Speaking a Common Risk Management Language with Executives and Program Managers

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Abstract

The characteristics of risk and risk management (RM) vary significantly from discipline to discipline. For instance, probability scales may differ by orders of magnitude, the severity definitions often have minimal overlap, and even the definition of "risk" typically differs and sometimes includes positive outcomes. These differences can create confusion and uncertainty during program execution, manufacturing, and/or operational implementation. As with most problems, mutual understanding is a key first step to determining solutions. Installation commanders, production and manufacturing executives, and program managers must make cost, schedule, and performance decisions daily and must rely, in part, on the safety professional's assessment of risk(s). This requires the safety professional to "tailor" the RM process and language to ensure understanding and optimize a commander's or PM's decision-making. This paper explores the risk and RM landscape between program and operational or system risks, environmental, safety and occupational health (ESOH) risks, and Ammunition and Explosive (AE) risks with the goal of clearly outlining how risk is described and managed from often-interacting disciplines.

Introduction

In today's approach of integrated program, project, and operational management, each contributing discipline employs a unique language. Similar words or phrases are often used across disciplines, though with disparate meanings. Interdisciplinary risk management (RM) approaches should always involve the commander, operational leader, and/or Project Manager (PM). In most projects, the commander or PM is either the approval authority of each identified risk, or the conduit to upper managers for final approval. Explosive manufacturers, demilitarization, storage and test sites, in addition to ships and weapons platforms have PMs, commanders, or directors that also assess risks and work to optimize multiple competing cost, schedule, and performance factors. These individuals control budgets and schedules associated with risk mitigations, investment, and verification. Meanwhile, the characteristics of system safety and explosive safety risk are often fundamentally different than the characteristics of risks regularly managed by the commander or PM – the probability scales differ by orders of magnitude, the severity definitions have minimal overlap, and the generally accepted PM definition of "risk" includes both positive and negative outcomes.

Do we understand these differences as engineering professionals? How can we mitigate the effects to improve the success of our projects? How do we quantify risks to assist the PM with decision-making?

To provide consistency and effectively communicate the challenges and solutions presented in this paper, we have attempted to use a "common language" familiar to government, industry, and program managers in global industry and government. We have also adapted a fundamental principle first presented by the "father of risk management," Blaise Pascal, stating, "Define your terminology as you go." Safety professionals must apply Pascal's principle assertion to ensure risks are mutually defined, understood, and tailored to ensure mitigations optimize program potential. Risk terms, language, arguments, discussions, recommendations, and decisions are similarly applicable to the explosive industry commander, PM, manager, and/or executives involved in development, manufacturing, storage or other areas of life-cycle management.

Risk in Project Management

Project management principles are applied differently across industries, with nuances in approach and terminology. The *Project Management Book of Knowledge Guide, 6th Edition,* (*PMBOK)* serves as a globally accepted collection of project management terms, processes, and best practices independent of specific industries. The *PMBOK* outlines and explains five process groups that make up any project and 14 knowledge areas needed to accomplish a project efficiently. One knowledge area is RM, which encompasses much of the work of the system safety and explosive safety professionals.

The *PMBOK* defines "individual project risk" as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives." This definition includes risks related to business, manufacturing, development, and human resources. The range of consideration goes from negative outcomes to positive outcomes, called "threats" and "opportunities," respectively. Thus, within the knowledge area of RM, these interdisciplinary RM approaches are a fraction of the total risk discussion.

The *PMBOK* is not industry-specific and does not specify risk outcome definitions or associated probability ranges. As an example of how the RM process is applied, consider the Department of Defense *Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs* (*DoD Risk Management Guide*), which is similar to RM guidance across government agencies. In this guide, risk is defined as:

> Potential future events or conditions that may have a negative effect on achieving program objectives for cost, schedule, and performance. Risks are defined by (1) the probability (greater than 0, less than 1) of an undesired event or condition and (2) the consequences, impact, or severity of the undesired event, were it to occur.

Therefore, risk is scoped down to negative or undesired events, while the term "opportunities" describes the positive spectrum of uncertain events.

The *DoD Risk Management Guide* provides sample consequences and probability criteria, which are depicted in Table 1 and Table 2, respectively.

The sample consequences criteria define five consequence levels from Minimal Impact to Critical Impact. Impacts associated with cost increases are primarily quantified as percentage ranges of the Acquisition Program Baseline (APB). Schedule and performance impacts typically contain more subjective definitions for the five consequence levels.

