2010 Insensitive Munitions & Energetic Materials Technology Symposium
Munich, Germany 12-14 October 2010

Expedited Transition of Propulsion Modeling and Simulation Capability — Enabled by a Knowledge Structure

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Abstract: U.S. government-developed high-fidelity modeling and simulation capability for Insensitive Munitions (IM) hazard analysis of propulsion systems is poised for transition to engineering application. Transition requires effective outreach to industry and government program managers responsible for developing new or modified munitions and weapon systems. The described knowledge structure provides a framework integrating the disciplines of IM and safety compliance, propulsion system design/development and physics/chemistry based modeling and simulation (M&S). It is intended to result in learning, understanding and adoption of best practices for designing to system safety needs and achieving propulsion IM qualification through the aid of modeling and simulation.

M &S tools anchored with tests and experiments can quantify uncertainty of IM safety thresholds and margins both vertically (from propellant to system/platform level) and horizontally (across operational and logistical domains) and enable assessment of the efficacy of hazard avoidance and mitigation approaches. This is high-payoff potential given the inherent global risk--from IM compliance to protection against hazards-- and the pitfalls of relying on testing alone. For larger propulsion systems in complex weapons systems testability and repeatability are special challenges if not practical impossibilities.

The technical work is led by Strategic Insight, Ltd. as the integrating contractor for the DoD in partnership with DoE laboratories who are developing the M&S toolset for these IM applications. The paper introduces the knowledge structure considerations and provides an application example and a proposed organization

Introduction

Strategic Insight, Ltd. is developing a “knowledge structure” under a small business technology transfer contract (STTR) sponsored by the U.S. Missile Defense Agency[1]. The purpose of the knowledge structure is to enable expedited transition of a government-developed high-fidelity modeling and simulation (M&S) capability for Insensitive Munitions (IM) hazard analysis of propulsion systems. A companion paper (1) by the same authors provides background and motivation. One driver is to reduce cost and time for safety design and qualification. This provides high payoff potential given the global risks of IM compliance and mission safety assurance, and the pitfalls of relying on testing alone. For larger propulsion systems in complex weapons systems installed in self-contained manned units/platforms (e.g., land vehicles, aircraft, ships and submarines) testability and repeatability are special challenges if not practical impossibilities.

Among the multi-faceted issues facing weapon systems or munitions Program Managers is how to invest in IM safety given inevitable fiscal constraints. Choices are limited, with emergence of high-fidelity M&S capability as a potentially important opportunity[2]. Traditionally, explosives science, and its associated M&S, has resided

1 Strategic Insight, Ltd. acknowledges technical partner Lawrence Livermore National Laboratory, Drs. Bruce Watkins, Keo Springer and Larry McMichael for expert assistance with the knowledge structure.

2 A 2008 assessment of the state of the practice of IM propulsion concluded: a) military and non-military application typically require high-performance propulsion designs; b) propellant technology is not sufficiently mature to enable propulsion designers to explore performance – safety trades using new propellant formulations; and c) system ignition technologies including modeling and simulation are sufficiently mature to support propulsion system acquisition programs (2).

mostly with specialists grounded in continuum mechanics (solids and fluids) and gas dynamics within the science and technology community, compared to the discrete M&S methods in broad use by weapon systems and munitions engineers. Toward the STTR objective, “Expedited Transition of Propulsion M&S Capability”, the knowledge structure is intended to:

- Portray the IM safety problem writ large-- fraught with global risk, from compliance to protection of munitions, weapon systems and platforms, and surrounding volumes
- Demonstrate a system approach to propulsion system safety using M&S to better manage safety risk
- Identify best practices to enable Program Managers and Project Teams to: incorporate state-of-the-art M&S toolsets and specialists into the team; better understand and deal with the uncertainty of propulsion reaction thresholds and margins; and inform strategies that avoid unintended ignition, and/or mitigate effects.

The end goal is to achieve system level IM protection/compliance without sacrificing propulsion/system performance.

