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HOW SAFE SHOULD OUR WEAPONS BE?

by

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Abstract

Congress incorporated language into the Fiscal Year 2002 Defense Appropriation Bill requiring the Secretary of Defense to ensure our munitions are developed or procured to be safe, to the extent practicable, from unplanned stimuli throughout their life cycle. However, to date, the Joint Air-to-Surface Standoff Missile (JASSM) is the only major Air Force weapon system to meet the insensitive munitions criteria for full compliance. This paper provides an objective assessment of whether there are compelling arguments that would lead the Air Force to expend the resources required to achieve a fully compliant insensitive munitions inventory. To facilitate the understanding of the basic issues and thus the compelling arguments for achieving or not achieving insensitive munitions compliance, this paper provides the reader with a basic understanding of insensitive munitions including: a definition of insensitive munitions with an explanation of the criteria required to achieve insensitive munitions compliance; a summary of munitions related accidents/incidents to establish the risk associated with non-IM compliance; a historical perspective of insensitive munitions within the Air Force; and a series of compelling arguments assessing the law, the changing world environment, and the operational impact of insensitive munitions. From the framework of these assessments, this paper recommends a way forward for the Air Force in addressing this federally mandated requirement.

I. Introduction

Based upon "fires on aircraft carriers over [the previous] 20 years that had taken over 200 lives and cost nearly $200 million…,"[1] the Chief of Naval Operations in May 1984 mandated that "all [United States (US)] Navy munitions will be designed to minimize the effects of unplanned stimuli. They will incorporate insensitive energetic material that meet or improve upon published insensitivity standards… Operational capability must be maintained, but every effort must be made to meet operational requirements with the least sensitive material available."[2] While there were previous efforts to develop more insensitive munitions, this edict provided the top-down management emphasis required to effectively pursue insensitive munitions technologies within the Navy. During the height of the Cold War, the Air Force became involved in insensitive munitions technology research, or more appropriate reduced hazard classification research, due to munitions storage issues especially at air bases outside the continental United States. This research was discontinued following the fall of the iron curtain resulting in the relief of the storage quantity/density issues. Insensitive munitions criteria have spread throughout the Department of Defense (DOD) and the international community becoming a DOD requirement,[3] subsequently a US federally mandated requirement,[4] as well as a US ratified North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) requirement[5] to incrementally improve our munitions ultimately achieving an insensitive munitions compliant inventory.

The purpose of this paper is to determine if there are compelling arguments that would lead the Air Force to expend the resources required to achieve a fully compliant insensitive munitions inventory. To facilitate the reader's comprehension of IM and accomplish the assessment, this paper has three primary objectives. First, provide the reader a basic understanding of insensitive munitions including a definition, an explanation of the criteria and process required to achieve an insensitive munitions compliant weapon system, a brief summary of the major munitions related incidents some of which prompted the DOD insensitive munitions program, and a historical Air Force perspective of insensitive munitions. The second objective is to review the compelling arguments for achieving or not achieving an insensitive munitions compliant inventory. To achieve this objective, the report will assess the law implementing the insensitive munitions mandate, the changing world environment, and the operational impact of insensitive munitions. Finally, from these assessments, the paper will provide conclusions and recommend a way forward for the Air Force in addressing its insensitive munitions requirements.

Insensitive Munitions Criteria

The US definition for IM as delineated in Military Standard (MIL-STD) 2105, "Hazard Assessment Tests for Non-Nuclear Munitions," has essentially been adopted as the international definition as well. It is: "Munitions which reliably fulfill (specified) performance, readiness and operational requirements on demand, but which minimize the probability of inadvertent initiation and severity of subsequent collateral damage to the weapon platforms, logistic systems and personnel when subjected to unplanned stimuli."[6] Unplanned stimuli are not specifically defined in MIL-STD-2105 but is the energy projected onto a munition item from an unintended conventional source. Thus, as delineated in the title of MIL-STD-2105, the description and assessments contained in this paper deal with the impact of insensitive munitions on our conventional (i.e., non-nuclear) munitions capability. In an effort to ultimately eliminate the US Military Standard in lieu of international standards, the current issue of MIL-STD-2105C, 14 July 2003 references a series of Standardization Agreements and Allied Ordnance Publications

(AOPs) in most of the test set-up, passing criteria, and reaction definitions for individual tests. Thus, achieving insensitive munitions compliance is not just an US issue, but is a topic that must be considered in today's coalition environment.

To assess whether or not an item is IM compliant, one must first assess its life cycle environment and probable exposure to the various unplanned stimuli. A Threat Hazard Assessment, as delineated in MIL-STD-2105, develops a life cycle environmental profile to establish "the worst case environmental conditions and limits that munitions will encounter throughout the life cycle, such as temperature, humidity, and vibration."[7] In addition, this assessment will delineate which of the insensitive munitions tests (i.e., fast cook-off, slow cook-off, bullet impact, fragment impact, sympathetic detonation, shaped charged jet impact, and spall impact tests) as well as the specific test parameters represent environments for which the munition may be exposed during its life cycle. The "test parameters [in this assessment are designed] to reflect the maximum stress levels forecasted…, e.g., bullet impact velocity, maximum storage temperature."[8] Therefore, the Threat Hazard Assessment is utilized to tailor the hazard assessment tests to the particular weapon system and its life cycle environmental profile. Once developed and approved by the appropriate Service's safety/IM board, this assessment document provides the framework for development of an insensitive munitions test plan delineating the tests and test parameters required to achieve insensitive munitions compliance.

These tests must be conducted and the test results assessed by the Service IM authority to determine if the item has successfully passed each of these tests. The passing criteria are dependent upon the particular test and the weapon system's reaction to that stimulus. For test assessment, the reaction types are divided into six levels consisting of: *detonation* which is the most violent type of explosive event (Type I); *partial detonation* where not all of the explosive material reacts in the detonation (Type II); *explosion* where the energetic material ruptures the case due to high pressure producing a lower yield output (Type III); *deflagration* which results from a nonviolent pressure release allowing the energetic material to burn propulsively (Type IV); *burning* which essentially consumes the energetic material through a non-propulsive, nonviolent event (Type V), and *no reaction* (Type VI). Each insensitive munitions test replicates different unplanned stimuli, produces a different mechanism for initiation of the explosive materials, and has different passing criteria based on its reaction type.[9]

The specific insensitive munitions tests "provide a basis to test munitions against meaningful, credible, potential threats and evaluate munition response against criteria which reflect the services IM vulnerability and hazard reduction goals."[10] It should be emphasized that the assessment document not only designates which test will be required but it also allows the test parameters to be tailored for the perceived threat environment. For example, during the life cycle of a weapon system, if the munition item will not be exposed to a potential spall environment (e.g., it is neither used nor transported inside of an armored vehicle), the Threat Hazard Assessment is used to provide the justification not to perform this test. Table 1 provides a summary of the generic or non-tailored environmental stimulus and the proposed North Atlantic Treaty Organization acceptable passing criteria for each test. Insensitive munitions are intended to reduce the potential catastrophic results of a munitions incident/accident while maintaining operational effectiveness of our weapon systems.

