IME Derailed Debris Collection

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The Institute of Makers of Explosives (IME) led a post-detonation debris collection project in conjunction with a large AN railcar detonation conducted by the Department of Homeland Security-Transportation Security Administration, Department of Defense-Combating Terrorism Technical Support Office, Sandia National Laboratories, and the U.S. Army Dugway Proving Grounds. This important work will aid in underpinning algorithms used in the IMESAFR Quantitative Risk Assessment tool. The test also provided valuable data about AN detonation characteristics when it is driven to detonation. The test took place at the Utah Dugway Proving Grounds on April 27, 2018 and the debris collection was conducted the following two weeks with an average of 20 persons per day and an approximate total of 1400 manhours. This paper details the collection efforts, challenges, and lessons learned. It also presents some of the initial findings relating to the debris distribution.

Introduction

The Institute of Makers of Explosives (IME) is a nonprofit association founded in 1913 with the mission “To promote safety and security and the protection of employees, users, the public and the environment and encourage the adoption of uniform rules and regulations in the manufacture, transportation, storage, handling use and disposal of explosive materials.” IME represents U.S. manufacturers and distributors of commercial explosives and oxidizers, and companies that provide related services. The ability to manufacture, use, transport, and distribute, commercial explosives safely and securely is critical to the explosives industry. Accordingly, IME has an interest in any guidance, standards and best practices and advocating at all levels of government the adoption of rules and regulations consistent with safety and security in the manufacture, transportation, storage, handling, use and disposal of explosive materials.

For more than a decade IME has pioneered IMESAFR, a quantitative risk assessment (QRA) tool used to calculate risk to personnel from commercial explosives facilities and operations as an effective supplement to the American Table of Distances (ATD). This QRA tool can utilize an Ammonium Nitrate (AN) engine as opposed to classical TNT engines. TNT engines prove to be insufficient for modeling AN-detonations as the detonation of AN is not only nonideal but also incomplete. The total amount of donor material cannot be expected to react and in turn the unreacted material will affect the resulting shock wave. Real world testing is necessary to underpin the AN engine. IME has invested in the science of QRA, and its continued improvement, knowing it to be a critical component toward advancements in safely storing commercial explosives. For these reasons, IME sponsored a debris collection effort following a large-scale detonation event to better populate the datasets utilized in IMESAFR’s AN Engine.

The primary purpose of this paper is to describe the post-detonation debris collection effort and the secondary purpose is to describe preliminary data analysis completed on the debris collection data.

AN Railcar Test

IME led a post-detonation, debris collection project in conjunction with a large AN railcar detonation conducted by the Department of Homeland Security-Transportation Security Administration, Department of Defense-Combating Terrorism Technical Support Office, Sandia National Laboratories, and the U.S. Army Dugway Proving Grounds.

The test took place at the Utah Dugway Proving Grounds on April 27, 2018 and the debris collection was conducted the following two weeks with an average of 20 persons per day and an approximate total of 1,440 manhours. The debris collection effort was funded by IME and APT Research was contracted to support the Debris Collection/Cataloging (DCC) crew. The United States Army Technical Center for Explosives Safety (USATCES) supported the test with debris recovery personnel and global positioning system (GPS) equipment.

185^{0} Debris Collection and Cataloging

Ideally a full 360-degree debris collection would have been conducted. Due to limitations on funding, personnel, equipment, and range time it was decided to plan for 185-degree collection with the intention to apply symmetry to the data. Fortunately, at the time of the test there was virtually no wind as evidenced by the release of a weather balloon. It was anticipated that the effort would require approximately two days before the test to establish a collection grid and approximately two weeks for the actual debris mapping and collection.

Debris Collection/Cataloging Crew

The pre-test grid survey was conducted by two to three individuals over the course of two days in advance of the test. The grid was designed and built in accordance with Rev. 2 of Department of Defense Explosives Safety Board Technical Paper-21[1]. This took take place the week prior to the test. A local surveying crew was contracted to provide GPS support for the accurate placement of grid markers.

It was anticipated that a minimum of 25 - 30 personnel were needed for the post-test processing including marking, weighing and collecting debris. However, the actual crew size ranged from 20 to 23 on any given day (Figure 1). About half of these individuals worked both weeks which helped with continuity and consistency in the debris collection methodology. The other half worked either the first or the second week. This introduced some inefficiency with having to train newcomers at the beginning of the second week. These individuals were divided into multiple teams, each with a team leader, for scene processing including locating, weighing and cataloguing debris. During the second week teams were divided to include both new and experienced workers.

