

Mishap Evaluations – Critical For Explosives Safety Criteria

K. A. Bigej; Department of Defense Explosives Safety Board; Alexandria, Virginia, USA

J. Covino, Ph.D.; Department of Defense Explosives Safety Board; Alexandria, Virginia, USA

Abstract

This paper is a progress report of the activities of the Department of Defense (DoD) Joint Service Accident Evaluation Working Group (JSAEWG). The JSAEWG is a Department of Defense Explosives Safety Board (DDESB) established working group consisting of individuals from the various Services' safety centers and members of the DDESB's staff and designed to address improvements in ammunition and explosives accident reporting and trend analyses. The working group's primary objectives are to improve the reliability of the mishap data contained in the Explosives Safety Mishaps Analysis Module (ESMAM), to expand its usability and query functions, and share appropriate lessons learned. This paper specifically focuses on the improvements already made to ESMAM, discusses the path detailed in the Explosives Safety Mishap Analysis and Evaluation Implementation Plan to collect, aggregate, and analyze data to determine trends and when applicable recommend changes to DoD explosives safety policy and technical requirements, and discusses recent analyses of mishaps and their impact on determining revisions to the DoD explosives safety criteria. Enhancing mishap reporting analyses and ESMAM capabilities will affect DoD explosives and system safety policies and standards. Leveraging these improvements within the North Atlantic Treaty Organization and international explosives safety standards is also a critical function of the DDESB. Information obtained from mishap evaluations is used by the DoD Services and the DDESB to verify and improve our explosives safety standards and issuances.

Introduction

Previous papers presented at the 2008 Department of Defense Explosives Safety Board (DDESB) Seminar (ref. 1) and the 2009 International Systems Safety Conference/Joint Weapons System Safety Conference (ISSC/JWSSC) (ref. 2) describe the DDESB's and the Joint Service Accident Evaluation Working Group's (JSAEWG) historical charters and missions as well as introduce the Explosives Safety Mishap Analysis Module (ESMAM) (ref. 3) database. This paper is the next installment on the improvements to ESMAM, progress of the JSAEWG, and impacts of recent and historical mishaps on explosives safety criteria.

ESMAM Improvements & JSAEWG Progress

Improvements to ESMAM are closely tied to the progress of the JSAEWG. As aspects of mishap reporting are discussed in the working group, changes to ESMAM are evaluated and proposed. The ESMAM system currently resides at the McAlester Army Ammunition Plant (MCAAP) in McAlester, OK and is managed by the US Army Technical Center for Explosives Safety (USATCES) for the DDESB. A decision was made by the Army that this site will discontinue serving as a primary data center; therefore, many of its systems must be moved to other facilities. ESMAM is one of the systems designated for relocation and will relocate to servers at Space and Naval Warfare Systems Command (SPAWAR) in Charleston, SC by the end of calendar year 2010.

The ESMAM system has been modified many times over its operational life. It has absorbed data and functionality previously performed by other systems. It has been pressed into use for short-term special projects that required the addition of intermediate, temporary, or modified data structures and functionality, some of which was not removed from the system at projects' closures. Over time, the system has grown to contain features that are obsolete, functions that are not used, and data that are incomplete due to changes in business practices for data collection. There is no current system documentation of the ESMAM architecture, configuration, operation, or use. The ESMAM system was established long before many of the DoD system design and implementation standards were developed, and prior to the information assurance and compliance requirements enumerated in the Defense Information Systems Agency's (DISA) Security Technical Implementation Guidelines (STIGs). The system's security posture has had to be modified after the fact to address illicit access attempts, and no threat model or mitigation plan currently exists.

Report Documentation Page		<i>Form Approved OMB No. 0704-0188</i>
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.		
1. REPORT DATE JUL 2010	2. REPORT TYPE N/A	3. DATES COVERED -
4. TITLE AND SUBTITLE Mishap Evaluations Critical For Explosives Safety Criteria		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Defense Explosives Safety Board; Alexandria, Virginia, USA		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited		
13. SUPPLEMENTARY NOTES See also ADM002313. Department of Defense Explosives Safety Board Seminar (34th) held in Portland, Oregon on 13-15 July 2010, The original document contains color images.		
14. ABSTRACT This paper is a progress report of the activities of the Department of Defense (DoD) Joint Service Accident Evaluation Working Group (JSAEWG). The JSAEWG is a Department of Defense Explosives Safety Board (DDESB) established working group consisting of individuals from the various Services safety centers and members of the DDESBs staff and designed to address improvements in ammunition and explosives accident reporting and trend analyses. The working groups primary objectives are to improve the reliability of the mishap data contained in the Explosives Safety Mishaps Analysis Module (ESMAM), to expand its usability and query functions, and share appropriate lessons learned. This paper specifically focuses on the improvements already made to ESMAM, discusses the path detailed in the Explosives Safety Mishap Analysis and Evaluation Implementation Plan to collect, aggregate, and analyze data to determine trends and when applicable recommend changes to DoD explosives safety policy and technical requirements, and discusses recent analyses of mishaps and their impact on determining revisions to the DoD explosives safety criteria. Enhancing mishap reporting analyses and ESMAM capabilities will affect DoD explosives and system safety policies and standards. Leveraging these improvements within the North Atlantic Treaty Organization and international explosives safety standards is also a critical function of the DDESB. Information obtained from mishap evaluations is used by the DoD Services and the DDESB to verify and improve our explosives safety standards and issuances.		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 44	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Consequently, the ESMAM does not currently have the ability to attain an Authority to Operate (ATO) without significant modification.

The following list outlines the types of changes required to bring the ESMAM system into STIG compliance, relocate it to a new operational site, and fulfill users' needs for new functionality.

- Redesign the system following a robust design and development process that documents compliance with required standards;
- Eliminate code, database tables, and other structures no longer in use;
- Streamline and expand search functionality so it is easier to use, and use correctly;
- Provide reporting, export, and printing capabilities to appropriate users;
- Ensure secure access and protection for the system and its data;
- Re-host the ESMAM system to an appropriately controlled environment that will fulfill all security and STIG compliance requirements.

The ultimate goal is to ensure that the migrated/modernized ESMAM system will continue to provide all its current required functionality and enable the attainment of an ATO. The JSÄEWG has worked with the contractor responsible for this migration process to ensure all of ESMAM's current functionality is maintained. A great deal of effort has been spent describing various improvements the JSÄEWG feels would benefit the user community. The working group defined user levels and their viewing, querying, downloading, and data entering permissions for the new version of ESMAM. Figure 1 illustrates the current ESMAM homepage and Figure 2 shows how the future ESMAM homepage may look. Note that the future ESMAM homepage will allow all users access to the search and chart tools that were previously only available to power users; although, records retrieved may be restricted by the user's Service association. For example, Army users will only be able to fully access Army records and Air Force users will only be able to fully access Air Force records. The list of all records will be viewable with a form to request more details from the owning Service. Figures 3 through 5 detail how the charting function works in ESMAM today for power users; the revised ESMAM will allow all users to chart the data this way, but will restrict, by Service association, the drill down feature. ESMAM's search capabilities appear in Figures 6 and 7.

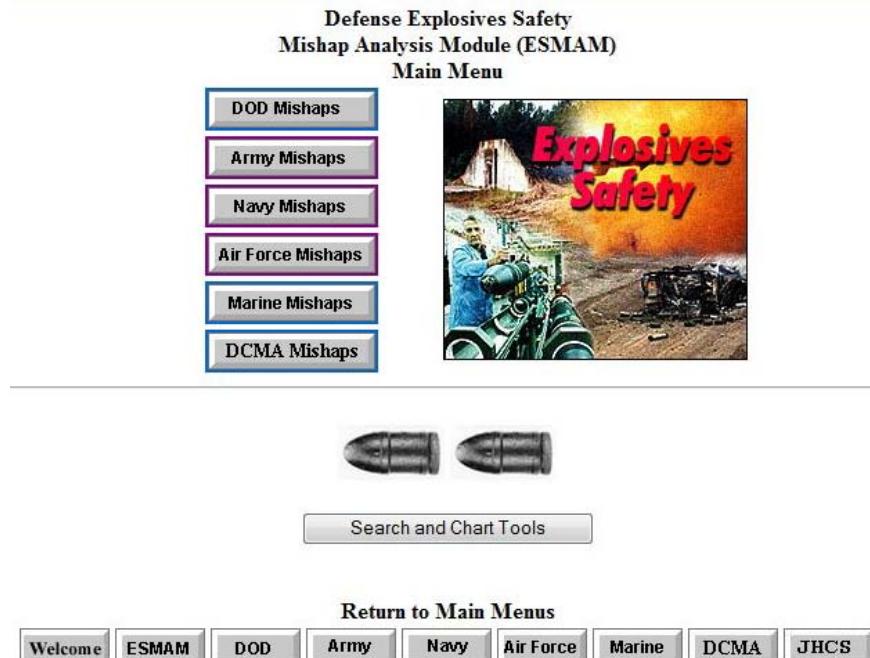


Figure 1 – ESMAM Current Homepage



ESMAM SEARCH & CHART TOOLS

ESMAM LINKS	LINK DESCRIPTION
CHARTS	Service Mishaps Class by Fiscal Year Service Mishaps Injuries and Fatalities by Fiscal Year Service Mishap Types by Fiscal Year Service Generic Causes by Fiscal Year Hazard Class/Division for Mishaps by Fiscal Year Hazard Class/Division for Mishap Class by Fiscal Year Lessons Learned By Fiscal Year
CLASS CHARTS	Mishap Class Charts
SEARCH	Service Injuries and or Fatalities Class and Fiscal Year Key Word Search and ID# Search
ESMAM ID SEARCH	Single ESMAM ID Search
CLASS SUMMARY	Summary of Mishap Classes for the Services
ACTIVITY	Weekly Report (Report takes awhile to run)
MISHAPS COUNT	Mishaps Count by Hour, Week, Month, FY
DOCUMENTS OF INTEREST	Documents of Interest
ESMAM LINKS OF INTEREST	ESMAM Links of Interest
ESMAM MAIN	ESMAM Main Menu

Figure 2 – Example ESMAM Future Homepage

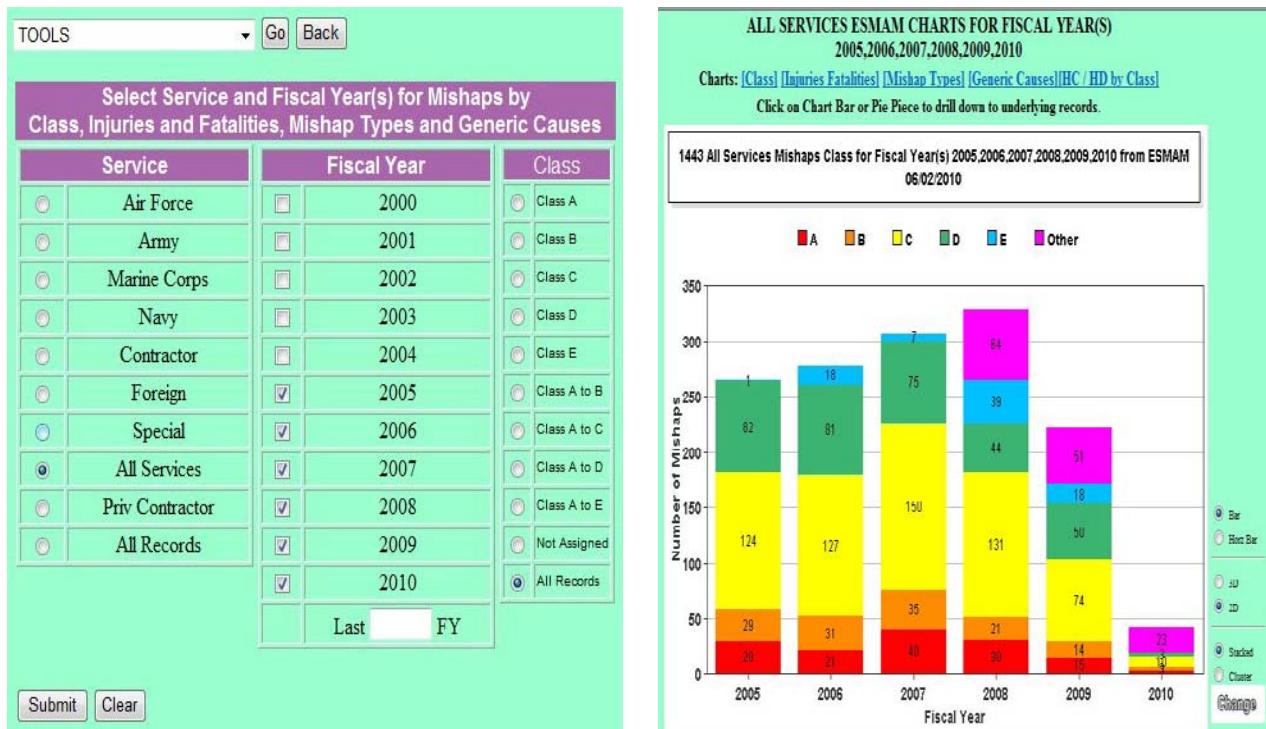


Figure 3 – ESMAM Charting: Fiscal Year by Mishap Class

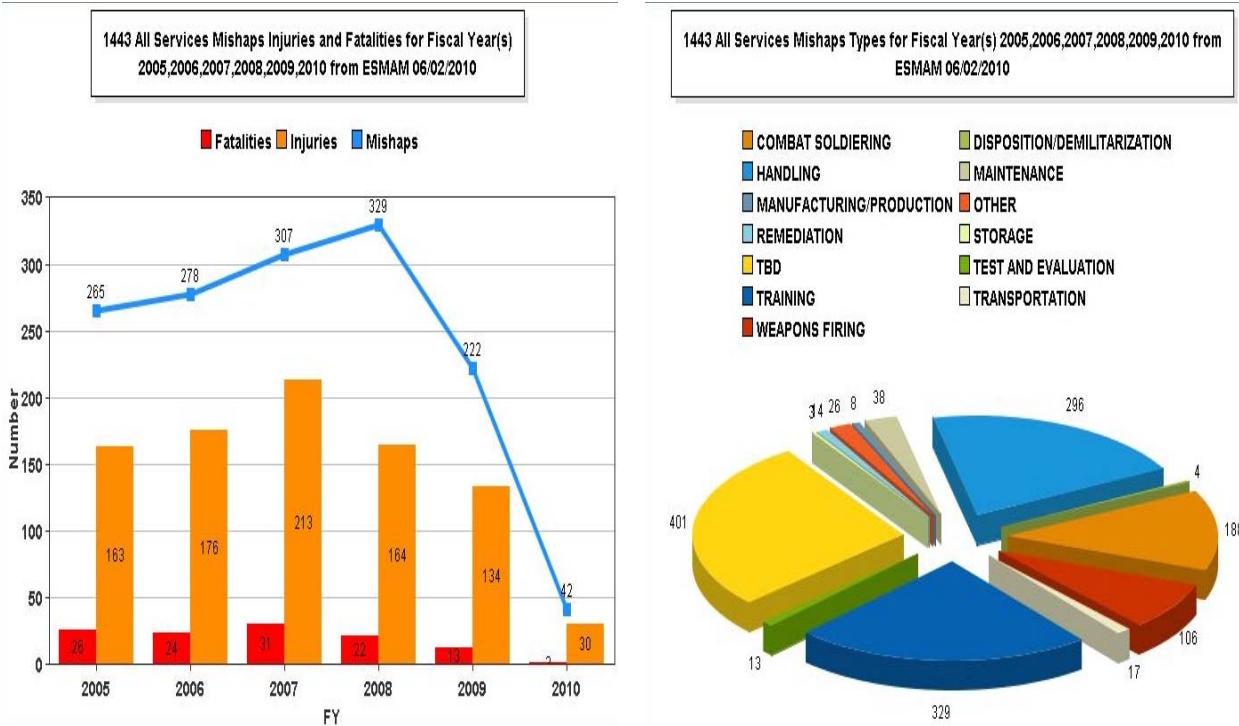


Figure 4 – ESMAM Charting: Fiscal Year by Mishaps/Injuries/Fatalities and by Mishap Types