Knowledge Structure

What is a knowledge structure? Its embodiment might take many forms--a briefing, paper, handbook, instruction course manual or interactive web page. We will discuss the basic considerations for a knowledge structure-- its focus and boundaries, organization and expected utility to weapons systems and munitions acquisition practitioners. An application example is provided. This paper builds on underlying concepts previously introduced at the 2009 Australian Explosive Ordnance Symposium at Adelaide, South Australia (3).

Developing and fielding high performance munitions is an inherently risky business across the range of life cycle activities including research and development, manufacture and assembly, transportation, storage and disposal. Even in their simplest form munitions are complex systems and the consequences of an accidental initiation can be extreme. The Program Manager and Project Team are responsible for adhering to design criteria for demanding performance requirements yet are safe to deploy and operate in pre-established (yet uncertain) conditions and environments. The knowledge structure is a tool for dealing in complexity and uncertainty associated with propulsion system development.

The knowledge structure aims to inform the Program Manager’s choices on investment of funds, facilities and human capital toward resolving the IM safety problem for the Program Manager’s system(s).

Propulsion Reaction

Rocket motors must burn fast and hot when intentionally ignited, yet remain as insensitive as possible to unintended stimuli occurring in operational or logistical situations, such as propellant heating from a fire, or impact shock and heating from threat bullets or fragments.

Intended Reaction (Normal Operation)

Under normal rocket motor operation, heat is intentionally applied (by an igniter) at a specific pre-determined location to cause the propellant to ignite and burn. Hot gases generated by the burning propellant are exhausted through the nozzle and begin transferring heat to the rocket motor components (propellant, liner, insulator, forward/aft closures and case) and the adjoining sections of the missile. The rocket motor chamber pressure rises (as internal heat rises from the burn) to its maximum intended operating value in equilibrium with the exit exhaust pressure at maximum thrust. The structural design of the confinement (closures and case) must be as lightweight as possible to maximize missile performance but strong enough, with safety margin, to not burst or vent at maximum operating pressure. To meet stringent performance requirements typical of air and missile defense interceptors, propellant formulations are designed to burn as fast and hot as possible consistent with the ability to confine the high chamber pressure.

Unintended Reaction (Caused by Threat Hazard)

Now consider the situation of threat hazard stimuli, where heat from an unspecified source is unintentionally applied to the propellant at a random location. The source of heat may be an external fire, ambient temperature, or friction induced by a mechanical insult (e.g., bullet or fragment impact). Shock impact from a bullet or fragment also can directly ignite the propellant. Compared with normal operation, the propulsion system's hazard response entails more complex phenomena, situational variations and unfavorable constraints:

- Hazards such as fire, ambient temperature rise or impact shock can damage portions of the propulsion system (case, insulation, liner, propellant, etc.).
- These hazards also cause heating of the propellant, with the damaged portions of the propulsion system also contributing to the likelihood of propellant ignition and reaction growth.
- Non-uniform heating of different regions of the propellant from heat flux sources of magnitudes and directions different than the normal ignition situation can result in widely varying reaction rates, or "violence" of response.
- Violent responses can cause severe collateral damage in the case of hazard-induced mishaps compared to a normal operation where the missile is quickly airborne and away from its surroundings[3].

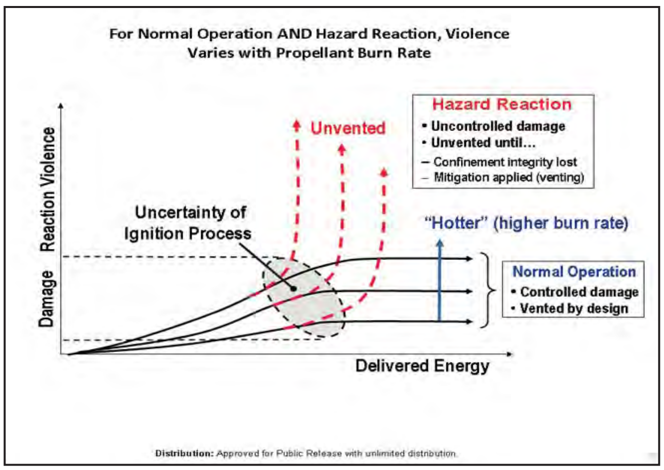

Figure 1. Propellant Response Violence Varies With Burn Rate

It can be stipulated that the propellant burn rate is set by the specifics of the propellant formulation--and the propellant's violence of reaction to hazard insults will be proportional to the "hotness", i.e. the propellant's burn rate behavior in normal operation. This is illustrated in **Figure 1**. During normal operation following ignition, venting is by design (i.e., burn rate is controlled by hot gases exiting through the nozzle). On the other hand, the propellant's burn rate behavior in response to a hazard induced ignition is dependent on many factors (e.g., propellant condition/history, damage, where ignition occurs, and degree of confinement) and can vary from smolder to burning to an extremely violent explosion.

