



# **IRON WARRIOR 4 & TECHNICAL PAPER 21**

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# OUTLINE

- Background
  - ▶ Test Overview
  - ▶ ATF Invites IME/APT/DDESB to Participate
  - ▶ Safety vs. Security
  - ▶ Test Details
- DDESB TP-21
- Test Execution
  - ▶ Collaboration
  - ▶ Results
- Future Plans
- Summary and Conclusions

# BACKGROUND: TEST OVERVIEW

- The National Ground Intelligence Center (NGIC) sponsored the Iron Warrior 4 (IW4) test as part of a larger test program.
- The U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) conducted the test.
- The test was conducted at Dugway Proving Grounds (DPG) in 2015.
- Many other agencies participated in the test, including the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF).
- ATF was interested in a debris recovery effort for IW4 and was aware that the Department of Defense Explosives Safety Board (DDESB) Technical Paper 21 (TP-21) methodology was being used by DoD to gather test debris data to support explosives safety models.
- ATF invited the Institute of Makers of Explosives (IME) to participate in the debris recovery, and sponsored APT's involvement to organize the crew and manage the effort.

# BACKGROUND: SAFETY VS. SECURITY

- The test was 60,000 lb of ANFO in a tractor-trailer (truck).<sup>†</sup>
- Although the test was originally designed to gather information for physical security (anti-terrorism) purposes, this scenario was/is also of interest to the explosives safety community.
- IMESA<sup>FR</sup> was used to predict the debris throw ranges and establish parameters needed to setup the TP-21 debris collection grid. However, IMESA<sup>FR</sup> had not been validated for this Potential Explosion Site (PES) model at this charge weight.

*NDIA Paper No. 20720, “IMESA<sup>FR</sup> Overview,”  
 Technical Track – C, Tuesday, 3:10-4:50*

- Numerous “target” experiments were included, so a 360° debris collection was not possible.

<sup>†</sup> - *The ANFO and trailer were donated by Dyno Nobel; the tractor (cab) was supplied by DPG.*

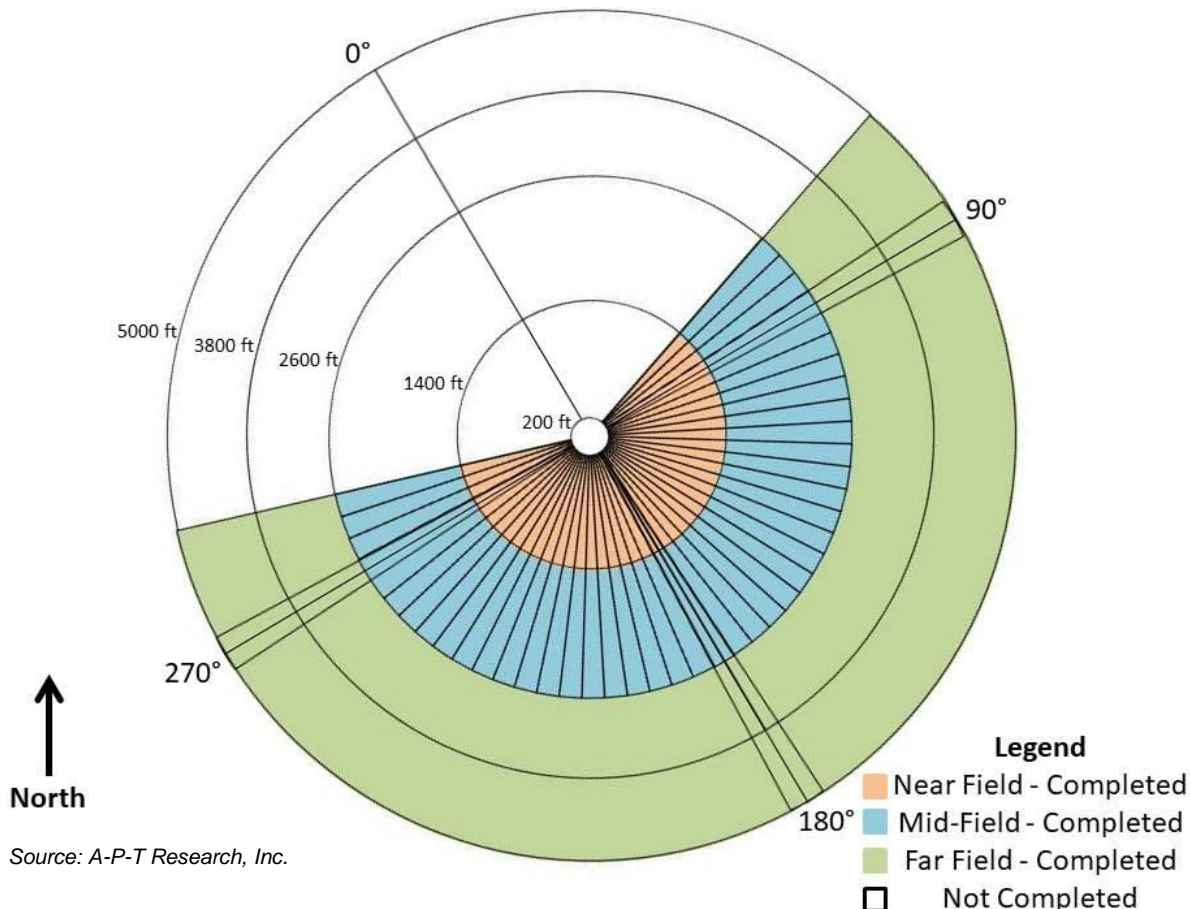
# BACKGROUND: TEST DETAILS (NOT COVERED)