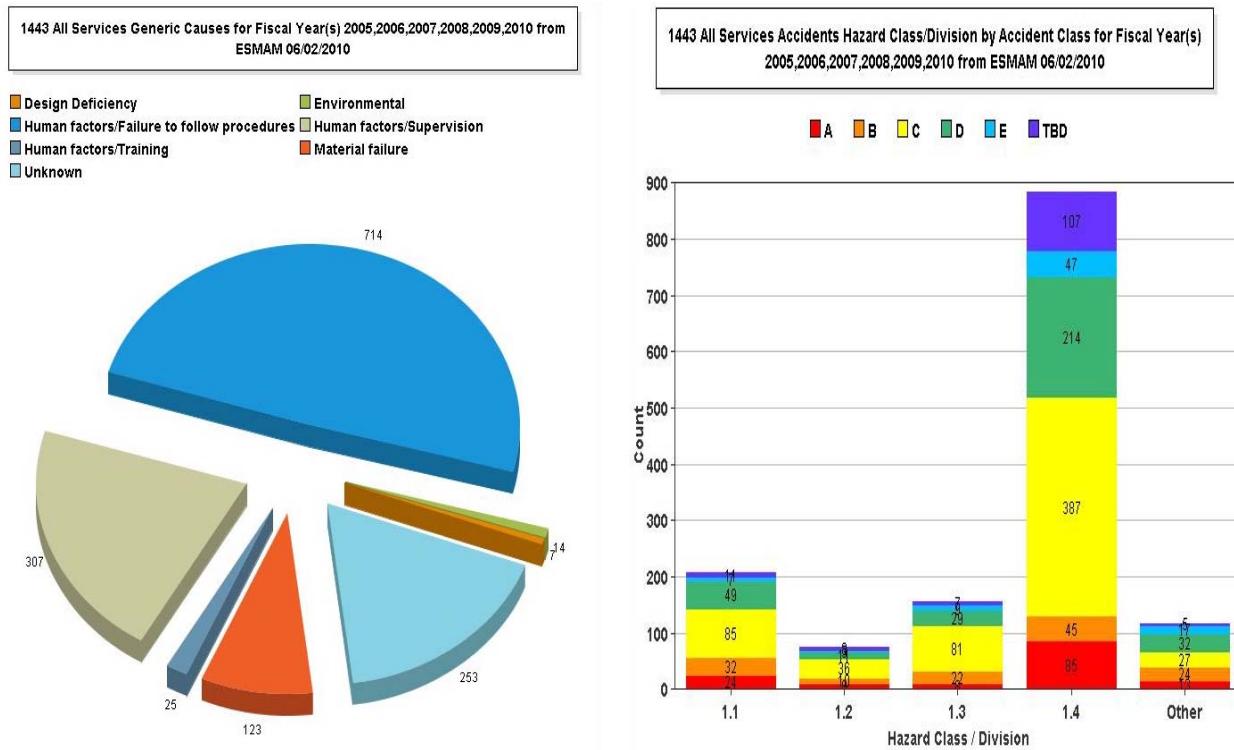


Figure 5 – ESMAM Charting: Fiscal Year by Generic Cause and by Hazard Class/Division

TOOLS ▾ Go Back

of Filtered Records 44

Service	Fiscal Year	Injury	Fatality	Class
All Records	2010 to Present	All Records	All Records	All Records

Date From all Date To %

Service		Fiscal Year to Present		
<input type="radio"/> Army	<input type="radio"/> Contractor	<input checked="" type="radio"/> Current FY	<input type="radio"/> Last 4 FYs	OTHER
<input type="radio"/> Air Force	<input type="radio"/> Foreign	<input type="radio"/> Last FY	<input type="radio"/> Last 5 FYs	TEST & EVALUATION
<input type="radio"/> Navy	<input type="radio"/> Special	<input type="radio"/> Last 2 FYs	<input type="radio"/> Last 10 FYs	WEAPONS FIRING
<input type="radio"/> Marines	<input type="radio"/> Other	<input type="radio"/> Last 3 FYs	<input type="radio"/> All FYs	WEAPONS FIRING (HANDLING)
<input type="radio"/> All Services	<input checked="" type="radio"/> All	Select FY to Present		
<input type="radio"/> All Services & Contractors				

Injuries	Fatalities	Class		
<input type="radio"/> W/O Injuries	<input type="radio"/> W/O Fatalities	<input type="radio"/> A	<input type="radio"/> Other	PYROTECHNICS, FLARES
<input type="radio"/> W/ Injuries	<input type="radio"/> W/ Fatalities	<input type="radio"/> B	<input type="radio"/> All Classes	PYROTECHNICS, SIM (ART/GREN/MORTAR)
<input type="radio"/> >10 Injuries	<input type="radio"/> > 10 Fatalities	<input type="radio"/> C	<input type="radio"/> Not Assigned	SIMULATOR, HAND GRENADE SIMULATOR M116A1
<input type="radio"/> > 50 Injuries	<input type="radio"/> > 50 Fatalities	<input type="radio"/> D	<input checked="" type="radio"/> All Records	VARIOUS
<input type="radio"/> > 100 Injuries	<input type="radio"/> > 100 Fatalities	<input type="radio"/> E	<input type="radio"/> A-B	KILLEEN
<input checked="" type="radio"/> All Records	<input checked="" type="radio"/> All Records		<input type="radio"/> A-C	MONTICELLO G1
			<input type="radio"/> A-D	Minden
			<input type="radio"/> A-E	OAK GROVE

Fiscal Year From // Fiscal Year To

From FY From To FY To

Filter **Reset** Check choices above and then click [Filter] to filter records

Place any word in the Key Word box.
(_ is wild card for single character; * or % are wild Cards for multiple characters)

Key Word Search		Reset
All Records	ID NO.	Reset
Category Search		
State Search		
Country Search		
Munition Search		
City Search		
Installation Search		
Nomenclature Search		

Figure 6 – ESMAM Search Page

TOOLS ▾ Go Back

ESMAM SEARCH RESULTS

ESMAM SEARCH RESULTS				Results for		Mishap Details		Check All Clear All			
45 Records				ESMAM Explosives Mishaps				Last Record			
No	FY	Select Records	Mishap ID Click for detail	Mishap Date	Service	Class	Location	Description		Generic Cause	DOCS
1	2010	<input type="checkbox"/>	20091214004	12/14/2009	Army	C	Ecp, Jss Salie, Iraq	Sm Was Attempting To Replace A Mounted M2 With A M240B. He Attempted To Hammer Out The Pin With A .50 Cal Bmg Round. He Struck The Primer Against The Weapon Mount And Detonated In His Hand.		HUMAN ERROR	
2	2010	<input type="checkbox"/>	20091205001	12/05/2009	Army	B	Camp Parra Training Area, Afghanistan	Soldier Was Using A Smoke Grenade During Combat Simulation When It Detonated In His Hand As A Result He Sustained The Loss Of Two Fingers And A Fractured Hand. Class B Injuries.		HUMAN ERROR	
3	2010	<input type="checkbox"/>	20091130009	11/30/2009	Army	D	Mct Yard At Camp Taji, Iraq	Soldier Was Prepping His Equipment In The Gun Turret Getting Ready To Depart Camp When A Pen Flare Deployed Striking Him In The Face And Eyes.		HUMAN ERROR	
4	2010	<input type="checkbox"/>	200911121003	11/21/2009	Army	D	At Test Fire Pit, Camp Korean Village, Iraq	Soldier Was Conducting A Test Fire Of His M2 .50 Cal Mg; During Firing The Barrel Became Unscrewed And The Headspace And Timing Became So Large Causing The Round To Explode Damaging The M2.		TBD	
5	2010	<input type="checkbox"/>	20091117005	11/17/2009	Army	C	Range 44, Ft Bragg, Nc 28310	Soldier Was Range Oic During Mk19 Range; He Was Observing The Firing Line When The Gunner Aimed The Weapon Causing 2 Rounds To Strike In The Sdz Resulting In Shrapnel Hitting Him In The Face Causing I		HUMAN ERROR	
6	2010	<input type="checkbox"/>	20091107002	11/07/2009	Army	C	Residence, 135 East Street, Clarksville, Tn 37042	Soldier Was Disassembling His Weapon When He Inadvertantly Discharged A Round Into His Hand Resulting In Injury.		HUMAN ERROR	
7	2010	<input type="checkbox"/>	20091031002	10/31/2009	Army	D	Convoy Lanes (North Trails), Ft McCoy, Wi	Soldier Was Conducting Deploying A Hand Grenade Simulator During Vbied Convoy Lane Exercise The Grenade Simulator Got Stuck On The Door Handle Of The Gov Van And Detonated Damaging The Van.		HUMAN ERROR	

Figure 7 – ESMAM Search Results

Many improvements have been made to the ESMAM database in both data quality/integrity and analyses. As the JSAEWG has determined the need for changes to ESMAM, the USATCES database administrator has worked to find and implement solutions within ESMAM. As seen in Figures 5 through 7, ESMAM now has data fields for generic causes and the ability to chart hazard class versus mishap class as well as provide for a variety of searches or queries. As stated previously, there will be no loss in current capabilities during the migration to a new database host location.

As a cross-Service representative group, the JSAEWG has reviewed and provided comments to the draft Department of Defense Instruction (DoDI) 6055.07 (ref. 4), *Accident Investigation, Reporting, and Record Keeping*, to ensure improvements to the reporting requirements for mishaps involving explosives thereby bringing greater visibility and lessons learned to the safety community. As of 1 October 2009, the cost thresholds for defining mishap classes increased (ref. 5), see Table 1. The JSAEWG continues to improve mishap data entry into ESMAM. As the Services upgrade their reporting/recordkeeping systems, the working group evaluates ways to leverage those improvements into ESMAM and eventually create a lessons learned database to improve accident prevention and training programs DoD-wide. To assist in these efforts, the working group is crafting a data dictionary that will not only define terms/fields currently in use in ESMAM, but will also define future terms/fields. These terms/fields will allow greater query functionality and eventually expanded charting capabilities.

Table 1 — Chart of Accident Classification (refs. 4-5)

Accident Class	Criteria (Property Damage/Injury Prior to FY2010)	Criteria (Property Damage/Injury As of FY2010)
A	$\geq \$1,000,000$ and/or Fatality/Permanent Total Disability Injury	$\geq \$2,000,000$ and/or Fatality/Permanent Total Disability Injury
B	$\geq \$200,000$, but $< \$1,000,000$ and/or Permanent Partial Disability Injury	$\geq \$500,000$, but $< \$2,000,000$ and/or Permanent Partial Disability Injury
C	$\geq \$20,000$, but $< \$200,000$ and/or Lost Time Injury	$\geq \$50,000$, but $< \$500,000$ and/or Lost Time Injury
D	$\geq \$2,000$, but $< \$20,000$ and No Lost Time Injury	$\geq \$2,000$, but $< \$50,000$ and No Lost Time Injury
E	Does not meet the severity criteria of A, B, C, or D	Does not meet the severity criteria of A, B, C, or D
Other	Not reported by the Service	Not reported by the Service

Impacts of Recent Mishaps

Mishaps involving explosives continue to average only around two percent of all DoD mishaps. However, when they do occur, they are usually very damaging and costly to life, munitions stores, facilities and the environment. Two recent mishaps have led to four fatalities and one serious injury. The first mishap happened on 21 May 2009 at the Edgewood Area of the Aberdeen Proving Grounds in Maryland (ref. 6). During accuracy and fire control system testing of a Soviet T-55 tank, a 100mm high explosive anti-tank (HEAT) round prematurely detonated during the firing sequence. As a result, there were two fatalities, 1 serious injury, and the tank was destroyed. See Figures 8 and 9 for photographs of the damage to the tank and gun tube. The investigation team determined nine findings of which seven were contributing either directly to the mishap or to the severity of the results. A lack of knowledge of the unique inspection requirements and the sensitive nature of the detonating cap of the 100mm HEAT round led to other failures in risk management such as planning, procedures, personal protective equipment, and execution. A working group has been established to work the safety issues of foreign munitions and the DDESB will improve DoD and applicable foreign munitions program issuances.



Figure 8 – Photo of Mishap T-55 Tank



Figure 9 – Photo of Right Side Gun Tube



Figure 10 – Photo of Mishap Building at Redstone Arsenal

An explosion occurred at the Aviation and Missile Research, Development and Engineering Center at the Redstone Arsenal in Alabama on 5 May 2010. Two individuals were killed as they worked on a process to separate ammonium perchlorate, an oxidizing agent used in missile fuel, from other elements. The process was intended to find out whether high-grade ammonium perchlorate could be recycled from old missiles to be used in new rocket systems. Figure 10 (ref. 7) is a view of the facility after the mishap. As the investigation is still on-going, little is known of the operations being performed or the causes of the mishap.

A third mishap occurred at the Alliance Techsystems-Alleghany Ballistics Laboratory (ABL) located in Rocket Center, West Virginia (ref. 8) on 24 May 2010. It involved an explosion at a remotely-operated production mix building used to manufacture rocket motor propellant and energetic material for warheads. The explosion occurred during an un-attended, remote controlled, mix operation. Two employees were transported to the hospital for treatment of minor injuries and released. ABL has temporarily stopped production until an internal investigation determines the cause of the explosion. All safety measures functioned as intended.

Impacts of Historical Mishaps

Lessons from past mishaps provided the current explosives safety quantity-distance (QD) criteria detailed in reference 9. An historical account of the mishap records in ESMAM since the inception of the DDESB in fiscal year (FY) 1928 through FY 2007 is displayed in Figures 11 and 12. These figures illustrate the decrease in severity of the mishaps since the institution of the QD criteria in the 1949-1950 timeframe. Figure 11 depicts the total number of fatalities, injuries, and total mishaps in 10-year increments with the various military conflicts shown and the increase in DoD installations. In FY 1994, the ESMAM was designated as the central DoD database for explosives mishaps.

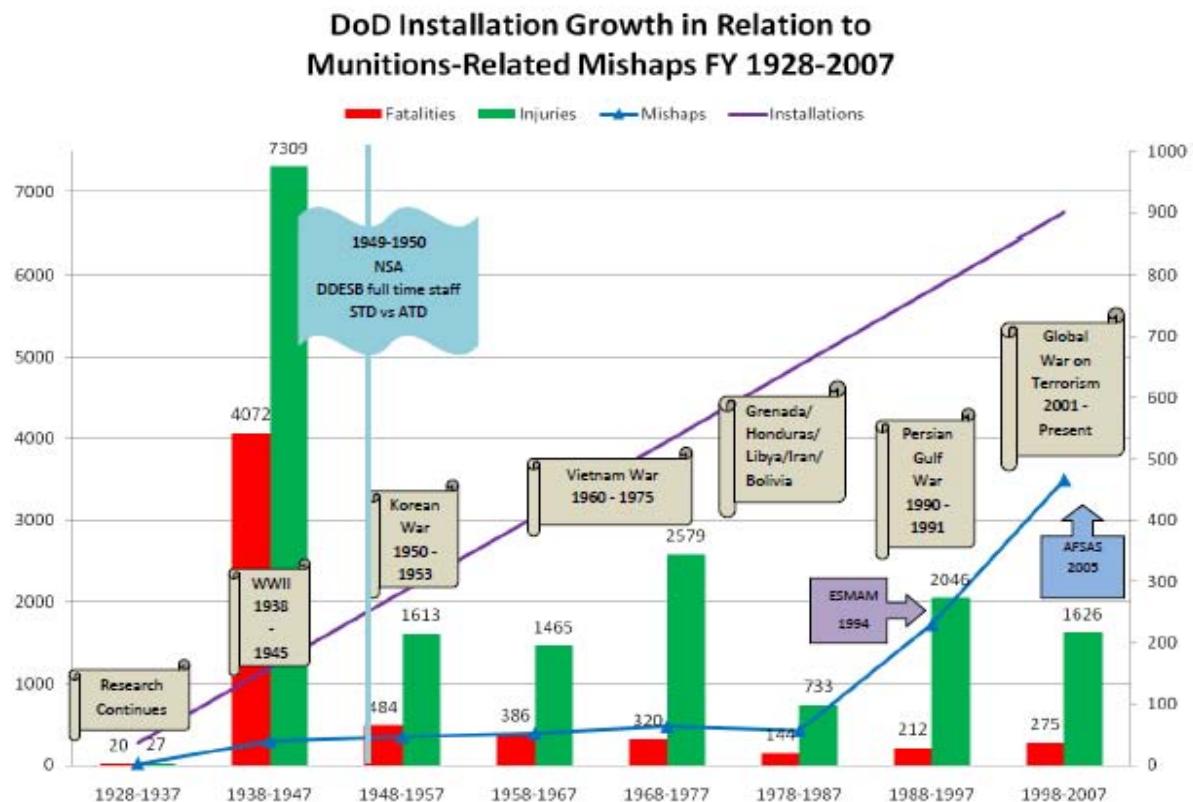


Figure 11 – DoD Installation Growth in Relation to Munitions-Related Mishaps for Fiscal Years 1928-2007

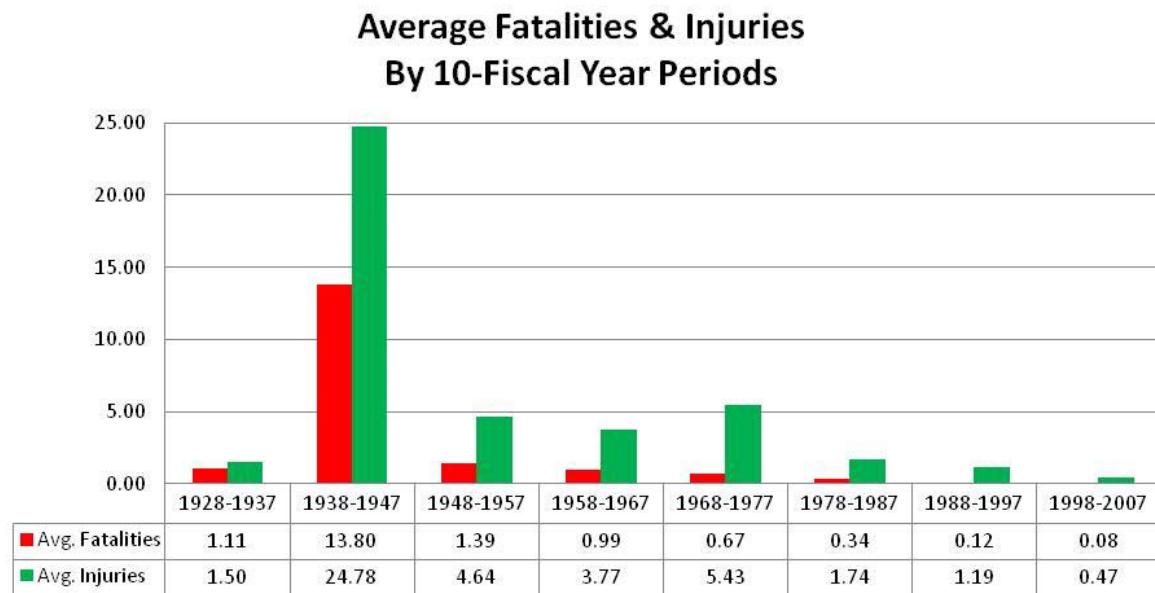


Figure 12 – Average Fatalities and Injuries by 10-Fiscal Year Periods for Fiscal Years 1928-2007

Also in FY 2005, the Air Force stood up the Air Force Safety Automated System (AFSAS) and an effort by all of the Services to clean up their mishap databases was initiated. As seen in Figure 11, the total number of mishaps increases dramatically. This is most likely due to better reporting and recordkeeping. However, as seen in Figure 12, the average number of fatalities and injuries per mishap decreases significantly from almost 14 fatalities and 24 injuries per mishap in the 1940s to significantly less than 1 fatality and injury per mishap in the early 2000s.