Table 1 — DoD Risk Management Guide – Sample Consequence Criteria

Level	Cost	Schedule	Performance
5 Critical Impact	10% or greater increase over APB objective values for RDT&E, PAUC, or APUC Cost increase causes program to exceed affordability caps	Schedule slip will require a major schedule re-baselining Precludes program from meeting its APB schedule threshold dates	Degradation precludes system from meeting a KPP or key technical supportability threshold; will jeopardize program success Unable to meet mission objectives (defined in mission threads, ConOps. OMS/MP)
4 Significant Impact	5% - <10% increase over APB objective values for RDT&E, PAUC, or APUC Costs exceed life cycle ownership cost KSA	Schedule deviations will slip program to within 2 months of approved APB threshold schedule date Schedule slip puts funding at risk Fielding of capability to operational units delayed by more than 6 months	Degradation impairs ability to meet a KSA. Technical design or supportability margin exhausted in key areas Significant performance impact affecting System-of-System interdependencies. Work-arounds required to meet mission objectives
3 Moderate Impact	1% - < 5% increase over APB objective values for RDT&E, PAUC, or APUC Manageable with PEO or Service assistance	Can meet APB objective schedule dates, but other non-APB key events (e.g., SETRs or other Tier 1 Schedule events) may slip Schedule slip impacts synchronization with interdependent programs by greater than 2 months	Unable to meet lower tier attributes. TPMs, or CTPs Design or supportability margins reduced Minor performance impact affecting System-of-System interdependencies; Work-arounds required to achieve mission tasks
2 Minor Impact	Costs that drive unit production cost (e.g., APUC) increase of <1% over budget Cost increase, but can be managed internally	Some schedule slip, but can meet APB objective dates and non-APB key event dates	Reduced technical performance or supportability; can be tolerated with little impact on program objectives Design margins reduced, within trade space
1 Minimal Impact	Minimal impact. Costs expected to meet approved funding levels	Minimal schedule impact	Minimal consequences to meeting technical performance or supportability requirements Design margins will be met; margin to planned tripwires
APB: Acquisition Program Baseline; APUC: Average Procurement Unit Cost; ConOps: Concept of Operations; CTP: Critical Technical Parameter; PAUC: Program Acquisition Unit Cost; PEO: Program Executive Officer; KPP: Key Performance Parameter; KSA: Key System Attribute; OMS/MP: Operational Mode Summary/Mission Profile; RDT&E: Research, Development Test & Evaluation; TPM: Technical Performance Measure			

The sample probability criteria define five likelihood levels from 1 (Not Likely) to 5 (Near Certainty). The quantitative ranges encompass approximately equal quintiles. The level 1 (Not Likely) probability of occurrence range is 1-20%. Probabilities below 1% are not addressed in the sample probability criteria.

Table 2 — DoD Risk Management Guide – Sample Probability Criteria

Level	Likelihood	Probability of Occurrence
5	Near Certainty	>80% to ≤ 99%
4	Highly Likely	>60% to ≤ 80%
3	Likely	>40% to ≤ 60%
2	Low Likelihood	> 20% to ≤ 40%
1	Not Likely	> 1% to ≤ 20%

Consequence and likelihood are combined in a risk matrix commonly used on DoD acquisition programs, which is regularly reviewed by the PM as part of RM, as shown in Figure 1. In this risk matrix, red represents areas of High project risk, yellow represents areas of Medium project risk, and green represents areas of Low project risk.

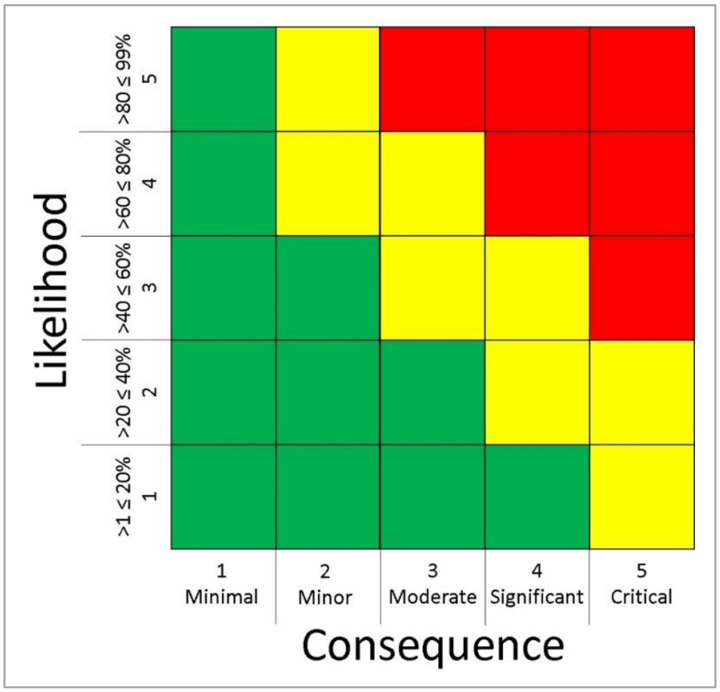

Figure 1 — Sample Risk Matrix

Finally, the *DoD Risk Management Guide* provides this direction related to incorporation of ESOH risk in the RM paradigm:

> Since safety and system hazard risks typically have cost, schedule, and performance impacts for the program, they should be addressed in the context of overall risk management. As a best practice, programs should include current high system hazard/**Environmental Safety and Occupational Health (ESOH)** risks together with other program risks on the prioritized risk matrix presented at key program decision points. Programs should use a Service-developed method to map these risks to the risk matrix and register, as appropriate.

