Iron Man, The Steel Crash Test Dummy, Measures Forces in an Avalanche

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1 EXTENDED ABSTRACT

Applied Research Associates (ARA) worked with the Snowbasin Resort on a National Geographic Television produced documentary on the effects of avalanches on humans and implications for avalanche rescue.

Tim Samaras, a scientist with ARA, has spent his career analyzing disasters. His work has included using cameras to assess characteristics of lightning strikes, using sensors to gauge impacts of bomb blasts, and using probes to predict the path and forces of tornados. For the work described here Tim teamed with Mike Jenkins of Utah State University to bring his expertise to measure what has never been measured—the forces imposed on an avalanche victim. The objective of the research was to determine the effects of avalanche motion on the human body and allow determination of acceleration, forces, the distance traveled and depth of burial.

Iron Man is a steel mannequin, 2 meters in height, and weighing 82 kg, to approximate the size of a human male. He was built to withstand extreme forces, and is a veteran of Tim’s explosive experiments. He is outfitted with sensors that measure pressure and impact to determine the trauma a human would suffer in a bomb blast. The challenge with this work was to adapt Iron Man to be an avalanche victim and transport him to an avalanche starting zone.

Gary Ogg of ARA is Iron Man’s inventor and was responsible for installation of the new instrumentation to measure avalanche parameters. The primary sensor was an accelerometer similar to those used to stabilize aircraft and was used to measure acceleration and motion and roll in multiple directions. Iron Man was further modified with flexible joints to provide a more realistic representation of the human form. Iron Man was equipped with 2 video cameras to allow filming from the eyes of the victim. Once modified Iron Man was taken from ARA in Colorado to Snowbasin, Utah where he was fitted with skis for the avalanche tests.

Iron Man’s partner was Foam Man, another crash test dummy, but without electronic measuring devices. Foam Man was outfitted with the Avalanche Airbag System (ABS) and placed in the starting zone along side Iron Man. The effectiveness of ABS is widely known and is available commercially in a variety of products.

The test was conducted on April 4, 2008. Prior to the test the snow study plot at Snowbasin received 50 cm of new snow with 2.8 cm of water for a snow density of about 6%. Ridgetop winds were moderate from the southwest preceding the test. Iron Man and Foam Man were transported to the starting zone by the Snowbasin Mountain Guides. Using ropes, the guides lowered the victims in place after starting the electronic sensors in Iron Man and inflating the ABS on Foam Man. From an observation area below the path Tim set up a high speed camera to record the event at 400-500 frames per second. Data from the camera allowed calculation of Iron Man’s speed during the avalanche. A thermal imaging camera was also set up to measure change in temperature of the moving snow due to frictional heating. Once the victims were in place the avalanche was triggered using 12 kg of explosives. The resultant avalanche was classified as a SS AE, AB 2 I. Both Iron Man and Foam Man were caught in the avalanche and carried 137 m vertically down slope. Iron Man was totally buried 30 cm deep and Foam Man remained on the surface. Iron Man stayed on his skis traveling with the slab for 2.5 seconds before hitting a rock, losing his skis, and disappearing in the flowing snow. He reached a speed of 40 km per hour and rotated 11 times with a
maximum of 2 rotations per second and experienced an acceleration of 10 times gravity. The thermal imaging camera measured a temperature increase in the moving snow of 4-7 degrees Celsius.

The avalanche was relatively small, yet typical of resort triggered avalanches and those involving humans in the backcountry. The Snowbasin Patrol used the opportunity to conduct an Initial Response Task Force exercise to locate Iron Man. Although many people watched Iron Man take his ride, and observed the point last seen, his final burial location was unknown. A ski was located during the initial search and Iron Man was found with a probe in 8 minutes after burial. His airway was exposed within 20 minutes. The rescue reinforces the well known fact that it is bad to be buried. Even with professional rescuers standing by Iron Man’s airway was buried for 20 minutes although he was only under 30 cm of snow. Foam Man remained on the snow surface during the entire event and his orange airbags were easily visible in the debris field.

The Iron Man test demonstrated that existing technology can be employed to measure forces acting on avalanche victims. Many additional tests are required to fully understand the nature of forces experienced by avalanche victims across the range of conditions encountered in human triggered avalanche incidents.