Since the original research performed on historical mishaps (FYs 1928-2007), further data analysis is being performed to verify all records are unique (no duplicates), ensure DoD-service involvement, and determine the type of operation performed at the time of the mishap. No new records were added for the FYs of 1928-1937. Figures 13 through 16 illustrate the findings of this further research as completed to date for FYs 1938-1977. Research and data analyses continue for FYs beyond 1977, but are not complete as of the writing of this paper. The majority of mishaps occurred during manufacturing/production type operations, with the greatest number of fatalities occurring during handling operations, and greatest injuries during handling and manufacturing/production operations. From the data analyzed so far, the Navy has the most fatalities per mishap on average even though the Army and DoD Contractors have overall the largest numbers of mishaps. Also, the DoD Contractors and Navy have the greatest average injuries per mishap.

Analyses of the latest historical mishaps from FY 2007 through FY 2009 have been conducted, as seen in Figure 17. The majority of mishaps occurred during weapons firing and training type operations. The greatest number of fatalities occurred during weapons firing and combat soldiering operations, with the greatest number of injuries occurring during weapons firing and training operations. DoD Contractors have the most fatalities per mishap on average even though the Army has overall the largest number of mishaps. Also, the DoD Contractors and Army have the greatest average injuries per mishap. Analyses of these mishaps indicate the vast majority involve hazard class/division 1.4 munitions, specifically, small arms ammunition, with human error being the main causes and only one or two individuals involved being injured or killed. In mishaps where significant numbers of fatalities or injuries are involved, the operations usually entail manufacturing /production and the causes usually track back to operational risk management.

These mishap data are also shared within the international community through bi-lateral agreements and Munitions Safety Information Analysis Center (MSIAC) for the purpose of improving explosives safety during joint operations. In the past, specific mishaps have been analyzed and evaluated in detail to provide validation of risk-based models regarding the probability of event in the Safety Assessment For Explosives Risk (SAFER) tool (ref. 10). Historical mishaps have been examined to determine if the current explosives safety criteria for remote operations were adequate. Also, research on mishaps related to fire has been performed and further studies are being conducted to determine if the current DoD explosives safety criteria in reference 9 are adequate or need revision.

Fiscal Years 1938 – 1947

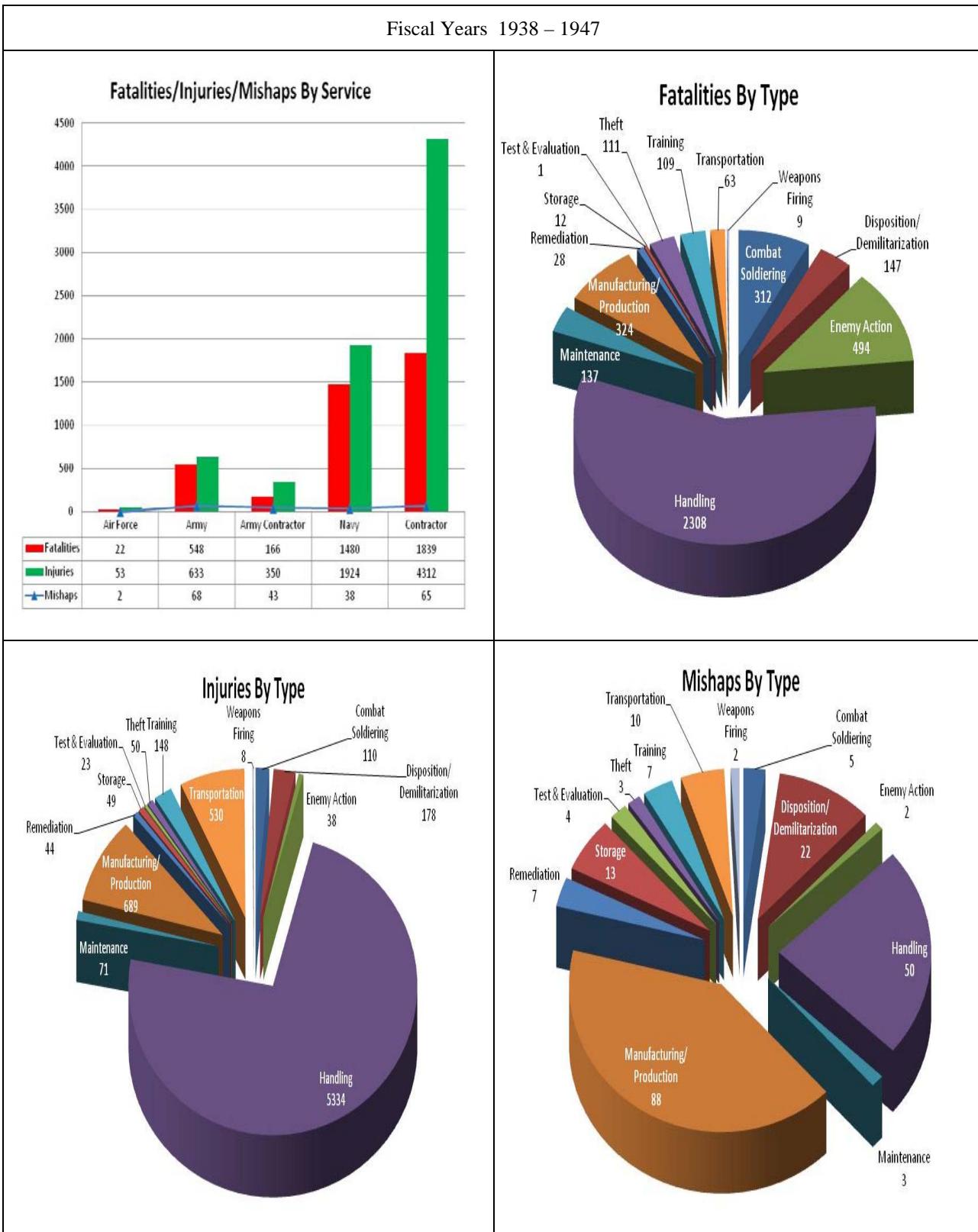


Figure 13 – Mishap Analysis for Fiscal Years 1938-1947

Fiscal Years 1948 – 1957

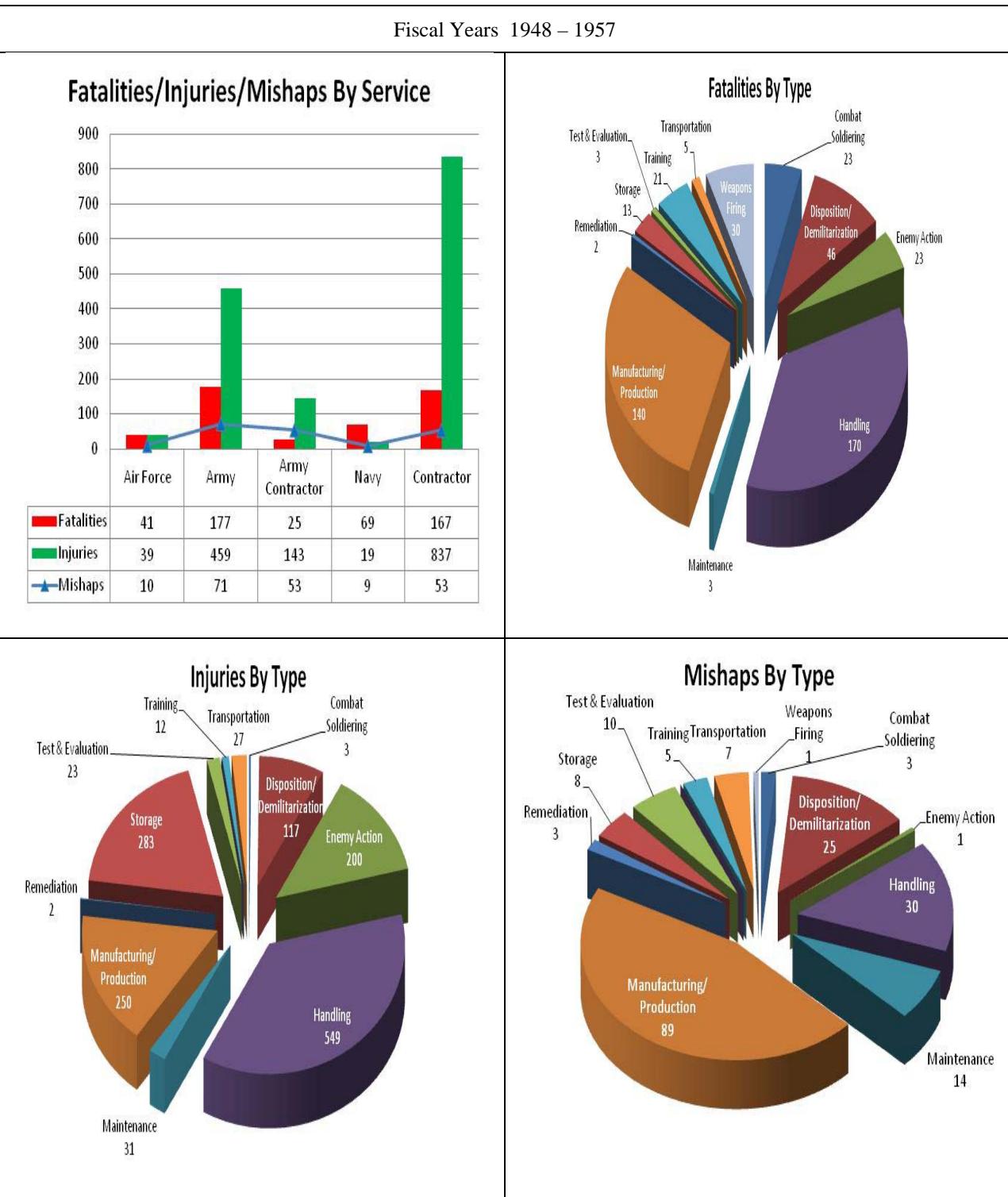
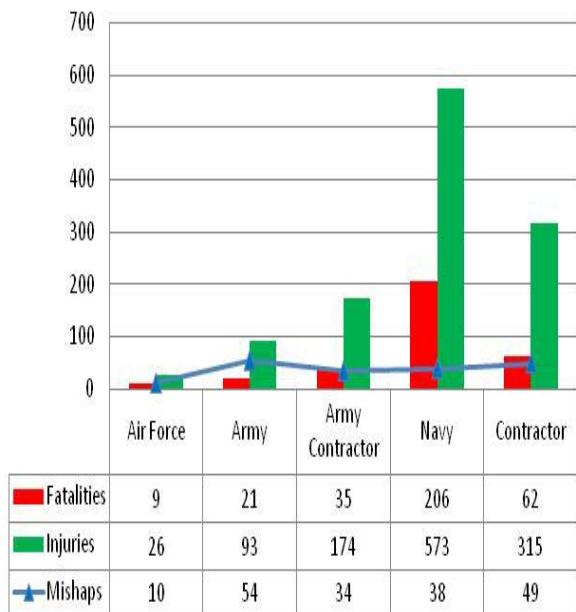


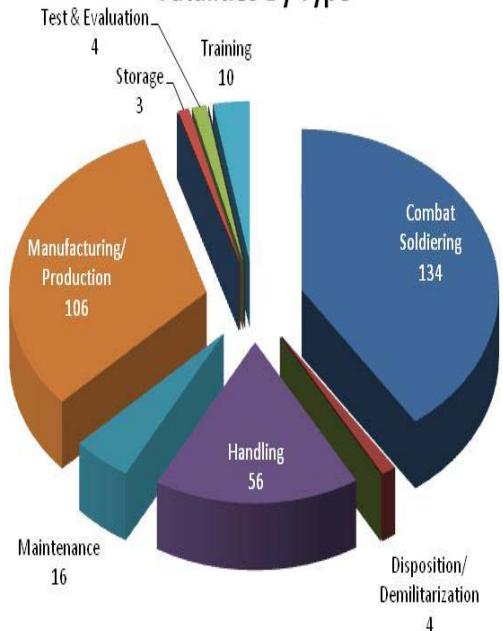
Figure 14 – Mishap Analysis for Fiscal Years 1948-1957

Fiscal Years 1958 – 1967

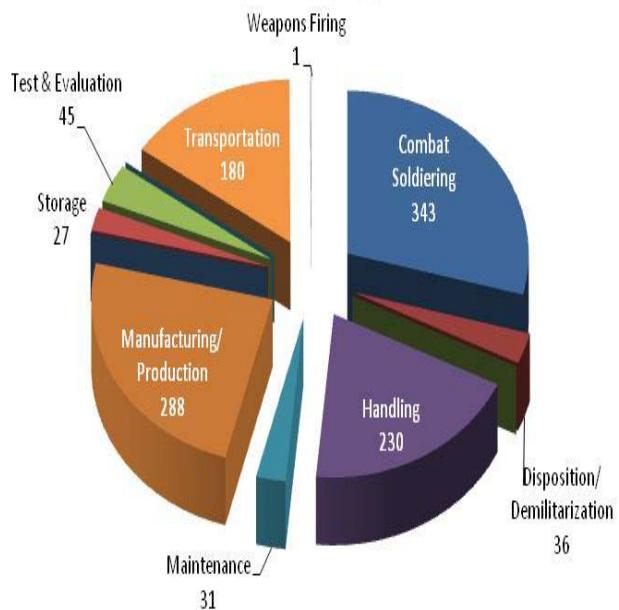
Fatalities/Injuries/Mishaps By Service



Fatalities By Type



Injuries By Type



Mishaps By Type

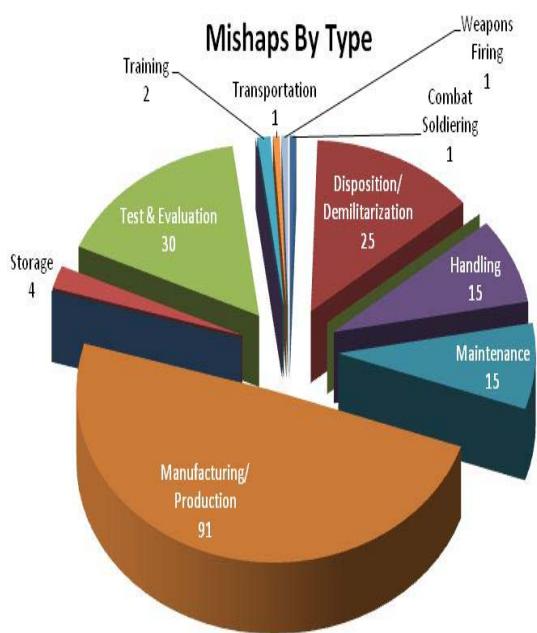
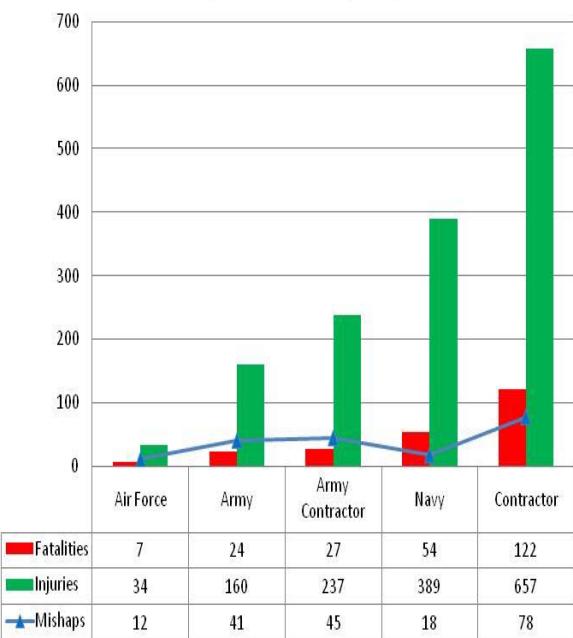


