Research Proposal: Measuring Success Rates, Reaction Times and Education Opportunities for Deploying Avalanche Airbags While Skiing Avalanche Terrain*

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Abstract

A study is proposed to observe and measure the success rates of subjects deploying an avalanche airbag while skiing avalanche terrain. A facilitator will alert the subject at a point midslope that a fictitious avalanche has occurred. The test will be recorded on video so that the attempt to pull the airbag can be evaluated.

Instrumentation will also be employed to record the time of alert of the fictitious avalanche event initiation and then the moment the subject pulls the trigger on his or her airbag. Reaction times can then be measured.

After the subjects complete the scenario, an educational component will be introduced to one subset of the subjects, providing them with a systematic approach or "mantra" for deploying the airbag. All subjects will then repeat the scenario and any difference in success or failure rates and reaction times will be recorded.

1 INTRODUCTION

Thus far, the effectiveness of avalanche airbag deployment has been studied through evaluating actual avalanches involvement statistics [1][2][3].

Haegeli and Zweifel et al, in The Effectiveness of Avalanche Airbags, [1] concluded that

> Non-deployment remains the most considerable limitation to effectiveness. Development of standardized data collection protocols is encouraged to facilitate further research.

While many avalanche airbag users test their devices to verify functionality, and perhaps familiarize themselves with the apparatus, informal surveys by the author have found that few users have attempted to deploy their airbags while skiing terrain that could actually produce avalanches.

The author has found that successful deployment of an avalanche airbag while skiing complex terrain is non trivial. Success depends on quick decision making, familiarity with equipment, sound skiing skills, and a psychological commitment to the decision of employing the device.

Additionally, the question remains if attempting to deploy the airbag can have detrimental effects on the skiers ability to remain upright and possibly attempt to ski out of the avalanche.

With this study, the author proposes to:

1. Evaluate a skier's ability to deploy an avalanche airbag while skiing avalanche terrain.
2. Determine if attempts to deploy the airbag result in detrimental effects to the ability of the skier to remain upright.
3. Measure the reaction time of skiers to deploy the airbag while skiing by instrumenting the airbag deployment handle.
4. Evaluate the influence of introducing an educational component to a subset of the skiers by giving them a mantra to follow in the case of the need to deploy the airbag.

*This work is being advised by Brian Lazar, Deputy Director of the Colorado Avalanche Information Center

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2 METHODOLOGY

2.1 Venue

The author proposes to conduct the experiment at the Snowmass Ski Area, on the AMF ski run.

Tab. 1: AMF Path Details

Path Name	AMF
Environment	Alpine
Hazard Class (D Size) Potential	2.5
Starting Zone Elevation	11,820′
Path Vertical	430′
Max Slope Angle	40° (entrance)
Average Slope Angle	36°
Central Aspect	NE
Loading Azimuth	SW

After a steep entrance, the AMF run has a consistent pitch with minimal obstacles mid-path.

2.2 Subjects

The author plans to use members of the Snowmass Ski Patrol as subjects for the experiments. This will somewhat control for skier ability.

2.3 Experimental Procedure: Overview

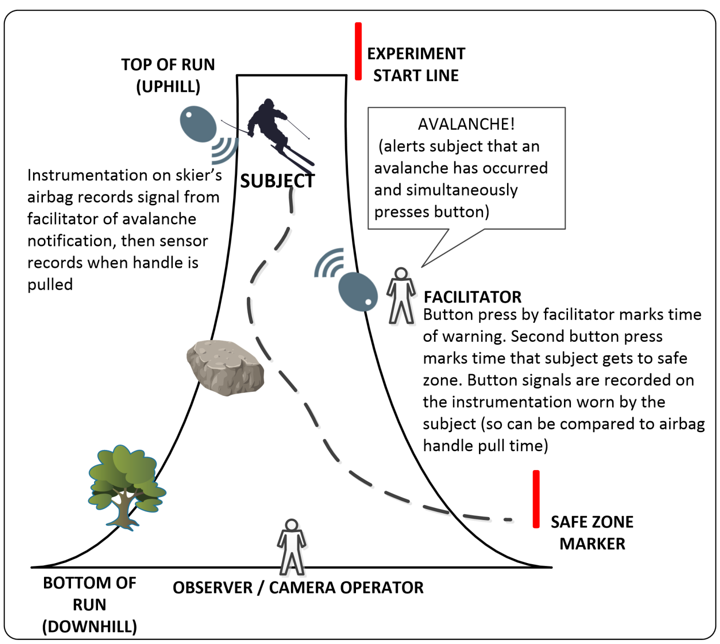


Fig. 1: Schematic of the Experimental Setup

Subjects will all be equipped with the same airbag, a Black Diamond JetForce airbag pack. This pack presents several advantages for use in this study:

1. Snowmass ski patrollers are familiar with its basic configuration.

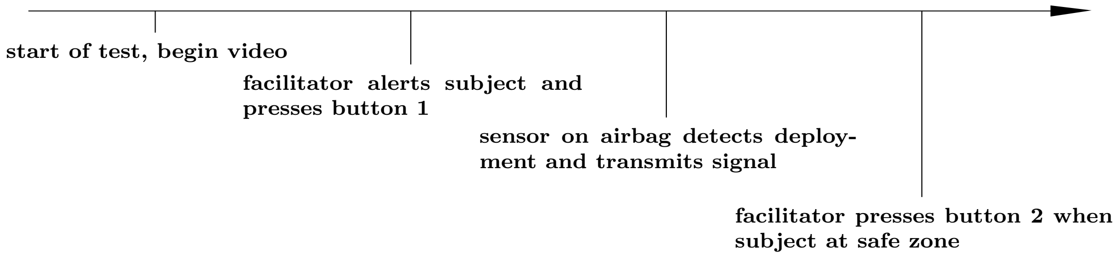


Fig. 2: Chronology, general experimental procedure

2. This pack is an electric fan powered pack, which allows for essentially unlimited number of deployments for this study.
3. The pack does not utilize compressed gas, which will minimize any downtime in testing for refilling air canisters associated with gas powered airbag packs.

Not every subject will be alerted by the facilitator that an avalanche event is happening. This way, the subjects will not know ahead of time if they will be presented with the opportunity to deploy their airbag or not.

Each test will be recorded on video by an observer at the bottom of the path so that events of the test can be reviewed and codified. Events such as failure to deploy the airbag, failure to find the deployment handle while skiing, falling as a result of attempted deployment, etc. will be noted.

2.4 Experimental Procedure - General

The facilitator will operate a main control box. The control box operates as follows:

1. The facilitator pushes a button when he or she alerts the subject that an avalanche has occurred. This marks the time of event initiation.
2. A sensor on the subject's airbag sends a signal wirelessly to the main control box when the avalanche airbag handle is deployed. This marks the time of deployment.
3. The facilitator pushes a second button when the skier reaches a marked safe zone.

2.5 Experimental Procedure - Time to Reach Safe Zone

A test will evaluate if there is a difference in time to reach the safe zone when a subject tries to deploy an airbag versus when the subject does not attempt to deploy the airbag. The following methodology will be implemented:

1. The subject skis the run without attempting to deploy the airbag. The time for the subject to reach the safe zone is recorded.
2. The subject skis the run and attempts to deploy the airbag. The time for the subject to reach the safe zone is recorded.
3. The delta between these two times is calculated.
4. The subject repeats this cycle a number of times and an average Δt is calculated for that subject.

2.6 Experimental Procedure - Educational Component

All subjects will go through the run once as described in the Experimental Procedure Overview section above. After completion of their first run, a subset of the subjects will go through a short educational experience. They will be encouraged to develop a mantra or system for reacting to an avalanche event.

Both groups will repeat the test procedure. The success and failure rates as well as reaction times of both groups can then be compared.

