Speaking Risk With Our Project Managers

by Dustin Nix, John Fellows and John Hall
Huntsville, Alabama

Effective communication between the system safety engineer and the project manager (PM) is an essential characteristic of good risk management in a robust system safety program. However, these two disciplines often use similar terms with disparate meanings that can lead to sub-optimal technical or programmatic outcomes. MIL-STD-882E defines "risk" as "a combination of the severity of the mishap and the probability that the mishap will occur" [Ref. 1]. *The Project Management Book of Knowledge (PMBOK) Guide, 6th Edition*, 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" [Ref. 2]. It is incumbent upon the system safety professional to clearly communicate safety-related issues, hazards, risks and concerns using language most likely to be understood by the PM to ensure that he or she has the requisite information to make a sound programmatic decision. This paper explores the discrepancies between project risk management and safety risk management standard processes that hinder clear communication [Ref. 3] and can drastically impact program performance. We present methods to consider that will improve understanding between the system safety professional and the PM, along with two framework approaches for integrating safety and project risks.

Introduction

Ineffective communication has been separating groups and stunting or stopping projects dating back to the Tower of Babel. In today's approach of integrated project management, each contributing discipline employs a unique language. Similar words or phrases are often used across disciplines, although with disparate meanings. Of all the relationships system safety professionals maintain during a project, perhaps none is as important as the relationship with the project manager (PM). In most projects, the PM is either the approval authority of each identified safety risk or the conduit to upper managers for final approval. The PM also controls budgets and schedules associated with risk mitigations, investment and verification.

Meanwhile, the characteristics of safety risks are fundamentally different from the characteristics of risks regularly managed by the PM — the probability scales differ by orders of magnitude, the severity definitions have minimal overlap, and the general PM definition of "risk" includes positive outcomes. Do we understand these differences as system safety professionals? How can we mitigate the effects of these differences to improve the success of the system safety program and, by extension, the project? How do we quantify risks to effectively assist the PM with decision making?

Risk in Project Management

Project management principles are applied differently across industries, with nuances in approach and terminology. The *PMBOK Guide* [Ref. 2] serves as a collection of project management terms, processes and best practices independent of specific industries. The *PMBOK Guide* outlines and explains the five process groups that make up any project and the 14 knowledge areas needed to accomplish a project efficiently. One knowledge area is risk management, which encompasses much of the work of the system safety professional.

The *PMBOK Guide* 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 business risks, manufacturing risks, development risks, and risks related to human resources. The range of consideration goes from negative outcomes to positive outcomes, called "threats" and "opportunities," respectively. Thus, even within the knowledge area of risk management, the system safety program is merely a portion of the overall risk discussion.

The *PMBOK Guide* is not an industry-specific manual and does not specify risk outcome definitions or associated probability ranges. As an example of how the risk management process is applied, consider the U.S. Department of Defense's *Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs (DoD Risk Management Guide)*, which is similar to risk management guidance across government agencies [Ref. 4]. In this guide, "risk" is defined as "potential future events or conditions that may have a negative effect on achieving

Table 1 — DoD Risk Management Guide – Sample Consequence Criteria.

Level	Cost	Schedule	Performance
5 Critical Impact	10 percent 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 percent to less than 10 percent 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 six 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 percent – less than 5 percent 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 two 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 less than 1 percent 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 and Evaluation; TPM: Technical Performance Measure 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.

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

Table 2 — DoD Risk Management Guide – Sample Probability Criteria.