Two weeks was expected to conduct the debris collection. It was planned that the DCC crew would work five days a week, and that the DCC crew will work seven-hour days, not including travel time from the hotel to the gate or the gate to the hotel. The travel time from the hotel to the gate of Dugway was approximately 45 minutes with an additional half hour to the test site.

Figure 1: Two DCC Crews

The 30-minute drive from the gate to the site resulted in only seven hours of debris collection for the crew. A summary of the crew size by day and the resulting man-hours can be seen in Table 1.

Table 1: Crew Size and Man-Hours

Date	4/30/2018	5/1/2018	5/2/2018	5/3/2018	5/4/2018	5/5/2018	5/6/2018	5/7/2018	5/8/2018	5/9/2018	5/10/2018	Total Man-Hours
Crew Size	21	22	22	22	20	8	0	21	20	21	23	1400
Man-Hours	147	154	154	154	140	56	0	147	140	147	161	

Pre-Test Grid Survey

To facilitate the debris collection process and identification of debris scatter on the video recordings, markers were placed at specified locations prior to detonation. During the installation of the makers the site was inspected for pre-existing debris to aid in any subsequent differentiation between preexisting debris and the debris resulting from the test. These markers were placed at the following positions:

- 5,000-foot radius (expected end of far field)— 6 (six) markers placed at the following angles: 357.5°, 2.5°, 87.5°, 92.5°, 267.5°, and 272.5°
- 3,000-foot radius (beginning of far field)—38 markers, placed one at every 5° (2.5° to 92.5° and 267.5° to 357. 5°)
- 1,600-foot radius (end of near field)—38 markers, placed one at every 5° (2.5° to 92.5° and 267.5° to 357.5°)
- 100-foot radius (beginning of near field)—72 markers, placed on at every 5° (2.5° to 357.5°)

The geometric centroid of the railcar was used as the center, or ground zero, of the grid. Markers were placed at each intersection of radial distance with azimuthal angle. These markers were to withstand the blast/debris environment, clearly marked with the azimuthal angle, and visible from distance with a ribbon. The markers located at the 100-foot radius were steel rebar. However, they were buried by earthen material ejected by the blast and had to be uncovered following the blast. The remaining markers were wooden survey stakes except for the 5,000-foot radius stakes. The 5000-foot radius stakes were 10 foot PVC pipes fixated over metal t-posts with flags attached to them. Figure 2 shows the layout of these survey markers.

The shaded portion of Figure 1 depicts the 185-degree arc of the debris recovery which was aligned so that zero degree is positioned at the southern facing end of the railcar and 90° and 270° are positioned along the long sides of the railcar.

