30mm Apache Ammunition In-Bore and Hang Fire Investigation Team (IHIT)

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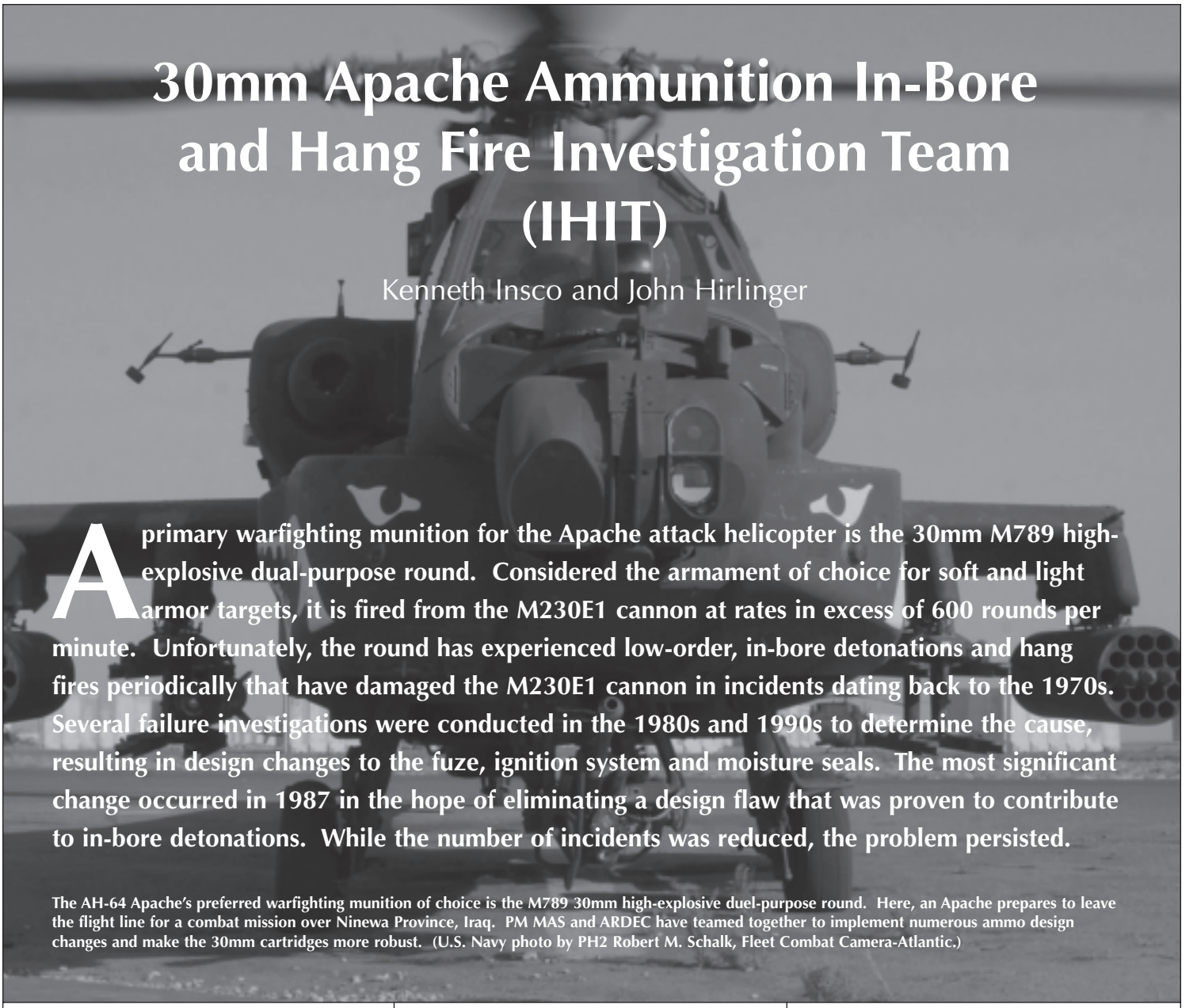
A primary warfighting munition for the Apache attack helicopter is the 30mm M789 high-explosive dual-purpose round. Considered the armament of choice for soft and light armor targets, it is fired from the M230E1 cannon at rates in excess of 600 rounds per minute. Unfortunately, the round has experienced low-order, in-bore detonations and hang fires periodically that have damaged the M230E1 cannon in incidents dating back to the 1970s. Several failure investigations were conducted in the 1980s and 1990s to determine the cause, resulting in design changes to the fuze, ignition system and moisture seals. The most significant change occurred in 1987 in the hope of eliminating a design flaw that was proven to contribute to in-bore detonations. While the number of incidents was reduced, the problem persisted.



The AH-64 Apache's preferred warfighting munition of choice is the M789 30mm high-explosive duel-purpose round. Here, an Apache prepares to leave the flight line for a combat mission over Ninewa Province, Iraq. PM MAS and ARDEC have teamed together to implement numerous ammo design changes and make the 30mm cartridges more robust. (U.S. Navy photo by PH2 Robert M. Schalk, Fleet Combat Camera-Atlantic.)

Warfighter Needs Increase Dramatically

The start of *Operations Enduring* and *Iraqi Freedom* resulted in a dramatic increase in Apache 30mm M789 cartridge use. Weapon failures continued to occur, and by 2003, enough incidents had been reported that Project Manager Apache issued a System Safety Risk Assessment. More than 1.1 million 30mm M789 cartridges produced prior to the 1987 design improvement incorporation were suspended, except for emergency combat use. To meet warfighting requirements, Program Manager Maneuver Ammunition Systems (PM MAS) initiated new ammunition production contracts, quickly ramping up to 75,000 rounds per month. However, there continued to be occasional in-bores and hang fires during operational use.