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

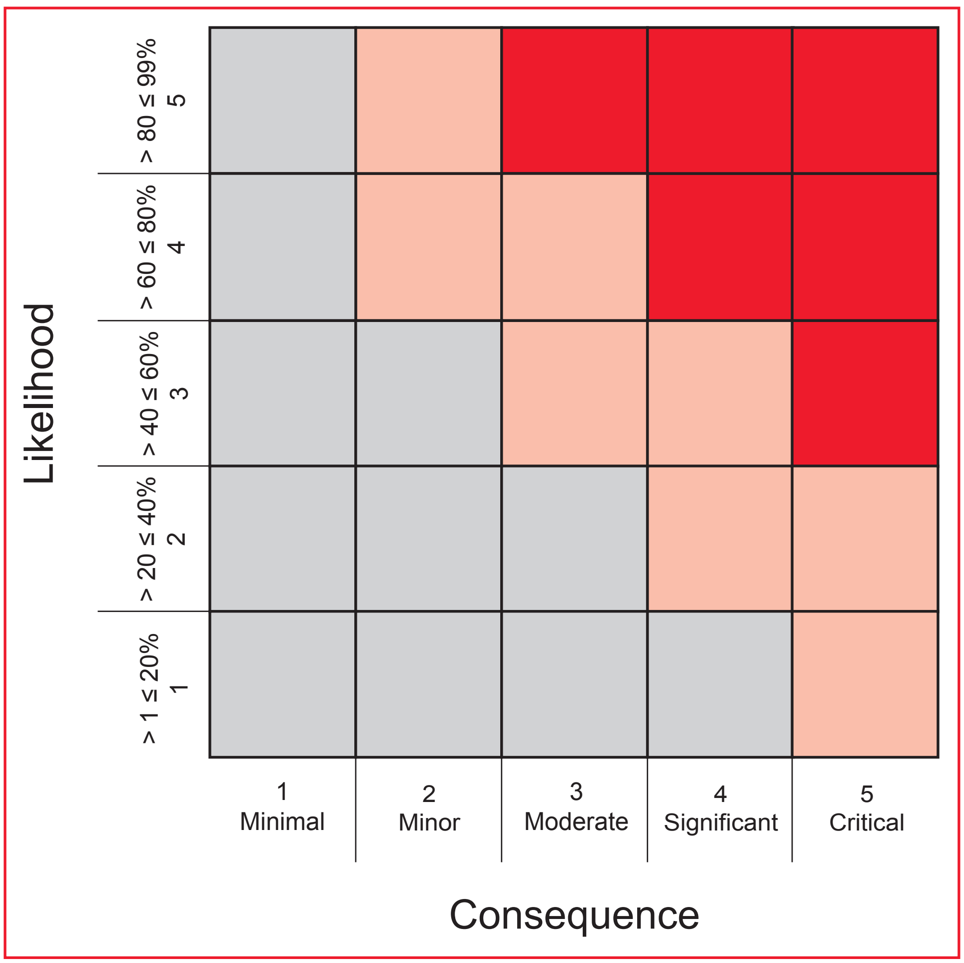

Figure 1 — Sample Risk Matrix.

Consequence and likelihood are combined in a risk matrix commonly used in DoD acquisition programs, which is regularly reviewed by the PM as part of risk management, as shown in Figure 1. In this risk matrix, red represents areas of high project risk, pink represents areas of medium project risk, and gray represents areas of low project risk.

Finally, the *DoD Risk Management Guide* provides this direction related to the incorporation of system safety into the risk management 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 for both the PM and the system safety professional becomes: How to map safety risks to program risks?

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 system safety 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 *DoD Risk Management Guide's* definition of risk, while encompassing approximately half of the *PMBOK Guide*'s definition of 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 Acquisition Program Baseline (APB). Schedule and performance impacts are not addressed. Personnel safety impacts are mostly objective, while environmental impacts criteria are subjective.

MIL-STD-882E example probability levels include six likelihood levels from F ("Eliminated") to A

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.

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 may possibly 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 that 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 occurring within the life of an item. This category is used when potential hazards are identified and later eliminated.		

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.

("Frequent"). The associated ranges are quantitatively defined by orders of magnitude, with A ("Frequent") mishaps having a probability of occurrence of less than 10 percent and E ("Improbable") mishaps having a probability of occurrence of less than 0.0001 percent. It is of note that only safety risks with probability levels A ("Frequent") and B ("Probable") would fall on the *DoD Risk Management Guide's* sample probability criteria scale. Therefore, all level C ("Occasional"), D ("Remote") and E ("Improbable") safety risks do not naturally fit within the typical PM risk management paradigm.

Table 5 — Communication Disconnect Summary.