Table 1. IM Test Environment and Passing Criteria

Test	Generic Environmental Stimulus	Acceptable STANAG Passing Criteria
Fast Cook-Off[11]	Liquid fuel/external fire test sustained for minimum 30 minutes	Type V reaction
Slow Cook-Off[12]	Incremental heating at 3.3°K per hour until the explosive reacts	Type V reaction
Bullet Impact[13]	Up to three 12.7mm (i.e., 50 caliber) rounds	Type V or VI reaction
Fragment Impact[14]	Single or multiple (up to 5) fragments (mass: 16 to 250 grams; velocity up to 2530m/sec)	Type V or VI reaction
Sympathetic Detonation[15]	Donor charge of similar munition item detonated adjacent to test article	Type III, IV, V or VI reactions
Shaped Charge Jet Impact[16]	Shaped charge jet based on threat (Shaped charge test diameters 50 to 62 mm)	Type III, IV, V or VI reactions
Spall Impact[17]	81mm precision shaped charged jet through 1 inch rolled homogeneous armor plate	Type V reaction

Munitions Related Accidents/Incidents

Since the establishment of the various Service munitions related mishap databases in the late 1980's, there has been only one major US munitions mishap.[18] The incident occurred at Camp Doha, Kuwait where "a heater fire in an artillery resupply vehicle… led to an accident that nearly decimated an entire Army battalion… Over 150 vehicles were destroyed. In fact, the Army lost more tanks in that one incident than it had during the entire war against Iraq"[19] during DESERT STORM. In addition, according to a Navy explosive incident summary report, there have been twelve incidents involving stored explosive materials within the US since 1948 with the latest occurring in 1994.[20] Thus, on average over the last half century, there was one incident with stored explosive materials in the US alone every five years. The frequency of munitions related incidents do not stop there. According to the Munitions Safety Information Analysis Center (MISICA), formally known as the NATO Insensitive Munitions Information Center (NIMIC), there were 17 accidents involving munitions around the world in the first six months of

2004.[21] These accidents resulted in approximately 49 casualties and 100 injuries. With the exception of transportation accidents, their accident summary includes only military munitions and military-grade energetic materials and covers the spectrum of accidents ranging from production to disposal. One of these 17 accidents was in the US and involved a demilitarization process where four individuals were injured in Rison, MD as they tried to disassemble a missile for disposal. Based on extensive research, Table 2 represents the major US munitions related incidents since the middle of the 20th Century. While the frequency of these major munitions incidents is relatively low, the magnitude of their consequences provided the impetus for the DOD IM program.

Table 2. US Major Munitions Related Incidents

Location	Date	Casualties	Injuries	Fiscal Losses (Then-Year $M)
Naval Ammunition Depot, Lake Denmark, NJ[22]	1926	21	51	$46
Port Chicago Naval Magazine, CA[23]	17-Jul-44	320	390	$12
USS Solar, Naval Ammunition Depot, Earle, NJ[24]	30-Apr-46	7	160+	$4.2
Bien Hoa Air Force Base, Vietnam[25]	16-May-65	26	60+	40 Aircraft Destroyed
USS Oriskany[26]	26-Oct-66	44	156	$11.0
USS Forrestal[27]	29-Jul-67	134	161	$182.1
USS Enterprise[28]	15-Jan-69	28	343	$126.2
Tobar, NV[29]	Jun-69	0	2	3 boxcars of 750 lb bombs destroyed
Roseville, CA[30]	28-Apr-73	0	48	$24
Benso, AZ[31]	24-May-73	0	2	$1
USS Nimitz[32]	26-May-81	14	48	$78.4
Camp Doha, Kuwait[33]	11-Jul-91	3	52	$40
Totals	12 Events	597	1,473+	Est. $3B in FY04[34]

Genesis of the DOD IM Program

The magnitude of these horrific events, while beyond the scope of this report, can only be appreciated militarily when the full scope of each tragedy is analyzed. After sustaining a number of fires aboard aircraft carriers including four of the major incidents included in the summary above, the Navy implemented an insensitive munitions program. Between these four aircraft carrier accidents, the Navy had lost 219 sailors, injured another 709 sailors, destroyed 72 aircraft, and damaged 42 more aircraft when they initiated their insensitive munitions program.[35] According to a more recent study, the Navy estimates it could have saved 148 lives, reduced the injuries by 577, destroyed 60 and damaged 32 fewer aircraft if their munitions inventory had been insensitive munitions compliant.[36] Fiscally, the equipment savings alone for these four accidents including the damage to the aircraft carrier would be approximately $1.5B in FY04 dollars.[37] Not withstanding the manpower and fiscal savings, one must also consider the impact to current operations to fully assess the benefits of insensitive munitions.

Historical Air Force IM Perspective

Based on the Air Force's mission and operational deployment structure versus the Navy, the Air Force has historically pursued reductions in Hazard Classification versus insensitive munitions compliance. The Hazard Classification of the weapon system determines the associated quantity-distance based on the level of risk considered acceptable for the type of storage or operating location. These risk factors are known as the "K-factor" and are delineated in Air Force Manual 91-201, "Explosive Safety Standards."[38] Explosive siting maps are developed with the necessary quantity-distance arcs to establish acceptable storage and operating locations. The Department of Defense Explosive Safety Board is the governing organization for siting approval and inspections of explosive safety facilities. Due to this emphasis, historically the Air Force has not incorporated insensitive munitions requirements into their weapon systems except for joint Air Force – Navy programs where the Air Force was the lead Service (e.g., Advanced Medium Range Air-to-Air Missile (AMRAAM), Joint Air-to-Surface Standoff Missile (JASSM), etc.). To understand this rationale, one must first understand the basic hazards associated with explosive materials as well as the Hazard Classification structure and its impact on munitions storage requirements and limitations.

Hazards Associated with Explosive Materials.

According to the Air Force System Safety Handbook:

> "There are three main causes of damage and injury from explosions. The most common cause of damage is a blast wave or pressure wave that radiates from the explosion. Another source of damage results from projectiles or fragments of the product and from surrounding structures affected by the explosions. A third source of damage is thermal radiation derived from combustion. While blast waves impacting on a secondary object tend to produce additional projectiles they decay with distance from the explosion source. The effects of blasts are explained by the associated overpressures created from the explosions. For instance, a blast overpressure of 1.0 psi (pounds per square inch) will knock a person down; an overpressure of 3 psi will shatter a 12-inch concrete wall; and, an overpressure of 7 psi will overturn a railroad car. The second hazard source, fragments, and the resultant scatter of the fragments depends on the size of explosion and the failure modes for materials. Again, distance is a primary consideration where fragmentation products are concerned. The last hazard mentioned, thermal effects, is difficult to predict since size of the fireball and its duration directly effect thermal radiation. As a general rule of thumb, most fireballs reach temperatures on the order of 2400°F and their radiant energy dissipates in relationship to distance squared. The one common thread that runs through these hazards is their shared relationship to distance."[39]

Therefore, as one might expect, the transportation and storage criteria for a particular munition are based on the potential magnitude for these damage mechanisms if the item was subjected to an unplanned stimuli.

Hazard Classification and Explosive Storage Criteria.

"The DOD hazard classification system is based on the system recommended for international use by the United Nations Organization… An assigned hazard classification [includes the] quantity-distance hazard class/division; storage compatibility group; [Department of Transportation] class, markings, shipping name and label; and United Nations serial number."[40] To obtain a hazard classification, which is required prior to introduction of a new weapon system into the inventory, the program office must conduct a series of tests in accordance with Technical Order 11A-1-47. These tests are similar to but not exactly the same as the insensitive munitions tests discussed above. In fact, in recent years there has been a tremendous effort to harmonize the Hazard Classification and insensitive munitions tests to the fullest degree possible. While the test series for each specific weapon may vary, there are four primary tests that overlap to the degree that they can be harmonized. These tests include "the IM sympathetic reaction test [which] can be combined with the [Final Hazard Classification] stack test; the IM fast cook-off test can be combined with the [Final Hazard Classification] external fire stack test; and finally, both IM and [Final Hazard Classification] require bullet impact and slow cook-off tests that can be combined."[41] As with the insensitive munitions tests and their specific test parameters, these tests and their associated test parameters must be approved by the Service's Safety Board and munitions hazard classifiers. Once the tests have been completed, the weapon system will be assigned a Final Hazard Classification based upon the results of these tests.

Of the nine hazard classes in the United Nations Organization classification system, ammunition and explosive items fall into either Class 1 or 6. "Articles that contain riot control substance without explosives components are classified as Class 6, Division 1."[42] All other ammunition and explosive devices are delineated Class 1 and are divided into one of the following Divisions based on the severity of their reactions during the Final Hazard Classification testing:[43]

1. Mass-detonating (Division 1)
2. Non-mass detonating fragment producing (Division 2)
3. Mass fire (Division 3)
4. Moderate fire-no blast (Division 4)
5. Very insensitive explosives (Division 5)
6. Extremely insensitive ammunition (Division 6)

Ammunition and explosives are divided into one of 13 different compatibility groups based upon their ability to "be stored together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident."[44] "The damage or injury potential of explosions is normally determined by the prevailing distance between the… [potential explosion site (PES)] and the [exposed site (ES)]; the ability of the [potential explosion site] to suppress blast overpressure, primary and secondary fragments, and debris; and the ability of the [exposed site] to resist explosion effects."[45] The quantity-distance relationships for a given facility will be determined by the type of structures in the compound, the hazard class/division of the items, and the overall net explosive weight being stored.