Presently there are modeling and simulation limitations in predicting violence of response to a hazard induced ignition--it is considered by practitioners to be a Grand Challenge[4].

Grand Challenge

Not only is the response uncertain it is variable[5]. IM compliant solutions require coping with the uncertainty of predicting propellant reaction to threat hazards and mishaps. Accordingly, the knowledge structure will focus on predicting thresholds and margins on damage/ignition (preceding and including the shaded region in **Figure**

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3 A hazard may occur prior to launch, when the missile including the propulsion system is in the launching system in a platform; or during transport or elsewhere in the logistics environment – resulting in missile damage and/or collateral damage.

4 A Grand Challenge in a science and technology area requires significant investment to meaningfully advance the required computational performance and the necessary understanding/modeling of physics/chemistry phenomena in order to provide useful solutions for relevant problems.

5 "Uncertainty" refers to whether a hazard insult will result in non-reaction (insensitive) or an undesired reaction. "Variable" refers to the nature of the undesirable reaction (pyrolysis, non-propulsive burn, propulsive burn, mild or strong explosion).

1)[6]. Since violence of reaction is proportional to propellant burn rate--which is set by the specific formulation--the knowledge structure will identify M&S capabilities to address IM safety hazard response, and damage avoidance and effects mitigation strategies at the system / platform level. It will seek to enable quantification of uncertainty about thresholds and margins on hazard-induced ignition time and temperature for system-specific propellants.

To summarize, the best IM safety strategy for the Program Manager seems to be to "design-in" the avoidance of hazards via the overall system architecture, in which weapons containing energetic materials including rocket motors and propellants are components. If possible, damage avoidance strategies should be backed with "design-in" of hierarchical protection layers including barriers to prevent unintended ignition of propellants, and passive or active effects mitigation strategies such as venting that preclude or lessen reactions and violence. *The knowledge structure will focus on applying modeling and simulation capabilities to the* <u>*system design*</u> *of hazard avoidance and mitigation of violent reaction to threat-induced or accidental hazards*

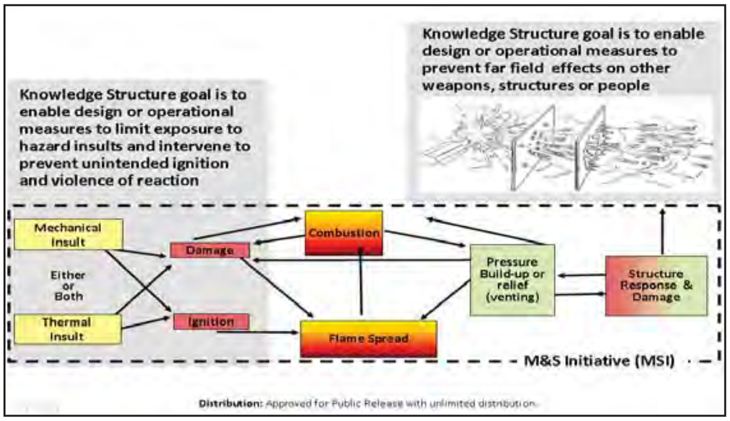

Figure 2. Knowledge Structure Focus is Avoidance/Mitigation Modeling and Simulation

M&S Analysis for Propulsion IM Hazards (Avoidance/Mitigation)

The knowledge structure effort under the Strategic Insight, Ltd. STTR tracks and leverages the IM propulsion modeling and simulation capability development comprised of many efforts (not detailed herein) that are coordinated via the Weapons & Munitions M&S Initiative (MSI) in the U.S. Office of Undersecretary of Defense (OUSD)/Munitions Safety. While the scope and complexity of these efforts cannot be captured simply, the diagram inside the dotted line in **Figure 2** is useful as a common communication means of representing IM hazard response analysis of interrelated events (the blocks) connected by phenomenology models (the arrows). It should be emphasized that the diagram is notional, representative--much research lies ahead to robustly define the events and models for predicting hazard-induced violence of reaction for propulsion systems of interest.

