Part I/Risk-Based Siting Criteria – Current and Future Efforts in Risk Management and Siting Applications

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Keywords: Risk Management, Risk Analysis, Explosives Safety and Munitions Risk Management (ESMRM), Qualitative and Quantitative Risk Analysis, Risk-Based Siting

Abstract

The U.S. Department of Defense Explosives Safety Board (DDESB) has established Explosives Safety and Munitions Risk Management (ESMRM) processes. These processes includes qualitative risk management in the acquisition lifecycle of munitions, and quantitative risk assessment (QRA) for explosives site plan submissions. Both qualitative and quantitative risk assessment processes approved by the Department of Defense Explosives Safety Board (DDESB) follow definitive risk management principles and have been applied to the U.S. Department of Defense (DoD) title munitions worldwide. The processes and tools provided by DDESB can be adopted by the DoD Components, Program Managers and Explosives Safety Professionals to assess the risk associated with all activities related to explosives safety and munitions operations.

Part I of this paper provides an overview of all the DDESB available processes and tools. It provides overarching guidance on implementing an ESMRM process in the DoD acquisition lifecycle of munitions. It further looks into the future of munitions risk management as it applies to explosives safety in the 21st Century where weapon systems development processes are required to streamlined and balance cost, performance, and safety.

Introduction

For the past 20 plus years, the DDESB, which serves as the major explosives safety policy-setting organization for the U.S. government, has been involved in the development of risk-based management approaches for explosives safety. These methods are based on significant testing and practical field experiences. The outcomes of the risk-based methods provide a practically feasible and cost-effective solution when the traditional Quantity-Distance (QD) criteria cannot be satisfied due to restrictions of the field situations.

Quantity-Distance (QD) criteria have been used as the primary means for the safe siting of facilities for more than 70 years. QD criteria consider only explosives quantity, Hazard Division (HD), and facility type to determine an explosives safety separation distance (ESSD). Safety professionals recognized that QD could be improved by considering other factors in the safety analyses to include type of activity, number of people, building construction, and environment to assess the overall risk of an operation related to ammunition and explosives (AE).

In the late 1990's, the DDESB recognized the usefulness of risk-based approaches for explosives safety analysis and pioneered the explosives safety community to embark on a comprehensive development of a risk-based methods and tools that would be used to improve explosives safety at large.

Since the late 1990's the DDESB has used, embraced and advocated the concept of risk-based management to improve explosives safety analysis. It has conducted pivotal research to improve the risk management processes and procedures in the areas of explosives safety, system safety, and range safety. The findings from the DDESB research have been leveraged and incorporated in both national and international standards that use and applying risk-based approaches to manage explosives risks. Some of these governing and policy setting entities include: the Range Commanders Council (RCC), The Institute of Maker of Explosives (IME), North Atlantic Treaty Organization (NATO), National Aeronautics and Space Administration (NASA), The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), Coast Guards and even in the United Nations.

Citations of the DDESB risk-based methodology can be found in DoDD 6055.09E [1] and DoDM 6055.09 [2]. Detailed results of these efforts are documented in TP-14 [3] for risk-based siting and in TP-23 [4] for risk assessments. In late 2018 these methods will be incorporated in the DDESB Explosives Safety Siting (ESS) Tool. Additional international implementation of requirements for risk assessment and management of explosives and ammunition are described in various UN IATG [5] NATO standards; ALP16 [6], AASTP-1 [7], AASTP-4 [8], AASTP-5 [9]. The recent U.S DoD's CSI4360.01A [10] for joint operation also adopt the DDESB Explosives Safety and Munitions Risk Management (ESMRM) methodology. In early 2000 the DDESB, as part of the industry government partnership release the technology to be used commercially. [11] Currently, IME and the U.S. Department of Homeland Security (DHS) use the concepts of the DDESB risk management methodology to govern the safety of commercial explosives.

Part I of this paper briefly describe the history of the development of risk-based management approaches for explosives safety by DDESB, followed by current efforts on qualitative risk management approaches in the DDESB's Technical Paper (TP) 23, the computer module to implement TP-23 (so-called RBESS module), and on quantitative risk assessment (QRA) processes in TP-14. It further discusses the efforts by DDESB to support of North Atlantic Treaty Organization (NATO) on similar risk-based explosives safety management initiatives. Part II of this paper provides the details on QRA in TP-14, including estimation of probability of event (P_e), exposure modeling for various population groups, consequences in terms of potential fatalities and injuries, and uncertainty modeling for the estimated risks.

The QRA methodology established by DDESB is based on the basic concept of risk and is fully documented in TP-14. [3] Using the basic risk concept, the risk to personnel can be defined as:

$$Risk = Probability\ of\ Event \times Consequences \times Exposure \qquad (1)$$

DDESB's QRA methodology is designed to calculate the annual probability of potential fatality to any individual (P_f). P_f is the product of three components, as shown below:

$$Risk = P_f = P_e \times P_{f|e} \times E_p \qquad (2)$$

The P_e is defined as the probability that an explosives mishap will occur at a potential explosion site (PES) in a year. The $P_{f|e}$ is defined as the probability of fatality given an explosives event and the presence of a person. The E_p is defined as the exposure of one person (as a fraction of a year) to a PES on an annual basis. DDESB's QRA methodology also calculates the risk to an entire group of people and provides the average number of fatalities per year. This is referred to as the "Group Risk" and is calculated as the summation of individual risk within the group.