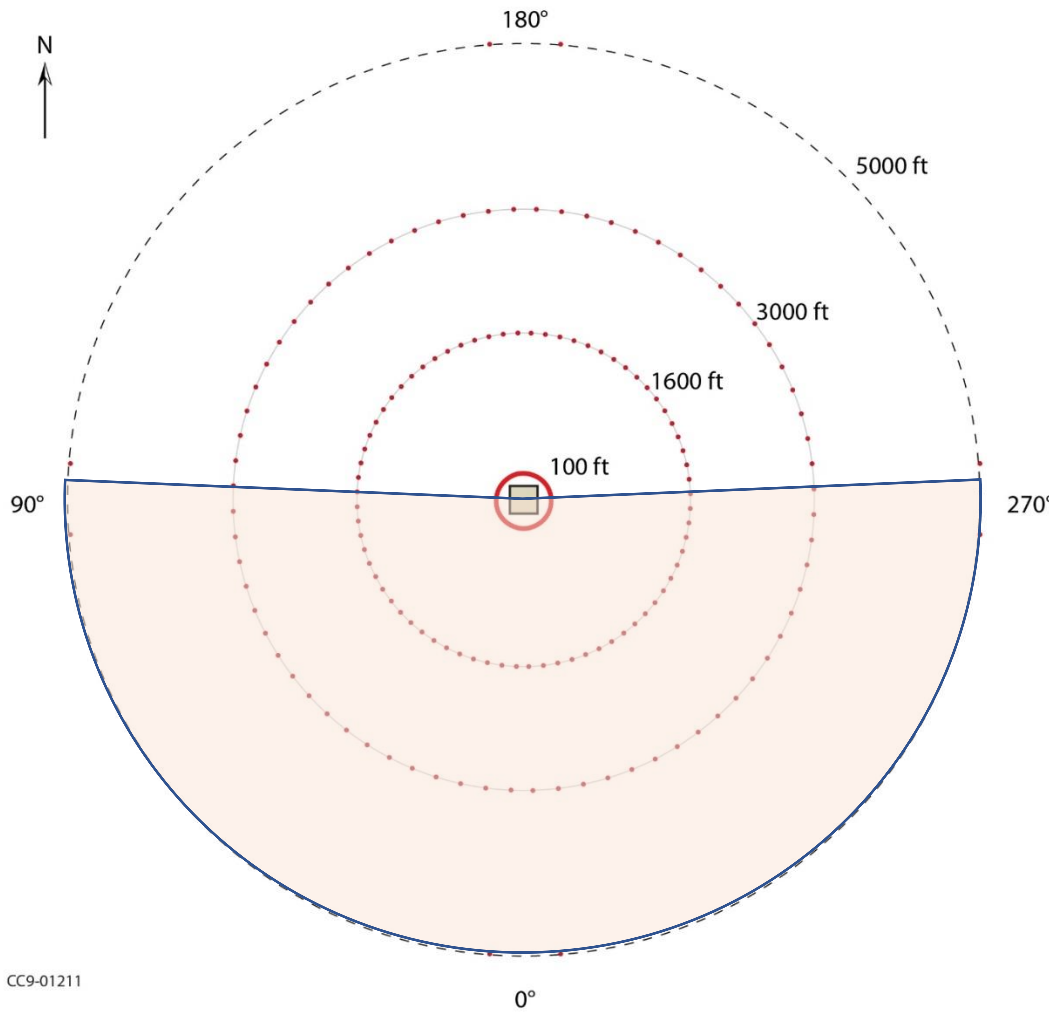

Figure 2: Range Schematic (Not to Scale)

Post-Test Debris Collection and Cataloging

A test of this size involves many stakeholders, each with their own instrumentation and hardware limitations. Getting to the instruments and downloading and backing up data is paramount. Communication with all stakeholders was critical to ensure that in performing their tasks they did not disturb the debris field before it was cataloged. Coordination occurred with Sandia National Laboratories during their equipment cleanup to insure debris is not disturbed and they have the needed access to their equipment. As soon as the site was deemed all clear following the detonation a limited crew of six participants conducted post-test initial debris collection efforts, such as clearing roads for vehicles and clearing crater ejecta that covered the close-in degree markers.

Debris Cataloging

Information from the fragments resulting from the test allowed the debris environment to be characterized, including but not limited to, the maximum fragment distance, fragment density by range and bearing, and the mass distribution of the fragments. Mass bins are defined in TP-21 Rev2[1]. These mass bins were used to characterize the debris for this test.

Fragments with a mass greater than 5 grams were cataloged by collecting the following information:

- The final resting position of each cataloged fragment was recorded in terms of range and bearing using the GPS units.
- The mass of each cataloged fragment was recorded.
- In the event the piece is too large to move by hand, a crane scale mounted to a front-end loader was utilized.

Debris Collection/Cataloging

The full DCC effort commenced on April 30, 2018 and concluded on May 10, 2018 for a total of 10 work days. The DCC process was conducted in accordance with Rev 2 of Department of Defense Explosives Safety Board Technical Paper-21[1]. During the cataloguing process, the source of each piece of recovered debris was identified to be part of the railcar. There was some residual debris from previous tests, but these components had undergone more oxidization and could be differentiated from railcar debris. This was a critical reason to comingle experienced crew members with inexperienced members on each team.

After the detonation, the DCC effort consisted of two concurrent tasks:

- Flagging: debris location and marking
- Cataloguing: determination of range, bearing, and mass of each debris piece

Once the range, bearing, and weight of each piece have been recorded, the material was transported to a central location for recovery and disposal.

Collection Efforts

The initial goal of the debris collection effort was to complete a 195° (92.5° to 267.5°) area from 100 ft from ground zero to 5,000 ft from ground zero. The debris collection area was broken into three separate areas: Near Field (100 ft - 1600 ft), Mid Field (1,600 ft - 3,000 ft), and Far Field (3,000 ft - 5,000 ft). Due to limited crew size and collection time, the Near Field was only collected from 92.5° to 342.5°. However, the Mid Field and Far Field collection was completed. The total area examined for debris was approximately 940 acres. The debris collection area can be seen in Figure 3.