Team Challenged to Find Solutions

A formal cross-organizational investigation team was chartered to finally determine the causes and corrective actions needed to eliminate the ongoing problem. Co-chaired by Apache Project Management Office and Product Manager Medium Cannon Caliber Ammunition, the IHIT consisted of personnel from the U.S. Army Armament Research, Development and Engineering Center (ARDEC); Joint Munitions Command; Army Research Laboratory; Tank-automotive and Armaments Command; U.S. Army Training and Doctrine Command Systems Manager Attack Helicopter; Boeing Co. (Apache prime contractor); and Alliant Techsystems Inc. (M230 weapon and ammunition prime contractor). Specifically, the team was chartered with identifying and evaluating root causes of in-bores and hang fires, recommending impacts on current ammunition

stockpiles and reducing or eliminating identified failures and potential risks.

Unlike previous investigations that focused mostly on the ammunition, the team looked at the problem from a total systems perspective. Using systems engineering and Lean Six Sigma (LSS) techniques, they explored all aspects of potential contributors from the aircraft, to the cannon and ammunition handling system, to the ammunition design and production processes, to fielding, handling and ammunition storage. The team's membership included a Six Sigma Black Belt. Process mapping, failure mode effects analysis (FMEA), fault tree breakdown, voice of the customer and design of experiments were some of the LSS tools the team employed.

Initially, the team's FMEA identified 215 potential failure modes. These were grouped into four major areas:

- Gun manufacturer, handling and aircraft systems (121).
- Ammunition metal parts and fuze manufacturer (55).
- High-explosive charge pressing and cartridge load, assembly and pack (36).
- Handling and storage of ammunition (3).

Through risk prioritization, potential failure modes were narrowed down to 24 and evaluated using fault tree analysis. Cartridges were built with the specific flaws ranked highest from the fault tree analysis, and were evaluated using a design of experiments test to determine individual contributions as well as interactions that contributed to causing an event. Results from the test firings replicated the observed field signatures for all of the event types that had been previously noted.

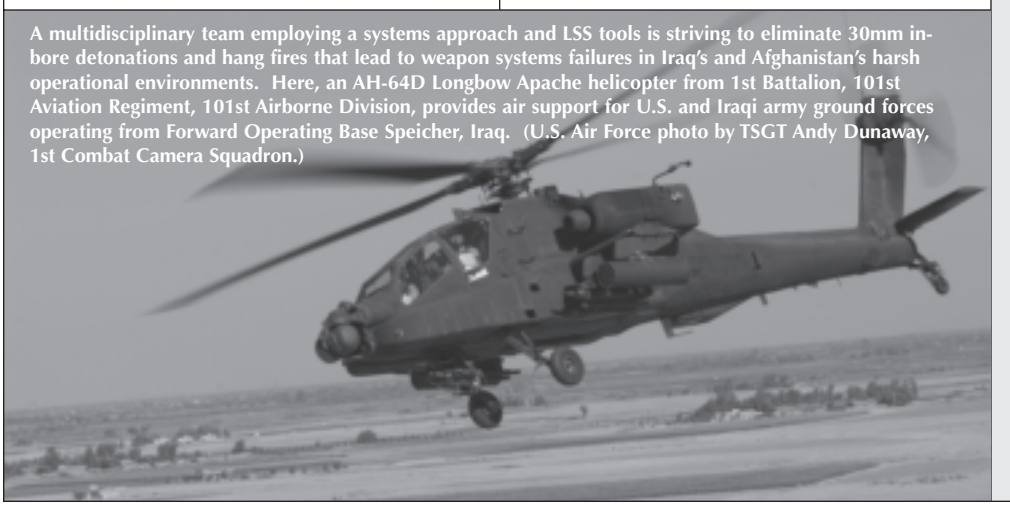
Hard Work = Successful Results

The IHIT effort took 2 years. The IHIT team eventually found three primary root causes for the various failures:

- Foreign material contamination in the warhead that could lead to in-bore detonation.
- Damage to the cartridge ignition train and propellant degradation as a result of long-term exposure to extreme temperatures and aircraft vibration that could lead to delayed ignition and hang fire or high-pressure events.
- Ammunition damage or degradation because of storage and loading procedures that could lead to high pressure or bullet-on-bullet events.

The team's findings led to implementing multiple production process improvements in the ammunition manufacturing facility to minimize occurrence of in-bore detonations. A more complete understanding of the aging effects of propellants was also gained, resulting in issuing instructions to the field on proper ammunition storage to prevent hang fires. This guidance also updated procedures for upload and download, and implemented procedures to rotate ammunition on the aircraft to minimize potential damage from prolonged aircraft vibration that could lead to hang fires and high pressure. The team recommended numerous ammunition design changes to make the cartridge more robust and new screening procedures for ammunition that had been suspended because of in-bores or hang fires. The net effect is that the Army was able to recover more than 100,000 rounds that otherwise would have been demilitarized at a loss to the Army of more than $7 million.

While the potential for another in-bore or hang fire cannot be positively eliminated, their occurrence has been dramatically reduced through these efforts. A multidisciplinary team employing a systems approach and tailored use of LSS tools resulted in considerable success in reducing a problem that has plagued the Army for more than 20 years.



A multidisciplinary team employing a systems approach and LSS tools is striving to eliminate 30mm in-bore detonations and hang fires that lead to weapon systems failures in Iraq's and Afghanistan's harsh operational environments. Here, an AH-64D Longbow Apache helicopter from 1st Battalion, 101st Aviation Regiment, 101st Airborne Division, provides air support for U.S. and Iraqi army ground forces operating from Forward Operating Base Speicher, Iraq. (U.S. Air Force photo by TSGT Andy Dunaway, 1st Combat Camera Squadron.)

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