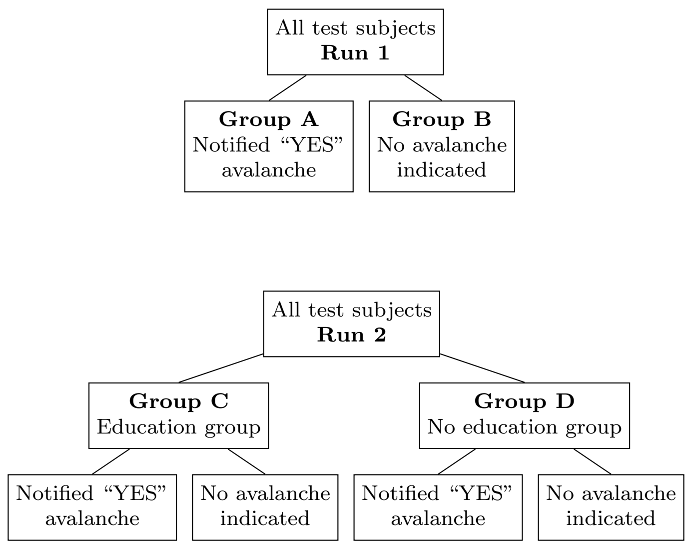


Fig. 3: Tree showing test subject groupings

3 DATA ANALYSIS

Data are gathered from each test run using

- video of the subject
- data recorded on the SD card in the main control box, which received input from the facilitator and input wirelessly from the instrumentation on the subject's airbag.

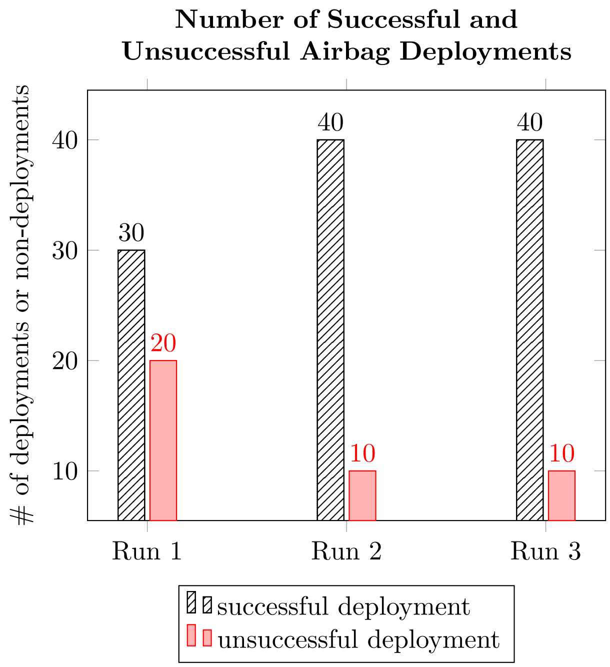


Fig. 4: Number of successful and unsuccessful airbag deployments

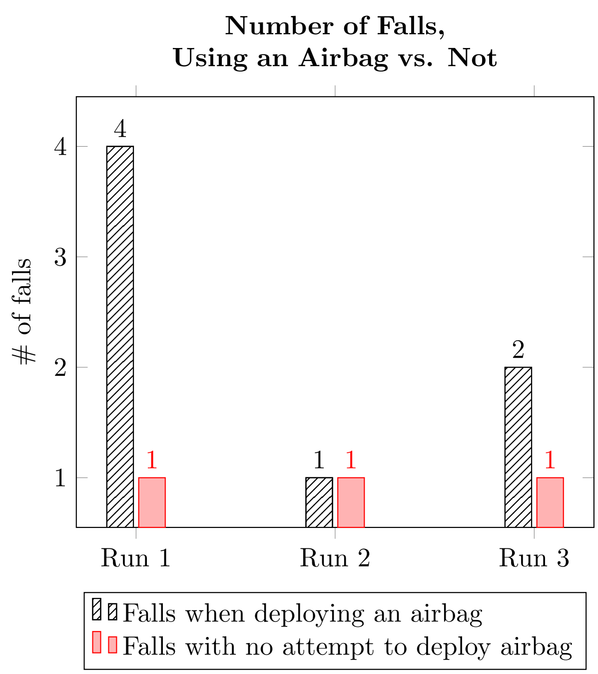
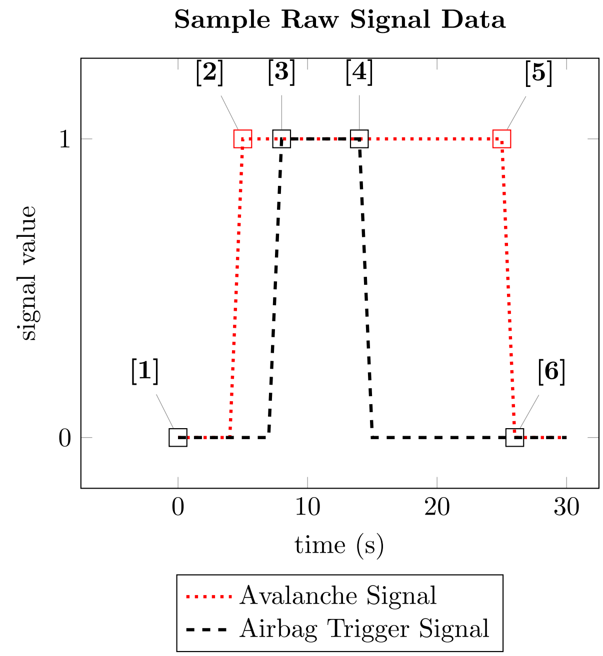