Characteristic	PM	System Safety Professional	Assessment
Risk definition – clear and consistent?	May include uncertain positive outcomes	Only addresses uncertain negative outcomes	Clear; Not consistent
Consequence/ severity – objective and equivalent?	Addresses cost, schedule and performance – cost objectively	Addresses safety, environmental impact, and cost – cost and safety objectively	Partially objective; Not equivalent
Likelihood/ probability – ranges overlap?	Five equally divided percentage ranges between 1-99 percent	Five percentage ranges with order of magnitude difference between 0.0001–99 percent	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	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 and LOW; action to reduce risk to the extent practical. HIGH and SERIOUS risks require elevation for risk acceptance.	Not equivalent in number or required action
Finding: Safety risks cannot be directly mapped to program risks without modifications in severity, probability, and risk levels.			

The system safety professional typically combines the severity and probability levels in a safety risk matrix, as shown in Figure 2.

Summary of Communication Disconnects

While the *DoD Risk Management Guide* directs programs to map high safety risks to program risks and then 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 two risk paradigms differs, as summarized in Table 5.

If it is assumed that only HIGH safety risks should be mapped, the nearest graphical depiction (as shown in Figure 3) would show "Catastrophic" safety risks with probability ratings of A, B and C on the far right edge of the Critical program risk column and "Critical" safety risks with probability ratings of A and B would be centered in the Critical program risk column. In almost all cases, safety 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 safety risk mapping does not adequately capture the potential risk to the program. For example, let's assume the first manned flight of an experimental aircraft has a 10 percent risk of two fatalities (represented as "R1" in Figure 3). Should such a risk be assessed as Medium on the programmatic risk scale?

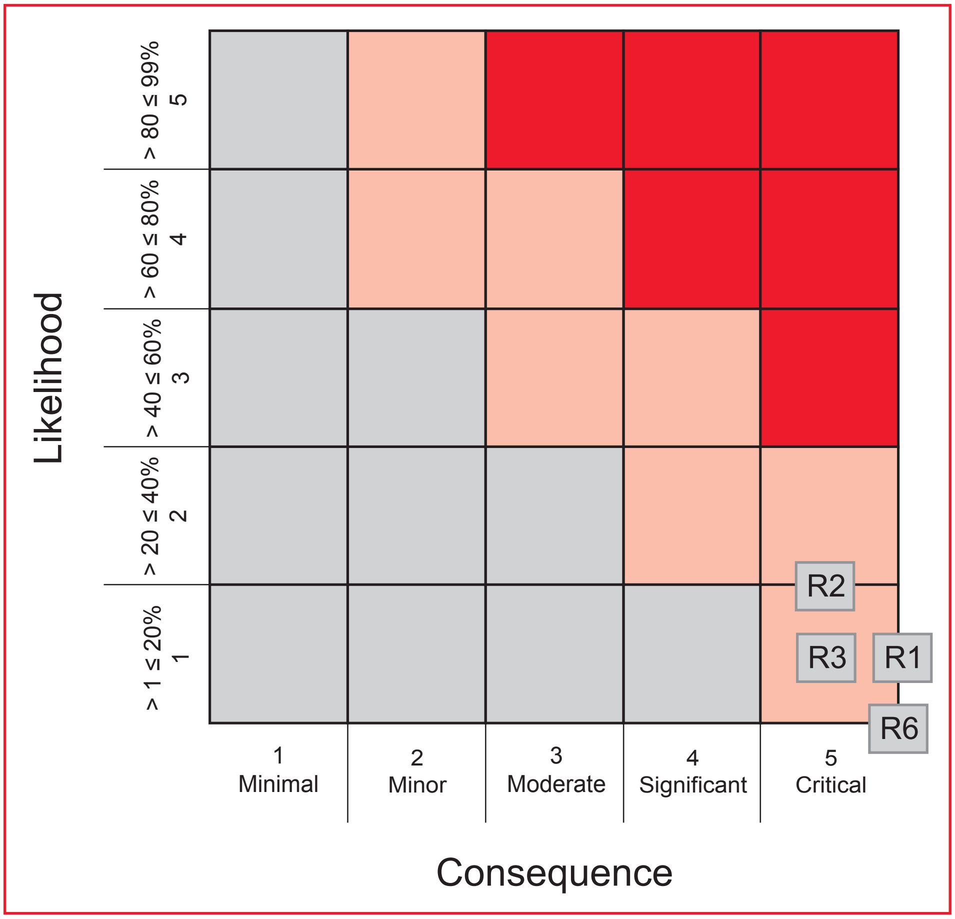

Figure 3 — HIGH Safety Risks Mapped.