Therefore, our ability to store munitions within and outside the continental US are based upon these quantity-distance criteria driven by the available storage facilities and the surrounding terrain/structures, the type of munitions and their associated hazard class/division, and the overall net explosive weight. However, given that the majority of our weapon systems are classified 1.1 munitions, most of our facilities are net explosive limited versus volume limited as would be the case for reduced hazard classifications munitions without obtaining a quantity-distance waiver. Making the issue worse, if you mix any of the other ammunition and explosives class/divisions with a 1.1 munition, all of the items in the storage facility must be treated as 1.1 munitions.

Thus, to realize increased storage density capability, the Air Force must pursue reduced hazard classification munitions.

II. Compelling Arguments

The second objective of this paper is to review the compelling arguments for achieving or not achieving an insensitive munitions compliant inventory. To achieve this objective, the following paragraphs will assess the law and the associated process of implementing the insensitive munitions mandate, the changing world environment and its impact on Air Force munitions, and the operational benefits and detriments of transitioning to an insensitive munitions compliant inventory. Based on these assessments, the subsequent section will provide conclusions along with a recommended way forward for the Air Force with respect to the insensitive munitions mandate.

"The Law"

The Air Force first acknowledged insensitive munitions as a requirement when it endorsed the March 1996 version of DOD Regulation 5000.2-R which included the following statement in paragraph 4.4.8:

> "Unplanned Stimuli. All munitions/weapons shall be designed to withstand unplanned stimuli and use materials consistent with safety and interoperability requirements. Requirements shall be determined during the requirements validation process and shall be updated as necessary throughout the acquisition cycle for all acquisition programs. Interoperability shall be validated per Chairman Joint Chiefs of Staff (CJCS), Memorandum of Procedure (MOP) 77, to include insensitive munition policies. Waivers for munitions/weapons, regardless of Acquisition Categories (ACAT) level, shall require validation by the Joint Requirements Oversight Council (JROC)."[46]

This requirements document in combination with the Chairman Joint Chiefs of Staff, Memorandum of Procedure (i.e., CJCS MOP 77 which later became CJCS Instruction (CJCSI) 3170.01, "Joint Capabilities Integration and Development System") ensured that insensitive munitions would be addressed in every munition/weapon system program, whether in initial development or production, regardless of its acquisition category level. If the item failed to pass its insensitive munitions criteria, the program would have to process an insensitive munitions waiver through its Service IM Executive Officer (i.e., Office of the Assistant Secretary of the Air Force for Acquisition, Director Global Power Program (SAF/AQP) for the Air Force) and the Joint Requirements Oversight Council (JROC) for approval to proceed with development/production. As a result of acquisition reform, these documents have gone through several revisions streamlining our requirements process. However, DOD maintained an insensitive munitions requirement in their top-level documents. The current version of DOD Directive 5000.1, Appendix E, paragraph E1.23 states: "All systems containing energetics shall comply with insensitive munitions criteria."[47] Also, the current version of Chairman Joint Chiefs of Staff Instruction, "Joint Capabilities Integration and Development System" requires the Joint Staff Logistics Directorate (i.e., J-4) to "perform munitions insensitivity certifications and will process insensitive munitions waiver requests as required."[48]

In parallel with the evolution of the insensitive munitions requirement in the DOD documents, Congress incorporated an insensitive munitions requirement into law in 2001. The law states: "The Secretary of Defense shall ensure, to the extent practicable, that munitions under development or procurement are safe throughout development and fielding when subjected to unplanned stimuli."[49] Reflecting their interest in insensitive munitions, the law included an annual requirement for DOD to report to Congress on their progress toward achieving an insensitive munitions compliant inventory.

While a number of smaller items have received insensitive munitions certification, the only major weapon system in the Air Force (or Navy for that matter) that has successfully completed all of its insensitive munitions tests and is fully certified is the Joint Air-to-Surface Standoff Missile (JASSM) as tested inside of its storage container. Thus, these requirements have generated a backlog of waivers and a tremendous need for the development of insensitive munitions technologies to enable the various munitions/weapon systems to comply with the insensitive munitions requirements or at least make incremental improvements in their insensitive munitions characteristics. Recognizing the potential impact of such a backlog and the need to take a more strategic approach, The Under Secretary of Defense, Acquisition, Technology, and Logistics (OUSD (AT&L)) Director issued a memorandum, 21 Jul 2004, requiring the Services to develop an IM Strategic Plan by February 2005. These plans are to be signed by the appropriate Acquisition Executive and Comptroller thus conveying a commitment of the Service to the execution and funding of the plan. The Services' plans will facilitate the Joint Requirements Oversight Council's insight into their overall strategy for transitioning toward a fully compliant insensitive munitions inventory when reviewing a waiver request on a particular munition/weapon system. In addition, the memorandum established the foundation to allow the Services to submit a consolidated waiver request covering multiple munitions/weapon systems allowing them to focus their limited resources on their highest priority insensitive munitions shortfalls.

The overall insensitive munitions process has been facilitated by the DOD IM Integrated Product Team, which was established in 1997 to "address IM policies, requirements, programs and issues, both foreign and domestic."[50] In addition, the Joint Services Insensitive Munitions Technical Panel was established in May 1999 as an advisory panel to the policy and requirements group. This panel provides insensitive munitions technical advice and assistance with the associated waiver process.

Given the statutory requirement for insensitive munitions, the proposed changes allowing the Services to submit a consolidated waiver request will reduce the pain associated with a noncompliant inventory. Also, the newly implemented requirement for each Service to develop and submit annual Insensitive Munitions Strategic Plans will facilitate the Services' effort to transition toward an insensitive munitions compliant inventory. However, the underpinning question is what priority does insensitive munitions have or should have in relationship to all of the other unfunded or under-funded DOD requirements?

Changing World Environment

To understand our changing environment as reflected by the major changes in the United States' 2002 National Security Strategy, one must first reflect on the evolving international scene over the last few decades. At the end of World War II, the United States and the Soviet Union emerged as the two dominant states. The ensuing Cold War began the age of nuclear deterrence, large standing forces to fight a symmetrical enemy, and an arms race that ultimately led to the economic demise of the Soviet Union in the late 1980s to early 1990s. When the Soviet Union dissolved into multiple smaller states in 1991, the US became the world's only superpower. However, during the Post-Cold War era, the US was slow to change its strategy from preparing for the next symmetrical adversary to one that addresses the escalation of terrorist attacks around the world. To understand the magnitude of our changing environment on insensitive munitions, this section will assess the increased terrorist threat as evident from the escalation of terrorist activities, their impact on our points of vulnerability, and the potential impact of the changing and ever evolving world of technology.

Increased Terrorist Threat.

During the 1990's our threat environment changed from a symmetrical state enemy to an asymmetrical, elusive, non-state adversary. According to the Office of Historian, Bureau of Public Affairs there were 246 terrorist incidents from 1961 to the end of 2003.[51] These terrorist incidents include events from around the world and range from the first US aircraft hijacked in May 1961 that ended without violence to the catastrophic events of September 11, 2001. This data, as summarized in Table 3, reflects how the terrorist threat has escalated with approximately 30 percent of the recorded events occurring during the 1990's thus doubling the rate of the previous decade. In fact, the four-year period from 2000 through the end of 2003 accounts for almost 48 percent of the total number of reported incidents since 1961 portraying a grim outlook on our efforts to fight terrorism.

Table 3. Historical Trends of Terrorist Activities

	1960s	1970s	1980s	1990s	2000s
Number of Significant Terrorist Incidents Recorded	4	15	35	75	117
Percentage of Incidents Recorded from 1961 through 2003	1.6%	6.1%	14.2%	30.5%	47.6%

The proliferation of terrorist incidents and the impact of 9/11 thrust the US into its current Global War on Terrorism and provided the stimulus for the revolutionary changes in the US's 2002 National Security Strategy. For the first time, the United States delineated a preemptive strategy that it deemed necessary to protect its vital interests against rogue states and terrorist organizations. In response to 9/11, "the initial military objectives of Operation Enduring Freedom, as articulated by President George W. Bush in his September 20th, [2001] address to a

Joint Session of Congress and his October 7th, [2001] address to [the] country, [included] the destruction of terrorist training camps and infrastructure within Afghanistan, the capture of al Qaeda leaders, and the cessation of terrorist activities in Afghanistan."[52] Subsequently, the preemptive posture of the US led to Operation Iraqi Freedom.