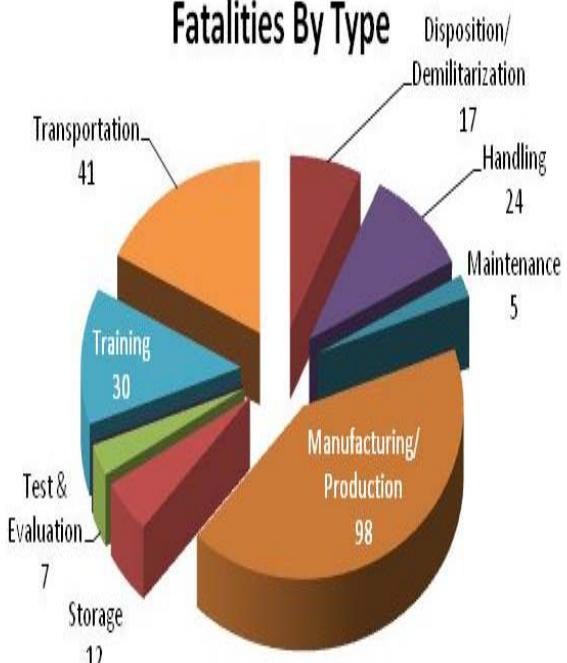
Figure 15 –Mishap Analysis for Fiscal Years 1958-1967

Fiscal Years 1968 – 1977

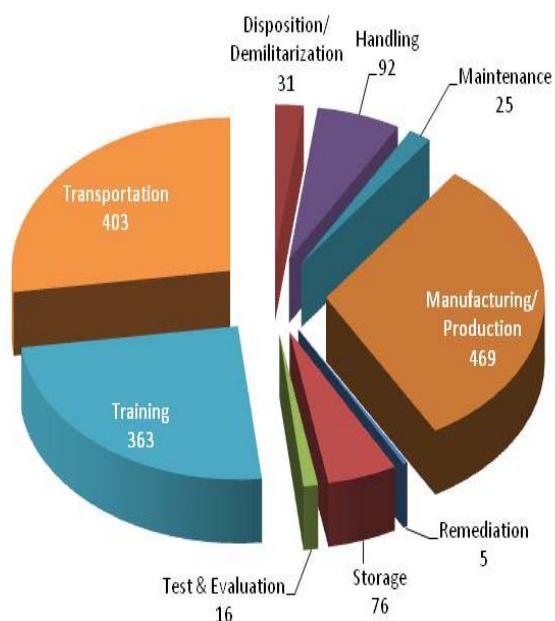
Fatalities/Injuries/Mishaps By Service



Fatalities By Type



Injuries By Type



Mishaps By Type

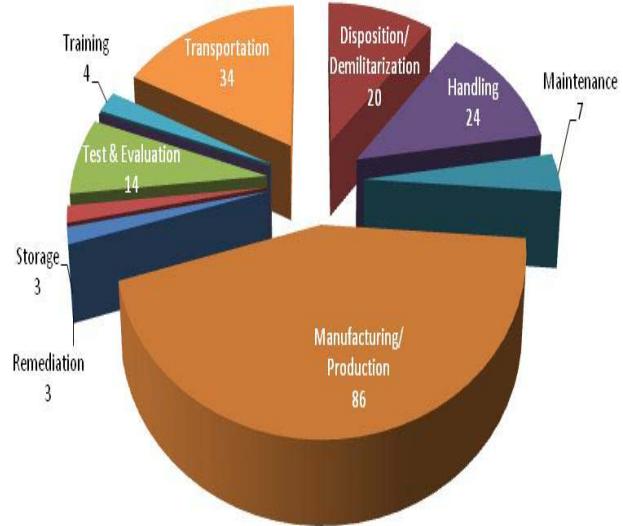


Figure 16 –Mishap Analysis for Fiscal Years 1968-1977

Fiscal Years 2007 – 2009

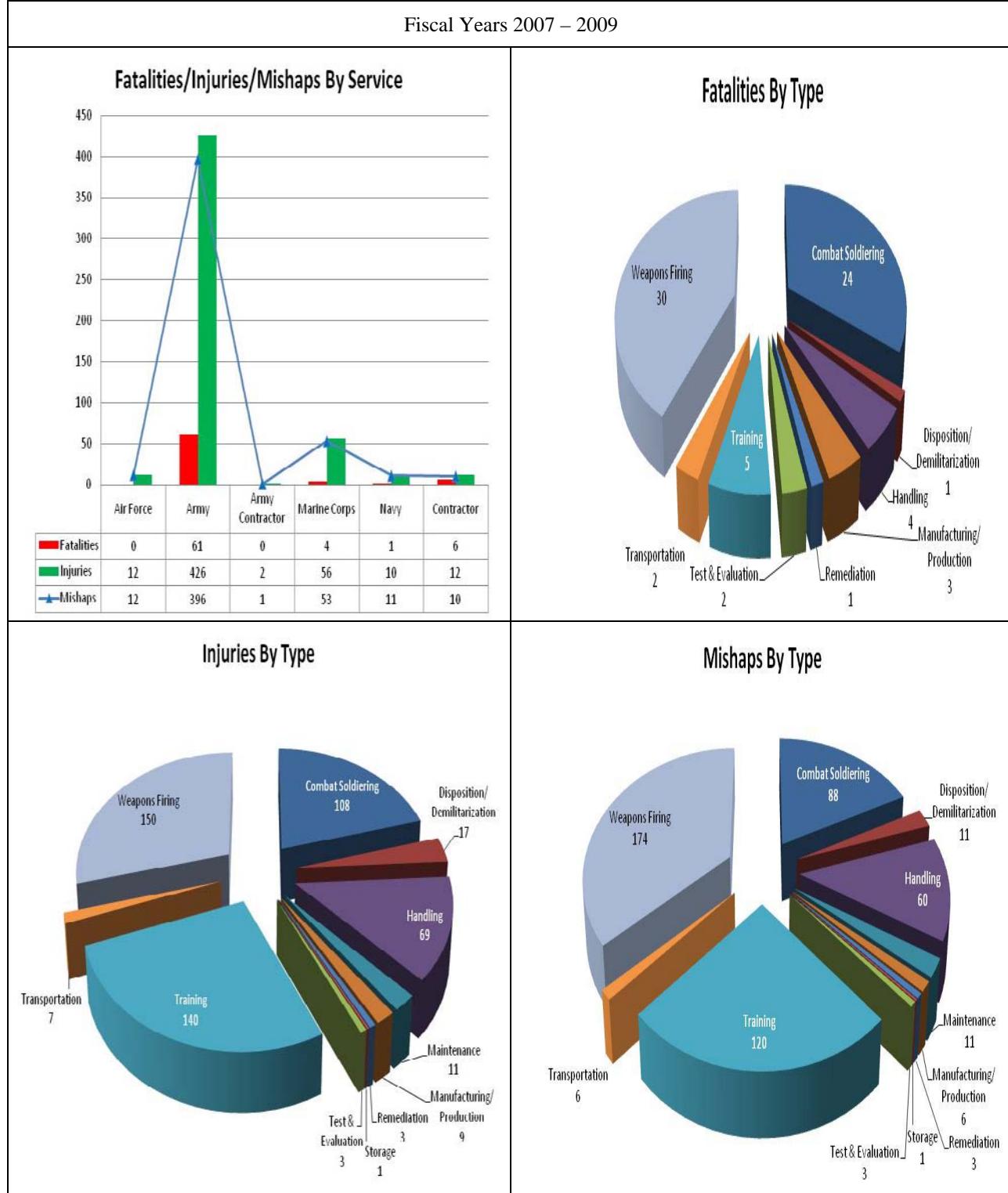


Figure 17 –Mishap Analysis for Fiscal Years 2007-2009

Conclusions

Since munitions processes are inherently dangerous and no one will ever be able to predict the magnitude and location of the next explosives mishap, complacency poses a significant risk. Therefore, appropriate explosives safety standards, awareness of safety procedures, and knowledge of explosives hazards along with a good safety culture are key ingredients of mishap prevention. While many challenges exist, through the cooperation and coordination within the JSAEWG, overall mishap reporting is improving. These efforts will be used to develop prompt distribution of lessons learned in an effort to prevent the next catastrophic explosives mishap. The members of the JSAEWG have shown a willingness to improve mishap reporting and recognize the following challenges:

- Providing lessons learned and mishap causes;
- Reporting only Class A, B, and C mishaps as required by DoDI 6055.07 (ref. 4), and not Class D; and
- Lacking Service visibility and involvement since explosives mishaps only make up about two percent of all DoD reportable accidents.

The Service safety centers and the DDESB staff are using the information from all of these mishaps in a variety of ways to verify and improve our safety standards and issuances. Past mishaps have led to reviews of our standards for inhabited building distance, barricading, protective construction design, and deliberations on intentional detonations including the issuance of DDESB Technical Paper (TP) 21, *Procedures For The Collection, Analysis, And Interpretation Of Explosion-Produced Debris – Revision 1*, (ref. 11).

As described in reference 1, the future work for the JSAEWG includes direct participation in mishap investigation and continuing improvement and clarification of DoD mishap record-keeping and reporting requirements in ESMAM by: 1) Creating better query functions and data filter choices; 2) Creating more user-friendly interfaces; 3) Adding lessons learned; and 4) Adding more mishap reports. As described in this paper, much progress towards these goals has been achieved and the groundwork for more improvements has been laid.

In conclusion, ESMAM is a comprehensive database used for:

- Services mishaps reporting and data improvements;
- International collaboration and information sharing;
- Validation of risk-based tools;
- Verification of quantity-distance standards; and
- Data mining for potential explosives safety criteria gaps.

References

1. Bigej, K. A., and Covino, J. "Status of Reportable DoD Explosives Accidents." *2008 DDESB Seminar*. Palm Springs, 2008.
2. Bigej, K. A., and Covino, J. "Mishap Evaluation – A Critical Role In Explosives Safety," *27th International System Safety Conference*. Huntsville, 2009.
3. United States Army Technical Center for Explosives Safety. *Explosives Safety Mishaps Analysis Module (ESMAM)*. <https://www3.dac.army.mil/esidb/login/> (accessed June 2, 2010).
4. Department of Defense. "DoDI 6055.07, Accident Investigation, Reporting, and Record Keeping." *DoD Issuances*. April 24, 2008. <http://www.dtic.mil/whs/directives/corres/pdf/605507p.pdf> (accessed May 17, 2010).

5. Carter, A. B. "Revision to Cost Thresholds for Accident Severity Classification," *Memorandum for Secretaries of the Military Departments, et al., from The Under Secretary of Defense Acquistion, Technology, and Logistics*. October 5, 2009.
6. United States Army Combat Readiness/Safety Center. "Command Outbrief, U.S. Army Aberdeen Test Center (ATC), Aberdeen Proving Grounds, Maryland, 21 May 2009," *Personal Communication*. June 2009.
7. Schultz, Eric. *Two Injured In Redstone Explosion*. The Huntsville Times. http://photos.al.com/huntsville-times/2010/05/two_injured_in_redstone_explos_5.html (accessed June 3, 2010).
8. Schultz, Edward A. E-mail to Kristene Bigej, 10 June 2010.
9. Department of Defense. "DoD 6055.09-STD, DOD Ammunition And Explosives Safety Standards." *DoD Issuances*. August 21, 2009. http://www.dtic.mil/whs/directives/corres/pdf/605509-STD_Cov.pdf (accessed June 3, 2010).
10. Department of Defense. "Technical Paper No. 14, APPROVED METHODS AND ALGORITHMS FOR DOD RISK-BASED EXPLOSIVES SITING." *Department of Defense Explosives Safety Board*. November 2008. <http://www.ddesb.pentagon.mil/TP14%20November%202008.pdf> (accessed June 8, 2010).
11. Department of Defense. "Technical Paper No. 21, PROCEDURES FOR THE COLLECTION, ANALYSIS, AND INTERPRETATION OF EXPLOSION-PRODUCED DEBRIS—REVISION 1." *Department of Defense Explosives Safety Board*. http://www.ddesb.pentagon.mil/tp_21%20_signed.pdf (accessed June 8, 2010).

Biography

K. A. Bigej, Safety Engineer, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue Hoffman 1, RM 856C, Alexandria, VA 22331, USA, telephone – (703) 325-3560, facsimile – (703) 325-6227, e-mail – Kristene.bigej@ddesb.osd.mil.

Ms. Bigej graduated from the University of Maryland in 1990 with a B.S. in Chemical Engineering. That same year, she began working for the Navy as a Design Agent Engineer for gun systems. She manufactured gun propellant as a Production Engineer and later transferred to the environmental office where she was an Environmental Engineer involved in the hazardous waste program. From there, she became a Navy hazard classifier. In 1997, she went to work as a Safety and Environmental Engineer for a private explosives manufacturing company. In 2002, she returned to the Navy as a Safety Engineer and eventually became the Explosives Safety Engineering Division Director and Explosives Safety Officer. She currently works at the DDESB in the Policy Development Division to develop expanded accident trend analysis capabilities, and capture and correlate lessons learned. She has co-authored three and presented two papers on mishaps involving explosives.

J. Covino, Ph.D., Safety Engineer, Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue Hoffman 1, RM 856C, Alexandria, VA 22331, USA, telephone – (703) 325-8625, facsimile – (703) 325-6227, e-mail – Josephine.covino@ddesb.osd.mil.

Dr. Covino has a B.S. in Chemistry from Adelphi University and a Ph.D. in Solid State Chemistry from Brown University. Her areas of expertise include: energetic materials/weapons system hazards, solid-state chemistry, energetic materials, explosives safety, and technical/program management. She is a leader in the areas of energetic materials hazards evaluation, including thermal and electrostatic discharge hazards. She has over 130 scientific publications and holds over 17 patents. During her over 25-year career, she has worked in areas of research and development, program management, nuclear and conventional weapons hazards and systems safety. Since 2000, she has held a position as a Safety Engineer at the Department of Defense Explosives Safety Board (DDESB) Policy Development (PD) Division where she is responsible for science and technology; explosives safety policy development and standards improvements.