- This paper is not a description of the entire test: only the details of the debris recovery are discussed.
- No pictures or videos of the test are included in this presentation (or in the paper).

# BACKGROUND: TEST DETAILS

- As mentioned, the debris recovery was not conducted over a full 360°.
- A grid was established with 5° intervals over a 215° area, from 200' to 5,000'.
- Distance “rings” were established at:
  - ▶ 200'
  - ▶ 1,400'
  - ▶ 2,600'
- Additional reference markers were located “on the normals” at 3,800' and 5,000'.

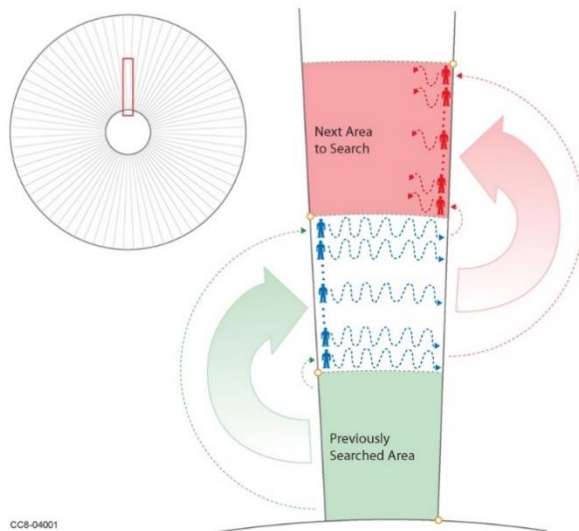


# BACKGROUND: TEST DETAILS

- Near Field (200'-1,400')
  - ▶ IMESA FR predicted that ~80% of the fragments would land in this region.
  - ▶ According to TP-21, this area must be treated the most meticulously.
- Mid-Field (1,400'-2,600')
  - ▶ IMESA FR predicted that almost all of the pieces that make it past the Near Field will land in this area.
  - ▶ Somewhere in this area, the debris recovery effort can move to a faster process.
- Far-Field (2,600'-5,000')
  - ▶ IMESA FR predicted that only a small number of pieces (all larger and ballistically efficient) will make it to this region.
  - ▶ The 95% confidence value for the maximum throw range was 4,200'.
  - ▶ This area is searched with the Far-Field Walk method from TP-21.