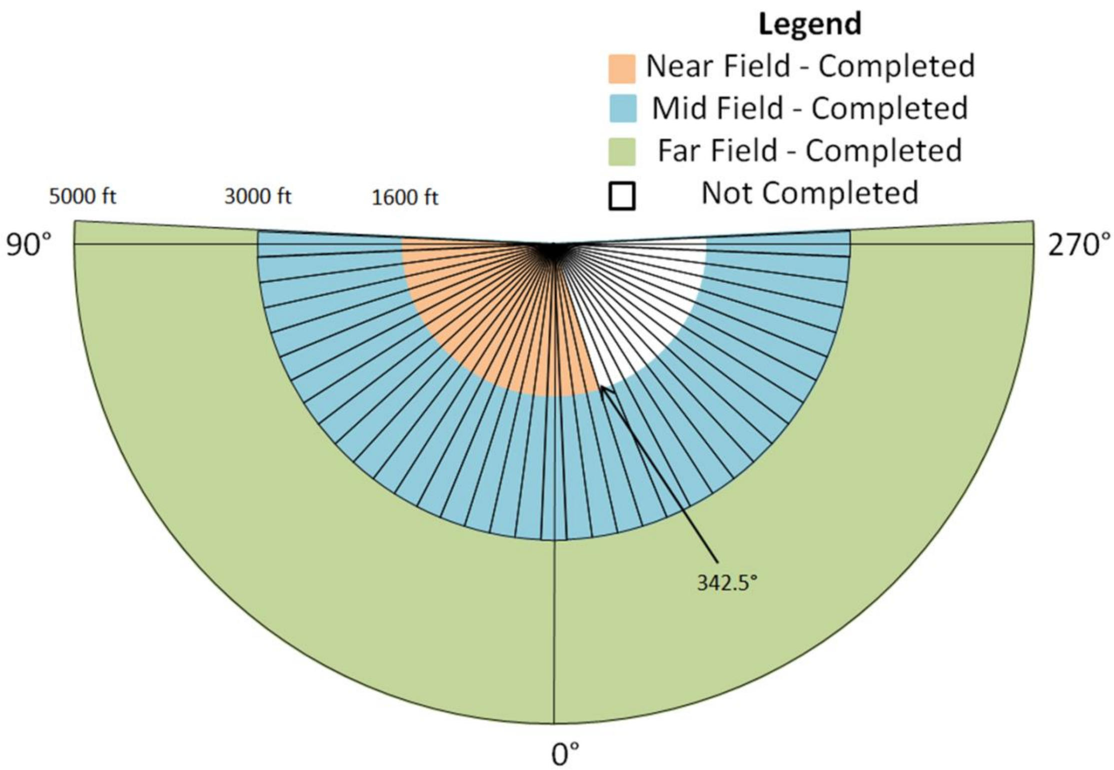

Figure 3: Debris Collection Area

A total of 21,066 pieces of debris with a mass of five grams or greater were cataloged. This was a total of 20,187 pounds of debris which was cataloged. Only debris with a mass of 5.9 grams or larger were assigned to a mass bin as defined in TP-21 Rev.2 and seen in Table 2[1].

Table 2: Mass Bins and Associated Energies

Bin Number	Steel	
	Mass	**Energy (ft-lb)**
1	>26 lbs. (11793g)	>103,389
2	10 – 26 lbs. (4536 -11793g)	28,900 – 103,389
3	4.5 – 10 lbs. (2040-4536g)	9,961 – 28,900
4	1.8 – 4.5 lbs. (816-2040g)	2,934 – 9,961
5	0.8 – 1.8 lbs. (363-816g)	995 – 2,934
6	0.3 – 0.8 lbs. (136-363g)	269 – 995
7	0.14 – 0.3 lbs. (63.5-136g)	97 – 269
8	0.06 – 0.14 lbs. (27.2-63.5g)	31 – 97
9	0.025 – 0.06 lbs. (11.3-27.2g)	9.6 – 31
10	0.013 – 0.025 lbs. (5.9-11.3g)	4.4 – 9.6
G	<0.013 lbs. (5.9g)	<4.4

The total pieces of debris within each bin can be seen in Figure 4 where it can be seen that as the mass bin decreases the relative proportion of debris pieces within that bin increases.