<u>Explosives Safety and Munition Risk Management (ESMRM) - Technical Paper 23</u>

The objective of the DDESB Risk analysis program is to assess and improve the overall safety associated with operations involving explosives and ammunition worldwide through the implementation of risk management processes. The execution of the program is accomplished by developing risk-based tools, procedures, and DDESB risk acceptance criteria that provide the DoD Components with the information needed to make informed risk-based decisions. TP-23 [4] has been rewritten to address the full munition lifecycle -"DoD Explosives Safety and Munitions Risk Management (ESMRM): Acquisition Lifecycle Considerations, Risk Assessment Process Framework, and Associated Tools"

TP-23 outlines Explosives Safety and Munitions Risk Management (ESMRM) fundamentals. It provides an overview of applicable Office of Management and Budget (OMB) and Department of Defense (DoD) risk management policies [12, 13], supplies acquisition Program Managers (PM) with explosives safety considerations applicable in each phase of the acquisition lifecycle, furnishes a comprehensive explosives safety risk assessment process, and summarizes tools available for executing explosives safety risk assessments.

DoD Instruction (DoDI) 6055.01 [14], *"DoD Safety and Occupational Health (SOH) Program"* outlines risk management principles applicable to DoD Components. The policy explicitly states, "Commanders, leaders, and personnel will use the risk management process to address SOH risks across all DoD operations and tasks, both on and off duty." The DoD risk management process is illustrated in Figure 1.

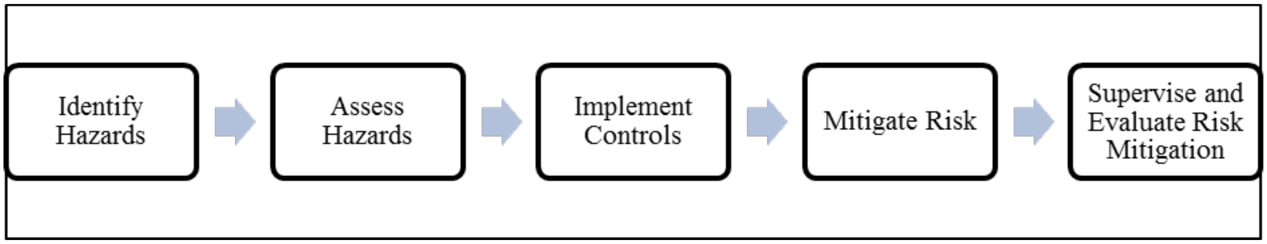


Figure 1. DoD Risk Management Process

TP-23 suggests that DoD Components may utilize the included process and associated tools to evaluate risks when DoD explosives safety criteria (*i.e.* the traditional QD criteria) cannot be met per DoD Directive 6055.9E [1] or as required for explosives safety siting per DODM 6055.09-M [2]. It further suggests that the DoD Components can develop, as needed, their own tools for explosives safety risk management provided that they adhere to the fundamental explosives Safety Risk Management Model as shown in Figure 2. These products assist leaders and decision makers, at all organizational levels, to better understand explosives hazards, reduce risk to mission, conserve resources, and maximize operational effectiveness. ESMRM is a force multiplier when explosives safety and munition risks are evaluated, assessed, and managed as part of the full system lifecycle. ESMRM enables DoD Components to effectively execute and often times improve and increase their mission capabilities.

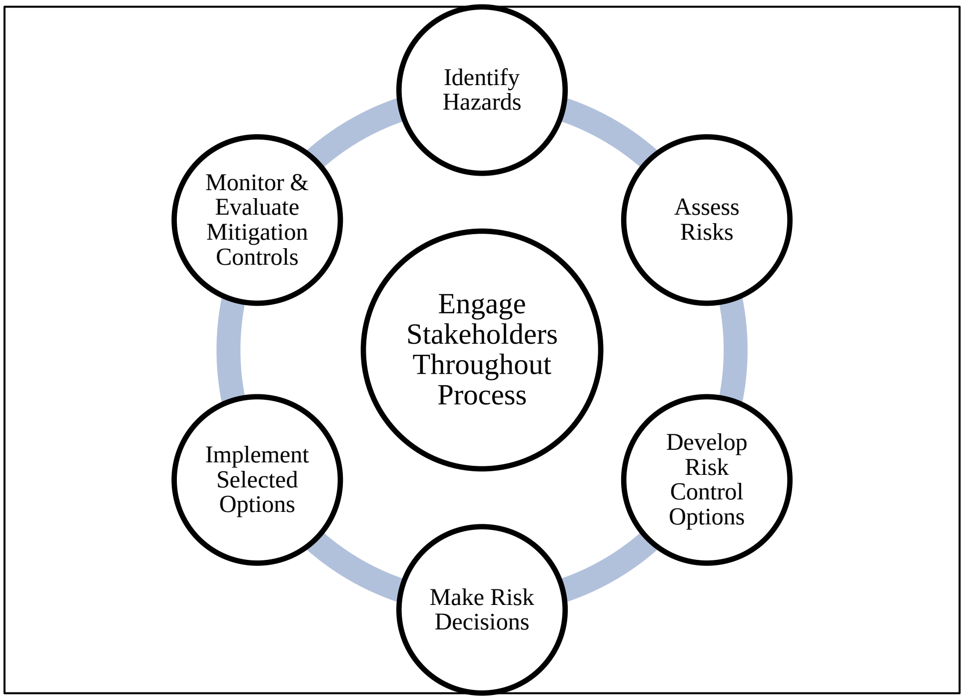


Figure 2. Explosives Safety Risk Management Model

The fundamental premise of the ESMRM involves upfront identification and clear communication, to the appropriate level of leadership, of all risks and consequences to and from explosives and munitions during all phases of a weapon system's life cycle. Systemic issues that negatively affect a program's cost, schedule, and/or performance may result from the failure to consider ESMRM elements early in the acquisition lifecycle. Such failures may result in the need for unplanned infrastructure investments to accommodate weapon and/or weapon systems, compatibility constraints that limit combat effectiveness, and unresolvable compliance issues requiring senior leader acceptance of increased risk to personnel, equipment, and infrastructure.