Solution 1: Risk Program Tailoring

As most system safety and risk management programs are tailorable, 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 these two programs for a specific project/program. Tailored system safety and risk management programs would improve communication throughout the project/program. For example, the system safety program could implement the cost consequence

Table 6 — Modified, Summarized Risk Management Guide – Example Consequence Criteria.

Level	Cost	Schedule	Performance	Safety
6 Catastrophic	**15 percent 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 percent** 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 percent 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 percent 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 percent 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				

Table 7 — Modified Risk Management Guide – Example Probability Criteria.

Level	Likelihood	Probability of Occurence
5	Near Certainty	>80 percent to ≤ 99 percent
4	Highly Likely	>60 percent to ≤ 80 percent
3	Likely	>40 percent to ≤ 60 percent
2	Low Likelihood	> 20 percent to ≤ 40 percent
1	Not Likely	> 1 percent to ≤ 20 percent
0	Remote	≤ 1 percent

definitions from the risk management program, as opposed to using standard system safety severity cost definitions. The program could also map the system safety mishap result criteria to the Minor through Critical severity categories while adding a Catastrophic category to include death, as shown in Table 6.

Additionally, a sixth likelihood definition category could be added to encompass the bottom three non-zero system safety probability categories, as demonstrated in Table 7.

These modifications would allow direct mapping of HIGH and SERIOUS safety risks to the project/program risk matrix, as well as a numerical count of MEDIUM and LOW safety risks into the project/program risk categories. This ensures that safety risks of concern receive regular PM-level visibility. Leveraging the previous example of the first manned flight of an experimental aircraft, with a 10 percent 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 4.