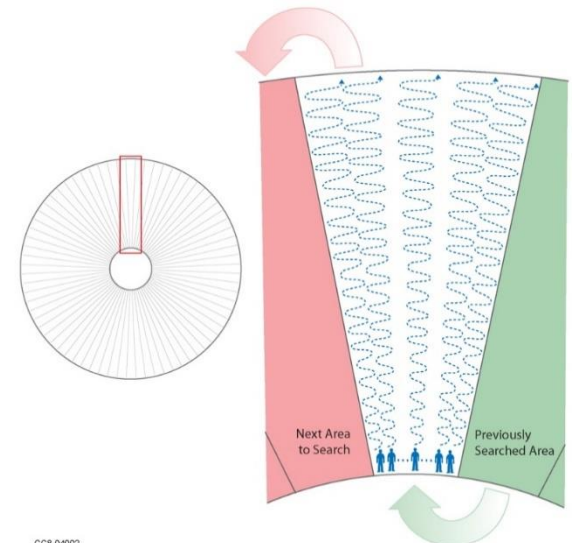
# TECHNICAL PAPER 21 (TP-21)

- TP-21 contains the DoD guidelines for debris recovery efforts after tests or accidents.
  - ▶ Originally a NATO publication in 1999
  - ▶ First DDESB TP-21 publication in 2007
  - ▶ Revision 2 released in 2017
- TP-21 provides techniques for organization and methods to avoid confusion and inefficiency.



CC8-04001

*TP-21 provides options for debris recovery approaches based on manpower, debris density, and area to be covered.*



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# TECHNICAL PAPER 21 (TP-21)

- IW4 used a technique detailed in TP-21 that involves two different types of teams performing different aspects of the debris recovery:
  - ▶ “Flaggers” – search the areas in an organized manner, marking fragments with survey flags.
  - ▶ “Catalogers” – use GPS equipment and scales to record the location and mass of all fragments located by the Flaggers (and remove the frags/flags).



- Other methods are also described in TP-21 (e.g., collection by sector).

# TEST EXECUTION

The debris collection crew included personnel from ATF and APT, IME staff members and students sponsored by IME, personnel from IME member companies Dyno and Orica, and DoD personnel from USATCES, NAVFAC EXWC, and DDESB.

*Crew picture cleared  
for release by DPG.*



# TEST EXECUTION

- The crew size varied daily, but a total of 48 people participated in the debris recovery. A total of 1,944 manhours were involved, not counting DPG personnel that were present to allow site access or otherwise support the test (but not actively involved in the debris recovery).

Organization	Total Manhours	Section Heads
ATF	744	1
IME (including students)	592	1
Dyno	176	-
APT	168	4
USATCES	168	1
NAVFAC EXWC	24	1
DDESB	16	-
Orica	16	-