For Acquisition Programs, The Program Manager (PM) is the designated individual with responsibility for and authority to accomplish program objectives for development, production, and sustainment to meet the user's operational needs. The PM is accountable for credible cost, schedule, and performance reporting to the Milestone Decision Authority per DoD Directive 5001.01, *The Defense Acquisition System*. [15] ESMRM requirements must be considered in all phases of the acquisition lifecycle and are critical to successful program execution and fielding where explosives and munitions are integral to the weapon or weapon system.

Figure 3, Defense Acquisition Process, illustrates the phases, decision points, milestones, and major reviews that form the cradle-to-grave lifecycle from pre-systems acquisition through disposal. TP-23 provides ESMRM considerations resident in each phase. The PM should recognize that at every phase of the lifecycle, earlier risk considerations should be revisited, at each subsequent phase as the program matures, program baselines adjust, or program threshold/objectives are changed.

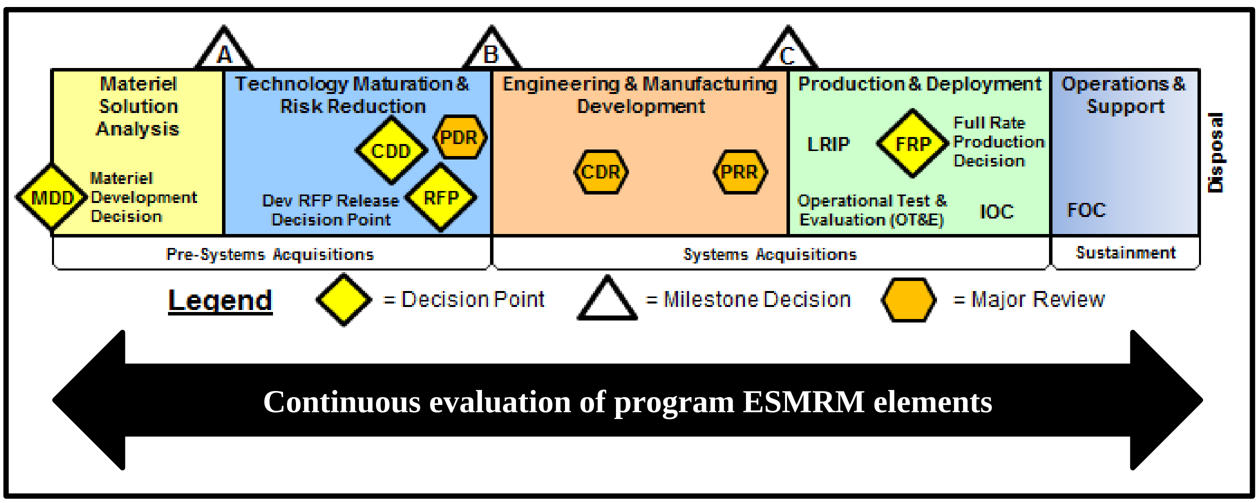
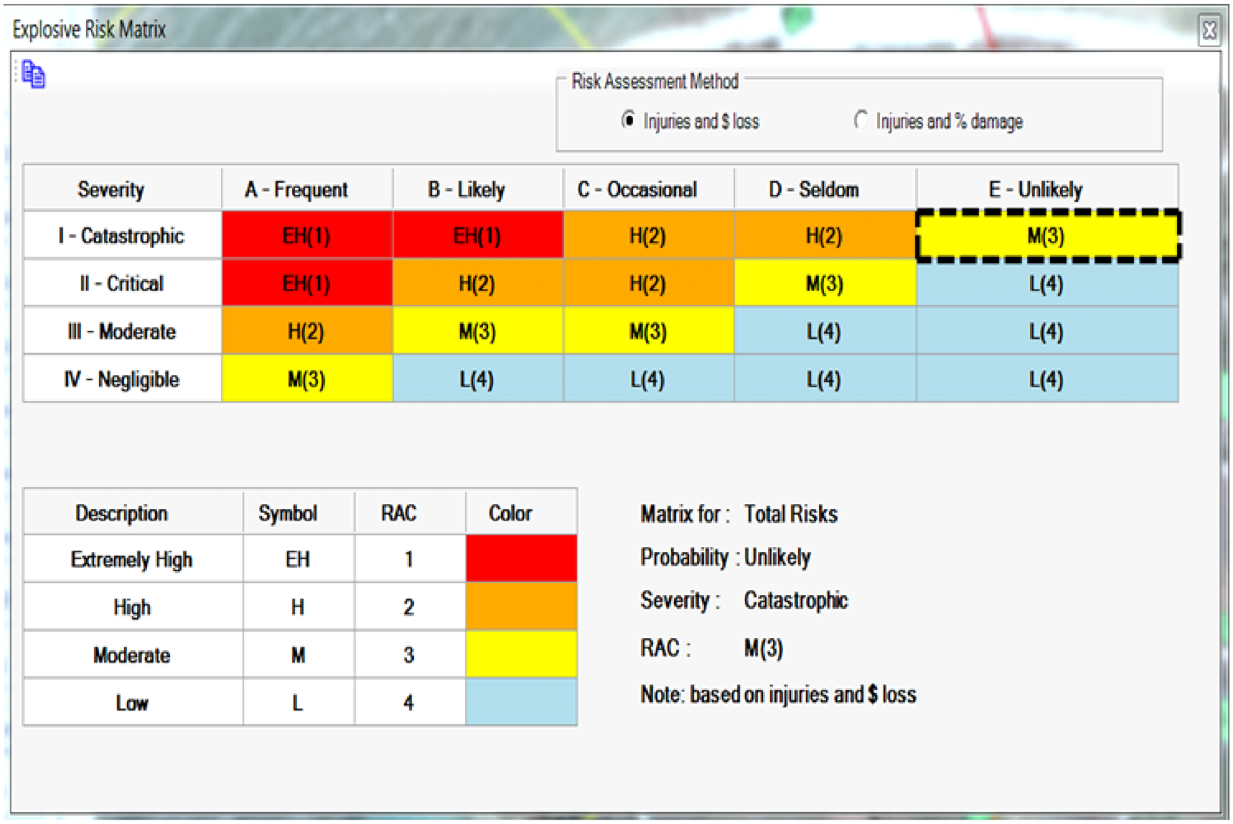


Figure 3. Defense Acquisition Process and Continuous Evaluation of Program ESMRM elements.