Increased Munitions Vulnerabilities.

The US's overwhelming military victory in both Operation Enduring Freedom and Operation Iraqi Freedom was a wakeup call to our enemies around the world including future peer or near-peer state competitors, regional powers, and sub-state, failed-state, or non-state actors. Thus, we should expect our future enemies to utilize guerrilla warfare tactics against our weak-links. According to the famous Chinese military theorist on guerrilla warfare, Mao Tse-tung, "the enemy's rear, flank, and other vulnerable spots are his vital points, and there he must be harassed, attacked, dispersed, exhausted and annihilated."[53] Therefore, our changing environment dictates that we must reassess our vulnerabilities associated with civilian targets in the homeland as well as those associated with engaging our enemies on foreign battlefields.

With respect to munitions vulnerabilities, this reassessment must take into consideration their entire life cycle. Their vulnerabilities can be broken into two categories: logistical (i.e., storage, handling, and transportation) and operational phases. The operational aspects will be covered in the section dealing with the operational impact of insensitive munitions. With respect to logistics, insensitive munitions obviously would improve the handling safety aspects of the weapon system but would not necessarily change their vulnerability to attack from an enemy. While a detailed study of the vulnerabilities associated with munitions storage and transportation is beyond the scope and classification of this essay, the following strategic level concerns should be considered in the overall assessment of potential insensitive munitions benefits.

Munitions storage, for the purposes of this high-level vulnerabilities assessment, includes production facilities where large quantities of munitions are accumulated for shipment, munitions depots, and demilitarization facilities both within the continental US and overseas locations. For munitions storage facilities in compliance with their quantity-distance criteria, based on the type of structures in the compound, the hazard class/division of the items, and the overall net explosive weight being stored, insensitive munitions do not necessarily represent a decrease in vulnerability but they should represent a decrease in the consequence of an unintended event. The level of security for each of these sites would be their primary vulnerability. If attacked, insensitive munitions would potentially reduce the total number of weapons/storage structures lost and/or damaged. In addition, as noted previously, reduced hazard classifications could drastically improve the storage capacity of existing facilities yielding a cost-avoidance for maintaining existing storage facilities/structures or reducing the number of future storage facilities/structures needed.

The highest vulnerability aspect of munitions related logistics is transportation. To begin with, three of the major incidents (i.e., Tobar, NV, Roseville, CA, and Benso, AZ) in Table 2 involved rail transportation accidents in the US. In addition, the incident at Port Chicago Naval Magazine in California involved the loading of merchant ships with munitions in support of World War II. Due to the magnitude of this event, it is worthy of a brief review. On 17 July 1944, two merchant ships (*E.A. Bryan* and *Quinault Victory*) were in port being loaded. At the time of the incident, the ships had been loaded with

> "high explosive and incendiary bombs, depth charges, and ammunition – 4,606 tons of ammunition in all… [In addition, there were] another 429 tons [of munitions on the pier]… Within six seconds… [of the first explosion,] the contents of the *E.A. Bryan* detonated in one massive explosion… The largest remaining pieces of the 7,200-ton ship were the size of a suitcase. A plane flying at 9,000 feet reported seeing chucks of white hot metal 'as big as a house' flying

> past. The shattered *Quinault Victory* was spun into the air. Witnesses reported seeing a 200-foot column on which rode the bow of the ship, its mast still attached. Its remains crashed back into the bay 500 feet away. All 320 men on duty that night were killed instantly. The blast smashed buildings and rail cars near the pier and damaged every building in Port Chicago. People on the base and in town were sent flying or were sprayed with splinters of glass and other debris. The air filled with the sharp cracks and dull thuds of smoldering metal and unexploded shells as they showered back to earth as far as two miles away. The blast caused damage 48 miles across the Bay in San Francisco."[54]

Although the damage caused by this horrific accident was tremendous, the causality and injury rate would have been much greater if the incident had occurred during normal business hours with the dock area and surrounding town bustling with people.

Another example of catastrophic results from a munitions related port accident is the Halifax, Nova Scotia explosion on 6 December 1917. Halifax was Canada's primary port city supporting

> "the movement of war ships carrying troops, relief supplies, and munitions… [for World War I. The French ship *Mont Blanc* who was entering the port] awaiting a convoy to accompany her across the Atlantic… [collided with the Belgian relief ship *Imo* who was departing the port. The *Mont Blanc* had] "35 tons of benzol, 300 rounds of ammunition, 10 tons of gun cotton, 2,300 tons of picric acid (used in explosives), and 400,000 pounds [or 200 tons] of TNT… [The collision caused a fire in the lower deck that propagated to an explosion in 20 minutes. The] *Mont Blanc* disintegrated in a blinding white flash, creating the biggest man-made explosion before the nuclear age… Over 1,900 people were killed immediately; within a year the figure had climbed well over 2,000. Around 9,000 more were injured, many permanently; 325 acres, almost all of north-end Halifax, were destroyed."[55]

Thus, even though there was less net explosive weight involved at Halifax versus the Port Chicago incident, the devastation the worse.

The difference in destruction and number of causalities and injuries between these two incidents is based on the physical layout of the surrounding harbors, their towns, and the time of day of the incident. For instance, the causality and injury rate for Halifax was significantly higher due to the proximity of the harbor to the town plus the accident occurred during the normal morning work hours. Making matters worst, "there were about 20 minutes between the collision and the [actual] explosion at 9:05 [am. This] was enough time for spectators, including many children, to run to the waterfront to watch the ship burning."[56] In addition, others gathered at their windows which resulted in many of the survivors sustaining eye damage when the blast shattered the majority of the glass in the town. On the other hand, the Port Chicago incident occurred at about 10:19 pm when the dock area was sparsely populated except for the evening shift.[57] Utilizing a damage survey conducted by the Navy in July 1944, the damage radii at Port Chicago is estimated in today's terms in **Error! Not a valid link.**.

Table 4. Port Chicago Damage Radii

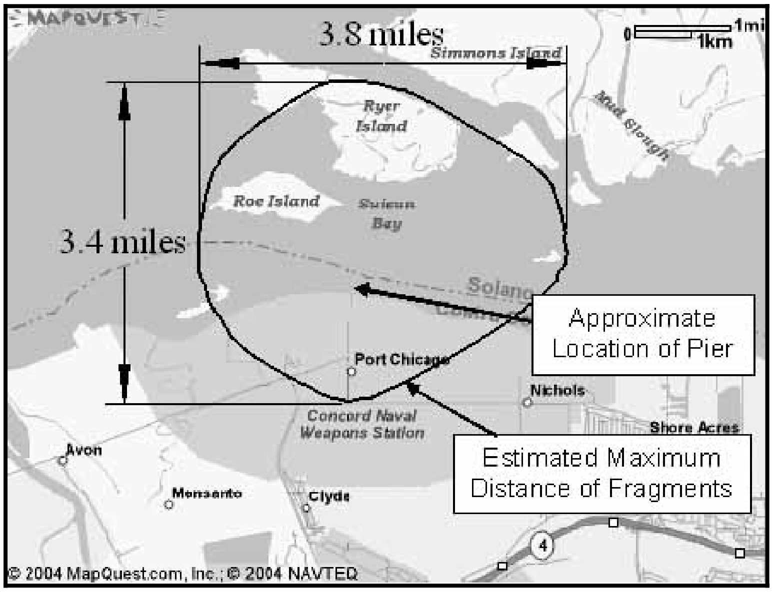
Mishap Classification	Classification Definition[58]	Damage Radii Probability[59]
Type A	Mishap cost $\geq$ \$1M, fatality or permanent total disability	Certain up to 1,000 ft with instances up to 10,000 ft
Type B	\$200K $\leq$ Mishap cost < \$1M or a permanent partial disability	Instances at 3,000 ft up to 5,000 ft
Type C	\$20K $\leq$ Mishap Cost < \$200K or an injury causing loss of time from work	Nearest 3,000 ft and farthest 6,000 ft