Solution 2: Quantifying Safety Impacts of Project Execution

Not all projects are in a phase that can accommodate risk program

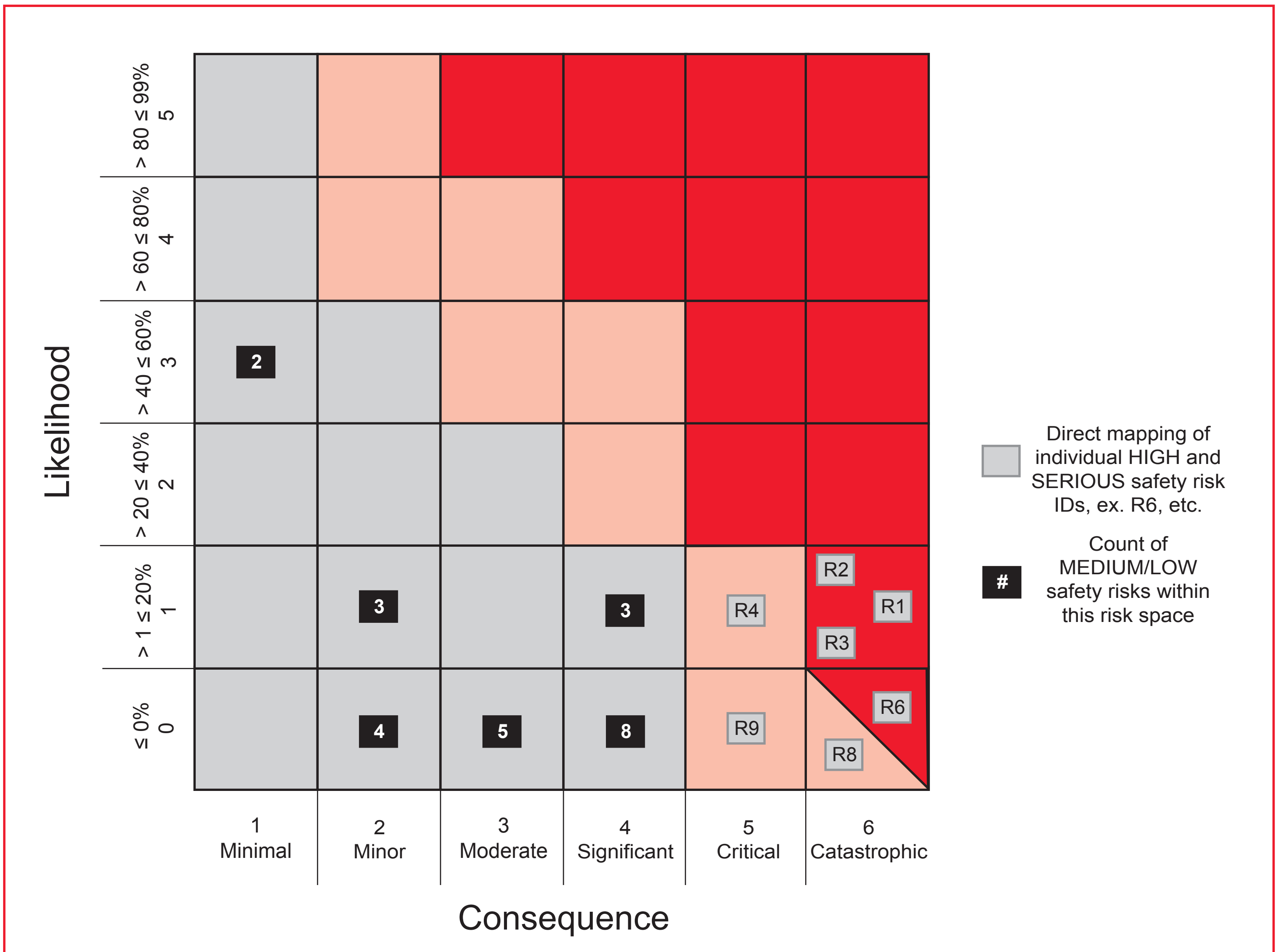

Figure 4 — Program Risk Matrix - Expanded.

tailoring. While MIL-STD-882E allows for risk acceptance of SERIOUS and HIGH safety risks, the existence of those risks presents cost, schedule and performance risks to the project/program. Sometimes they present themselves as risks to key milestones, due to a low risk appetite among upper management. Other times, a low-risk appetite among external stakeholders may impact cost, schedule and performance negatively.

As a hypothetical example, a missile system under development suffers a late failure in environmental testing for a pressure vessel containing hazardous material. The system is scheduled for transport via military ship to a test range in two months to conduct a missile test in support of a fielding decision. The responsible agency assesses the safety risk as 1D (Catastrophic/Remote) – SERIOUS – and the acceptance authority accepts the risk. However, the test range or military ship commander declines the risk. This results in a Critical Impact to the schedule and cost baselines, while the system undergoes redesign and/or retesting.

Any safety 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 should include each SERIOUS and HIGH safety 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 as well as the impact to cost or sched-

Table 8 — DoD Risk Management Guide – Example Risk Register Excerpt.

Risk Number	821	822
Linked WBS/IMS ID #	3.1.2	3.1.2
Owner	Nix	Nix
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 test range	Residual HIGH risk "Hazmat Release 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 range 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