ESMRM consideration throughout the acquisition lifecycle should include a risk management process at all stages with critical elements addressed and pertinent risk mitigation measures implemented. Some of the areas that are critical include: materiel solution analysis, engineering and manufacturing development, production and development, operation support, and disposal. TP-23 provides a list of critical explosives safety questions that should be considered during the acquisition lifecycle. It aligns the risk assessment matrix with Mil-STD 882E [16]. Figure 4 illustrates the risk matrix implemented in TP-23 and the accompanying tools. Table 1 summarizes the severity categories agreed to by the DoD Components for conducting an ESMRM assessment.



Explosive Risk Matrix

Risk Assessment Method: (•) Injuries and $ loss ( ) Injuries and % damage

Severity	A - Frequent	B - Likely	C - Occasional	D - Seldom	E - Unlikely
I - Catastrophic	EH(1)	EH(1)	H(2)	H(2)	M(3)
II - Critical	EH(1)	H(2)	H(2)	M(3)	L(4)
III - Moderate	H(2)	M(3)	M(3)	L(4)	L(4)
IV - Negligible	M(3)	L(4)	L(4)	L(4)	L(4)

Description	Symbol	RAC	Color
Extremely High	EH	1	
High	H	2	
Moderate	M	3	
Low	L	4	

Matrix for : Total Risks
Probability : Unlikely
Severity : Catastrophic
RAC : M(3)
Note: based on injuries and $ loss

Figure 4. Risk Matrix used in TP-23 and in the Risk Assessment Tools.

Table 1. Severity Categories agreed to by the DoD Components.

Description	Category	Definition
Catastrophic	**1**	Mission Failure One or more deaths and/or serious injuries of individuals not meeting quantity-distance criteria.
Critical	**2**	Mission Interrupted Multiple serious injuries of individuals not meeting quantity-distance criteria.
Marginal	**3**	Mission Degraded Minor injuries of individuals not meeting quantity-distance criteria.
Negligible	**4**	Mission Unaffected No anticipated injuries and/or other effects for individuals not meeting quantity-distance criteria.

TP-23 implements a hierarchy of tools ranging from simple requiring little data and using the linguistics of DODM 6055.09-M to complex requiring significant data, physics based on test results and models per TP-14. The methodology will be implemented in a modular fashion in the Explosives Safety Siting Software (ESS) and is called Risk-Based Explosives Safety Siting Software (RBESS). This is hierarchy is illustrated in in figure 5. Future version of TP-23 will incorporate more capabilities and additional tools either developed by the DDESB or the DoD Components to better conduct ESMRM assessment for the entire acquisition lifecycle.