Because of the overlap in types of destruction, the initial Navy survey concluded the radii to be approximately 2,000 feet for Type A, 3,000 feet for Type B, and 5,000 feet for Type C mishap damage. Nevertheless, "the buildings of the Naval Magazine were damaged extensively; sporadic damage to structural members of buildings was proven up to 13 miles – Suval [Railroad] Station, California; plate glass was broken up to 35.5 miles – Petaluma, California; and a legitimate claim for plaster damage was reported at 48 miles – Calistoga, California. The devastation at the pier can be seen in **Error! Not a valid link.** and the remains of the USS Quinalt Victory can be seen in **Error! Not a valid link.**.[60] Of the 320 deaths, there were only 81 bodies recovered and of those recovered only 30 could be identified with the technology available in the early 1900's. The deaths outside the immediate pier area were primarily caused by the fragments produced from the blast. Based on Peter Vogel's "The Last Wave From Port Chicago," **Error! Not a valid link.** provides a rough estimate of the maximum fragment radius from the Port Chicago Pier.[61] It should be noted that the explosion not only created an ellipsoid crater approximately 600 feet by 300 feet in the sea floor directly under the *E.A. Bryan* but also created a tidal wave. The combination of the blast wave, the fragments, and this tidal wave caused total loss of some ships that were in the near-by channel up to approximately 4,200 feet away.[62]

Figure 1. Port Chicago Pier Area Day After Explosion

Figure 2. USS Quinalt Victory Flipped and Thrown 500 Feet

Figure 3. Estimated Fragment Radius



Approximate Location of Pier

Estimated Maximum Distance of Fragments

Historically accidental environments have caused these types of transportation incidents. Although with the increased worldwide animosity against Americans along with our enemies searching for our weak-links on and off of the battlefield, munitions related transportation poses an extremely vulnerable target. With today's asymmetrical threat, a well placed explosive laden vehicle or even a rocket propelled grenade (RPG) attack could provide the stimulus for our next major explosive storage or transportation incident. The horrific results from our next incident could be magnified based on the attack occurring during a busy time exposing more people to the explosive event, since the impetus would be carefully planned by our enemy for maximum intentional harm instead of an accident with unintended consequences.

This issue is compounded by the US's involvement in regions where there is limited forward basing and thus limited forward stockpiles of munitions to conduct a war. For example, "during OPERATION DESERT SHIELD, the Army's 22d Support Command reported the continuous presence of 30,000 tons of munitions at the port of Al Jabayl, Saudi Arabia"[63] (Reference **Error! Not a valid link.**).[64] Considering the magnitude of the damage at Port Chicago with a little over 5,000 tons and Halifax with even less explosive materials, one can only imagine the devastation to the Al Jabayl's port and its surrounding structures and population that would have been associated with even a partial detonation of this amount of explosives.

Figure 4. Crowded Dock at Al Jubayl

To make things worse, "Al Jubayl was well publicized as a major logistics port"[65] thus highlighting our vulnerability. In fact, "the potential for a munitions disaster during the buildup was so obvious that it was highlighted by the CBS television news program 60 Minutes."[66] During the first Gulf War 88 Scuds were fired against Al Jubayl, one of which "landed 150 meters from the pier."[67] With an estimated circular error probability of 1,500 meters, the Scuds did not pose a particular high-risk threat. Nonetheless, it highlights the need for a reassessment of our munitions transportation operations plan and associated force protection for these transit operations especially at critical nodes.

The terrorist attack on the USS COLE, 12 October 2000 in the port of Aden, Yemen further highlights the vulnerability of our ships in foreign ports. This was a routine refueling stop "when a small boat laden with explosives was detonated beside the ship, blasting a hole in its side."[68] This incident resulted in the death of 17 Sailors and 39 injuries. After 14-months and an approximate cost of about $250M in Fiscal Year 2002,[69] the USS COLE returned to the Fleet. However, if the terrorist attack had struck the hull adjacent to a munitions storage area, the damage and loss of life for both the USS COLE and Aden, Yemen would have been much worse and the international political ramifications would have been immense.

Impact of Future Weapons Technology.

Considering the magnitude of the effort in terms of both fiscal and developmental time that will be required to achieve a fully compliant insensitive munitions inventory, one must consider the future of weapon system technologies to determine where to expend the limited resources available to achieve insensitive munitions compliance. The Under Secretary of Defense, Acquisition, Technology, and Logistics (OUSD (AT&L)) initiated this process by requiring each Service to develop an IM Strategic Plan starting in 2005 that will prioritize their investments toward meeting the insensitive munitions mandate. As typical for these types of plans, the IM Strategic Plan will project their research, development, test, and evaluation (RDT&E) and procurement profiles, with respect to insensitive munitions, over the Future Years Defense Program (FYDP) which is the DOD's 6-year planning budget. Thus, the IM Strategic Plan will be an extremely valuable tool in prioritizing the near-term objectives for achieving insensitive munitions compliance. Although, one must also assess the impact of future weapons technology that might negate the need for insensitive munitions and determine whether or not the funding spent in the short term for insensitive munitions will be overcome by events before the inventory can become insensitive munitions compliant. This assessment must include directed energy technology that has been claimed to have the potential to "revolutionize military affairs in the future."[70] Thus, in an effort to determine if directed energy weapons should impact how we approach the requirements of insensitive munitions, this section will briefly look at their current status and projected timeline to field large quantities of weapon systems.

Lasers and high-power microwaves have been around for a long time. However, "recent scientific advances now enable the production of lethal lasers and high-powered microwaves."[71] For instances, the Air Force Research Laboratory (AFRL) scientists at the Directed Energy Directorate's Starfire Optical Range at Kirtland, AFB have developed adaptive optics techniques which allow them to overcome the atmospheric distortions that drastically limit the projected power of a laser.[72] This scientific breakthrough allows the Starfire Range with its 1.5m telescope to create artificial beacons (i.e., artificial stars) 60 miles above the earth's surface. Another example is the Air Force's Airborne Laser (ABL) Program that utilizes 100kW-class Chemical Oxygen Iodine Laser modules "to create an airborne, megawatt-class chemical laser for theater ballistic missile defense… The [Airborne Laser's] multi-megawatt systems are advertised as being able to destroy missiles at distances of over 200 nautical miles (370km)."[73] With these scientific advancements on the available power, at least for the larger platforms, the question becomes how long will it take to weaponize this technology?

According to the trends developed by the author of *Directed Energy Weapons on the Battlefield*, "the technology will exist to field tactically significant lasers on small to medium sized aircraft, and on large ground vehicles by 2025."[74] In addition, he forecasts that large ground fixed directed energy sites will play a major role in a country's defense by 2025. For this technology to have the effect on the battlefield that is proposed by the author, the remainder of the system's integration technologies will have to be developed and incorporated into the weapon. For example, real-time target detection and tracking capability will have to be enhanced to take advantage of these directed energy systems. Also, the author does not address the countermeasures that could potentially reduce the effects of these systems. Therefore, even though directed energy weapons are the way of the future, they have a long way to go to replace our entire inventory of high-explosive munitions.

To assess the development cycle for directed energy weapon systems, one can look at the advances in conventional munitions technology. The trend over the last decade for munitions in the Air Force has been miniaturization. Miniaturization started with individual components/ subsystems such as guidance and control inertial guidance systems and fuzing components in the 1970s and 1980's. This miniaturization of components and subsystems led to advanced development technology demonstrations like the Low Cost Autonomous Attack System (LOCAAS)[75] and the Miniaturized Munition Technology Demonstration (MMTD) Program[76] in the 1990's. The LOCAAS is a miniature, autonomous… munition… [equipped with a multimode warhead,] capable of broad area search, identification, and destruction of a range of mobile ground targets"[77] and the MMTD was a "72 [inch] long, 6 [inch] diameter, seekerless, 250 [pound] penetrator with an integrated [Global Positioning System/Inertial Navigation System (GPS/INS)] navigation system."[78] The next generation of miniaturized munitions technologies for persistent area dominance and multi-warhead long-range cruise missiles are currently under development. Thus, even if the component and subsystem technologies are relatively mature, it historically still takes more than a decade to field a new weapon system.