The question becomes how to map ESOH risks to program risks. While explosive safety can be (and often is) captured in the ESOH RM approach, *DoD 6055.16, DoD Explosives Safety Management Program* does not direct the user to follow the MIL-STD-882E approach for assessing AE operational risks. A similar approach to RM is described in Enclosure 4 of DoD 6055.16. The *DoD 6055.09-M, DoD Ammunition and Explosives Safety Standards, Volume 6,* does mention MIL-STD-882D in relation to toxic chemical munitions and agents, but does not specifically call out explosives. Each of the military services addresses operational risk from AE differently, with diverging terms, definitions, and acceptance authorities. One of the tenants of the planned Technical Paper (TP) 23 update is to recognize unique service requirements while establishing consistent terminology, acceptance criteria, and definitions.

The goal of mapping risk to the program risk matrix is to facilitate PM understanding of the full spectrum of risks generated by the execution of his/her program. Only through understanding can a PM allocate resources to mitigate the most severe risks to the program. Enclosure 4 of DoD 6055.16 (Section 1.d) speaks to the role of DoD Military Munitions Explosives and Chemical Agent Risk Stewardship (MMRS) as follows:

> MMRS is a cornerstone of ESM and provides a means to:
> (1) Support the DoD Components in reducing costs and eliminating unnecessary expenditures.
> (2) Provide tools to leaders and managers who are responsible for implementing an effective ESMP and making informed explosives safety risk management decisions.

Risk in System Safety

The system safety discipline widely accepts MIL-STD-882E as a primary authority on system safety practice. Additionally, since it is a DoD standard, it should adequately serve as the ESOH equivalent to the example *DoD Risk Management Guide*. MIL-STD-882E defines risk as "a combination of the severity of the mishap and the probability that the mishap will occur." This definition loosely fits within the definition of the *DoD Risk Management Guide* definition for risk, while encompassing approximately half of the *PMBOK Guide* definition for risk.

MIL-STD-882E provides severity categories and an example for probability levels, which are depicted in Table 3 and Table 4. Both tables are tailorable IAW MIL-STD-882E Section 4.3.3.d.

MIL-STD-882E defines four severity categories from "Negligible" to "Catastrophic." Impacts associated with cost are quantified as a range of dollars, as opposed to percentage of the APB. Schedule and performance impacts are not addressed. Personnel safety impacts are mostly objective, while environmental impacts criteria are subjective.

Table 3 — MIL-STD-882E - Severity Categories

Description	Severity Category	Mishap Result Criteria
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following; injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

MIL-STD-882E example probability levels include six likelihood levels from F (Eliminated) to A (Frequent). The associated ranges are quantitatively defined by orders of magnitude, with A (Frequent) mishaps having a probability of occurrence >10% and E (Improbable) mishaps having a probability of occurrence <0.0001%. It is of note that only probability levels A (Frequent) and B (Probable) safety risks would fall on the *DoD Risk Management Guide* sample probability criteria scale. Therefore, all level C (Occasional), D (Remote), and E (Improbable) safety risks do not naturally, by definition, fit within the typical PM RM paradigm.

Table 4 — MIL-STD-882E Example Probability Levels

Description	Level	Individual Item	Fleet/Inventory	Quantitative
Frequent	A	Likely to occur often in the life of an item	Continuously experienced.	Probability of occurrence greater than or equal to 10^{-1}.
Probable	B	Will occur several times in the life of an item	Will occur frequently	Probability of occurrence less than 10^{-1} but greater than or equal to 10^{-2}.
Occasional	C	Likely to occur sometime in the life of an item	Will occur several times.	Probability of occurrence less than 10^{-2} but greater than or equal to 10^{-3}.
Remote	D	Unlikely, but possible to occur in the life of an item	Unlikely but can reasonably be expected to occur.	Probability of occurrence less than 10^{-3} but greater than or equal to 10^{-5}.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item	Unlikely to occur, but possible.	Probability of occurrence less than 10^{-6}
Eliminated	F	Incapable of occurrence within the life of an item. This category is used when potential hazards are identified and later eliminated.		

The system safety professional typically combines the severity and probability levels in a safety risk matrix, as shown in Figure 2. A PM or executive must understand both the origin and impact (outcome) these precise measures in the safety risk matrix indicate in terms of cost and loss of life. Additionally, in the case of explosives safety, increasingly higher fidelity of probability does not necessarily impact the commander's or PM's options to mitigate an outcome. For example, non-developmental leaders will generally assume products have some level-of-safety analysis completed and inherent within a product. They must then correlate this information with other factors (safe separation, location, environment, etc.) as a function of their own risk analysis.