Fig. 5: Falls when attempting to deploy the airbag vs. falls when not trying to deploy the airbag



[1] Test start; video begins

[2] Avalanche indicated

[3] Airbag triggered

[4] Airbag handle released

[5] Skier reached safe zone marked

[6] End of test

Fig. 6: Raw data sample demonstration

To compare the time to reach the safe zone when deploying the airbag (run 1A) versus not deploying the airbag (run 1B), "run pairs" are examined. For run pair 1, Δt is then computed as $\Delta t_1 = t_{1\,airbag} - t_{1\,no\,airbag}$.

A positive Δt means that it took longer for the subject to get to the safe zone when trying to deploy the airbag, while a negative Δt means that the subject reached the safe zone in a shorter amount of time when not deploying the airbag.

Multiple "run pairs" are then executed, and named Run 2, Run 3, etc. The average Δt from all three of these runs for each subject is then plotted below.

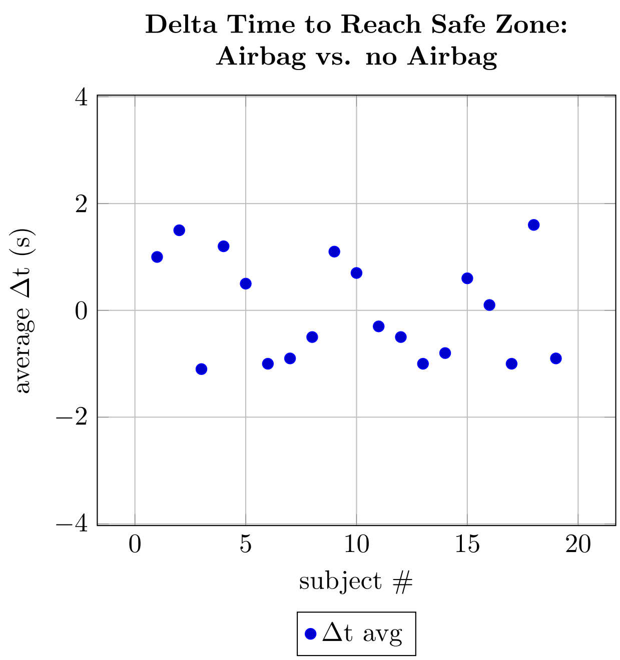


Fig. 7: Difference in time it takes to reach the safe zone, using an airbag vs. not using an airbag