The Small Diameter Bomb (SDB) Program is a good example. The technology was initially developed at the Air Force Research Laboratory, Munitions Directorate under the Miniaturized Munition Technology Demonstration (MMTD) Program, 1996 – 2001, "whose purpose was to design and demonstrate a small, highly accurate, air-to-surface weapon capable of penetrating all but the most hardened targets."[79] The initial laboratory program culminated with an extremely successful live flight test with the technology transitioning to the Small Diameter Bomb program office in 2001. At this point, the technology underwent a two-year Concept Advanced Development phase with competing prime contractors prior to entering the System Design and Demonstration phase in 2003. The initial operational capability is projected to be in 2006, ten years after the laboratory technology program was initiated. Thus, even though the Small Diameter Bomb Program is one of the premier programs under the new Agile Acquisition initiative in DOD,[80] the technology will still have been ten years in development before it reaches the inventory not including any previous component or subsystem exploratory technology development time that fed the Laboratory's Miniaturized Munition Technology Demonstration program.

Therefore, even though the author of *Directed Energy Weapons on the Battlefield* predicts directed energy weapons will be deployed in significant quantities by 2025, the vast majority of our systems will still rely on conventional high-explosive munitions. Once the directed energy weapons have been developed and initially deployed on special platforms, it will take decades, if ever at all, before our inventory weapon system platforms will be retrofitted with this technology unless it is via an external pod which would require the next generation of miniaturization of the directed energy systems. Therefore, our inventory of tactical aircraft including the F-15, F-16, F-117, F/A-22, and even the earlier models of the F-35 will be heavily dependent on conventional high-explosive munitions until 2025 and beyond.[81]

Given the timeline of these platforms, the Small Diameter Bomb was designed to support the F/A-22, F-35 Joint Strike Fighter (JSF), Unmanned Combat Air Vehicle (UCAV), and Predator B[82] and will be in the inventory for many decades. From an insensitive munitions perspective, the Small Diameter Bomb program incorporated IM into their initial requirements documents. Also, based on the size of the munition, the quantity of explosive materials, and the technology available for smaller unitary warheads it has a good chance of being insensitive munitions compliant.

There are at least two other aspects of directed energy weapon systems that need to be considered. With the defensive edge that ground based directed energy systems will have due to their available power and thus their projected power, it would be easy to postulate that even when directed energy systems are widely available for our larger platforms a need will still exist for long-range, miniaturized missiles with multiple high-explosive warheads to employ as our first wave of attack on enemy defenses. The second aspect that needs to be considered is whether or not these systems produce a unique stimulus, which could be used to initiate high-explosive munitions, that is not covered in the current spectrum of insensitive munitions test criteria. This exposure could be the results of an accident or an intentional use by our asymmetrical enemies. Thus, during the decades of transition to directed energy weapon systems they will have to be assessed to determine if they create another unplanned stimulus for which conventional high-explosive systems will have to be assessed in order to maintain their insensitive munitions characteristics.

Operational Impact

Part of the perceived concern with transitioning to an insensitive munitions compliant inventory is predicated on the fear that they will not perform as well as our current inventory assets. Thus, this section will briefly discuss the impact of insensitive munitions criteria on weapon system cost, performance, and effectiveness. But first it will discuss the political risk associated with complying or not complying with insensitive munitions requirements as they may impact our ability to achieve our military objectives and the impact of our technology revolution on the need for insensitive munitions compliance.

Political Risk.

According to Carl Von Clausewitz, “war is not merely an act of policy but a true political instrument, a continuation of political intercourse, carried on with other means.”[83] Therefore, it only makes sense to evaluate the political risk associated with not achieving IM compliance and how they may affect our ability to achieve our political objectives through military means. The political risk associated with a potential incident can be assessed from three perspectives: (1) US populace support; (2) Coalition support; and (3) International community, especially the country where the potential incident would occur.

With respect to the US populace support, the political risk is associated with the risk of an incident of sufficient magnitude occurring that would highlight the lack of IM compliance onto the radar screen of the US media. Thus, until a major incident occurs either within the continental US or overseas involving US interests, the perceived political risk to the US populace is relatively low.

For potential Coalition partners, the perceived lack of IM compliance would be seen as just another incident of US hegemony where we ratify an international standardization agreement to improve our IM compliance, not to mention the US federal mandate, but fail to take prudent action to pursue an acceptable level of IM compliance. However, this issue would probably not be elevated unless there was an incident where improved IM characteristics would have reduced the catastrophic results. Thus, similar to the US populace, until a significant incident occurs involving US assets overseas, the perceived political risk of Coalition partners is relatively low.

IM compliance or our attempts to improve IM characteristics for our munitions is definitely below the radar screen of the international community and will probably remain there until an event occurs. At this point, as with the US populace, there is a high probability that the media would ultimately raise the issue about our lack of pursuing IM compliance and how much better or less severe the incident would have been if the US had only implemented their own laws as well as their commitment to the North Atlantic Treaty Organization Standardization Agreements. However, until a significant incident occurs, especially within their own borders, the risk from the international community is extremely low.

This does not mean that the overall political risk of not achieving an IM compliant inventory is acceptable. Peter F. Drucker, a top business philosopher, emphasizes this philosophy in his axiom "management is doing things right; leadership is doing the right things."[84] To follow this philosophy, our senior leadership needs to either make a commitment to implement IM to the degree feasible within our DOD fiscal constraints or they need to change the law and officially notify the international community to the degree that we will abide by the international IM Standardization Agreements. If the commitment is to pursue IM compliance, then the leadership needs to ensure that the resources applied would be considered sufficient and justifiable in hind site during an incident investigation. Otherwise, the political risk from all three perspectives would be considered high to extremely high depending upon the magnitude of the next munitions related incident.

Impact of Technology Sophistication.

The evolution of precision-guided munitions since they were first introduced in the Vietnam War is a prime example of the impact that technology has had on our warfighting capability as well as our doctrine. "The Gulf War [in 1991] was America's first serious war after Vietnam…

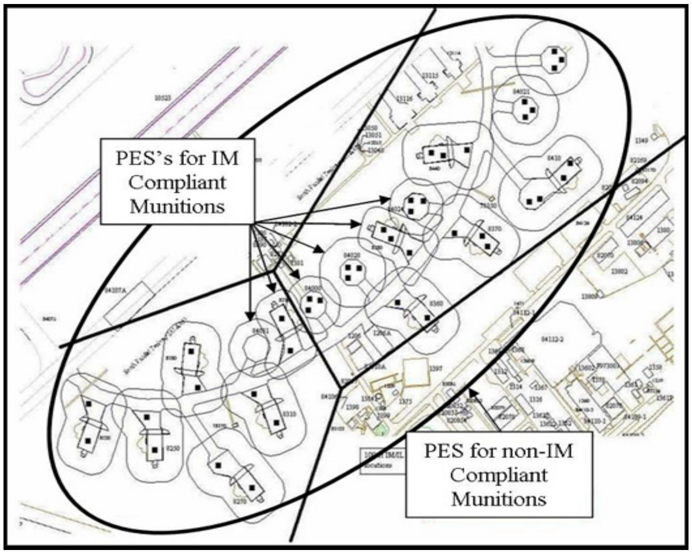
[It was a showcase for US technological superiority. However,] only five percent of the bombs dropped were precision-guided… In Afghanistan [during Operation Enduring Freedom] the equivalent figure was about 60 percent."[85] This technology sophistication comes at a price both in additional unit cost as well as fewer assets procured. Therefore, the operational impact of a munitions related incident would be magnified. These losses would account for a higher percentage of our munitions being destroyed but more importantly the potential exists for a single munitions accident to destroy a high percentage of our more advanced aircraft.

To understand the potential ramifications of our technology sophistication, the following notional flight line scenario is offered.[86] Figure 5 provides the layout of the notional airfield. The example includes a notional mix of F-18, F-16, and F-117 aircraft where each individual aircraft is denoted by a small black square. For the purposes of this example, the aircraft parking area is divided into two sections. The F-117's are parked in the lower section and a mix of F-18 and F-16 are parked in the upper section. It is extremely important to note that the potential explosion site (PES) circles for IM compliant munitions assume that the items also achieved a reduced hazard classification similar to Joint Air-to-Surface Standoff Missile (JASSM).[87] Based on the limited operating space available for US forces at overseas airfields, the example takes a realistic view in that individual aircraft and their associated munitions could not be spaced far enough apart to establish themselves as individual potential explosion sites. Thus, based on the spacing reflected in Figure 5, the entire grouping of 42 aircraft would be exposed to a single accident involving a non-IM (i.e., a hazard classification/division munition of 1.1) item.