SEVERITY / PROBABILITY	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A) ≥ 10%	HIGH	HIGH	SERIOUS	MEDIUM
Probable (B) ≥1<10%	HIGH	HIGH	SERIOUS	MEDIUM
Occasional (C) ≥0.1<1%	HIGH	SERIOUS	MEDIUM	LOW
Remote (D) ≥0.0001<0.1%	SERIOUS	MEDIUM	MEDIUM	LOW
Improbable (E) <0.0001	MEDIUM	MEDIUM	MEDIUM	LOW
Eliminated (F)	Eliminated			

Figure 2 — Safety Risk Matrix

AE Risk in the Army

Department of the Army Pamphlet 385-30 (DA PAM 385-30) is the Army guidance for Mishap Risk Management. DA PAM 385-30 defines risk as "the probability and severity of loss linked to hazards. It is simply the measure of the expected loss from a given hazard or group of hazards, usually estimated as the combination of the likelihood (probability) and consequences (severity) of the loss." This definition fits within the definition of MIL-STD-882E definition for risk.

DA PAM 385-30 provides severity categories and probability levels, which are depicted in Table 5 and Table 6. Neither are identified as tailorable within the pamphlet.

DA PAM 385-30 defines four severity categories from "Negligible" to "Catastrophic." Impacts associated with cost are quantified as a range of dollars. Environmental impacts are not addressed. Personnel safety impacts are mostly objective, while mission performance and readiness impacts criteria are subjective. Although severity titles mimic the MIL-STD-882E titles and the definitions associated with personnel safety are essentially equivalent, the definitions associated with cost are noticeably different.

Table 5 — DA PAM 385-30 - Severity Categories

Severity	Symbol	Quantitative value – Injury or Illness	Quantitative value — Dollars	Definition
Catastrophic	1	1 or more death or permanent total disability	Loss equal to $2 million or more	Death, unacceptable loss or damage, mission failure, or unit readiness eliminated
Critical	2	1 or more permanent partial disability or hospitalization of at least 3 personnel	Loss equal to or greater than $500 thousand but less than $2 million	Severe injury, illness, loss, or damage; significantly degraded unit readiness or mission capability
Marginal	3	1 or more injury or illness resulting in lost time	Loss equal to or greater than $50 thousand but less than $500 thousand	Minor injury, illness, loss, or damage; degraded unit readiness or mission capability
Negligible	4	1 or more injuries or illnesses requiring first aid or medical treatment	Loss less than $50 thousand	Minimal injury, loss, or damage; little or no impact to unit readiness or mission capability

DA PAM 385-30 probability levels include five likelihood levels from E (Unlikely) to A (Frequent). The associated ranges are not quantitatively defined. It is of note that none of the probability levels include quantitative definitions.

Table 6 — DA PAM 385-30 Probability Levels

Probability	Symbol	Definition
Frequent	A	Continuous, regular, or inevitable occurrences
Probable	B	Several or numerous occurrences
Occasional	C	Sporadic or intermittent occurrences
Remote	D	Infrequent occurrences
Improbable	E	Possible occurrences but improbable

The severity and probability levels are combined into the Army's standard risk matrix, as shown in Figure 3. This matrix does not align with the MIL-STD-882E risk matrix in risk category placement or quantitative definition.

		Probability (expected frequency)				
		Frequent: Continuous, regular, or inevitable occurrences	Likely: Several or numerous occurrences	Occasional: Sporadic or intermittent occurrences	Seldom: infrequent occurrences	Unlikely: Possible occurrences but improbable
Severity (expected consequence)		A	B	C	D	E
Catastrophic: Death, unacceptable loss or damage, mission failure, or unit readiness eliminated	I	EH	EH	H	H	M
Critical: Severe injury, illness, loss, or damage; significantly degraded unit readiness or mission capability	II	EH	H	H	M	L
Moderate: Minor injury, illness, loss, or damage; degraded unit readiness or mission capability	III	H	M	M	L	L
Negligible: Minimal injury, loss, or damage; little or no impact to unit readiness or mission capability	IV	M	L	L	L	L

EH – extremely high risk ; H – high risk ; L – low risk ; M – medium risk

Figure 3 — Standardized Army Risk Matrix

The guidance for Navy and Air Force operational RM, *OPNAVINST 3500.39C* and *Air Force Materiel Command Instruction 90-902*, respectively, demonstrate even less alignment with MIL-STD-882E. It should be noted that none of these documents is required to align with MIL-STD-882E and likely has sound rationale for misalignment. However, for the task of mapping ESOH risks to the program risk matrix, as desired per the *DoD Risk Management Guide*, common definitions would prove helpful. Additionally, further initiatives for TP-23 revisions to employ common definitions and processes among the services are also encouraging.

Summary of Communication Disconnects

While the *DoD Risk Management Guide* directs programs to map high ESOH risks to program risks and include them on the prioritized risk matrix, there is no direction on how to do this task. In fact, it is unclear if "high" indicates those safety risks with a HIGH safety rating on the safety risk matrix, or subjectively high safety risks (both HIGH and SERIOUS safety risks). Additionally, almost every characteristic of the various risk paradigms differs, as summarized in Table 7.