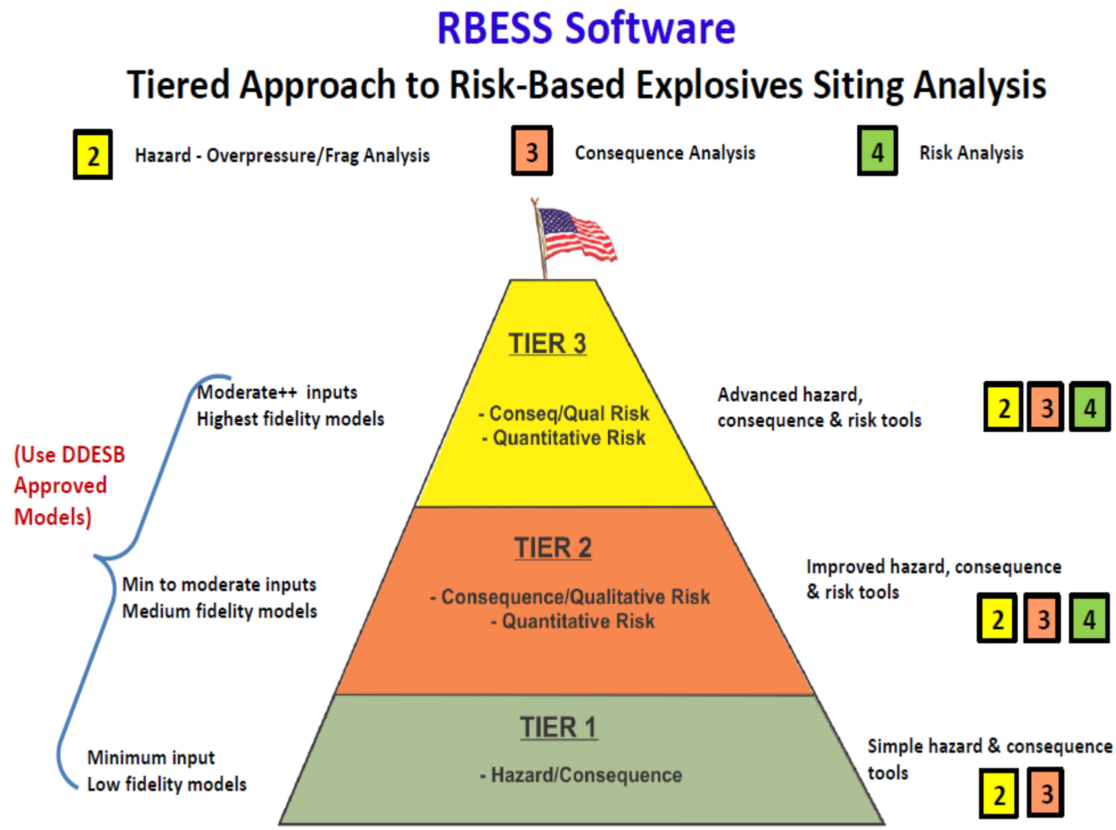


Figure 5. Diagram of RBESS

<u>Risk-Based Explosives Safety Siting (RBESS) Module</u>

RBESS is a module that has been incorporated within the ESS software. RBESS is comprised of multiple tools designed to model various explosives effects and consequences. These various tools are organized into groups, referred to as “tiers,” based on the level of input and analysis detail required in the model. Some of the risk management tools that the current TP-23 makes available include: ASAP-X (Tier 1), MRAS (Tier 1), Fast-Site (Tier 1), and a TP-14 type tool (Tier 2a) HAZX Risk Tool (Tier 2a), HRT (TP14-based), and the QD engine modules. A summary of each tier is explained below:

Tier 1: This is a qualitative risk management analysis that requires little to no additional input from a user beyond typical information required for an ESS analysis. The analysis uses hazard zones that correspond to explosives safety quantity-distances (QD) (i.e. intermagazine distance, intraline distance, inhabited building distance, etc.) to estimate consequences in terms of facility replacement cost, fatalities, and injuries. This qualitative risk management analysis requires little to no additional user input beyond information already entered into ESS. The simplified analyses are based on translating scaled distances (k-factors) into estimates of consequences like a TP-23 type analysis. A Tier 1 qualitative risk analysis should help a user complete a Department of Army (DA) Form 7632 which is known as the Deviation Approval and Risk Acceptance Document (DARAD) Deviation Approval and Risk Acceptance Document (DARAD) or other deviation forms.

Tier 2A: This is a qualitative risk analysis tool that calculates hazards and consequences based on the combination of methods and algorithms in DDESB Technical Paper (TP) 14 Revision 4 [17] and TP-23 [4]. This is a more advanced tool than Tier 1. Most of the input required to run RBESS Tier 2a can be read from an existing ESS dataset, such as number of occupants and replacement cost, but some additional input is required to determine event probability; PES category, soil type, and more.

Both RBESS Tier 1 and Tier 2a have been developed to generate risk information for a single PES that affects multiple exposed sites (ES's). The output for both Tier 1 and Tier 2a RBESS include color-coded maps that display information on replacement cost, fatalities, and injuries. The output also displays consequence information for individual ES's as well as summary information for all the ES's affected by the PES. Both tiers of RBESS automatically populate the Department of Army (DA) Form 7632 which is known as the Deviation Approval and Risk Acceptance Document (DARAD). RBESS is being released in ESS v6.1.4 and will be available to ESS users in the near future.

Tier 2B: This is a quantitative risk analysis per TP-14 – where risk estimates are based on numerical values for the event probability (*e.g.,* 1x10-6 per year) and the probability of consequences given the event occurs (*e.g.,* probability of potential fatality given the event = 2x10-3) are used to make decisions. This capability is not currently in ESS.

Tier 3: This is a notional advanced engineering analyses and other scenario-specific analyses that are not properly captured in a Tier 2 analysis. Currently, this capability has not been developed by the DDESB and may actually change in scope and expectations if and when it will be developed.

As stated above, RBESS will be a module within ESS software. It is envisioned that RBESS can be assessed by the user if QD cannot be met. Since RBESS is within ESS, it will use the existing data defined for QD purposes and ask the user for the additional information to conduct QRA per TP-14. [17] Also, because RBESS is a module within ESS, the data used for the TP-14 QRA will be stored within the ESS software.

In the future, RBESS be used for risk-based site planning, it will also have the ability to conduct risk management. It can be used to conduct a simplified risk management, using scaled distance (Tier 1) to setting up scenario-specific analysis (Tier 3). Using the ESS graphical user interface (GUI), RBESS will have the capability to visualize risk through various contours (debris, pressure, risk, etc.).

Tier 1 and Tier 2A of RBESS have been incorporated into ESS v6.1.4. Validation efforts of both Tier 1 and Tier 2A are underway. The current plan is for ESS Web v2.0 (not v1.0) to have RBESS and include Tier 1, 2A and 2B. Both Tier 2A and 2B will use TP-14 Rev 5 models. Development of ESS Web v2.0 will begin after release of ESS Web 1.0, which is scheduled for 2019.

Incorporating RBESS into the ESS software tool provides critical risk-based management capabilities both as part of the day to day missions of the installations and near real-time oversight for the DDESB. The DoD Component, the PMs and the DDESB can evaluate the overall explosives safety health of the installation and the DoD. For the first time assessments of how safe is QD siting on a case by case bases can be conducted. Specific risk management scenarios can be run to determine the best and safest location for new facilities and new capabilities. The DDESB will have more visibility of the explosives safety environments at each installation. Moving forward, this should significantly improve the overall explosives safety and munitions risk management capabilities for the U.S. DoD.

Quantitative Risk Management -"Approved Methods and Algorithms for DoD Risk-Based Explosive Siting" TP-14

This section provides an overview of the architecture of the TP-14. [17] TP-14 provides the details in quantitative risk analysis (QRA) process for explosives safety an overview of the architecture of the latest version of TP-14.

(*i.e.* TP-14 Rev. 4a) [17]. TP-14 Rev 4a details a sequence of 26 steps to estimate the annual probability of potential fatality. These procedures are arranged in the architecture as presented in Table 2. The architecture presented in Table 2 is complicated, however, to facilitate discussion of the associated tool, the 26 steps in Table 2 are divided into six functional groups.