In reality, the potential explosion site for the non-IM compliant scenario not only encompasses all of the aircraft but it also encompasses a large portion of the base as well. This situation results from processing quantity-distance waivers to fit the given operational circumstances. In fact, the example provided would have required over 100 quantity-distance waivers to meet the operational requirements. However, with a fully compliant IM inventory, the potential explosion site is limited to the number of aircraft on a single parking apron and the quantity-distance waivers are drastically reduced for the given notional scenario.

Even though all 42 aircraft depicted in this example may not be completely destroyed in a non-IM incident, the probability of destroying or damaging all 42 aircraft is relatively high for a major accident. This is compared with a maximum of two F-117 or a maximum combination of four F-18 and F16 aircraft based on the location of the IM compliant incident. Thus, based on this notional scenario, a single non-IM compliant major accident at some of our forward operating locations would be devastating to the operational tempo. In addition, a major accident as described would create a tremendous percentage loss for our more specialized aircraft like the F-117. These losses do not even account for the devastation that would occur at the local operating location or the human toll in killed and injured which may be more difficult to replace than the aircraft and whose loss would have a higher political cost.

Figure 5. Notional Flight Line Operations.



Impact of IM on Weapon System Cost/Effectiveness.

A detailed review of the impact of weapon system cost and effectiveness due to the incorporation of IM requirements is beyond the scope and classification of this essay. However, there are at least three top-level considerations that should be considered by senior leadership when determining how much of their limited resources should be utilized in pursuing an IM compliant inventory. These considerations include: (1) how much IM compliance will cost in developmental resources and reoccurring production costs; (2) will IM degrade the weapon system performance/effectiveness; and (3) due to its insensitivity, will IM increase the munitions systems' failure rate.

The first consideration must be broken into two categories: new developmental weapon systems and reprocurement of existing legacy weapon systems. Based on the language in the requirements document discussed under "The Law" section above, weapon systems under development will address IM as part of their system level requirements. The Joint Air-to-Surface Standoff Missile (JASSM) is a prime example where the program office integrated IM requirements into their overall weapon system design philosophy. The cost of incorporating relatively mature technologies into this missile system including "vents in the [warhead's] aft closure… [along with the development of] a proprietary Thermally Reactive Retaining ring"[88] is estimated to be less than five percent of the development cost. As with most System Design and Demonstration programs, JASSM adapted and incorporated technologies that had been developed in the Service laboratory and thus is not included in the overall program office developmental cost for this missile system. In this case, the program office selected an explosive fill, AFX-757, previously developed by the Air Force Research Laboratory, Munitions Directorate due to "its increased blast energy and improved insensitivity relative to tritonal"[89] which has been historically used in the Air Force's large unitary warheads. To manage its overall budget, the program office incorporated cost as a major design requirement in parallel with all of its technical requirements including IM. As a result, "each missile will cost us under $300,000, well below our requirement of no more than $400,000 per unit, and the… Cost Analysis Improvement Group estimate of $700,000. Thus, utilizing the Joint Air-to-Surface Standoff Missile (JASSM) as an example, if IM is incorporated into the original design requirements, there would appear to be a relatively minor cost associated with achieving IM compliance when mature technology is available.

The second category for the first consideration is reprocurement of existing inventory weapon systems which contain the vast majority of the items being reviewed for IM compliance. For those weapon systems that do not meet the IM compliance requirements or those which have never been tested or assessed against the IM criteria, IM is a more costly endeavor. The cost of achieving IM can run anywhere from a few hundred thousand to tens of millions of dollars depending on the particular munitions design, the availability of mature IM technologies that can be applied to the particular munitions design, the number of IM and/or final hazard classification tests that need to be reaccomplished, the magnitude of the integration effort, and any additional system level performance and/or safety tests required for the proposed design modifications. In fact, due to the limited IM technology base, most of these items end up only achieving incremental improvements toward IM compliance. This is why the Under Secretary of Defense, Acquisition, Technology, and Logistics' (OUSD (AT&L)) IM Strategic Plan is essential in prioritizing where the Service's limited resources will be expended.

The second top-level consideration is whether or not IM will degrade the weapon system performance or effectiveness. Based on the definition stated previously, the internationally accepted definition of IM is "Munitions which reliably fulfill their performance, readiness and operational requirements on demand, but which minimize the probability of inadvertent initiation and severity of subsequent collateral damage to the weapon platforms, logistic systems and personnel when subjected to unplanned stimuli." Thus, the issue of degraded performance is truly a matter of the system design trade studies to ensure an acceptable level of insensitive munitions compliance is achieved while meeting the overall performance and operational effectiveness requirements. When retrofitting munitions items to incrementally improve their insensitive munitions characteristics, the requirement should be no system performance degradation with a goal to enhance performance while improving the insensitive munitions characteristics. This may seem counterintuitive, however, AFX-757 which was the fill selected for use by the Joint Air-to-Surface Standoff Missile (JASSM) was originally designed for the Miniaturized Munition Technology Demonstration 250-pound warhead to provide increased blast performance with increased penetration survivability for the smaller warhead size. This does not mean that you can achieve increased insensitivity while increasing all of the performance attributes of an explosive fill. For example, explosive fills are designed based on their intended use and the associated target vulnerabilities to provide a certain level of gurney energy (i.e., ability to throw fragments) and blast energy. Although, for a particular weapon system design, the explosive fill can usually be tailored to provide the required energy while obtaining the maximum insensitivity for the particular formulation. Therefore, concerns over degraded performance with the incorporation of insensitive munitions characteristics are a matter of system level requirements prioritization. Due to the lack of a solid insensitive munitions technology base and the accepted IM definition that acknowledges the need to achieve weapon system operational performance criteria, the insensitive munitions mandate process is essentially being implemented via incremental improvements.

The final top-level consideration concerns the potential for increased dud rates due to the insensitivity of the IM compliant weapon systems. This is a systems integration issue and if designed and tested properly insensitive munitions compliance should not affect the system level dud rate. There are standard explosive train propagation tests that have historically been conducted to predict the reliability of a weapon system design even prior to the consideration of insensitive munitions characteristics. Even though the selection of the explosive materials utilized will be governed by the overall weapon system insensitive munitions considerations, the explosive train design must still meet the predicted reliability for the weapon system to meet its operational requirements.

III. Conclusions

Based on today's fiscal constraints and growing budget deficits, the fact that only one major Air Force weapon system is currently IM compliant, the operational shelf-life of our existing weapons, and the lack of readily available insensitive munitions enabling technologies, it is unrealistic to expect to achieve insensitive munitions compliance for all of our weapon systems within the next twenty years. Nonetheless, with the changing world environment, the US can not afford not to strive for incremental improvements in their inventory's insensitive munitions characteristics. There are at least three major environmental changes which dictate the pursuit of an insensitive munitions inventory. First, the implementation of our expeditionary force structure, versus previous overseas basing strategy, exposes more time-critical munitions transportation nodes due to the need to deploy large quantity of assets to 3rd world theaters of operation. The second major change is the increased threat from evolving international terrorist organizations, especially those with anti-American sentiments, whose tactics are not limited to the boundaries of the historical battlefields. Finally, the third reason for the need to pursue an insensitive munitions inventory revolves around the potential national and international political ramifications of a major non-IM related incident if the US is not making legitimate progress toward its federally mandated and internationally ratified insensitive munitions requirements.

The Under Secretary of Defense, Acquisition, Technology, and Logistics' (OUSD (AT&L)) initiated requirement for the Services to develop an IM Strategic Plan will forge the path in addressing this federally mandated requirement. In particular, once approved by the Joint Requirements Oversight Council, these IM Strategic Plans will define each Service's fiscal limit to the qualitative phrase in the insensitive munitions mandate "to the extent practicable."[90]

However, senior leadership must contemplate the strategic and tactical implications of insensitive munitions when deciding on these fiscal limits especially the increased risks associated with today's international asymmetrical enemies versus the vulnerabilities associated with non-IM compliant munitions.