Mishap Evaluations – Critical For Explosives Safety



K. Bigej and J. Covino

**Department of Defense Explosives Safety Board
DDESB**

July 2010





Outline



- ESMAM Improvements & JSAEWG Progress
- Impacts of Recent Mishaps
- Impacts of Historical Mishaps
- Conclusions





ESMAM Improvements & JSAEWG Progress



- **Explosives Safety Mishap Analysis Module (ESMAM)**
 - Data Sources
 - Army
 - Navy
 - Air Force
 - Marine Corps
 - Defense Contract Management Agency (DCMA)
 - Foreign
 - Developed in 1994
 - Managed by US Army Technical Center for Explosives Safety (USATCES) for DDESB
 - Future – Relocate servers and re-design





ESMAM Improvements & JSAEWG Progress (*continued*)



➤ Joint Service Accident Evaluation Working Group (JSAEWG)

- Established 29 November 2006
- Membership
 - DDESB – J. Covino (Chair)/K. Bigej
 - ODUSD(I&E) Environmental Readiness & Safety (DoDI 6055.07) – J. Seibert
 - DCMA – L. James
 - Army – T. Roberts/A. Powers/T. Gallagher
 - Navy – Cdr. A. Wooten/B. Hayes/A. Malson
 - Air Force – Maj. S. Frith/G. Campbell
 - Marine Corps – M. James
 - Other representatives as needed





ESMAM Improvements & JSAEWG Progress *(continued)*



➤ Current Database Improvements

- Data Quality/Integrity
- Data Analyses
- Data Fields for Generic Causes
- Ability to Chart Hazard Class vs. Mishap Class
- Variety of Searches/Queries





ESMAM Improvements & JSAEWG Progress *(continued)*



➤ Future ESMAM System Changes

- Redesign using robust design and development process that documents compliance with required standards
- Eliminate code, tables, and other structures no longer in use
- Streamline and expand search functionality so it is easier to use, and use correctly
- Provide reporting, export, and printing capabilities to appropriate users
- Ensure secure access and protection for the system and its data
- Re-host to an appropriately controlled environment which will fulfill all security and STIG compliance requirements



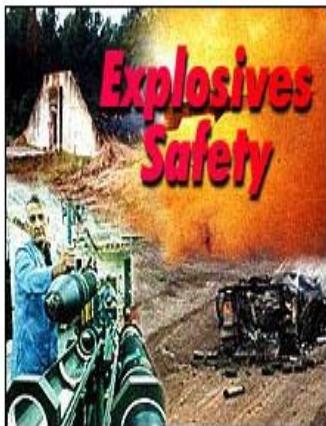
ESMAM Screenshots: Current & Future Homepages



Current

Defense Explosives Safety
Mishap Analysis Module (ESMAM)
Main Menu

- DOD Mishaps
- Army Mishaps
- Navy Mishaps
- Air Force Mishaps
- Marine Mishaps
- DCMA Mishaps



Search and Chart Tools

Return to Main Menus

Future



ESMAM SEARCH & CHART TOOLS

ESMAM LINKS	LINK DESCRIPTION
CHARTS	Service Mishaps Class by Fiscal Year Service Mishaps Injuries and Fatalities by Fiscal Year Service Mishap Types by Fiscal Year Service Generic Causes by Fiscal Year Hazard Class/Division for Mishaps by Fiscal Year Hazard Class/Division for Mishap Class by Fiscal Year Lessons Learned By Fiscal Year
CLASS CHARTS	Mishap Class Charts
SEARCH	Service Injuries and or Fatalities Class and Fiscal Year Key Word Search and ID# Search
ESMAM ID SEARCH	Single ESMAM ID Search
CLASS SUMMARY	Summary of Mishap Classes for the Services
ACTIVITY	Weekly Report (Report takes awhile to run)
MISHAPS COUNT	Mishaps Count by Hour, Week, Month, FY
DOCUMENTS OF INTEREST	Documents of Interest
ESMAM LINKS OF INTEREST	ESMAM Links of Interest
ESMAM MAIN	ESMAM Main Menu



ESMAM Charting: Fiscal Year by Mishap Class



TOOLS

▼ Go Back

Select Service and Fiscal Year(s) for Mishaps by Class, Injuries and Fatalities, Mishap Types and Generic Causes

Service	Fiscal Year	Class
<input type="radio"/> Air Force	<input type="checkbox"/> 2000	<input type="radio"/> Class A
<input type="radio"/> Army	<input type="checkbox"/> 2001	<input type="radio"/> Class B
<input type="radio"/> Marine Corps	<input type="checkbox"/> 2002	<input type="radio"/> Class C
<input type="radio"/> Navy	<input type="checkbox"/> 2003	<input type="radio"/> Class D
<input type="radio"/> Contractor	<input type="checkbox"/> 2004	<input type="radio"/> Class E
<input type="radio"/> Foreign	<input checked="" type="checkbox"/> 2005	<input type="radio"/> Class A to B
<input type="radio"/> Special	<input checked="" type="checkbox"/> 2006	<input type="radio"/> Class A to C
<input type="radio"/> All Services	<input checked="" type="checkbox"/> 2007	<input type="radio"/> Class A to D
<input type="radio"/> Priv Contractor	<input checked="" type="checkbox"/> 2008	<input type="radio"/> Class A to E
<input type="radio"/> All Records	<input checked="" type="checkbox"/> 2009	<input type="radio"/> Not Assigned
	<input checked="" type="checkbox"/> 2010	<input type="radio"/> All Records
Last	FY	

Submit

Clear

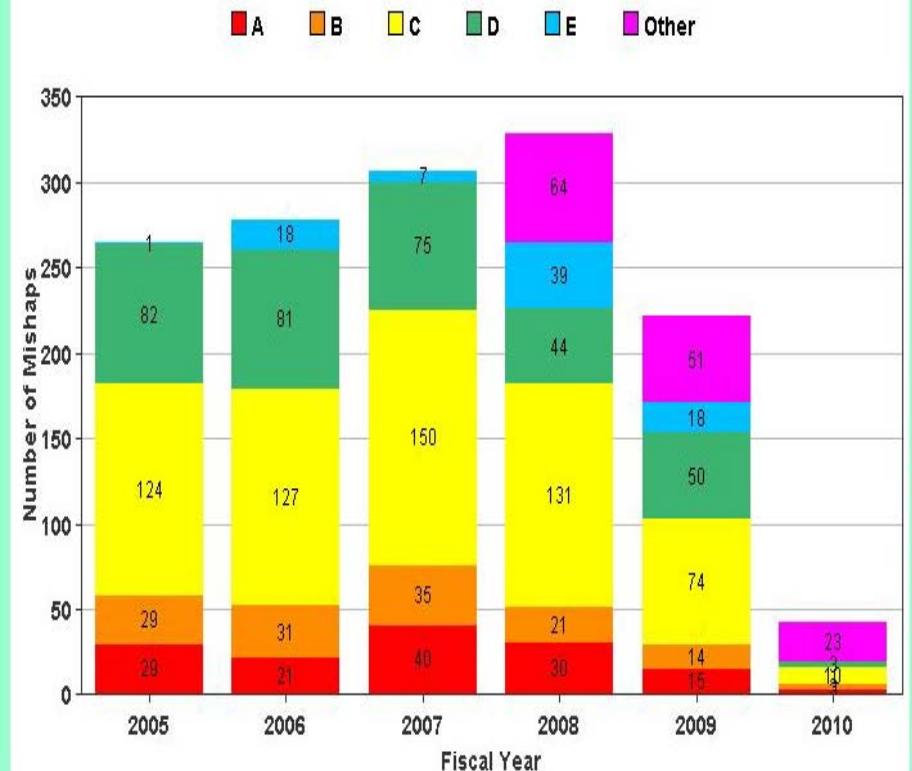
ALL SERVICES ESMAM CHARTS FOR FISCAL YEAR(S)

2005,2006,2007,2008,2009,2010

Charts: [\[Class\]](#) [\[Injuries Fatalities\]](#) [\[Mishap Types\]](#) [\[Generic Causes\]](#) [\[HC / HD by Class\]](#)

Click on Chart Bar or Pie Piece to drill down to underlying records.

1443 All Services Mishaps Class for Fiscal Year(s) 2005,2006,2007,2008,2009,2010 from ESMAM
06/02/2010



- Bar
- Horz Bar
- 3D
- 2D
- Stacked
- Cluster

Change

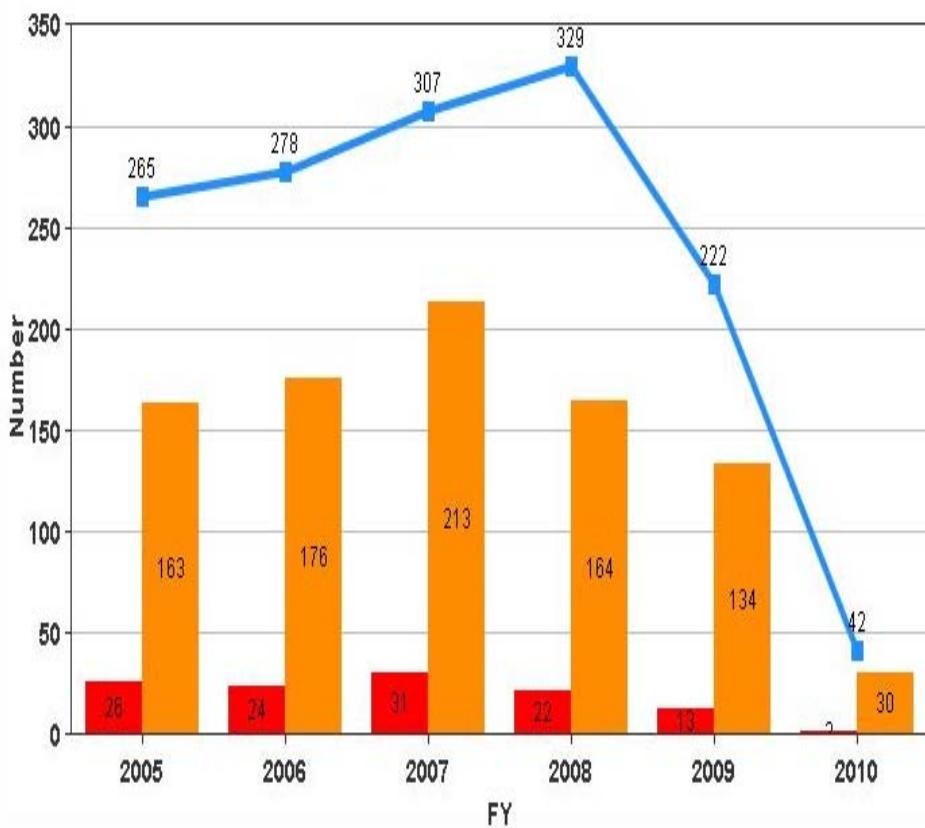


ESMAM Charting: Fiscal Year by Mishaps/Injuries/Fatalities and by Mishap Types



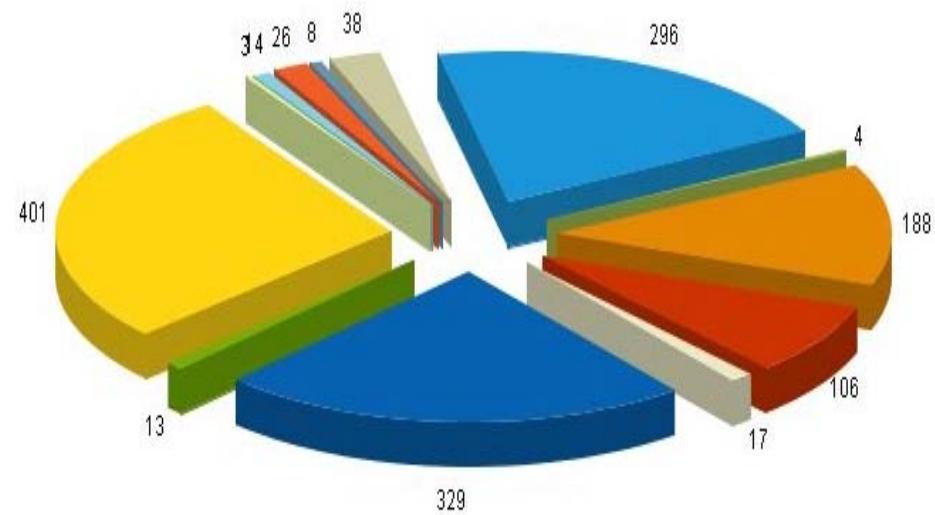
1443 All Services Mishaps Injuries and Fatalities for Fiscal Year(s)
2005,2006,2007,2008,2009,2010 from ESMAM 06/02/2010

■ Fatalities ■ Injuries ■ Mishaps



1443 All Services Mishaps Types for Fiscal Year(s) 2005,2006,2007,2008,2009,2010 from
ESMAM 06/02/2010

■ COMBAT SOLDIERING ■ DISPOSITION/DEMILITARIZATION
■ HANDLING ■ MAINTENANCE
■ MANUFACTURING/PRODUCTION ■ OTHER
■ REMEDIATION ■ STORAGE
■ TBD ■ TEST AND EVALUATION
■ TRAINING ■ TRANSPORTATION
■ WEAPONS FIRING



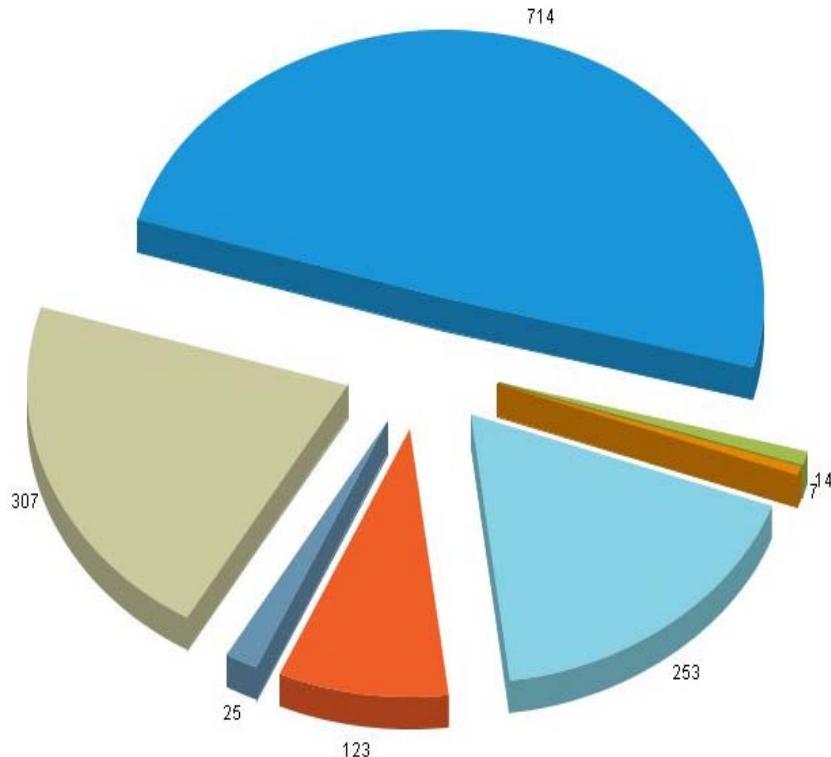


ESMAM Charting: Fiscal Year by Generic Cause and by Hazard Class/Division



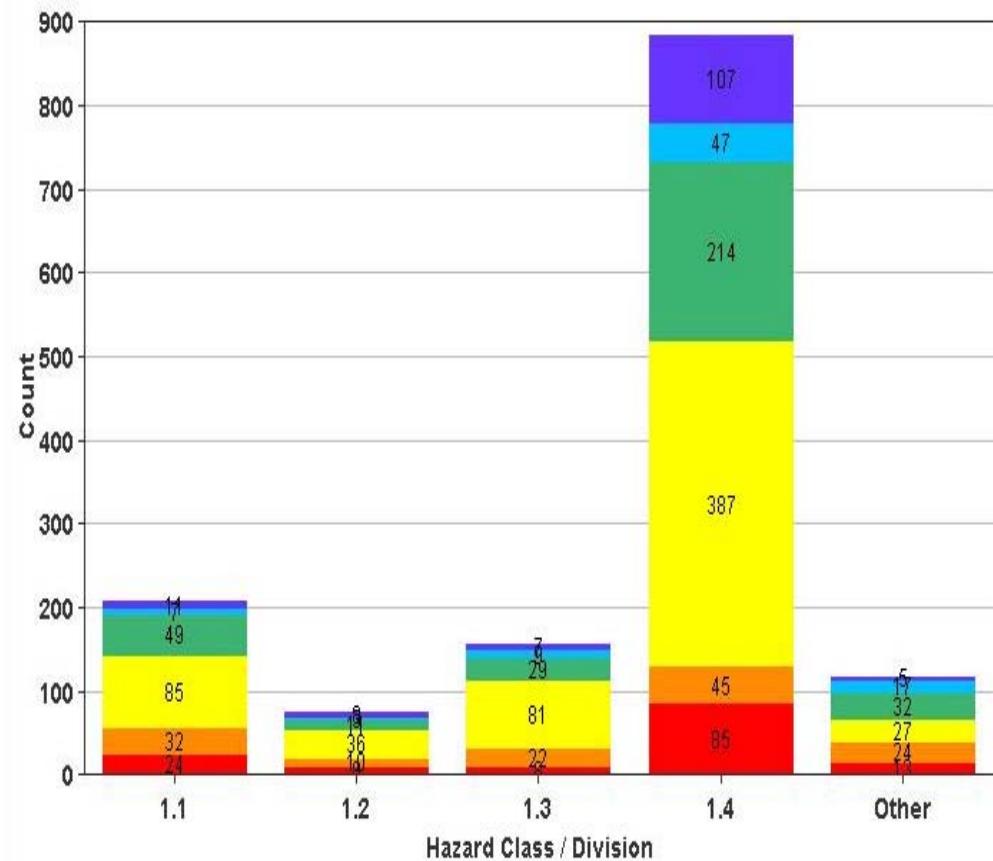
1443 All Services Generic Causes for Fiscal Year(s) 2005,2006,2007,2008,2009,2010 from ESMAM 06/02/2010

- | | |
|--|---------------------------|
| Design Deficiency | Environmental |
| Human factors/Failure to follow procedures | Human factors/Supervision |
| Human factors/Training | Material failure |
| Unknown | |



1443 All Services Accidents Hazard Class/Division by Accident Class for Fiscal Year(s) 2005,2006,2007,2008,2009,2010 from ESMAM 06/02/2010

- A ■ B ■ C ■ D ■ E ■ TBD





ESMAM Search Page



TOOLS

Go Back

of Filtered Records 44

Service	Fiscal Year	Injury	Fatality	Class
All Records	2010 to Present	All Records	All Records	All Records

Date From all Date To %

Service	Fiscal Year to Present				
<input type="radio"/> Army <input type="radio"/> Air Force <input type="radio"/> Navy <input type="radio"/> Marines <input type="radio"/> All Services <input type="radio"/> All Services & Contractors	<input type="radio"/> Contractor <input type="radio"/> Foreign <input type="radio"/> Special <input type="radio"/> Other <input checked="" type="radio"/> All	<input checked="" type="radio"/> Current FY <input type="radio"/> Last FY <input type="radio"/> Last 2 FYs <input type="radio"/> Last 3 FYs <input type="radio"/> Select FY	<input type="radio"/> Last 4 FYs <input type="radio"/> Last 5 FYs <input type="radio"/> Last 10 FYs <input type="radio"/> All FYs	to	Present

Injuries	Fatalities	Class		
<input type="radio"/> W/O Injuries <input type="radio"/> W/ Injuries <input type="radio"/> >10 Injuries <input type="radio"/> > 50 Injuries <input type="radio"/> > 100 Injuries <input checked="" type="radio"/> All Records	<input type="radio"/> W/O Fatalities <input type="radio"/> W/ Fatalities <input type="radio"/> > 10 Fatalities <input type="radio"/> > 50 Fatalities <input type="radio"/> > 100 Fatalities <input checked="" type="radio"/> All Records	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D <input type="radio"/> E <input type="radio"/> A-B <input type="radio"/> A-C <input type="radio"/> A-D <input type="radio"/> A-E	<input type="radio"/> Other <input type="radio"/> All Classes <input type="radio"/> Not Assigned <input checked="" type="radio"/> All Records	

Fiscal Year From // Fiscal Year To

From FY From

To FY To

Filter

Reset

Check choices above and then click [Filter] to filter records

Place any word in the Key Word box.