Table 7 — Communication Disconnect Summary

Characteristic	PM/Executive	MIL-STD-882	Services Sample – DA PAM 385-30	Assessment
Risk definition	May include uncertain	Only addresses uncertain	Only addresses	Clear;

Characteristic	PM/Executive	MIL-STD-882	Services Sample – DA PAM 385-30	Assessment
– clear and consistent?	positive and/or negative outcomes	negative outcomes	uncertain negative outcomes	Not consistent
Consequence/ severity – objective and equivalent?	Addresses cost, schedule, and performance – cost objectively	Addresses safety, environmental impact, and cost – cost and safety objectively, cost does not align with DA PAM 385-30	Addresses safety, environmental impact, and cost – cost and safety objectively, cost does not align with MIL-STD-882E	Partially objective; Not equivalent
Likelihood/ probability – ranges overlap?	Five equally divided percentage ranges between 1-99%	Five percentage ranges with order of magnitude difference between 0.0001–99%	Five subjective probability definitions	Partially objective; Minimal overlap
Risk matrices – equivalent?	Five by Five; Lowest risk in bottom left, highest risk in top right	Four by Six; lowest risk in bottom right, highest risk in top left	Four by Five; lowest risk in bottom right, highest risk in top left	Not equivalent
Risk levels – equivalent in number and required action?	Three risk levels – High, Medium, and Low; Action to burn-down High, Medium, and some Low risks. No required action to elevate risks.	Four risk levels – HIGH, SERIOUS, MEDIUM, & LOW; Action to reduce risk to extent practical. HIGH and SERIOUS risks require elevation for risk acceptance.	Four risk levels – Extremely High, High, Medium, & Low; action to reduce risk to extent practical. Risk acceptance authority based on military rank.	Not equivalent in number or required action.
Finding: ESOH risks cannot be directly mapped to program risks without modifications in severity, probability, and risk levels.				

If it is assumed only HIGH ESOH risks should be mapped, DA-PAM 385-30 qualitative probability levels are similar to MIL-STD-882E probability levels, and DA-PAM 385-30 Extremely High risks loosely map to MIL-STD-882E High risks. Under this assumption, the nearest graphical depiction (as shown in Figure 4) would show “Catastrophic” safety risks with probability ratings of A, B, and C on the right edge of the Critical program risk column, and “Critical” ESOH risks with probability ratings of A and B centered in the Critical program risk column. In almost all cases, ESOH risks are relegated to the bottom-right blocks of the program risk matrix, and are unlikely to be considered above a Medium program risk, no matter the severity of the uncertain event. This approach to ESOH risk mapping does not adequately characterize the potential risk to the program. For example, assume the transportation and demilitarization of an aged hazard division (HD) 1.1 has a 10% risk of two fatalities (represented as “R1” in Figure 4). Should such a risk be assessed as Medium on the programmatic risk scale?