There are three primary strategic implications which need to be considered when establishing the fiscal constraints for the pursuit of an insensitive munitions inventory. First, the political ramifications associated with the increased magnitude of a non-IM compliant US incident in a foreign country as well as in the US. This risk is magnified if the US is perceived as not attempting to comply with its own insensitive munitions mandated requirements and its commitment to the international Standardization Agreements it ratified. In today's coalition environment, the US can not afford to be perceived as an arrogant hegemon who did not take prudent steps toward the protection of its own and its allies' forces and the associated civilian populations. The second strategic implication is the impact of a non-IM compliant incident on the US military's operational capability. As our weapon system platforms and associated munitions become more technologically sophisticated, the trend is increased cost per unit item and thus fewer items in the inventory. Therefore, a single major accident may have a significant impact on our short-term operational capability for both equipment and experienced personnel with a huge price tag to recover the capability. The final primary strategic implication is the impact of our long-term transition to directed energy weapons on the short-term investments to achieve insensitive munitions compliance for existing high-explosive weapon systems.

In addition, there are three primary tactical implications which should be considered when establishing the fiscal constraints for the pursuit of an insensitive munitions inventory. First, the incremental transition to an insensitive munitions inventory should focus on achieving a reduced hazard classification. Secondly, to reduce the burden of assessing the IM characteristics of a weapon system, the insensitive munitions and hazard classification tests should be integrated together whenever practical. Finally, an insensitive munitions technology base should be development to facilitate incorporation of IM characteristics into existing as well as future weapon systems.

IV. Recommendations

The ultimate solution in achieving insensitive munitions compliance is a hardware system design issue. However, even with unlimited fiscal constraints, it will be a long time before the Services will achieve an insensitive munitions compliant inventory. Thus, based on our changing world environment, the Services need to assess their risk during this interim transitional period. According to General George Patton, "It is the duty of the military to foresee and prepare against the worst possible eventuality."[91] There are three primary areas of increased risk during this transitional period that needs to be taken into consideration. First, the increased risk from an asymmetrical threat needs to be incorporated into the operational risk management assessment when considering a quantity-distance wavier. After all, the unplanned stimuli for our next major munitions incident may very likely come from a terrorist attack. Next, the Services need to reassess logistical transportation vulnerabilities especially at "munitions logistics nodes, such as seaports, airfields, and munitions storage areas."[92] These vulnerabilities need to be controlled by procedures to minimize the potential catastrophic event if there were a munitions incident. For example, the flow of munitions needs to be controlled to prevent the buildup of an excessively large quantity of munitions at any one location. Finally, the third primary area of increased risk that needs to be considered is the force protection requirements at these vulnerable sites to reduce the probability of a terrorist attack being the stimulus for the next major munitions incident.

The IM Strategic Plans will not only identify the Service's prioritized strategy and associated funding for incrementally improving the insensitive munitions characteristics of their weapon systems they will become the impetus for an annual review at the Joint Requirements

Oversight Council (JROC). Thus, for the Air Force, these IM Strategic Plans should prioritize the Service's weapon systems based on an assessment which includes the following four factors. First, the assessment should consider the overall net explosive weight of each weapon system and the percentage of the total inventory's net explosive weight that the weapon system represents. Next, the potential consequences of a reaction due to an unplanned stimulus should be factored into the assessment. The third factor should include an assessment of the weapon system's acquisition timeline and associated opportunity for insensitive munitions technology insertion. Finally, the overall cost of inserting and qualifying the proposed technology versus the predicted improvement in insensitive munitions characteristics should be factored into the assessment.

Based on this assessment, funding should be reprogrammed to supplement existing technology programs to a level that at a minimum would be considered prudent under an accident investigation. Next, the results of the Strategic Plans should be incorporated into the Service's planning, programming, budgeting, and execution system to secure out year funding. The overall weapon system prioritization and associated funding levels projected in the IM Strategic Plan should be reviewed annually to ensure that the Air Force is expending its limited resources to achieve the greatest enhancement in insensitive munitions improvements.

As indicated previously, based on today's fiscal constraints and growing budget deficits, the fact that only one major Air Force weapon system is currently IM compliant, the operational shelf-life of our existing weapons, and the lack of readily available insensitive munitions enabling technologies, it is unrealistic to expect to achieve insensitive munitions compliance for all of our weapon systems within the next twenty years. For the majority of the weapon systems, the first step is the development of the insensitive munitions technology required to incrementally improve its IM characteristics. Thus, it is imperative that the Services work together in the pursuit of these technologies. Therefore, it is recommended that a separate funding line be included in the President's Budget specifically delineated for pursuit of insensitive munitions technology. This line should be managed by the Under Secretary of Defense, Acquisition, Technology, and Logistics' (OUSD (AT&L)) to facilitate the joint development of technologies to address the Services' highest priority insensitive munitions deficiencies.

In the author's assessment, based on the limited military and industrial expertise available in insensitive munitions research and development, a relatively small investment could go a long way in establishing the technology base required to enable weapon systems to incrementally improve their IM characteristics. The first year could be as little as two to three million dollars per Service building up to approximately five million dollars each over the Future Years Defense Program forecast for basic, exploratory and advanced development research. The development of the technology base should be focused on a joint prioritization of the individual Service's IM Strategic Plan. In addition, it should be acknowledged that these funding levels do not include the final weaponization and associated integration costs (e.g., environmental, safety, or flight certification revalidation requirements; insensitive munitions tests in all-up round; etc.). Although, the magnitude of these efforts for each weapon system versus the potential incremental improvements in insensitive munitions characteristics should be estimated as part of the Services' annual IM Strategic Plan update.

Overall, assuming sufficient program funds are available to integrate the insensitive munitions technology as it matures, this approach should lead to the majority of our weapon systems being insensitive munitions compliant over the next two decades. During this transitional period, when approved each year, the IM Strategic Plan should be structured to provide a blanket wavier for all of the systems included in its assessment and prioritization process. Therefore, only out-of-cycle systems not covered by the IM Strategic Plan will require a separate wavier package to be processed during any one year. Thus, if implemented correctly, the IM Strategic Plan will focus the Services' insensitive munitions efforts and minimize the impact of the mandated wavier requirement.

This author does not claim any divine insight into the future to predict the exact timeline of the next major munitions incident nor when high-explosive munitions will become extinct. However, based on the increased international terrorist threat, the perceived future decades of high-explosive munitions existence, the magnitude of a major non-IM compliant munitions incident, and its potential impact on both strategic political objectives and on short-term operational capability, the pursuit of IM compliance within the fiscal constraints of each Service is the right thing to do.

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[8] Ibid.

[9] Ibid, pp 7-8.

[10] Ibid, p 16.

[11] Note: MIL-STD-2105C states that this test will be performed in accordance with STANAG 4240. *Liquid Fuel/External Fire, Munition Test Procedures*. Test environment is summarized at the NATO Insensitive Munitions Information Center website http://www.nato.int/related/nimic/about_im/tests.htm.

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[18] Data received from AFSC/SEWOP, Daniel Orchowski’s review of mishap data bases via a series of emails and telephone conversations.

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[21] Data extract from NIMIC Newsletters for 1st and 2nd Quarter of 2004. On-line. Internet, 29 October 2004. Available from http://www.nato.int/related/nimic/newsletter/news.htm.

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[24] *Explosive Incident Summaries,* p 28.

[25] *Civil Engineering During the Vietnam War: Prime BEEF*. On-line. Internet, 30 October 2004. Available from http://www.wpafb.af.mil/museum/history/vietnam/ce3.htm.

[26] Joint Requirements Oversight Council (JROC) Briefing: *Joint Capabilities Integration and Development System (JCIDS) & Insensitive Munitions (IM) Waiver Process*, Chart 11. On-line. Internet, 30 October 2004. Available from http://www.dtic.mil/ndia/2004guns/wed/martinez.ppt.

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[28] Ibid.

[29] *Explosive Incident Summaries,* p 13.

[30] Rossi, p 2.

[31] *Explosive Incident Summaries,* p 27.

[32] Joint Requirements Oversight Council (JROC) Briefing, Chart 11.

[33] Rossi, p 1.

[34] The estimated current year cost of these incidents was based on the historical data assuming a conservative average of 3.5% annual increase due to inflation since 1926. Also, the cost of the Bien Hoa incident was estimated at $200 million in FY65 dollars assuming $5 million per aircraft and the cost of the Tobar incident was estimated at $1 million in FY69 dollars.

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[35] Joint Requirements Oversight Council (JROC) Briefing, Chart 11.

[36] Ibid.

[37] Ibid, Note: Estimated current year saving is based on the historical data assuming an average of 3.5% annual increase due to inflation for FY03 and FY04.

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[46] DOD 5000.2-R.

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