(_ is wild card for single character, * or % are wild Cards for multiple characters)

Key Word Search	ID NO	
All Records	Category Search	OTHER TEST & EVALUATION WEAPONS FIRING WEAPONS FIRING (HANDLING)
State Search	NORTH CAROLINA TENNESSEE TEXAS WISCONSIN	
Country Search	KOREA, REPUBLIC OF (SOUTH) KUWAIT UNITED STATES USA	
Munition Search	PYROTECHNICS, FLARES PYROTECHNICS, SIM (ART/GREN/MORTAR) SIMULATOR, HAND GRENADE SIMULATOR M116A1	
City Search	KILLEEN MONTICELLO G1 Minden OAK GROVE	
Installation Search	OKLAHOMA CITY G7 REDSTONE ARSENAL RODRIGUEZ RANGE Rodriguez Range	
Nomenclature Search	Grenade, Fast Obscurant (FOG) MACHINE GUN GRENADE 40MM MK19 MATCHES MATCH MORTAR, 81MM, M29-SERIES M1 WITH MOUNT, M4; CARTRI NOL-130 PRIMER MIX/STAB DETONATOR PYROTECHNICS, FLARES PEN FLARE PYROTECHNICS, SIM (ART/GREN/MORTAR) M115A2/ ARTY SIMULATOR, HAND GRENADE SIMULATOR M116A1/GOV LEASE	



ESMAM Search Results



TOOLS

ESMAM SEARCH RESULTS				Results for		Mishap Details		Check All Clear All			
45 Records				ESMAM Explosives Mishaps					Last Record		
No	FY	Select Records	Mishap ID Click for detail	Mishap Date	Service	Class	Location	Description		Generic Cause	DOCS
1	2010	<input type="checkbox"/>	20091214004	12/14/2009	Army	C	Ecp, Jss Salie, Iraq	Sm Was Attempting To Replace A Mounted M2 With A M240b. He Attempted To Hammer Out The Pin With A .50 Cal Bmg Round. He Struck The Primer Against The Weapon Mount And Detonated In His Hand.		HUMAN ERROR	
2	2010	<input type="checkbox"/>	20091205001	12/05/2009	Army	B	Camp Parsa Training Area, Afghanistan	Soldier Was Using A Smoke Grenade During Combat Simulation When It Detonated In His Hand As A Result He Sustained The Loss Of Two Fingers And A Fractured Hand. Class B Injuries.		HUMAN ERROR	
3	2010	<input type="checkbox"/>	20091130009	11/30/2009	Army	D	Mct Yard At Camp Taji, Iraq	Soldier Was Prepping His Equipment In The Gun Turret Getting Ready To Depart Camp When A Pen Flare Deployed Striking Him In The Face And Eyes.		HUMAN ERROR	
4	2010	<input type="checkbox"/>	20091121003	11/21/2009	Army	D	At Test Fire Pit, Camp Korean Village, Iraq	Soldier Was Conducting A Test Fire Of His M2 .50 Cal Mg; During Firing The Barrel Became Unscrewed And The Headspace And Timing Became So Large Causing The Round To Explode Damaging The M2.		TBD	
5	2010	<input type="checkbox"/>	20091117005	11/17/2009	Army	C	Range 44, Ft Bragg, Nc 28310	Soldier Was Range Oic During Mk19 Range; He Was Observing The Firing Line When The Gunner Aimed The Weapon Causing 2 Rounds To Strike In The Sdz Resulting In Shrapnel Hitting Him In The Face Causing I		HUMAN ERROR	
6	2010	<input type="checkbox"/>	20091107002	11/07/2009	Army	C	Residence, 135 East Street, Clarksville, Tn 37042	Soldier Was Disassembling His Weapon When He Inadvertantly Discharged A Round Into His Hand Resulting In Injury.		HUMAN ERROR	
7	2010	<input type="checkbox"/>	20091031002	10/31/2009	Army	D	Convoy Lanes (North Trails), Ft McCoy, Wi	Soldier Was Conducting Deploying A Hand Grenade Simulator During Vbied Convoy Lane Exercise The Grenade Simulator Got Stuck On The Door Handle Of The Gov Van And Detonated Damaging The Van.		HUMAN ERROR	



ESMAM Improvements & JSAEWG Progress *(continued)*



➤ JSAEWG Tasks & Accomplishments

- Reviewed and commented on draft DoDI 6055.07, *Accident Investigation, Reporting, and Record Keeping*
 - Improve reporting requirements
 - Greater visibility
- Improving mishap data entry into ESMAM
 - Services upgrade reporting/recordkeeping systems
 - Create lessons learned database
 - Coordination on users' viewing permissions
- Crafting data dictionary
 - Agreement on definitions of generic causes
 - Agreement on definitions of mishap types
 - Coordination on defining mishap terms





Mishap Classification Changes



Accident Class	Criteria (Property Damage/Injury) Prior to FY2010	Criteria (Property Damage/Injury) As of FY2010
A	$\geq \$1,000,000$ and/or Fatality/Permanent Total Disability Injury	$\geq \$2,000,000$ and/or Fatality/Permanent Total Disability Injury
B	$\geq \$200,000$, but $< \$1,000,000$ and/or Permanent Partial Disability Injury	$\geq \$500,000$, but $< \$2,000,000$ and/or Permanent Partial Disability Injury
C	$\geq \$20,000$, but $< \$200,000$ and/or Lost Time Injury	$\geq \$50,000$, but $< \$500,000$ and/or Lost Time Injury
D	$\geq \$2,000$, but $< \$20,000$ and No Lost Time Injury	$\geq \$2,000$, but $< \$50,000$ and No Lost Time Injury
E	Does not meet the severity criteria of A, B, C, or D	Does not meet the severity criteria of A, B, C, or D
Other	Not reported by the Service	Not reported by the Service

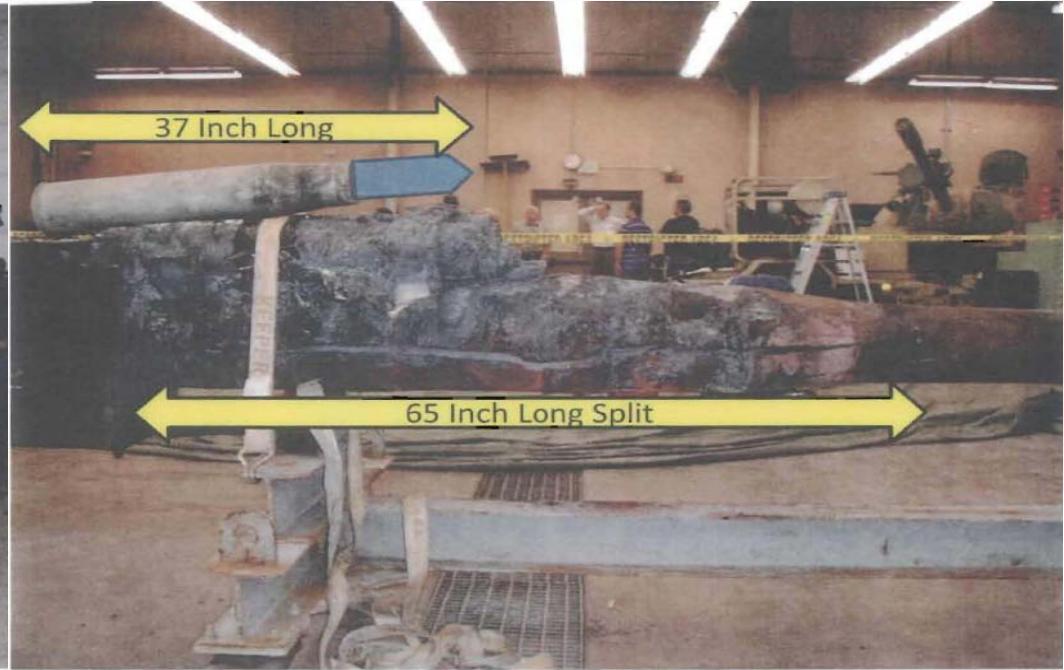




Impacts of Recent Mishaps



- **Aberdeen Proving Grounds (Maryland)**
 - 2 Fatalities & 1 Serious Injury; Tank Destroyed
 - Foreign Munition Test Firing (21 May 2009)
 - Working Group





Impacts of Recent Mishaps *(continued)*



➤ Redstone Arsenal (Alabama)

- 2 Fatalities;
Facility
Severely
Damaged
- Separate
Ammonium
Perchlorate
from Missiles
(5 May 2010)
- Investigation
On-going





Impacts of Recent Mishaps *(continued)*



- **Alleghany Ballistics Laboratory (West Virginia)**
 - 2 Minor Injuries; Facility Destroyed
 - Remote Controlled Mix Operation (24 May 2010)
 - Investigation On-going