Referring to the two gray-shaded areas of **Figure 2**, it is believed that available modeling and simulation capabilities can be applied to the front and back end of the violence of reaction prediction problem. On the front end (left-hand gray shaded region), it is believed feasible to use lab-scale experimentation to anchor propellant response models and quantify uncertainty on damage/ignition thresholds and margins via an assortment of available modeling and simulation tools. On the back end (right-hand gray shaded region) the tools can be used to design mitigation of far field effects--fires, overpressure, fragments, firebrands and toxicity.

It is noted that uncertainty surrounds scalability-- rocket motors of identical design in different diameters can exhibit different performance since propellant behavior is driven by responses of the web geometry/grain which are not all independent of reaction path length. However, scaling uncertainties are just one of many uncertainties that must be resolved via design of experiments anchoring overall quantification of uncertainty from consideration of variables affecting IM safety of the entire system.

The knowledge structure will enable Program Managers and Project Teams to regard IM safety in a system context and select an appropriate set of modeling and simulation tools to assess margins, plan and "design-in" damage avoidance and effects mitigation strategies that ensure operational/logistical robustness against threat-induced and accidental hazards.

6 Uncertainty of propellant reaction to hazard insult in the context of this paper was first introduced in 2009 (3).

Knowledge Structure Application Example

The knowledge structure will include methodology for experiment-anchored modeling and simulation analysis of specific operational and logistical scenarios as well as for prediction of IM Standard Tests. The discussion below illustrates how a Program Manager and Project Team including safety engineers might currently perform an analysis of IM threats and hazards--usually referred to as a Threat Hazard Analysis (THA).

Mapping Threats/Hazards to Standard Tests and Specific Scenarios

The typical procedure for weapon acquisition programs is to identify the various system configuration items and the specific life-cycle environments to which each configuration item is exposed. For example, a program manager might identify one configuration item as an all-up-round (AUR) in its shipping container and then correspondingly identify a relevant life-cycle stage as over-the-road transport by truck with other AURs. A subsequent analysis of potential threat exposures yields one or more specific hazards – bullet impact, fuel fire, etc. – associated with the configuration item and associated life-cycle stage.

For illustration purposes, a “fuel fire” might be identified as a specific hazard. The specific hazard identified typically will map to one or more standard tests and associated test procedures and scoring criteria. For U.S. systems, those tests, procedures and criteria are contained in MIL-STD-2105C (4) including related NATO standardization agreements (STANAGS). In this example the fuel fire maps to two standard tests and their related criteria, namely, slow cook-off and fast cook-off, as well as one or more Specific Scenarios such as on a naval ship during operations or a truck during transportation.

Recognizing that the standard tests often are executed with simplified configuration items and fairly idealized test conditions, the knowledge structure addresses mapping to Specific Scenarios. These scenarios comprise the totality of configuration items and associated structures, including avoidance and mitigation implementations, exposed to specific hazards under a variety of conditions that may affect the operational or logistical situation outcome and consequences.

“Real World” Analysis of IM Safety Risk Avoidance/Mitigation

“Real world” analysis of IM safety risk avoidance/mitigation for Specific Scenarios entails devising means to avert multiple risks comprising:

- Combination of threat hazards
- Multiple weapons/types at risk
- Combat damage to launching systems and platforms
- Safety of operating area

The analysis must be systematic and tailored to the system under study including the threat hazards and hazards avoidance and effects mitigation strategy. **Table 1** summarizes representative elements of such an analysis.