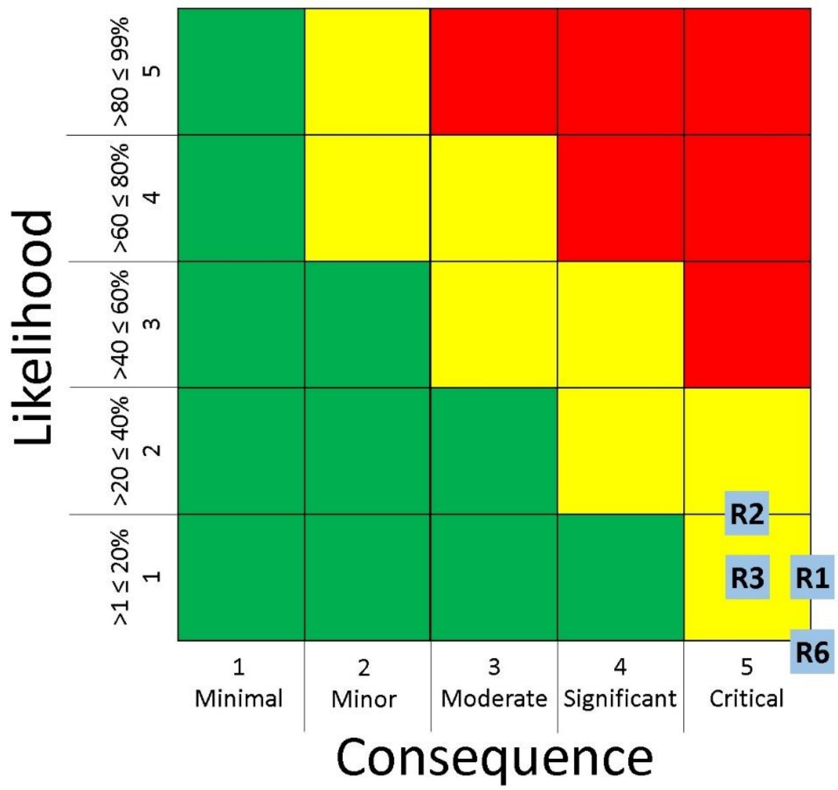

Figure 4 — HIGH Safety Risks Mapped

Solution 1: Risk Program Tailoring

Another significant reference for RM is the ANSI *Standard for Best Practices in System Safety Program Development and Execution*. This standard, developed by the G48 National Committee on System Safety, advocates for practices that include more academically correct means of characterizing risk. The standard provides a consistent approach to assess and evaluate ESOH risks with the understanding that some risk must be accepted by appropriate authorities such as commanders, PMs, and executives. Additionally, quantitative and qualitative features of the ANSI Standard are applicable across the full system lifecycle for products, sites and installations, and manufacturing facilities.

For example, the standard defines desirable characteristics of a risk assessment matrix to include:

a. Tailoring of scales to specific systems
b. Orienting scales upward and to the right, as in a Cartesian coordinate system
c. Use of log scales rather than linear (percentage) scales.

In the spirit of the ANSI Standard, Solution 1 advocates both the tailoring of risk scales and the orientation of scales upward and to the right. Early recognition of the differences in risk definitions, consequence/severity equivalence, likelihood/probability range overlap, and risk matrix overlap could be documented and leveraged to tailor programs for a specific project/program. Tailored RM programs would improve communication throughout the project/program. For example, the ESOH program could implement cost consequence definitions from the RM program as opposed to standard MIL-STD-882E severity cost definitions, and map ESOH mishap result criteria to the Minor-through-Critical severity categories, while adding a Catastrophic category to include death, as shown in Table 8.

Table 8 — Modified, Summarized Risk Management Guide – Example Consequence Criteria

Level	Cost	Schedule	Performance	Safety
6 Catastrophic Impact	**15% or greater increase over APB objective values**	N/A	**Degradation precludes system from meeting multiple key technical supportability thresholds; will jeopardize program success**	**Results in one or more fatalities**
5 Critical Impact	10%- <15% increase over APB objective values	Schedule slip will require a major schedule re-baselining Precludes program from meeting its APB schedule threshold dates	Degradation precludes system from meeting a key technical supportability threshold; will jeopardize program success Unable to meet mission objectives	**Results in one or more of the following: permanent total disability, irreversible significant environmental impact**
4 Significant Impact	5% - <10% increase over APB objective values	Schedule deviations will slip program to within 2 months of approved APB threshold schedule date Schedule slip puts funding at risk	Technical design or supportability margin exhausted in key areas Significant performance impact affecting System-of-System interdependencies. Work-arounds required to meet mission objectives	**Results in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact.**
3 Moderate Impact	1% - < 5% increase over APB objective values	Can meet APB objective schedule dates, but other non-APB key events may slip	Unable to meet lower tier attributes. Design or supportability margins reduced Minor performance impact affecting System-of-System interdependencies. Work-arounds required to achieve mission tasks	**Results in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact.**
2 Minor Impact	Costs that drive unit production cost increase of <1% over budget	Some schedule slip, but can meet APB objective dates and non-APB key event dates	Reduced technical performance or supportability; can be tolerated with little impact on program objectives Design margins reduced, within trade space	**Results in one or more of the following; injury or occupational illness not resulting in a lost work day, minimal environmental impact.**
1 Minimal Impact	Minimal impact. Costs, expected to meet approved funding levels	Minimal schedule impact	Minimal consequences to meeting technical performance or supportability requirements Design margins will be met	N/A

APB: Acquisition Program Baseline

Additionally, a sixth likelihood definition category could be added to encompass the bottom three non-zero system safety probability categories, as demonstrated in Table 9.

Table 9 — Modified Risk Management Guide – Example Probability Criteria

Level	Likelihood	Probability of Occurrence
5	Near Certainty	>80% to ≤ 99%
4	Highly Likely	>60% to ≤ 80%
3	Likely	>40% to ≤ 60%
2	Low Likelihood	> 20% to ≤ 40%

Level	Likelihood	Probability of Occurrence
1	Not Likely	> 1% to ≤ 20%
0	Remote	≤ 1%

These modifications would allow for direct mapping of HIGH and SERIOUS ESOH risks to the project/program risk matrix as well as a numerical count of MEDIUM and LOW ESOH risks into the project/program risk categories. This ensures ESOH risks of concern receive regular commander or PM-level visibility. Leveraging the previous example of the transportation and demilitarization of an aged HD 1.1, with a 10% chance of two fatalities, a more accurate risk posture emerges on the hypothetical programmatic risk matrix. Namely, "R1" is depicted as a High program risk. An example of this and other modifications is depicted in Figure 5.