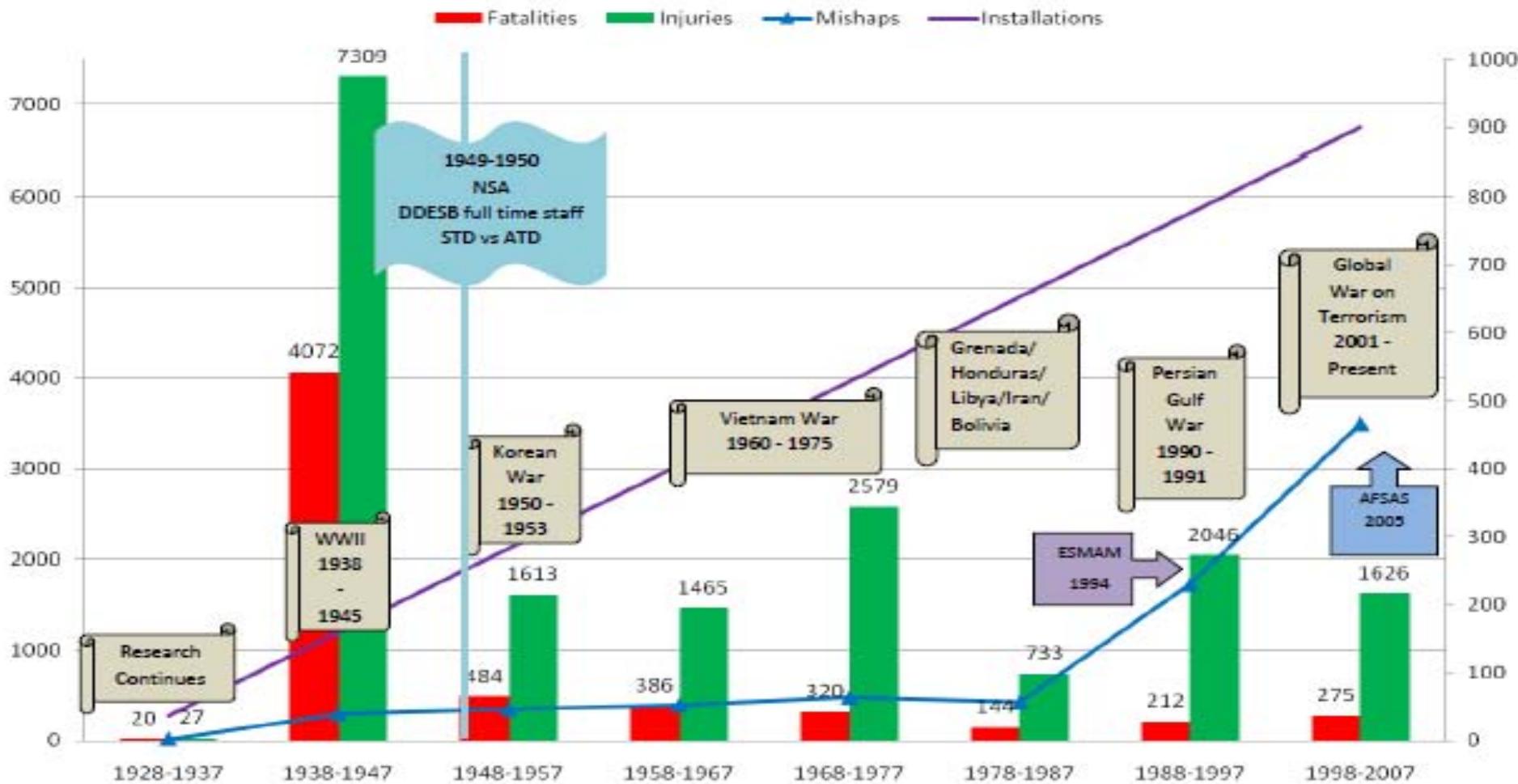




Impacts of Historical Mishaps



DoD Installation Growth in Relation to Munitions-Related Mishaps FY 1928-2007

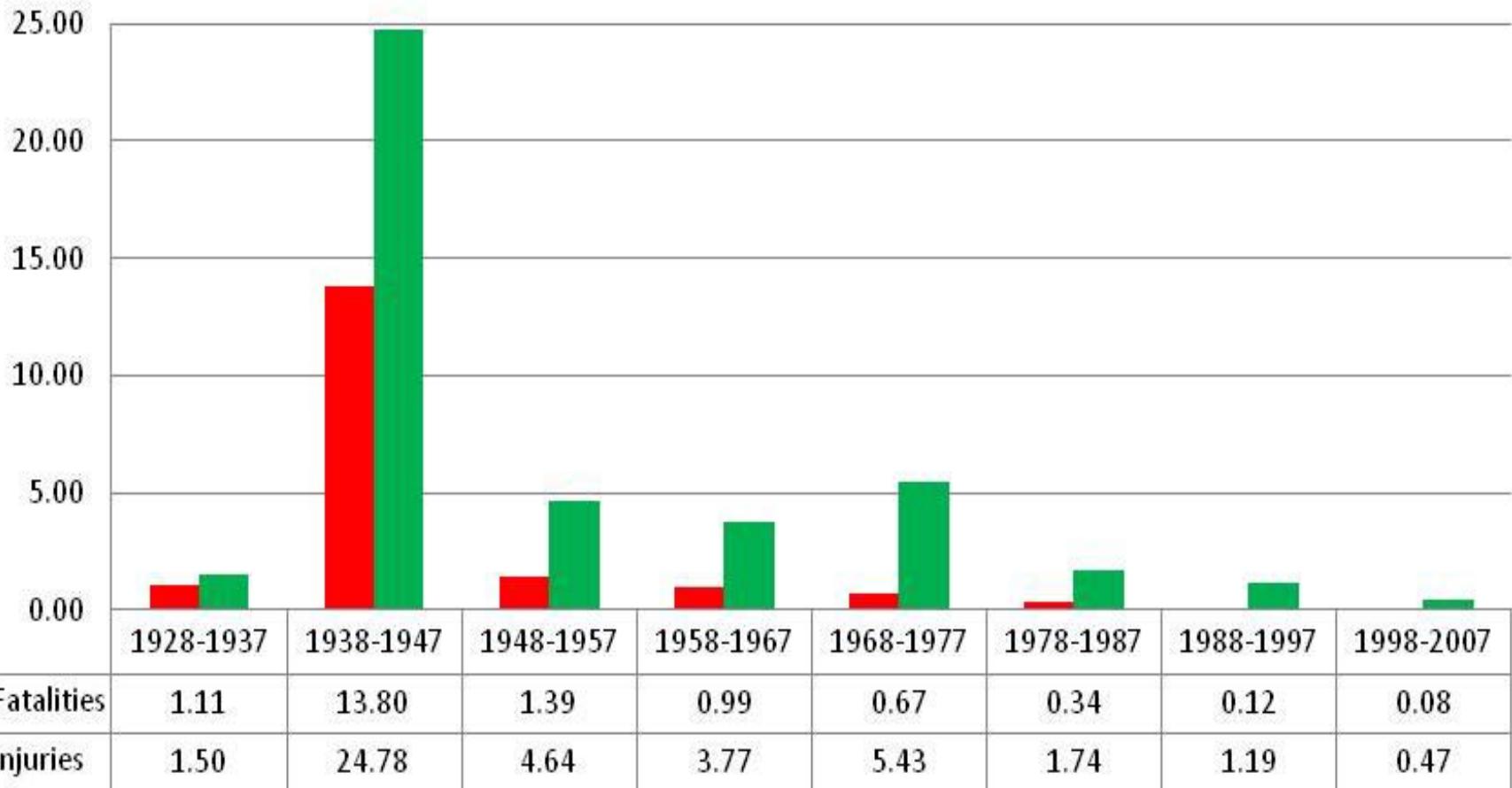




Impacts of Historical Mishaps *(continued)*

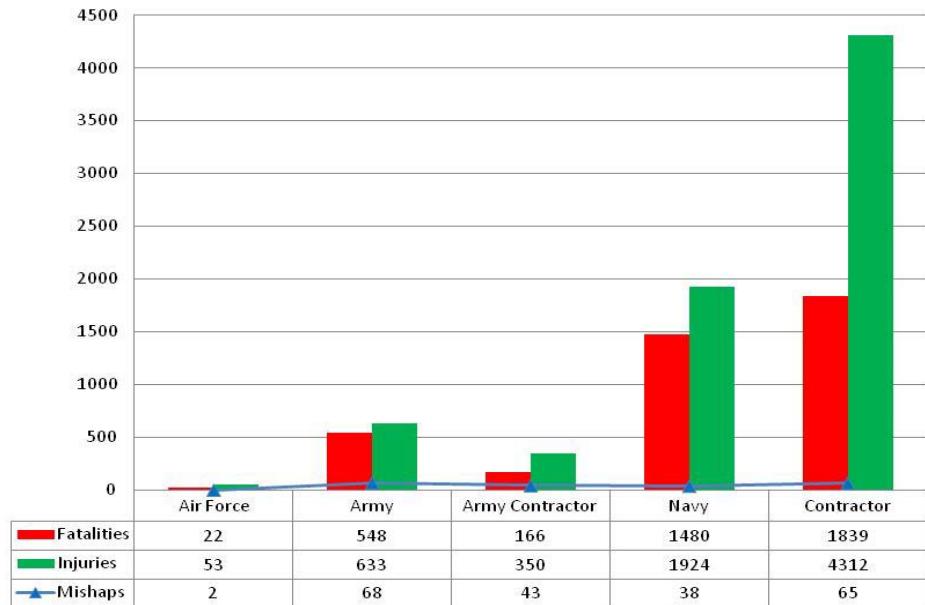


Average Fatalities & Injuries By 10-Fiscal Year Periods

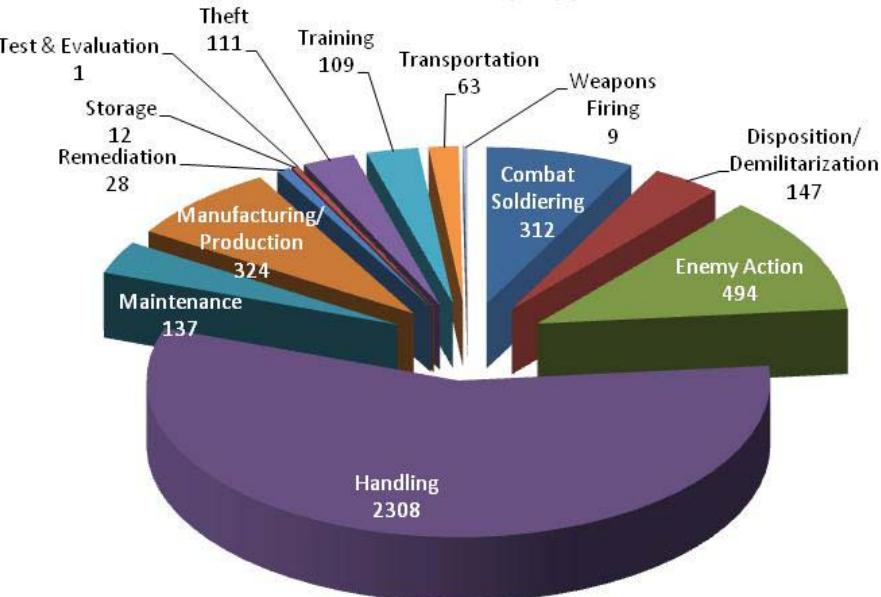


Fiscal Years 1938 – 1947

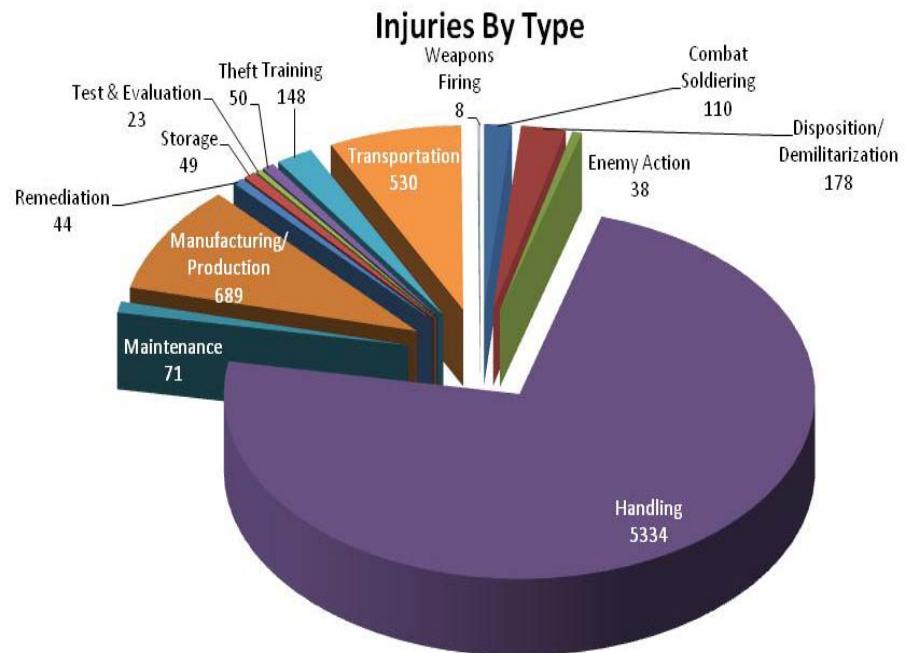
Fatalities/Injuries/Mishaps By Service



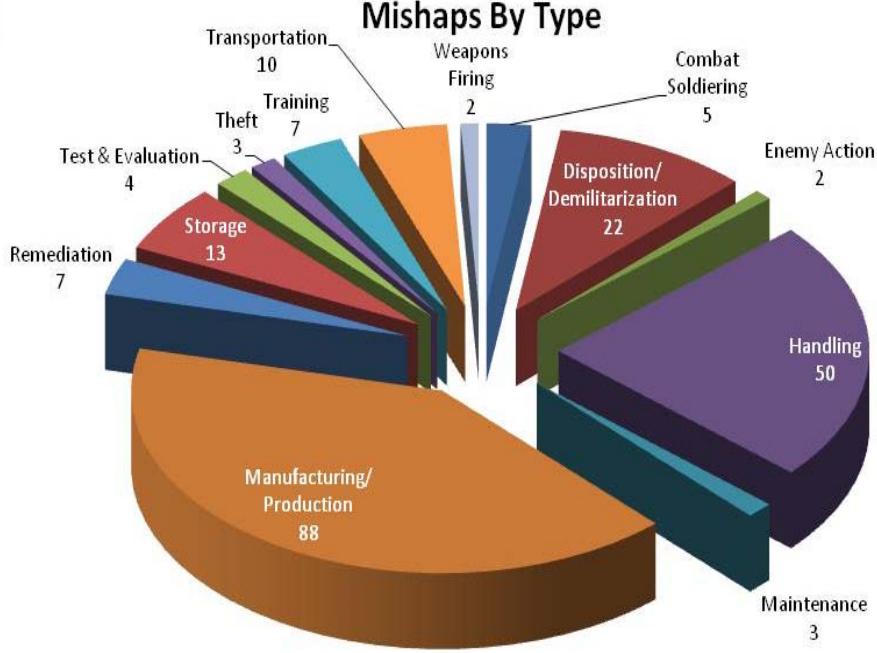
Fatalities By Type



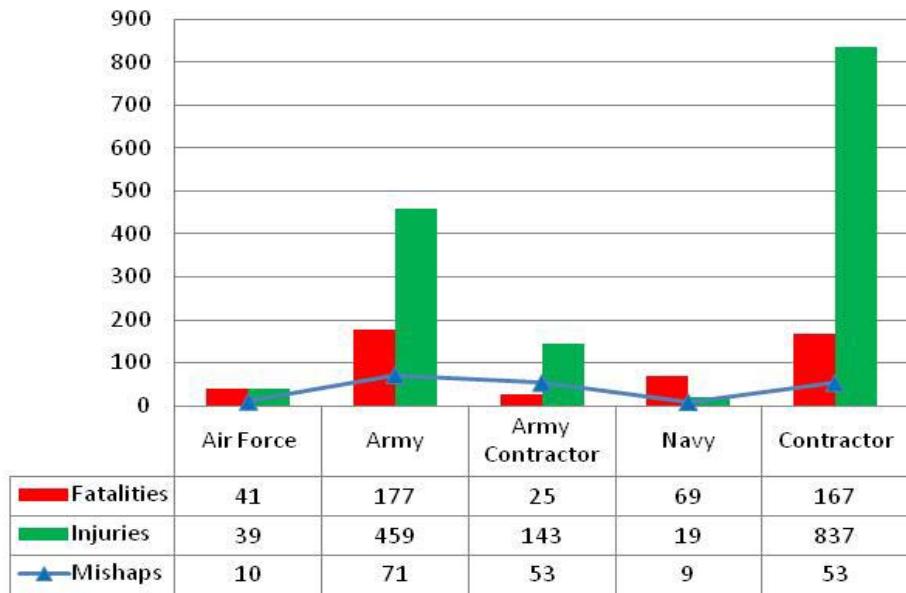
Injuries By Type



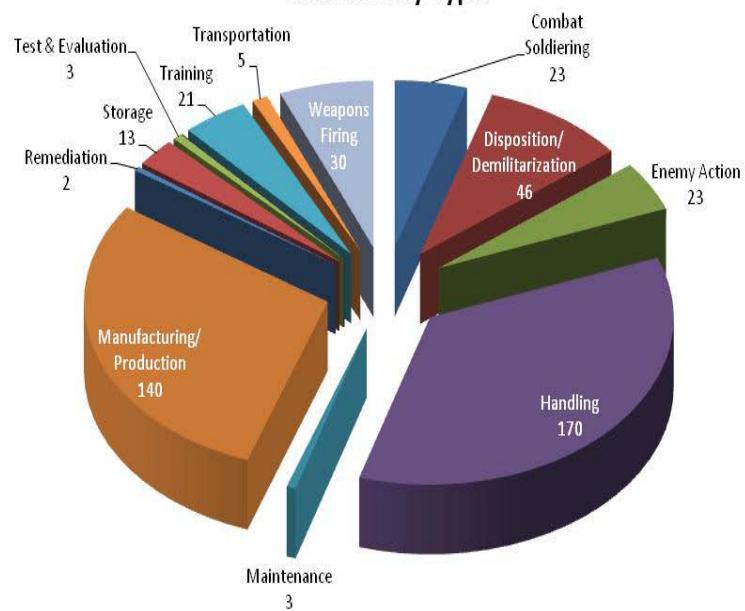
Mishaps By Type



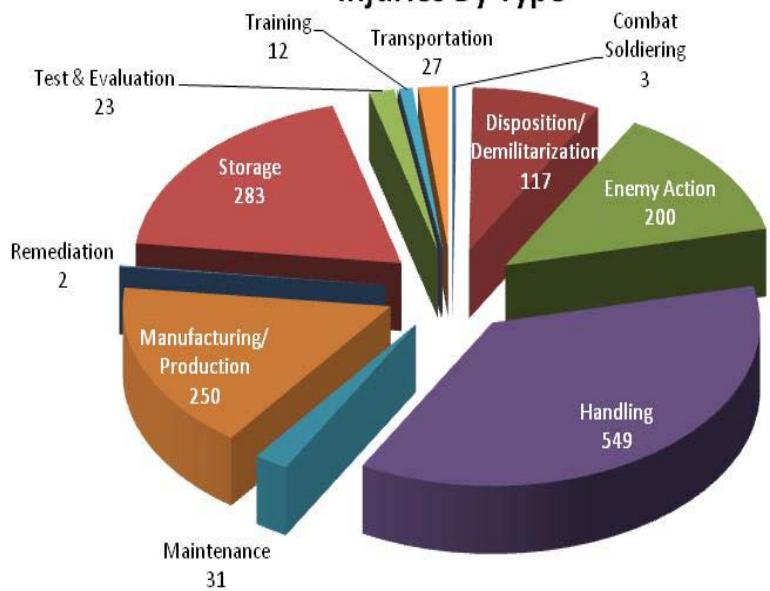
Fatalities/Injuries/Mishaps By Service



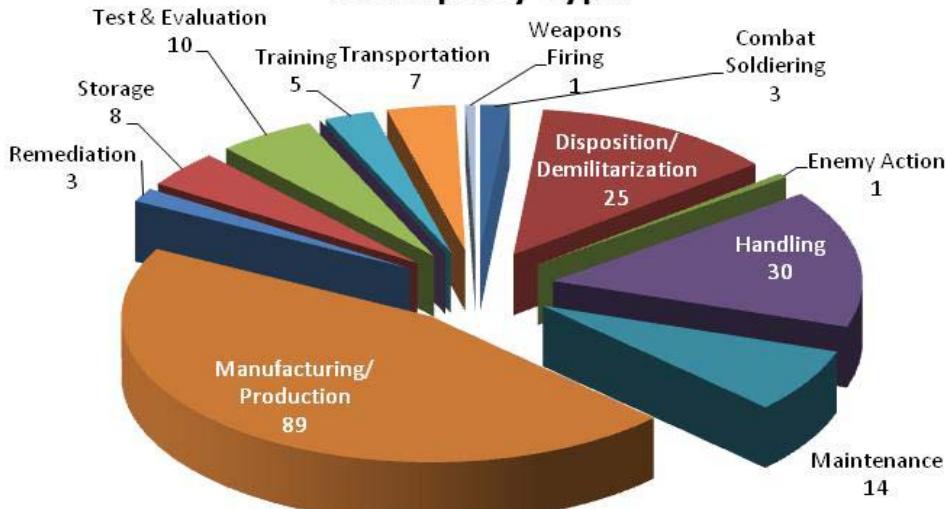
Fatalities By Type



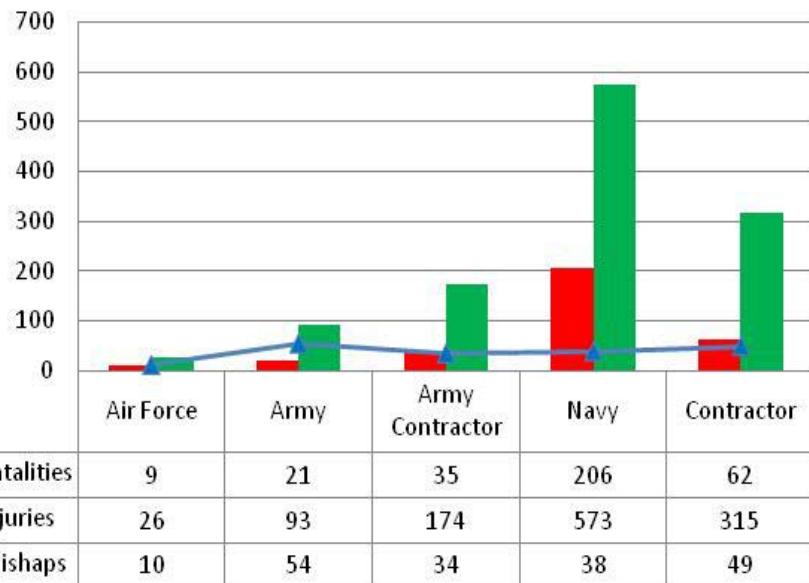
Injuries By Type



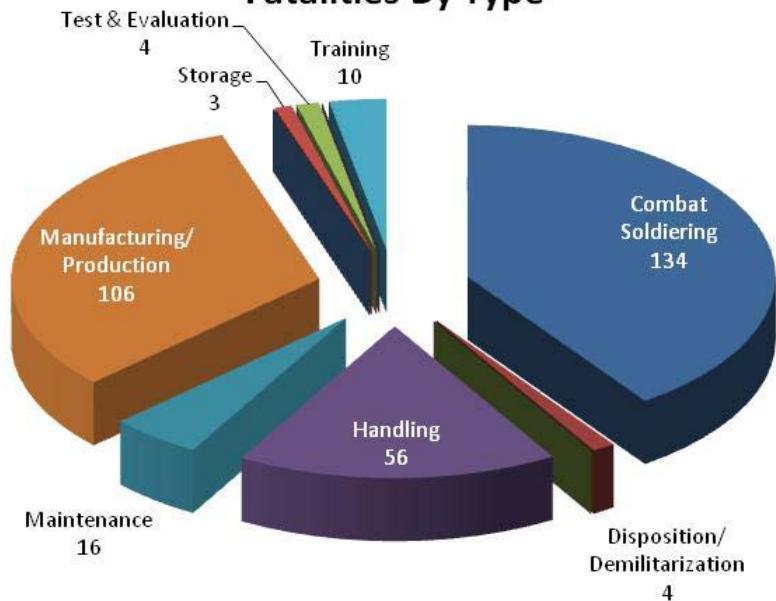
Mishaps By Type



Fatalities/Injuries/Mishaps By Service



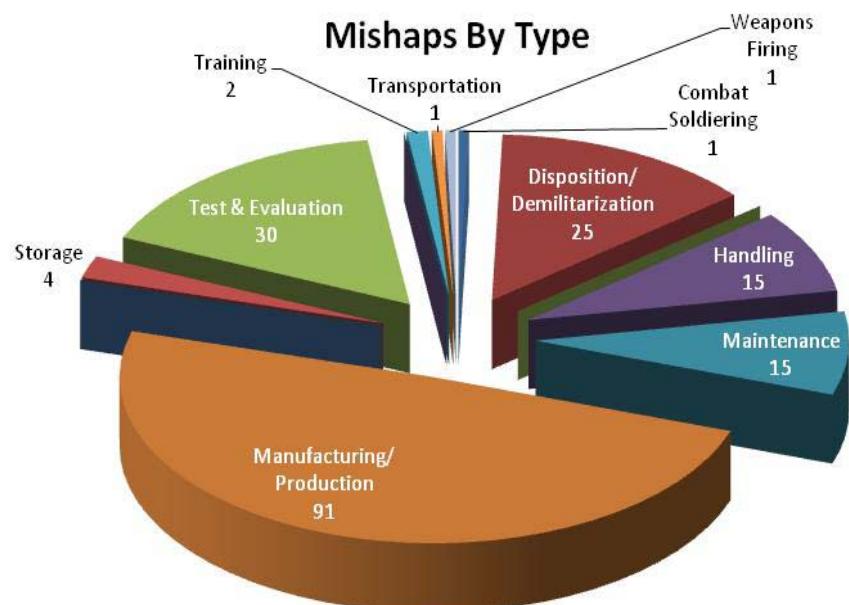
Fatalities By Type



Injuries By Type

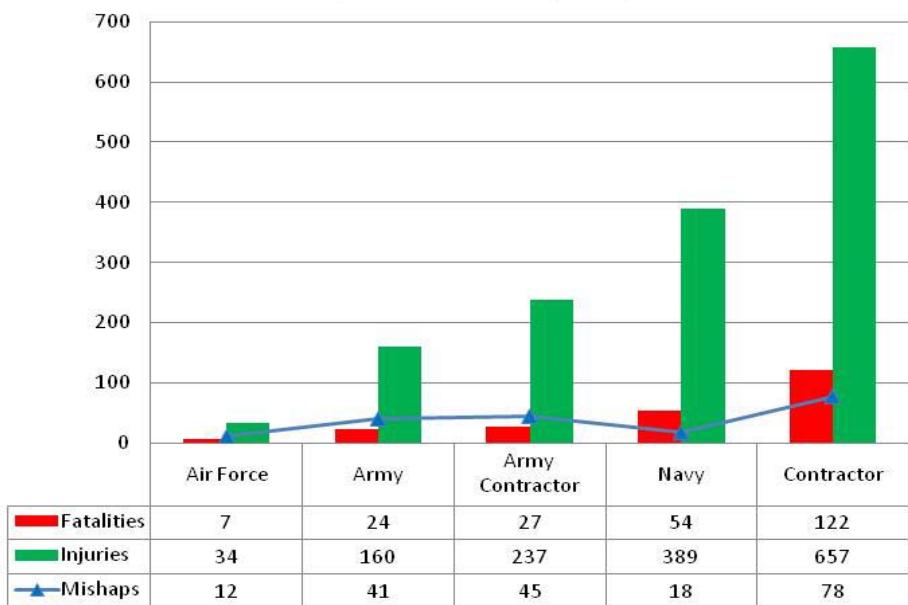


Mishaps By Type

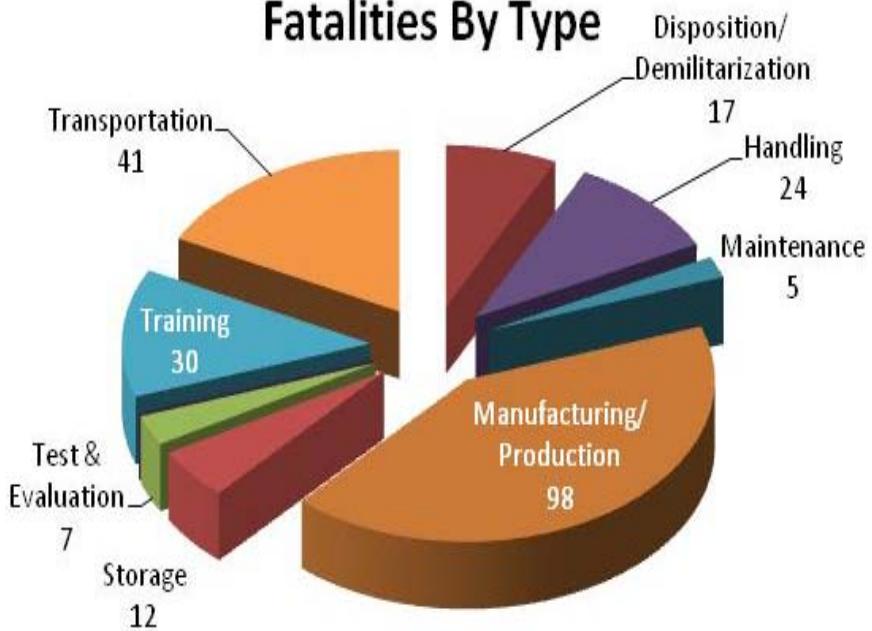


Fiscal Years 1968 – 1977

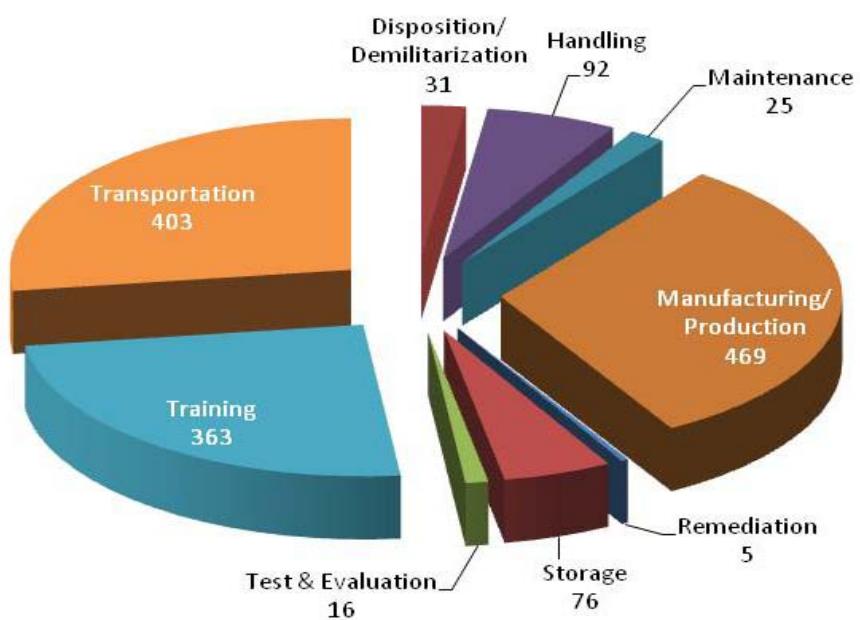
Fatalities/Injuries/Mishaps By Service



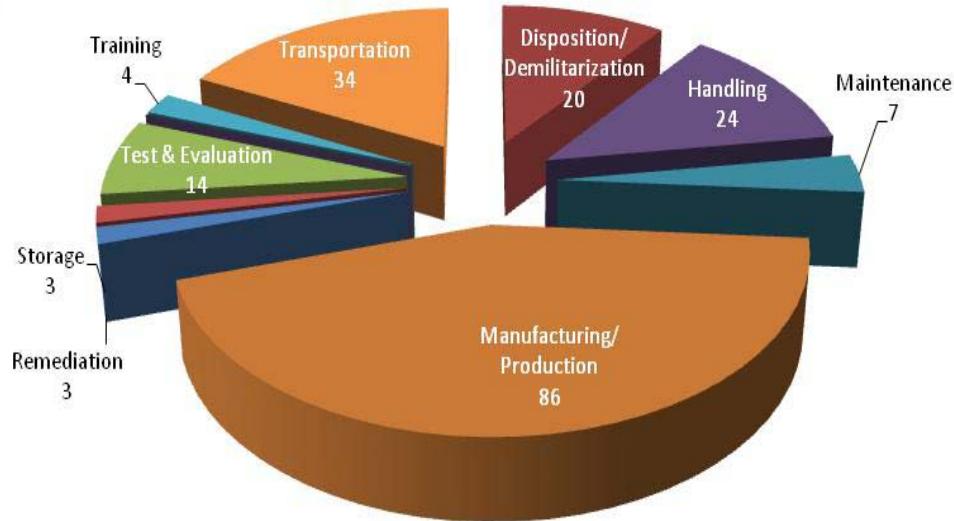
Fatalities By Type



Injuries By Type