Table 1. Establishing an Analytic Framework for Hazard Analysis including Avoidance/Mitigation Strategies

System and Decomposition:
• Naval task force (could include closely-spaced combatants and service vessels) and operating area (could be close to shore or in port) • Ship (hull, equipments, weapons, fuels, firefighting, personnel) • Topside equipment and below deck compartments near or surrounding multi-weapon launching system • Launching system and weapons • Missile in all-up-round canister • Missile including energetic components • Propulsion systems • Propellants
Modeling and Simulation Hazard Analysis:
• Hydrocarbon fuel fires and resultant heat flux impingement on various surfaces of the ship structure, equipments and weapons • Radiative, conductive or convective heat transfer to launching system and missiles • Heat transfer to solid rocket motor propellants • Energetic responses of the propellants
Avoidance & Mitigation Approaches:
• Thermal and kinetic protections and interventions to prevent, delay and control heating in order to engineer predictable responses • Sensing and intervention to avoid overheating and unintended ignition • Active or passive venting to prevent pressure rise • Barriers and armor to prevent secondary effects

Protection of munitions and weapons systems from IM safety hazards in real world scenarios requires multiple defense layers. The system analysis of these layered protection systems can be decomposed to discrete, well-defined analysis tasks to be performed by specialists using appropriate M&S tools.

The knowledge structure will equip the Program Manager and Project Team for collaboration with M&S specialists in order to develop a system-specific modeling and simulation plan including design of experiments to anchor inert and energetic material response models.

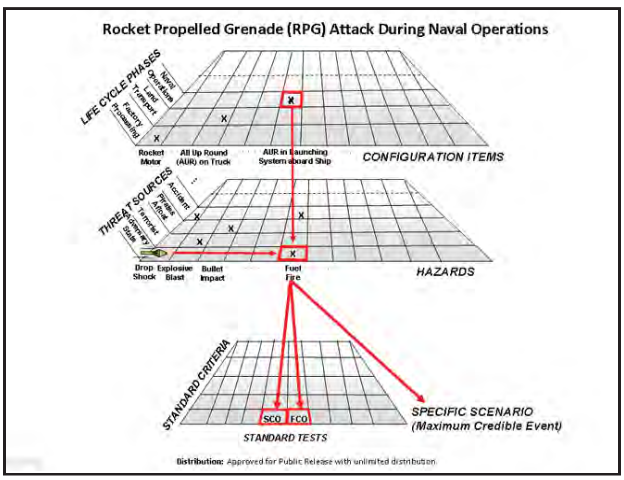

Figure 3. Mapping Configuration Items/Life-cycle Phases to Threat Exposures and Hazards

Described next are a sequence of methodology steps to enable a Program Manager and Project Team to define/ execute an experiment-anchored modeling and simulation analysis plan to quantify uncertainty of IM safety margins for munitions, weapon systems and platforms/systems of interest. The example herein relates to a shipboard fuel fire hazard stemming from a rocket propelled grenade (RPG) attack during naval operations at sea.

The first step, shown in **Figure 3**, utilizes a Threat Hazard Analysis (THA) comprised of a mapping of configuration items and life-cycle phases to threat exposures and hazards[7]. The second step maps the RPG-induced fuel fire hazard to one or more standard IM tests and criteria--in this example, fast cook-off (FCO) and slow cook-off (SCO) as well as to a Specific Scenario, neither FCO nor SCO. The Specific Scenario will include a maximum credible event (MCE) discussed in the next step.

7 Compared to a full analysis, the sparsely populated example matrix focuses on a single threat (RPG) and associated related hazard (fuel fire).

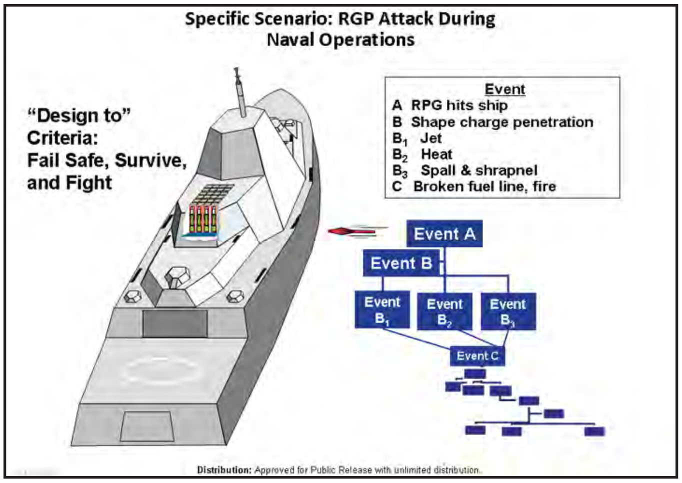

Figure 4. Creating a System Context for Analyzing Insensitive Munitions Threats and Hazards