Table 2. Six Functional Groups

Group 1	Steps 1-4	Situation Definition, Event and Exposure Analyses Includes user inputs that describe the situation (PES and ES) and calculates Pe, exposure, and yield
Group 2	Steps 5-8	Pressure and Impulse Branch Calculates the magnitude of the fatality mechanisms of pressure and impulse
Group 3	Steps 9-10	Structural Response Branch Calculates the magnitude of the fatality mechanisms of building collapse and broken windows (overall building damage)
Group 4	Steps 11-18	Debris Branch Calculates the magnitude of the fatality mechanisms for multiple types of flying debris
Group 5	Steps 19-22	Thermal Branch Calculates the magnitude of the fatality mechanism heat for HD 1.3 scenarios only
Group 6	Steps 23-26	Aggregation and Summation Aggregates the total magnitude and risks of all fatality mechanisms, calculates the desired measures of risk, and assesses overall uncertainty

The DDESB uses a set of four risk criteria for managing explosives risk at DoD facilities. The current DDESB criteria values are shown in Table 3. The Risk-Base Program sponsored by DDESB has recently been discussing group risk criteria because it has been found in the past that some of the facilities could meet individual risk criteria, but failed the group risk criteria. The DDESB Program is researching if the current group risk criteria in Table 3 is too restrictive, although the current group risk criteria is a factor of 10 more relaxed than the individual criteria. Other options are also being investigated as suitable method to handle group risk. Some of the methods being examined include F/N curves, the use ALARP, relaxing the group risk criteria, or a combination of these proposed methods. Comparison of these criteria to other US agencies' criteria is being researched in an effort to remove conservatism in the current risk criteria in Table 3.

Table 3 Risk Criteria Per DODM 6055.09-M

Risk to:	**DDESB Criteria**	**Service Guidance**
Any 1 worker[a] (Annual P_f)	Risks below 1×10^{-4} are acceptable	
All workers (Annual E_f)	Risks below 1×10^{-3} are acceptable (advisory)	If risks are above 1×10^{-3} apply ALARP principle[c] Accept above 1×10^{-2} with significant national need only[c]
Any 1 person (Annual P_f)	Risks below 1×10^{-6} are acceptable	
All public[b] (Annual E_f)	Risks below 1×10^{-5} are acceptable (advisory)	If risks are above 1×10^{-5} apply ALARP principle[c] Accept above 1×10^{-3} with significant national need only[c]

a) Worker criteria apply to people that are associated with the explosives activity, but not directly involved (hands-on).
b) Public criteria apply to government employees working on the installation but not related to the explosives activity, and the general public.
c) For Service's waivers and exemptions ALARP is the safety principle whereby risks are reduced "as low as reasonably practicable."

The tool to implement the TP-14 QRA is the computer software called SAFER. For the details of the SAFER tool refer to the user's manual, TP-19 [18]. The description of the SAFER is too complicated to fit in this paper, but the model architecture diagram, shown as Figure 6, depicts a "flow" of the algorithms in TP-14 and the SAFER tool.