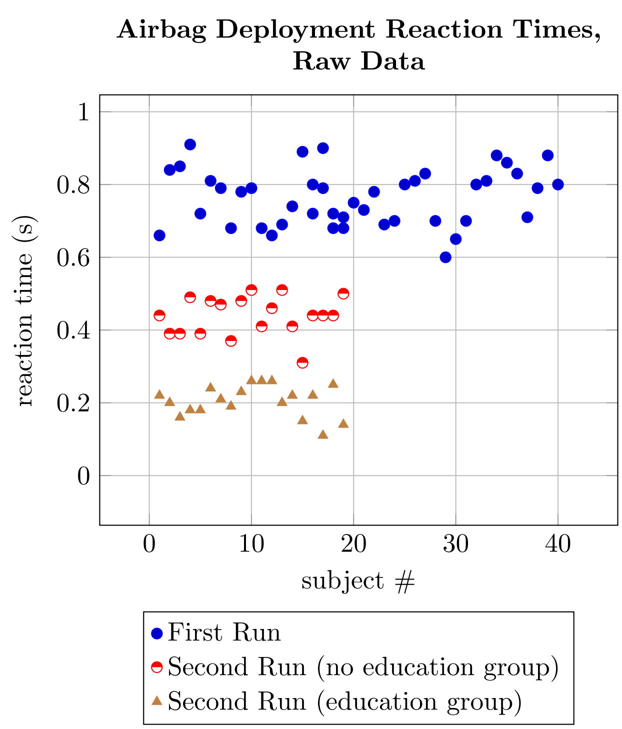


Fig. 8: Airbag deployment reaction times raw data

3.1 Statistical Methods

Initially, a univariate analysis will be completed to quantify the results of the experiment.

Variables in the experiment include

- Δt_{avg}
- falls
- reaction time

n $\approx$ 65. The number of subjects can be increased by using members of the ski school with expert skiing skills.

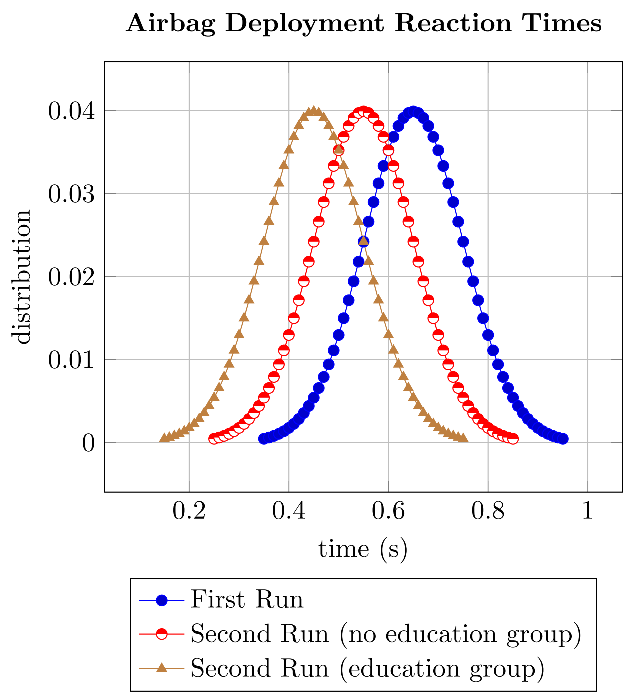


Fig. 9: Distribution of airbag deployment reaction times

4 INSTRUMENTATION DETAILS

The instrumentation needed for recording reaction times has already been assembled and tested. It consists of two units:

1. **Main Control Box** - operated by the facilitator. Records all events times and has buttons for the facilitator to mark event times and LEDs to confirm the instrumentation has recorded the subject activating his or her airbag handle.
2. **Airbag Instrumentation** - a sensor on the subject's airbag that creates a digital signal when the handle is activated. The signal is then transmitted wirelessly to the main control box via radio signal.

4.1 Main Control Box

The main control box utilizes a Teensy 3.5 Microcontroller for recording data on a micro SD card. The specifications of the microntroller are as follows:

- 120 MHz ARM Cortex-M4 with Floating Point Unit
- 512K Flash, 256K RAM, 4K EEPROM
- Microcontroller Chip MK64FX512VMD12
- 1 CAN Bus Port
- 16 General Purpose DMA Channels
- 5 Volt Tolerance On All Digital I/O Pins

To receive data from the subjects unit wirelessly, an XBee Pro RF module is used, with the following specifications:

- 2.4GHz XBee XBP24-AUI-001 module
- 802.15.4 stack

The system is powered by a rechargeable 3.3V LiPO battery.

4.2 Airbag Instrumentation

A magnetic reed switch is used to sense when the airbag deployment handle is pulled (figure 10).

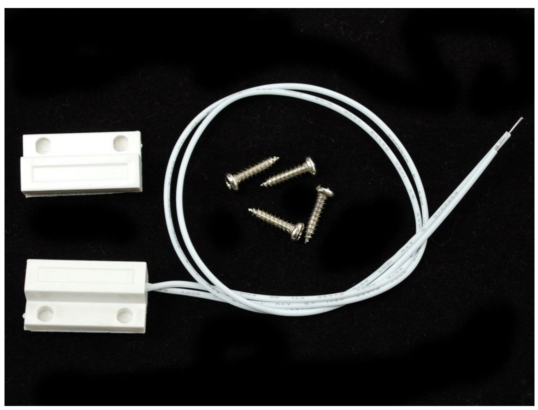


Fig. 10: Magnetic switch for detecting when the airbag handle is pulled

The digital signal created when this switch is activated is send over an XBee Pro RF module to the main control box.