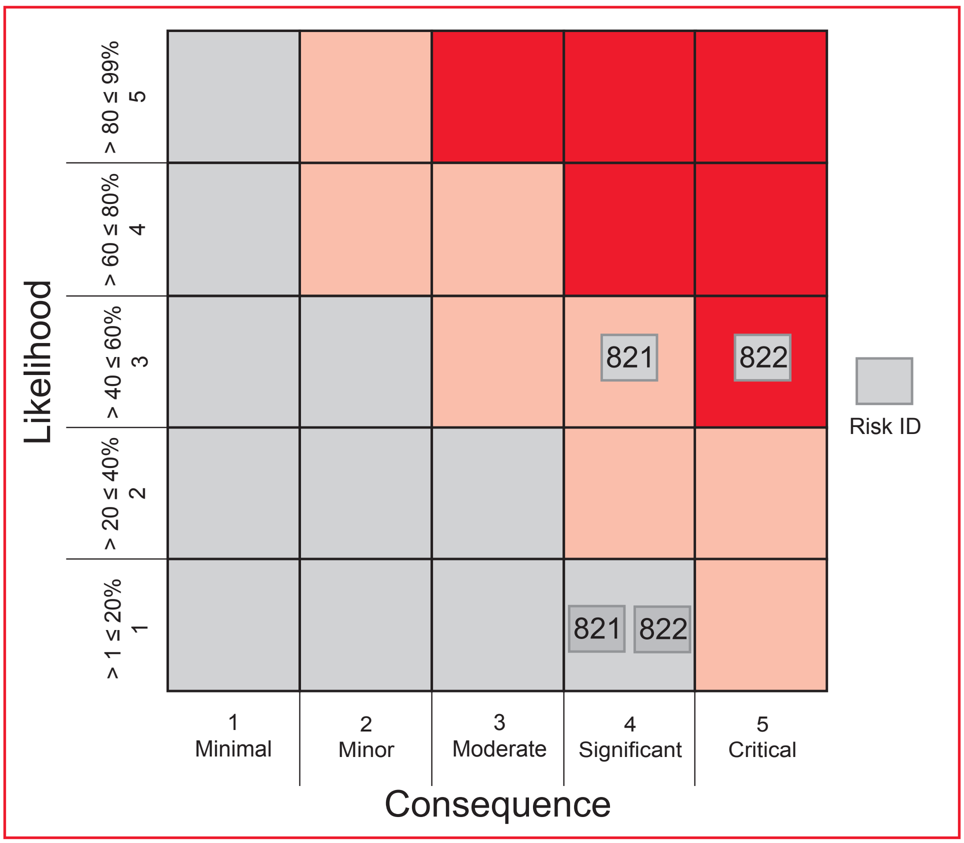

Figure 5 — Program Risk Matrix – Safety Impact Mapped.

ule 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 8, with mapping to the program/project risk matrix depicted in Figure 5.

Simple Recommendation for Clarity

In all cases, the system safety professional should orient the PM to the system safety risk matrix by correlating it to the project/program risk matrix when seeking safety risk acceptance. Use the top-right, highest-risk formatting for the briefing, as demonstrated in Figure 6. Explain the differences in risk, severity and probability definitions early in the discussion. Be prepared to discuss potential program impacts associated with HIGH and SERIOUS safety risks, or with safety risks lacking robust closure verifications.

Conclusions

Effective communication with the PM may be the most important interdisciplinary trait for the system safety professional to acquire and apply. An essential safety responsibility is to ensure that a PM considers and integrates safety-related risks with other program/project risks, as each has a measure of statistical probability of occurrence and could, therefore, 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 the PM nominally approaches risk, the system safety professional can most appropriately influence and map safety risks to program/project risks. This "tailoring" of program/project and safety risks is essential for the PM to optimize his/her limited resources associated with risk mitigation actions. By participating in the program/project risk development discussion, the system safety professional can effectively minimize safety-related impacts and ensure program/project success.

About the Authors

Dustin Nix is a systems safety engineer and project manager with APT Research, Inc. in Huntsville, Alabama. 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