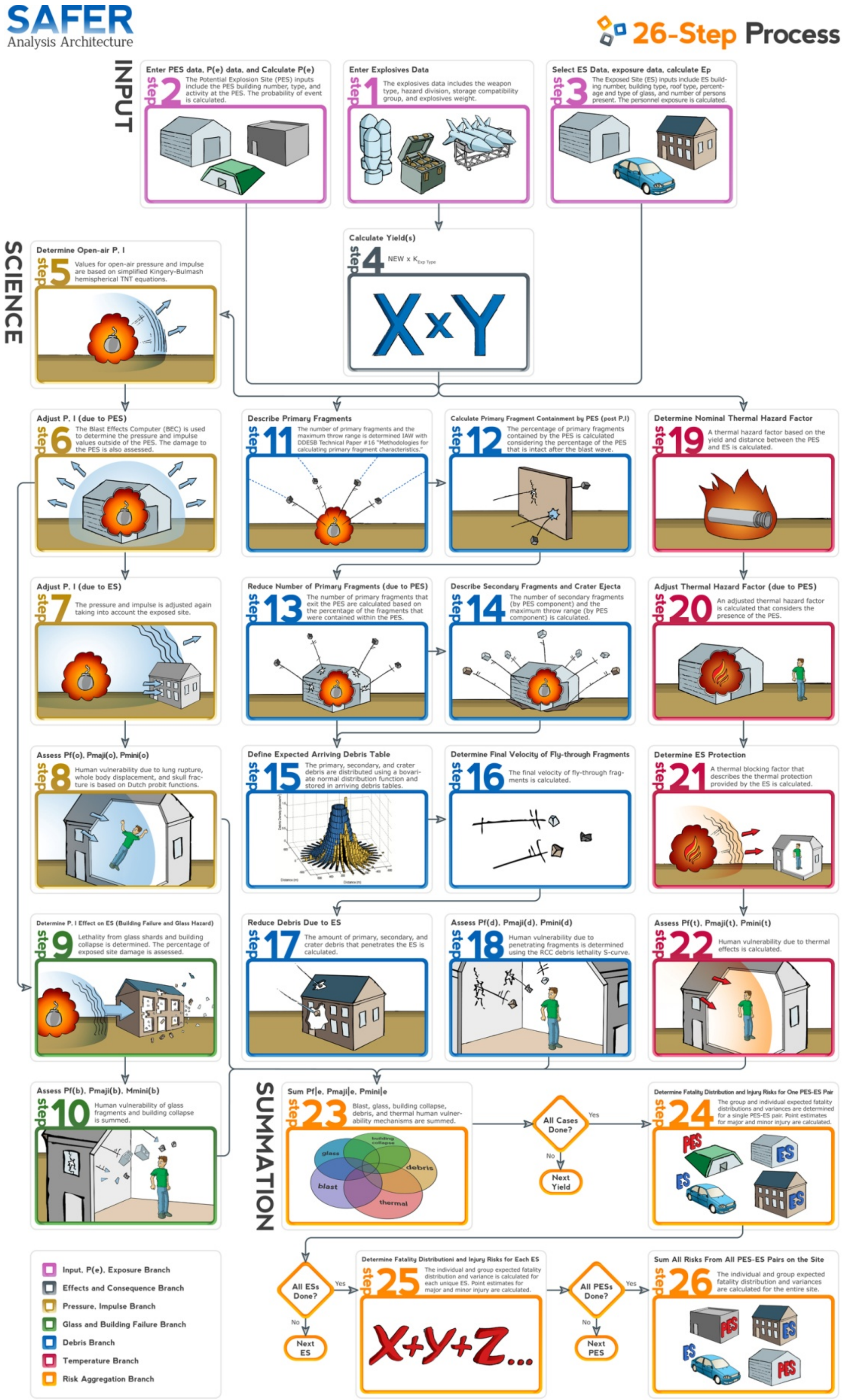


Figure 6. TP-14 SAFER Version 3.1 Architecture [17]

TP-14 is going through a major revision. The updated version, when completed, will be known as TP-14 Revision (Rev) 5 and will feature updated, state-of-the-art models for debris, pressure/impulse, building collapse, glass hazard, and thermal effects. Also, this revision will include updates to the probability of event (P_e) and the uncertainty model as discussed in Part II of this paper. Drafting of TP-14 Rev 5 is currently in its closing stages, and the algorithms and methodology presented in TP-14 Rev 5 will be incorporated into RBESS Tier 2B when it is developed. TP-14 methodology is based on the best science available to date. Data from many test programs has been analyzed and modeled and incorporated in the consequence algorithms used in TP-14. Figure 7 is a time line of the test programs. It also illustrates the test programs that feed the science that is going into RBESS Tier 2B and TP-14 Rev 5.

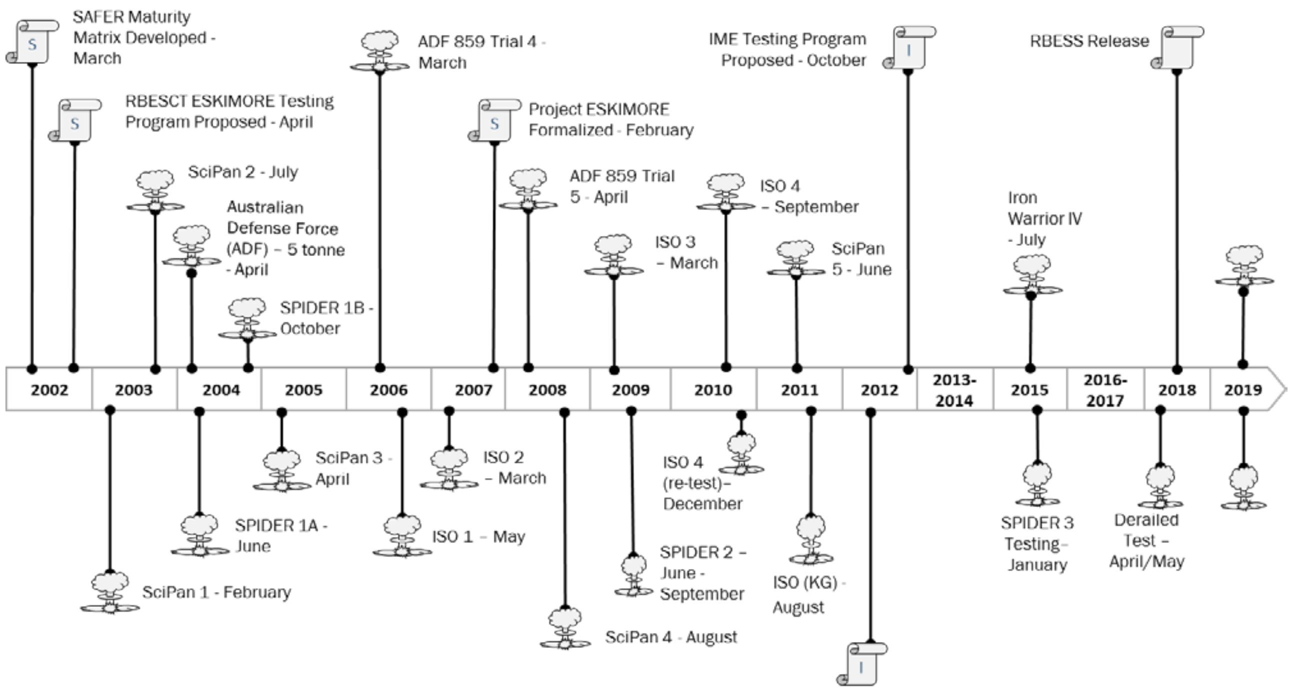


Figure 7. Time Line of Test Programs that have been used to develop the current consequence criteria for TP-14.

In the past few years the DDESB Risk-Base Analysis Program has been focusing many different improvements of the risk methodology to be incorporated in TP-14. Some of the short-term goals, include:

- Updating the probability of event (Pe) used in TP-14 methodology
- Implementing a “warning system” as the criteria for a TP-14 QRA analysis
- Updating the Universal Risk Scale (URS)
- Updating the uncertainty methodology used in TP-14 methodology
- Removing undue conservatism in TP 14 methodology to create a more realistic model
- Creation of RBESS v1.0 for incorporation into Explosive Safety Siting (ESS) to be released in late 2018.

The longer term goals for the Risk Analysis Program include:

- Implementing an “As Low as Reasonably Possible” (ALARP) methodology into the criteria used for a TP-14 QRA analysis
- Implementing an F/N process to consider catastrophic risk criteria for a TP-14 QRA analysis
- Continue to remove undue conservatism in TP-14 methodology to create a more realistic model
- Continue to support future versions of RBESS and web based RBESS
- Continue to assist the DoD Components in utilizing Risk analysis and risk management principles thought-out a munition system lifecycle.
- Continue to develop practical tools in support of DoD Components ESMRM process.