The system is powered by a rechargeable 3.3V LiPO battery.

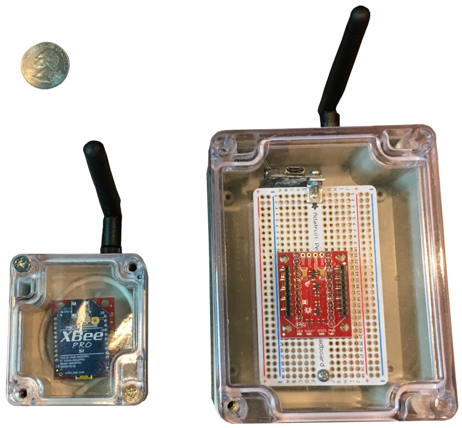


Fig. 11: Instrumentation built by the author showing the airbag data transmitter on the left and the main control box on the right. US Quarter on the upper left is for scale.

5 BUDGET

The budget for this study has two main components:

1. Airbag packs
2. Instrumentation and data recording equipment

Details for the budget are shown in the table below.

Tab. 2: Budget Estimate

	Cost ($)	**Quan.**	**Total ($)**
Airbag Packs			
Black Diamond Jetforce Tour	1200	3	3600
Instrumentation and Data Recording			
Teensy 3.5 Microcontroller	25	4	100
XBee Pro RF Module	38	4	152
XBee carrier board	11	4	44
Enclosures	15	4	60
Micro switches	5	4	20
Antennas	8	4	32
LiPo batteries	13	4	52
Micro SD cards for data	20	2	40
Assorted LED's and buttons	20	1	20
Video camera	330	1	330
SD card for video	40	1	40
Total			**4,490**

6 TIMELINE

The author proposes to conduct this research during the winter season of 2019/2020. The terrain used for this study typically opens in late December.

Tab. 3: Timeline

Month	Task
Oct 2019	Finalize and test instrumentation
Nov 2019	Finalize experimental setup
Dec 2019	Begin experiment setup
Jan 2020 - Mar 2020	Conduct experiment.
	Adjust instrumentation as needed
Mar 2020	Begin data review
Apr - May 2020	Summarize data, make plots
May - June 2020	Write formal summary
June - Aug 2020	Review findings with advisors
Aug - Sep 2020	Revise and make edits
	Prepare for ISSW
Following	Plan for further research

7 POSSIBILITIES FOR FUTURE INVESTIGATION

This study presents the opportunity to examine other variables that can influence the outcome of the experiment, for example:

- Terrain as a covariable
- Skier ability as a covariable
- Airbags from different manufacturers
- Location of airbag handle
- Skiers vs. snowboarders
- Gloves vs. mittens
- Wearing pole straps vs. no pole straps

8 MERGING THEORY AND PRACTICE

In the accident report of an avalanche incident on 2019/01/05 in the Upper Senator Beck Basin of Colorado, investigators from the Colorado Avalanche Information Center found that [6]

> Skier 2 was wearing an airbag backpack. After the accident we determined that the system was functioning properly, the trigger out of the pack strap, but the bag was not deployed.

Avalanche airbags have become standard equipment for professional avalanche practitioners, and are now commonly utilized by recreational users as well. A statistical study of airbag deployment failures in actual avalanche incidents found that 60% of non-inflations were due to non-deployment by the user [1].

In theory, airbag deployment while skiing should be straightforward. Most users do not practice deployment or do not practice under realistic conditions such as being caught in an avalanche or while skiing.

With this study, I propose to measure an expert skier's ability to deploy an avalanche airbag while skiing steep avalanche terrain and how the act of deploying the bag effects the skier's ability to remain upright. The study will also record the reaction time of the skier to deploy the airbag while skiing, and if deploying the airbag changes the time for the skier to reach a safe zone.

References

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