure cameras, mounts and other external devices are “snag free.”

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May 16, 2016

Reviewed and Approved by the Technical Committee
Second Regular Meeting of 2016.
August 18, 2016

T.K. DONLE
Technical Committee Chair
Parachute Industry Association

APPENDIX – A

Test Matrix - Results

APPENDIX - B

Skydiver Advisory - 31 March 2010

SYSTEM ID	JUMP #	TYPE	PEAK LOAD	AVERAGE PEAK	JSTAINED LOAD	AVERAGE SUSTAINED
A	1	TERM	*64*	88.0	*28*	34
	2	TERM	*112*		*38*	
	3	TERM	*88*		*36*	
	1	SUBTERM	*49*	65.3	*32*	34.3
	2	SUBTERM	*76*		*34*	
	3	SUBTERM	*71*		*37*	
	1	AAD FIRE	18			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
B	1	TERM	*108*	99.3	60	55.7
	2	TERM	*108*		51	
	3	TERM	*82*		56	
	1	SUBTERM	*58*	62.0	42	44.7
	2	SUBTERM	*64*		45	
	3	SUBTERM	*64*		47	
	1	AAD FIRE	*46*			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
C	1	TERM	*70*	100	43	46
	2	TERM	*115*		45	
	3	TERM	*115*		50	
	1	SUBTERM	*58*	62.3	40	40
	2	SUBTERM	*61*		40	
	3	SUBTERM	*68*		40	
	1	AAD FIRE	*66*			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
D	1	TERM	*90*	92.3	45	45
	2	TERM	*105*		45	
	3	TERM	*82*		45	
	1	SUBTERM	*46*	55.2	35	35.7
	2	SUBTERM	*59*		35	
	3	SUBTERM	*60.5*		37	
	1	AAD FIRE	*59*			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
E	1	TERM	*89*	124	47	57.7
	2	TERM	*142*		61	
	3	TERM	*141*		65	
	1	SUBTERM	*84*	87.3	49	54.3
	2	SUBTERM	*97*		58	
	3	SUBTERM	*81*		56	
	1	AAD FIRE	*78*			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
F	1	TERM	*85*	85.7	47	45.3
	2	TERM	*97*		49	
	3	TERM	*75*		40	
	1	SUBTERM	*50*	51.7	40	38.0
	2	SUBTERM	*53*		37	
	3	SUBTERM	*52*		37	
	1	AAD FIRE	*65*			
SYSTEM ID	**JUMP #**	**TYPE**	**PEAK**	**AVERAGE PEAK**	**SUSTAINED**	**AVERAGE SUSTAINED**
G	1	TERM	*72*	89.3	38	39.3
	2	TERM	*86*		38	
	3	TERM	*110*		42	
	1	SUBTERM	*58*	67.5	34	34.3
	2	SUBTERM	*70.5*		35	
	3	SUBTERM	*74*		34	
	1	AAD FIRE	*47*			

Skydiver Advisory

Jointly Issued by the U.S. Parachute Association
and the Parachute Industry Association

Reports indicate that 2009 was the safest year for skydiving in the U.S. for nearly five decades with regard to fatalities. To grasp the statistical significance of this, one also has to realize that more than 10 times as many jumps were made in 2009 as in 1961, the most recent year with fewer fatalities than 2009. Although skydivers and the whole industry collectively should be proud of this accomplishment, there is room to do even better. In this regard, the United States Parachute Association and the Parachute Industry Association are collaborating to take a look at various fatalities that, although low in overall numbers, are still important to consider.

One example is low reserve deployments. Research shows that in the past 10 years there has been about one fatality per year in the U.S. in which, for uncertain reasons, the jumpers struck the ground without a fully functional reserve parachute after *apparent* reserve activation at a sufficient altitude. Although most of these incidents occurred after the automatic activation device (AAD) initiated reserve deployment, others occurred after a manual reserve ripcord pull or activation by a reserve static line (RSL). PIA has tasked its Technical Committee to collect and review relevant data, to work within the industry in order to identify any trends or specific causes and to make any relevant recommendations.

Possible factors may include, but are not limited to, body position of the jumper, the reserve pilot chute getting caught in the burble, inhibitory actions by the jumper, entanglement with the jumper or other equipment, condition of the container and reserve components, exact combination of components utilized, fit of the reserve canopy in the container, AAD setting or functionality, reserve packing methods, container design and reserve pilot chute spring strength, as well as various combinations of these factors and other factors that have yet to be determined.

USPA and PIA want skydivers and riggers to be aware of these factors and related issues and to take the following three actions.

1) Each skydiver should carefully review and set personal altitudes for main canopy deployment, initiation of emergency procedures and reserve ripcord activation that provide more than sufficient altitude for full reserve deployment. USPA’s Basic Safety Requirements require C- and D-licensed jumpers to initiate main canopy deployment by at least 2,000 feet above the ground. However, this is a minimum deployment altitude which, particularly with today’s slower-opening main canopies, provides very little time for initiating emergency procedures should the jumper experience a pilot-chute-in-tow or certain other high-speed main canopy malfunctions. Higher main deployment and emergency procedure altitudes can help ensure there is more time to successfully deploy a reserve parachute.

   Skydiver’s Information Manual Section 5-1 recommends that emergency procedures be initiated by at least 1,800 feet above the ground for B- through D-licensed skydivers and 2,500 feet above the ground for students and A-licensed skydivers. In order to accomplish this, it is imperative that main deployment be planned and initiated at sufficient altitude to obtain a functionally open main parachute by these emergency procedure minimums.

2) When a reserve parachute is due for a repack, each owner should put his rig on (fully adjusted with the main parachute packed to simulate a total malfunction) and, in the presence of his rigger, pull the cutaway handle and reserve ripcord and have the rigger observe the pilot chute launch. Following this, with the aid of the rigger, carefully place the harness and container on a flat surface (or perhaps on someone else's shoulders) and have the rigger extract the reserve freebag from the container by the bridle. Any anomaly to a normal, unrestricted pilot chute launch and freebag extraction should be thoroughly investigated and documented by the rigger and reported to the equipment manufacturers and PIA's Technical Committee. Use this opportunity to ask the rigger any questions about the equipment and obtain a working knowledge of the parachute system.

3) Skydivers should review their equipment owner's manuals (including harness-container, reserve canopy, main canopy, AAD and visual/audible altimeters) and should consult an instructor, rigger and/or the equipment manufacturers with any questions or concerns. Skydivers using AADs should understand that they are strictly backup devices and are not intended to replace training or timely manual execution of emergency procedures. AADs may or may not initiate reserve parachute deployment at a sufficient altitude, depending upon various combinations of circumstances. There have been numerous reports of skydivers who decided to take no action on their own and to just "wait for the AAD to activate" for various reasons, which is contrary to recommended procedures. All skydivers should review proper emergency procedures and be prepared to manually deploy the reserve parachute before ever reaching AAD activation altitude.

Any equipment questions should be directed to the appropriate manufacturer(s). Any component or deployment anomalies should be thoroughly documented and reported to the equipment manufacturers and PIA's Technical Committee (email: technicalchair@pia.com).