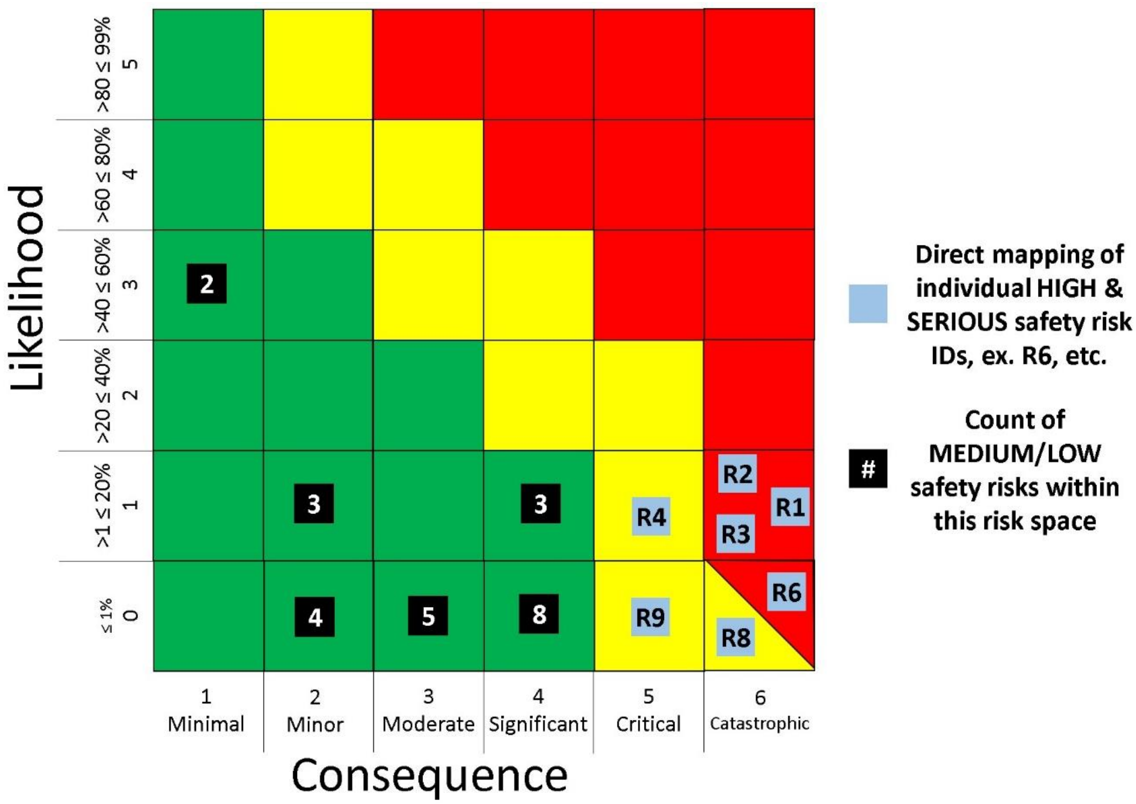

Figure 5 — Program Risk Matrix - Expanded

<u>Solution 2: Quantifying Safety Impacts of Project Execution</u>

Not all projects or systems are in a phase to accommodate risk program tailoring. While MIL-STD-882E and DoD AE guidance allow for risk acceptance of elevated safety risks, the existence of those risks present cost, schedule, and performance risks to the project/program. Sometimes they present themselves as risks to key delivery or schedule milestones due to a low risk appetite among upper management. Other times, a low risk appetite among external stakeholders may negatively impact cost, schedule, and performance simultaneously, but at varied levels. This concern increases as the complexity of systems or facilities necessitate more interaction between the systems safety professional and PMs whose programs are managed by different military services or industry paradigms.

As a hypothetical example, a rocket motor by the Army suffers a late failure in explosive sensitivity testing prior to a scheduled transport via Navy ship to a demilitarization location. The Army assesses the safety risk as 1D (Catastrophic/Remote per MIL-STD-882E / Catastrophic/Seldom per DA PAM 385-35) and the acceptance authority accepts the risk. However, the Navy ship commander declines the risk. This results in a Critical Impact to schedule and cost baselines while the system undergoes retesting and/or transportation system redesign.

Any ESOH risk that may impact external stakeholders and has not been driven to the MEDIUM or LOW safety risk areas and closed with verifications, has potential program/project implications. To address this type of scenario, the program/project (government or industry) should include each SERIOUS and HIGH ESOH risk in the program/project risk matrix. The risk consequence becomes "Residual risk (risk description) may be unacceptable to (external stakeholder)." The severity of that outcome should be assessed based on the complexity and interrelationship of the system and impact to cost, technical/performance, or schedule baselines should the external stakeholder decline the risk. The risk probability is assessed based on the number of planned mitigations, mitigation contingencies, verification schedules relative to decision dates, and estimated risk appetite of external stakeholders who must also accept the risk.

An example of this approach is demonstrated in Table 10, with mapping to the program/project risk matrix depicted in Figure 6.