- Incorporate new science to include new test data, new physics based sub-models, non-detonation centric consequences geared to benefit from the Insensitive Munition Program and the DDESB Combustion Driven Hazards Program.
- Continue to socialize technical improvements and silicit inputs of the Services in support of DoD Components ESMRM process.

The Risk-Base Analysis Program relooked at risk acceptance criteria in other related industrial sectors. The findings from this initiative is documented in reference [19]. Two industries very similar to the DDESB in mission include the RCC and IME. The RCC mission is to serve the technical and operational needs of the U.S. test, training, and operational ranges. The RCC current technical standards address risk per mission on a per mission bases. IME is a consortium of industrial partners in the field of explosives. Their mission is to promote safety and security and the protection of employees, users, the public and the environment and encourage the adoption of uniform rules and regulations in the manufacture, transportation, storage, handling, use and disposal of commercial explosive materials. IME adopted TP-14 methodologies early in 2000 and use a risk bank approach for communicating risk. Some of the details of the IMESAFR will be presented in other papers at this symposium and are also documented in reference [11].

From both the literature review and relooked at risk acceptance criteria [19], the Risk-Based Program is recommending in the future the DoD adopt a more commonly used risk acceptance criteria. The two that are easiest to implement are the three-level risk paradigm system and the As Low As Reasonably Practicable (ALARP). These both use a range in criteria as opposed to a fixed criteria. The Program also recommends that for site plans that use this approach to identify their risk levels the DoD Components also present a "get-well-plan" to properly communicate their mitigation strategies and improvements in safety. Moving in this direction allows the DDESB to be more consistent with the RCC and the IME approach of risk communication. These concepts are further explained in Part II of this paper.

The DDESB has been conducting science improvement programs geared to improve both the QD tables in DODM 6055.09-M [2] and the consequence models in TP-14. [17] Additional details on these programs can be found in another papers presented at this symposium.

Support of NATO

The DDESB is involve in significant support of the ESMRM process in NATO. Activities include: improve and develop new risk based methodology, update pertinent documentations, develop of ESMRM training, and support NATO missions with appropriate risk assessments. The pertinent documents that are being updated include but are not limited to updates of: ALP-16, AASTP-1, AASTP-4 and AASTP-5. Some of these activities will also be presented in other papers at this symposium.

AASTP-4 is the NATO guideline for conducting QRA studies for allied explosives facilities. This document (comprising two parts) discusses the national methods for assessing risk, to include probability of event and consequence modeling. The document also contains a "unified approach" section that describes the models and algorithms accepted by all participating nations. The U.S. has supported the AASTP-4 Risk Assessment Working Group (RAWG) by contributing material to the document, hosting annual working meetings, and participating in studies conducted by the group. In addition to writing the U.S. approach sections in the document, the U.S. has contributed technically and provided secretarial support to produce ongoing updates. Most recently, the U.S. material was updated to reflect many of the model changes in accordance with moving from TP-14 Rev 4a to TP-14 Rev 5. The U.S. is planning to host the group's next meeting in October 2018.

Conclusions

The DDESB Risk Analysis Program is focused on developing methods and tools in support of ESMRM for the U.S. DoD components, NATO and other national and international organizations. The program is also addressing ESMRM in the DoD acquisition lifecycle. These efforts all have a consistent approach to Risk Assessment and Management and have adopted the following OMB principles [12]:

- They employ the best reasonably obtainable scientific information to assess risks to health, safety, and the environment.
- Characterizations of risks and of changes in the nature or magnitude of risks should be both qualitative and quantitative, consistent with available data. The characterizations should be broad enough to inform the range of policies to reduce risks.
- Judgments used in developing a risk assessment, such as assumptions, defaults, and uncertainties, should be stated explicitly. The rationale for these judgments and their influence on the risk assessment should be articulated.
- Risk assessments should encompass all appropriate hazards (e.g., acute and chronic risks, including cancer and non-cancer risks, to human health and the environment). In addition to considering the full population at risk, attention should be directed to subpopulations that may be particularly susceptible to such risks and/or may be more highly exposed.
- Peer review of risk assessments can ensure that the highest professional standards are maintained. Therefore, agencies should develop policies to maximize its use.
- Agencies should strive to adopt consistent approaches to evaluating the risks posed by hazardous agents or events.

The program has incorporated qualitative and quantitative risk management principles for ESMRM into the entire DoD acquisition lifecycle. These approaches are continuously improving and evolving to stay current with new findings improved understanding. The national and international explosives safety communities have leveraged the DDESB efforts into their day to day explosives safety programs. Currently, the DDESB Risk-Base Program is involved in advancing the state-of-the-art and science of Risk analysis and management in areas related to explosives safety. Some of these areas include: incorporation combustion driven processes in TP-14, ESMRM in the acquisition lifecycle, and risk management in operations. Participation in all these activities will continue.

Acknowledgement

The current Risk Analysis Program sponsored by DDESB has been or will be conducting science improvement projects geared to improve both the Quantity-Distance (QD) tables in DODM 6055.09-M and the consequence models in TP-14. Under the leadership of Dr. Josephine Covino of DDESB, the Naval Facilities Engineering & Expeditionary Warfare Center (NAVFAC EXWC) in Port Hueneme, California is executing the Program, which is supported by the primary contractor of the A-P-T Research Inc. in Huntsville, Alabama and the sub-contractor of ACTA in Torrance, California. Additionally, Mr. Robert Conway and Dr. Michael Oesterle of NAVFAC EXWC have been making significant contributions to the Program.

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