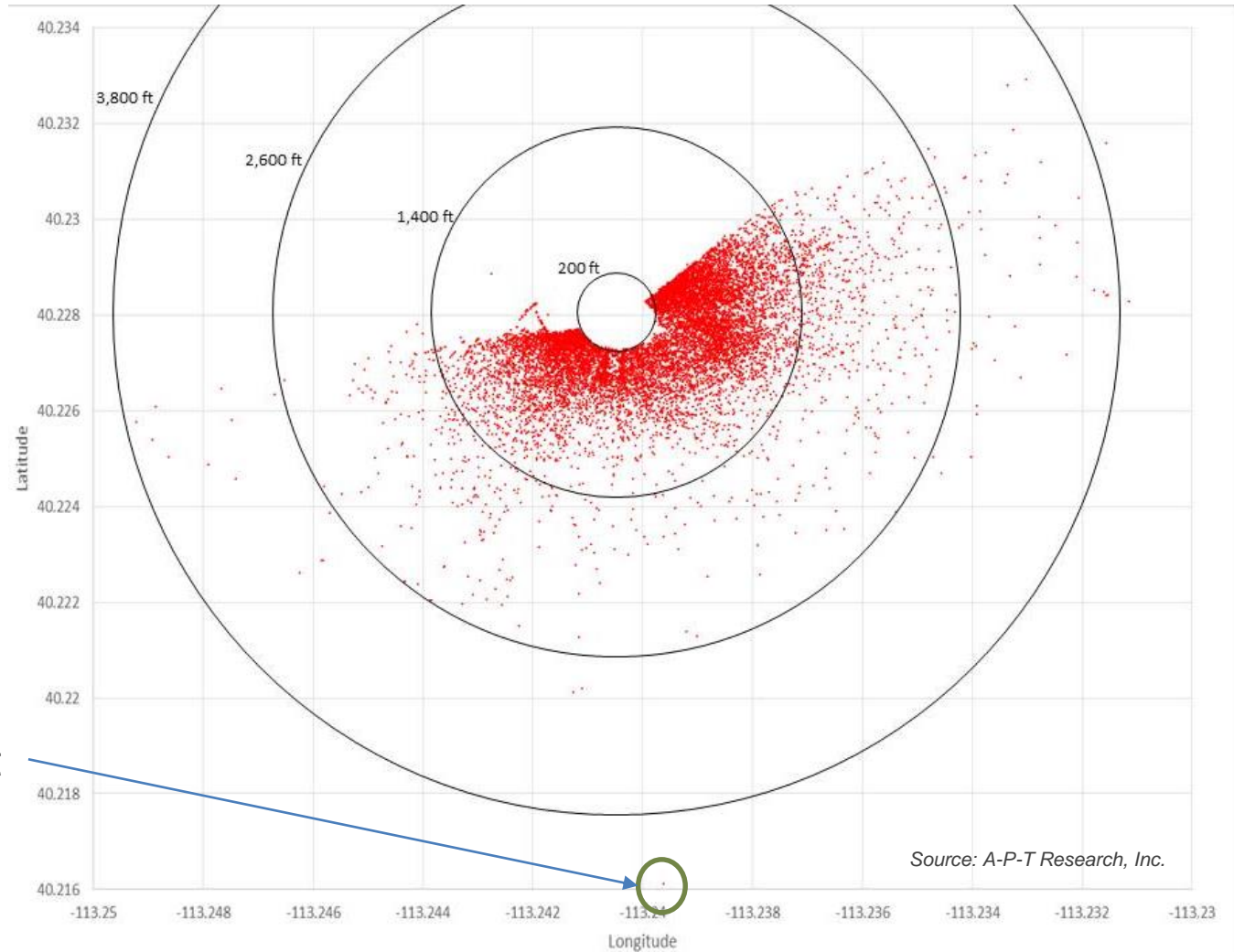
- USATCES also supplied the GPS equipment.
- ATF provided all other equipment and supplies for the debris recovery.

# DEBRIS RECOVERY EFFORT

- Approximately 12,600 debris pieces were cataloged, which means about 6.5 points were found, weighed, GPS-located, and recorded per manhour.
  - ▶ This rate accounts for the time it takes to search all the area with no debris, too.
  - ▶ Although the majority of the area searched beyond the Near Field produced only a small number of debris, these results are critical for analytical and regulatory purposes.
- After the debris collection was completed, statistics showed that in fact 75% of the recovered fragments were in the Near Field, and only five fragments were in the Far Field. The farthest fragment was at approximately 4,300 feet.

# DEBRIS RECOVERY EFFORT

Scatter plot of all debris recovered



Farthest fragment

Source: A-P-T Research, Inc.

# DEBRIS RECOVERY EFFORT

- USATCES has completed the official debris catalog and provided it to DDESB, NAVFAC EXWC, ATF, and IME.
- Only preliminary analysis has been done on additional information available from this catalog:
  - ▶ Mass distribution
  - ▶ Debris density versus range and azimuth
  - ▶ Post-impact debris behavior (bounce, skid, roll)
  - ▶ Comparison of results to QD (ATF and DoD)

# FUTURE PLANS

- IME plans to incorporate the IW4 findings in a future version of IMESA FR.
- ATF and DoD will also study the debris catalog for regulatory and modeling purposes.
- ATF, IME, and DoD will continue to look for collaborative testing opportunities, proposing the use of TP-21 to collect useful and consistent debris data catalogs.

# SUMMARY AND CONCLUSIONS

- Iron Warrior 4 was successfully conducted with the involvement of numerous agencies.
- The debris recovery effort was a collaborative effort.
- The IMESA FR predictions were quite good, but there is much more to be analyzed and incorporated.
- TP-21 has been used outside of DoD and provides approaches to produce consistent, useful debris data catalogs.