Table 10 — DoD Risk Management Guide – Example Risk Register Excerpt

Risk Number	821	822
Linked WBS/IMS ID#	3.1.2	3.1.2
Owner	Smith	Smith
Type of Risk	Technical - Safety	Technical - Safety
Status	Open	Open
Risk Event	Residual SERIOUS risk "Support arm failure due to corrosion" may be unacceptable to demil range	Residual HIGH risk "Sensitivity to shock/vibe during transit" may be unacceptable to ship commander
Likelihood, Consequence Rating	**L=3, C=4**	**L=3, C=5**
Risk Mitigation Strategy	Control – Prioritize completion of verifications on subject risk; Include demil rep in safety verification planning	Control – Prioritize completion of verifications on subject risk; Include ship rep in safety verification planning; Coordinate alternate transport
Risk Identified Date	8/20/2015	8/20/2015
Risk Approval Date	2/10/2016	2/10/2016
Planned Closure Date	7/15/2016	7/15/2016
Target Risk Rating	**L=1, C=4**	**L=1, C=4**
Plan Status	On Schedule	On Schedule

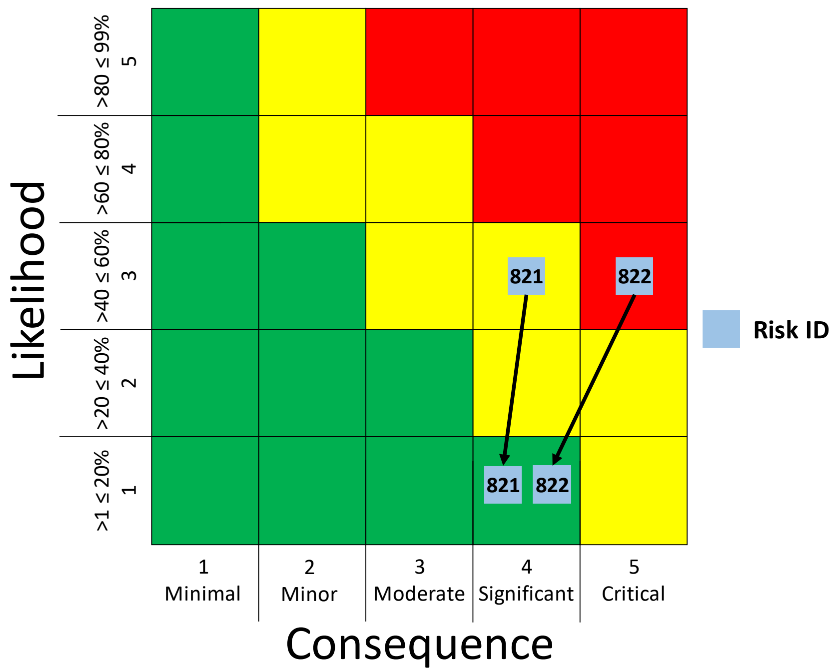

Figure 6 — Program Risk Matrix – Safety Impact Mapped

Conclusions

Scheduling, funding, performance, and associated risk mitigation decisions are all ultimately made by PMs, executives, and/or commanders of organizations. Therefore, effective communication between the safety professionals and these leaders may be one of the most important interdisciplinary traits to acquire and apply. An essential engineering responsibility is to ensure responsible authorities consider and integrate safety-related risks with other program/project risks as each has some measure of statistical probability of occurrence and could, positively or negatively impact the eventual outcome. The honest exchange and early notification of concerns are key to productive stakeholder interactions. By cultivating a better understanding of how PMs and other leaders approach risk, the safety engineering professional can most appropriately influence and map AE and other ESOH risks to program/project risks. This "tailoring" of program/project and ESOH risks is essential in order to optimize limited resources associated with risk mitigation actions. By participating in the program/project risk development discussion, the safety engineering professional can effectively minimize AE and ESOH-related impacts and ensure program/project success.

Biography

Colonel (Retired) Fellows is the Chief Executive Officer of APT Research, Inc. in Huntsville, AL. He has over 32 years of U.S. Army and industry experience in Research & Development, Defense Acquisition, Program & Executive Management and Operational Risk & Safety. Prior to joining APT in 2015, he was the Vice President for Programs, DoD Agencies & Commands for Science Applications International Corporation (SAIC). He managed multiple ACAT 1D developmental and operational weapons and radar systems for the Army and Missile Defense Agency during his military career. He holds a B.S. in Business Management from Brigham Young University, an M.S. in Management from Florida Institute of Technology, and an M.S. in National Resource Strategy from the Industrial College of the Armed Forces. He is Defense Acquisition, level 3 certified and a Project Management Professional (PMP).

Mr. Nix is a Systems Safety Engineer and Project Manager with APT Research, Inc. in Huntsville, AL. He has been responsible for various areas of safety-related work in APT's business base, including project management and serving as an instructor for APT's System Safety and Software Safety professional development courses. His primary role is system safety support to the Missile Defense Agency (MDA). Mr. Nix holds an M.S. in Missile Systems from the University of Alabama in Huntsville and recently acquired a PMP Certification.

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