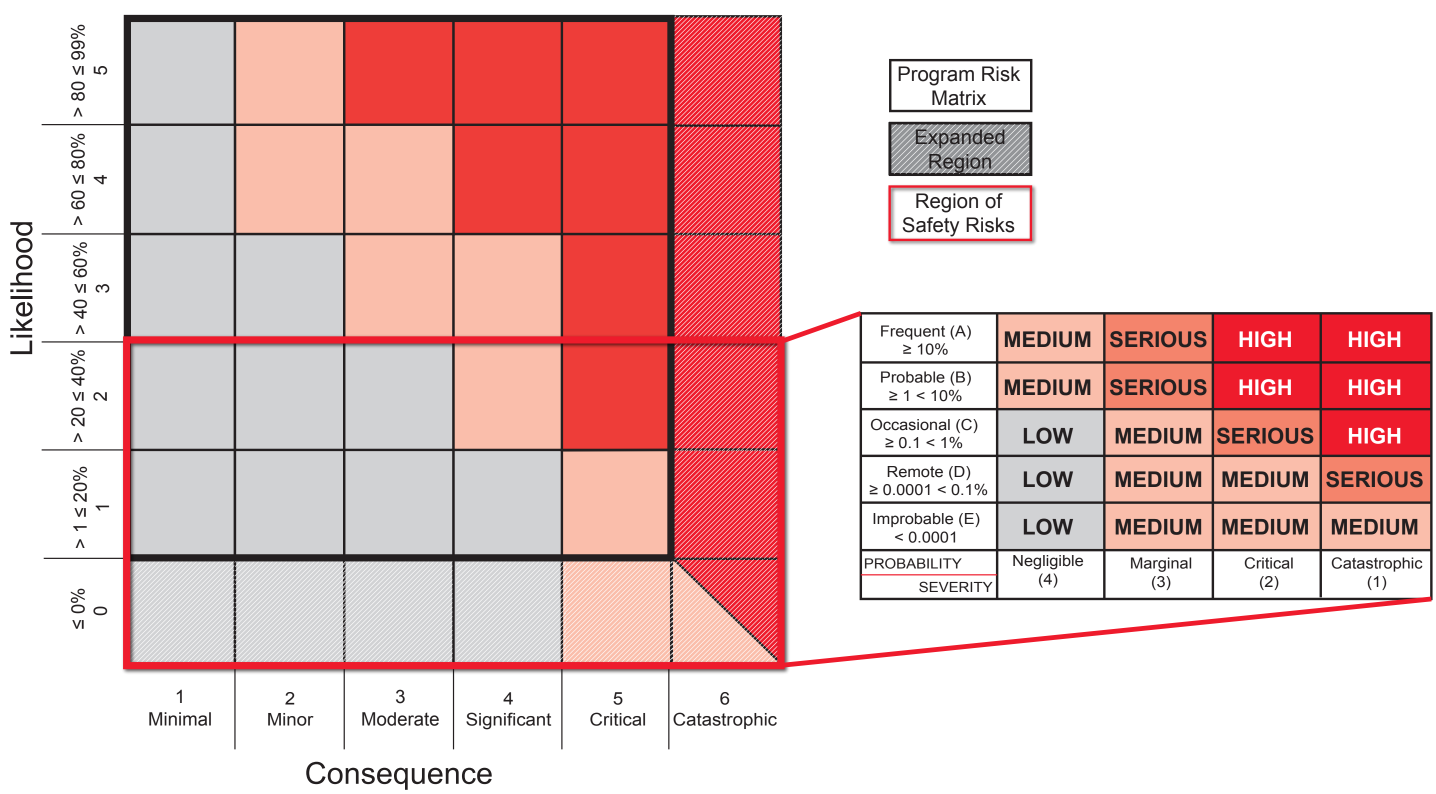

Figure 6 — System Safety Risk Matrix – Oriented.

support to the Missile Defense Agency (MDA). He holds a master's degree in missile systems from the University of Alabama in Huntsville and recently acquired a Project Management Professional (PMP) certification.

Colonel (Retired) John Fellows is the chief executive officer of APT Research, Inc. in Huntsville, Alabama. He has more than 32 years of U.S. Army and industry experience in research and development, defense acquisition, program management, and operational risk and safety. Prior to joining APT in 2015, he was the vice president for programs, DoD Agencies & Commands for Science Applications International Corporation (SAIC). He also managed multiple ACAT 1D weapons and radar systems for the Army and Missile Defense Agency during his military career. He holds a bachelor's degree in business management from Brigham Young University, a master's degree in management from Florida Institute of Technology and a master's degree in national resource strategy from the Industrial College of the Armed Forces. He is Defense Acquisition, level 3 certified and a PMP.

Dr. John Hall is the technical director of APT Research, Inc. in Huntsville, Alabama. He has more than 33 years of military, technical and executive experience, with 15 years providing executive-level technical and management support within the safety, quality and mission assurance disciplines. He holds a bachelor's degree from the U.S. Military Academy, a master's degree in industrial engineering (IE) from California Polytechnic State University, and a Ph.D. in IE from Mississippi State University. ◆

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