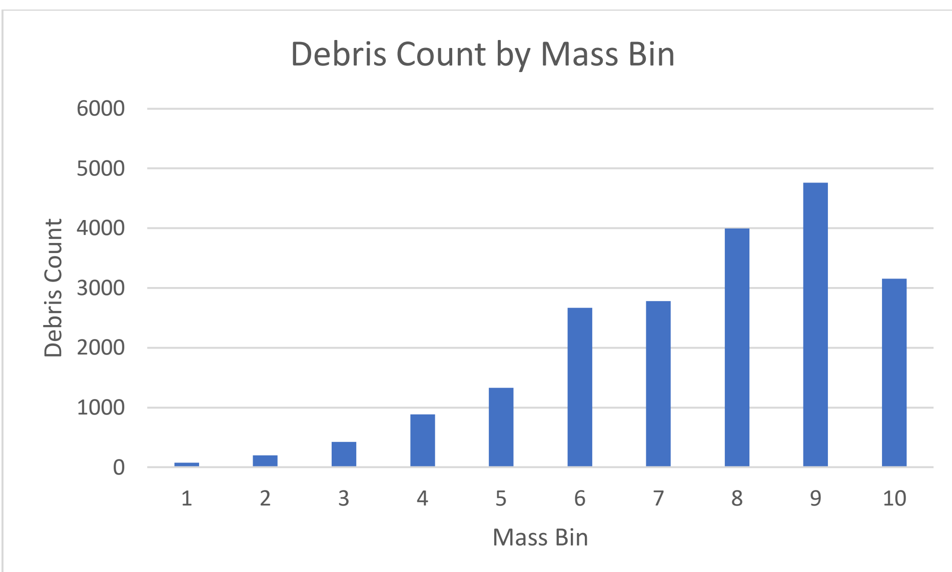

Figure 4: Debris Count by Mass Bin

Figure 5 in contrast shows that as mass of the individual debris decreases the total proportion of mass within the bin decreases.

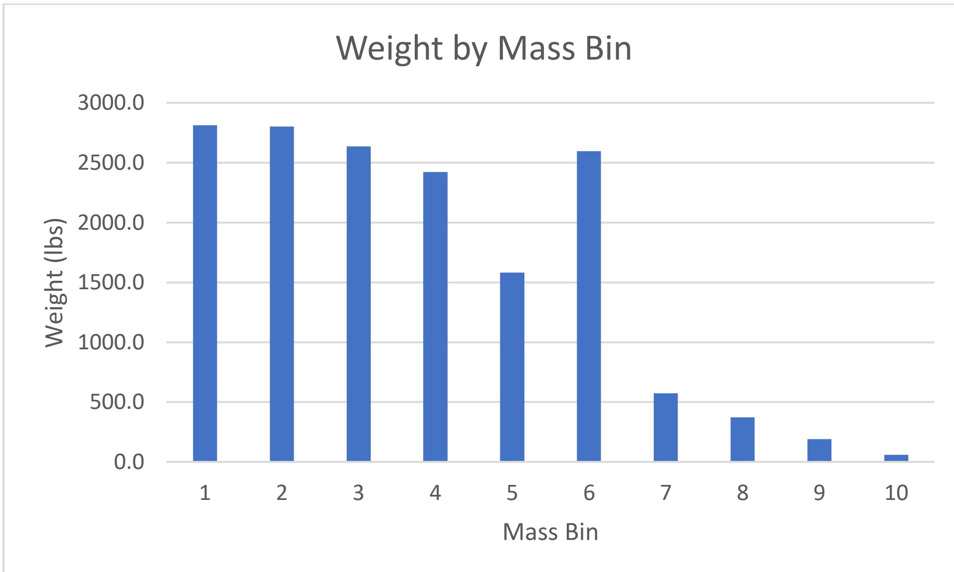

Figure 5: Total Weights in Each Mass Bin

Figures 4 and 5 shows that although there are proportionally few pieces of larger debris much of the total mass is present in them. While there are a lot of debris pieces in the smaller mass bins the don't amount to much of the overall mass and therefore less hazardous.

Conclusions

The Institute of Makers of Explosives (IME) led a post-detonation debris collection project in conjunction with a large AN railcar detonation conducted by the Department of Homeland Security-Transportation Security Administration, Department of Defense-Combating Terrorism Technical Support Office, Sandia National Laboratories, and the U.S. Army Dugway Proving Grounds. The test took place at the Utah Dugway Proving Grounds on April 27, 2018 and the debris collection was conducted the following two weeks with an average of 20 persons per day and an approximate total of 1400 manhours. This important work will aid in underpinning algorithms used in the IMESAFR Quantitative Risk Assessment tool.

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A total 20,187 pounds of debris was cataloged and was comprised of 21,066 pieces of debris with a mass of five grams or greater. As the mass bin decreases the relative proportion of debris pieces within that bin increases and although there are proportionally few pieces of larger debris much of the total mass is present in them. While there are a lot of debris pieces in the smaller mass bins they don't amount to much of the overall mass and therefore less hazardous.

References

Swisdak, Michael M., Tatom, John W., and Hoing, Craig, "Procedures for the Collection, Analysis, and Interpretation of Explosion-Produced Debris—Revision 2," Department of Defense Explosives Safety Board Technical Paper 21, 01 February 2017.