The third step, referring to the specific scenario depicted in **Figure 4**, sets up the problem to be solved-- determination of a MCE characterizing the thermal insult to the propellant with and without measures to avoid/mitigate the insult and resultant effects-- and the success criteria for overcoming the MCE. In this example, the first part of the problem will be to create a detailed definition of the encounter between RPG and ship. This involves: defining the internal spaces and systems, including those with energetic materials, at risk from the threat source (Table 1, System Definition and Decomposition); and translating the initial threat event/induced hazards into subsequent events/hazards presented to ship spaces/systems – such as producing and/or propagating energy in the form of heat, shape charge jet and shrapnel leading to a fuel fire near a ship weapon magazine/launching system. As illustrated, the "design to" success criteria for "protection" of the ship system are: a) the system will fail safe, b) the ship and its weapons and crew will survive, and c) the ship will retain its capability to fight, including counterattack. For munitions Program Managers, this involves avoiding ignition of energetic materials and/or mitigating the effects/consequences to the larger system.

Hazards have cascading effects. Response of each system layer to the threat load (fire, blast, fragments, firebrands, shape charge jet, heat, schrapnel...) affects the threat load on subsequent layers. The system approach enables understanding threat loads and consequences on the energetic materials, and their reaction to these loads (Table 1, Modeling and Simulation Hazard Analysis). The protection strategy will take advantage of the ability of each layer to dissipate mechanical and heat energy to reduce delivered energy at the propellant (mechanical and thermal insults).

In this scenario, the RPG is triggered at the ship hull by impact (Event A) and penetrates one or more spaces. The energy released, i.e., energy applied at the hull is in the form of heat, shape charge jet and shrapnel. (Event B). The hull absorbs some hazard induced energy by work (translation, dampening and deformation) and heat transfer. An effect caused by these hazards in this example scenario is to sever a fuel line within the space adjacent to the launcher and initiate a fuel fire (Event C) creating a new source of energy for the thermal part of the combined (mechanical and heating) hazard. As hazard induced energy is further absorbed by the mechanical damping and heat absorption within the spaces and by bulkheads, the fuel fire adds energy to the thermal portion of the combined hazard. Conductive, convective and radiate heat transfer occurs through subsequent layers preceding the surface of the propellants. At this point heating of the propellants begins, the rate a function of spatial and temporal non-uniformity of the heat input sources, the thermal gradient and the thermal coefficients of the layers. It is the hazard energy induced at the surface of the rocket motor propellant, i.e., energy delivered, that acts as the insult (Figure 2) causing propellant damage and possibly ignition (Figure 1).

The richness of M&S characterization enables detailed assessment of a system response including mitigations contained in the system. The assessment will flow-down to the specific propellants included in the system and flow-up to the integrated system response (effects) to a threat source (RPG attack).

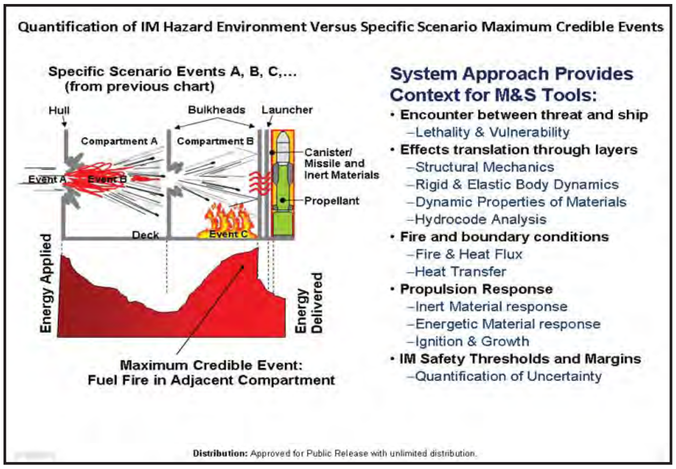

Figure 5. Establishing Modeling and Simulation Strategy and Toolset in a System Context

The fourth step, portrayed in **Figure 5**, defines modeling and simulation tools (functional types) that will be useful in characterizing the system under study (the ship and surrounding volume) and studying the response of each system layer to adjacent layers for the specific scenario(s).