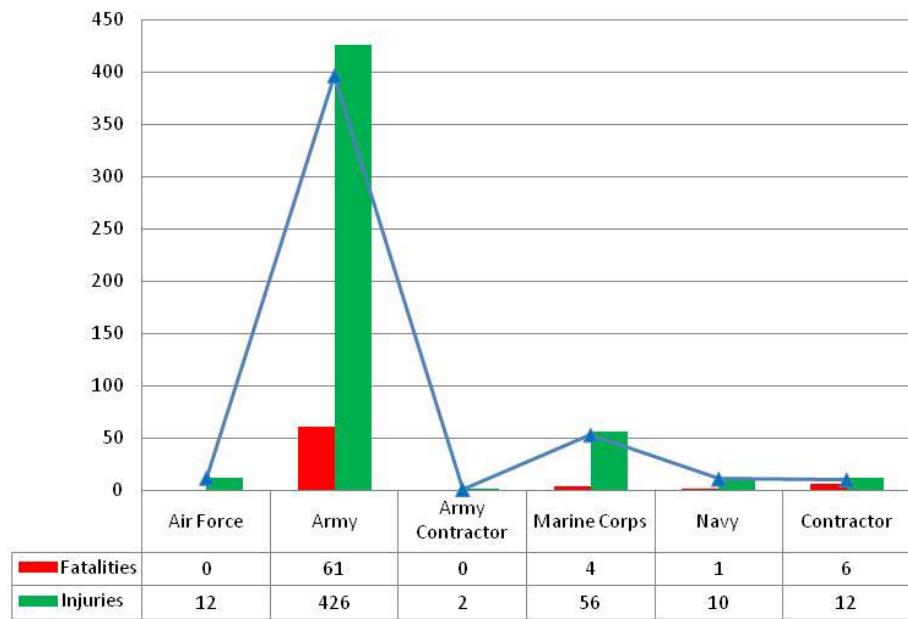


Mishaps By Type

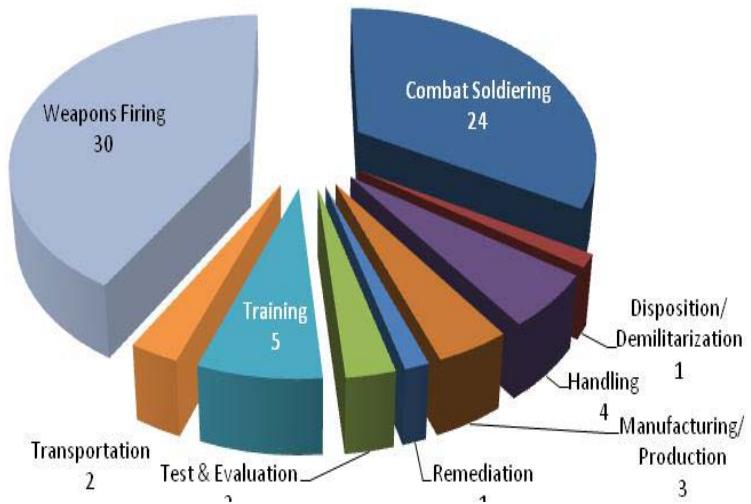


Fiscal Years 2007 – 2009

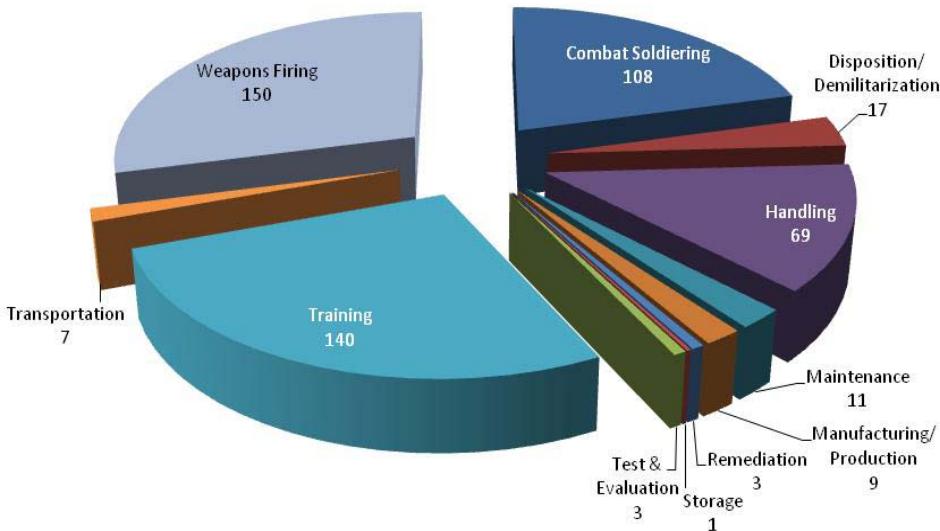
Fatalities/Injuries/Mishaps By Service



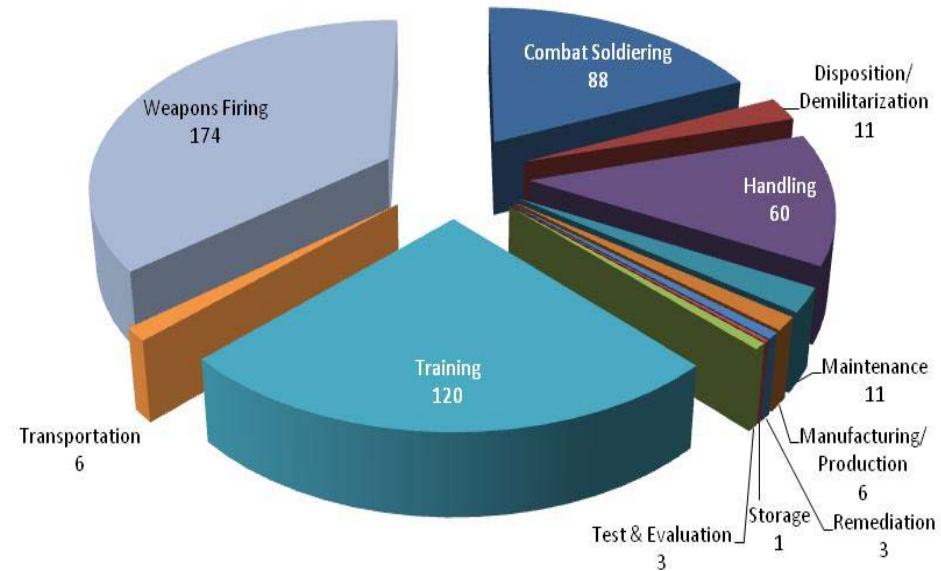
Fatalities By Type



Injuries By Type



Mishaps By Type





Conclusions



- Mishap Reporting Improving
- Challenges
 - Lessons learned
 - Mishap causes
 - DoDI 6055.07 requires only Class A, B, and C be reported
 - Service visibility and involvement
- Improve/Verify Safety Standards and Issuances
 - IBD, Barricading, and Protective Construction Design
(TP-21: Procedures for the Collection, Analysis, and Interpretation of Explosion-Produced Debris – Rev. 1)
 - Program Evaluations
 - Intentional Detonation Working Group





Conclusions *(continued)*



➤ Future Work

- Continue to participate in significant mishap investigations
- Continue to improve ESMAM
 - Better query functions and data filter options
 - More user-friendly interfaces
 - Lessons learned added to records
 - Mishap reports added to records
- ESMAM is a comprehensive database used for:
 - Services mishaps reporting and data improvements;
 - International collaboration and information sharing;
 - Validation of risk-based tools;
 - Verification of quantity-distance standards; and
 - Data mining for potential explosives safety criteria gaps.





Questions?