The fifth step is to set system IM protection goals (Table 1, Avoidance and Mitigation Approaches). The system is first decomposed and then "design-to" goals and mitigating features for each layer of the system are specified. For example, at the ship layer, a design to goal might be to control damage. Mitigating features might include the use of hull structure shapes or armor. At the propellant the design to goal might be fail safe using an IM intervention technique as the mitigating feature.

The last step of the knowledge structure methodology is tedious but rewarding. It comprises several different types of iterative processes:

- System engineering and analysis to characterize the energy delivered at the propellant using alternative passive and active (kinetic and thermal) damage avoidance and effects mitigation strategies in response to alternative ship-threat encounter conditions, material properties, and fire scenarios (Figure 2, gray shaded regions);
- Physics/chemistry modeling of inert and energetic material responses (thermomechanical and chemical) to kinetic and thermal stimuli (Figure 2, within the MSI dotted rectangle);
- Design/conduct of lab-scale thermomechanical and chemical experiments to calibrate response of system-specific propellants;
- Stochastic modeling and simulation-based numeric trials to quantify uncertainty of propellant ignition thresholds and margins (Figure 1, shaded ellipse).

Collectively, these processes promote design confidence, and reduce safety risk through quantification of uncertainty.

The knowledge structure methodology case example has demonstrated a system approach and iterative process using M&S prediction to help Program Managers and Project Teams achieve IM safety without sacrificing propulsion performance. The strength of the proposed methodology is to inform the THA by application of M&S technologies to weapon systems and munitions. It maps the life cycle to IM threat sources/hazards and the identified hazards to Standard Tests and Specific Scenarios. Traditionally, standard testing has been used to assess by comparison with changes from previous testing, Scenario-based system-level M&S enables designers to comprehend worst case hazard exposures and proactively design to avoid reaction violence and its unacceptable effects/consequences. The knowledge structure methodology contributes a system approach and best practices for transition of the U.S. government's propulsion M&S capabilities to engineering application for better managing propulsion/system safety risk.

The knowledge structure will yield valuable, archivable artifacts for the Program Manager and Project Team's investment in application of its methodology. Primary of these are the documented characterization of possible system damage states for different threat/hazard assumptions; efficacy of various potential avoidance and mitigation measures; and quantification of the uncertainty about IM safety thresholds and margins

The above IM protection/compliance system analysis and engineering documentation can be revisited anytime in the future. It is thus an investment that keeps giving back--it enables life-cycle system design, and provides permanent corporate memory for agility in pacing future threats and responding to emergent operational logistical needs

Knowledge Structure Preview

The knowledge structure is organized into three interactive parts as illustrated in **Figure 6**.

Part I – Managing Propulsion Insensitive Munitions Safety Risk: provides general information useful to Program Managers and Project Teams responsible for developing and fielding munitions in general and solid rocket motor propellants specifically. This level addresses the underlying elements that contribute to uncertainty and safety risk including practices and methods in use today, a discussion of the underlying physics and chemistry of ignition and combustion as it applies to solid rocket motor propellants, and a methodology for establishing safety thresholds and quantification of uncertainty about margins.

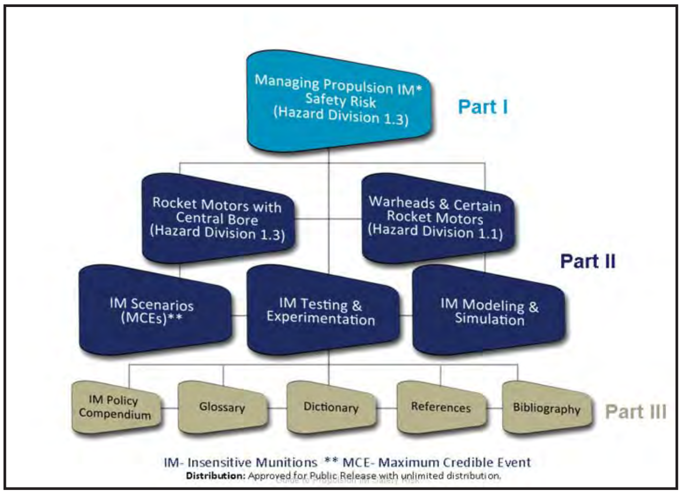

Figure 6. Proposed Knowledge Structure Organization

Part II – Appendices: is segmented by domains of interest to the Project Team (project personnel and task- assigned practioners working in Munitions). These are intended as ready reference material for use by Project Teams pursuing Insensitive Munitions compliance.

Part III – Reference Material: captures important supporting information used to create the knowledge structure, and which will assist users and support future research.

Over a period of decades, large bodies of knowledge, subject matter experts and specialists, and formal science and engineering-based practices, procedures and methods have been refined to assist Program Managers and Project Teams develop and field safety compliant munitions. During that same time, demand for higher performance has challenged the community to manage risk while maintaining or improving safety margins. Part I of the knowledge structure, “Managing Propulsion IM Safety Risk” is organized into seven knowledge areas to assist understanding the uncertainties of working with munitions and managing risk. In particular, understanding the complexity of munitions as systems, the limitations of current knowledge and practices, and the methods and tools available to the Program Manager and Project Team to quantify uncertainty and improve safety margins

- Understanding Energetic Munitions Safety Risk: threat- induced or accidental hazards, effects and consequences.
- Underlying Physics and Chemistry: hazard induced damage to propellants; reaction including ignition, combustion, thermal run-away, overpressure, loss of confinement.
- Compliance Testing and Analysis: policy/criteria for propellant sample testing (commercial transportation safety) and propulsion/system testing (military operational/logistical safety).
- Lab-scale and Small-scale Experimentation: protocols for lab-scale (inert and propellant material reaction) and small scale (propulsion system reaction) testing.

- Experiment-anchored Modeling: materials dynamic response (thermomechanical and chemical) manifested as change in temperature, pressure and physical/chemical composition leading to gas generation and multiphase flow (gases and solids).
- Avoidance and Mitigation Methodology: system analysis of potential damage from unmitigated hazards and benefit of protection measures such as barriers, armor and passive/active venting.
- Safety Margins (Quantification of Uncertainty): numerical methods and trials to rank the importance of input variables, characterize them as random or statistically ordered and quantify the expected mean and variance of the output.

In summary – advances made by the Modeling and Simulation Initiative coupled with the knowledge gain from use of the knowledge structure will enable evolution toward common best practices and toolsets for the munitions community. It will enable practioners in general, and Program Managers and Project Teams specifically, to better integrate emerging physics based high-fidelity M&S tools and specialists into their teams. These evolved practices address management of global risk to achieve propulsion performance and safety compliance and protection of surroundings through: use of a system approach; uncertainty quantification of ignition threshold/margins by test- and experiment-anchored numeric trials; and quantification of avoidance/mitigation approaches, e.g., add-on/design-in layered protection.

REFERENCES

1. Jones, D.A., McCants, and Swierk, T.E., "Modeling and Simulation – An Enabler for IM Development and Assessments," 2010 Insensitive Munitions & Energetic Materials Technology Symposium, Munich Germany, October 2010

2. Jones, D.A., "Expedited Transition of Propulsion Modeling and Simulation Capabilities," Final Report, Missile Defense Agency, Contract No. W9113M-08-C-0019, January 2008

3. Jones, D.A., McCants, T.M., Miller, K.K., and Swierk, T.E., "Expedited Transition of Modeling and Simulation Capability for Insensitive Munitions Hazards Analysis," 2009 Australian Explosive Ordnance Symposium, Adelaide, South Australia, November 2009

4. Department of Defense Test Method Standard, MIL-STD-2105C, "Hazard Assessment Test for Non-Nuclear Munitions," 14 July 2003

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