# Enterprise Opportunity and Risk

B. E. White
The MITRE Corporation
202 Burlington Road
Bedford, MA 01776-1420



**Abstract.** In traditional systems engineering (TSE) environments, and particularly in recent years, many are concerned about *risk* management. So much so that risks are identified early and often, and mitigation techniques are aggressively pursued. In contrast one does not hear as much about *opportunity* management. What about enterprise systems engineering (ESE) environments? Do traditional methods of handling risk and opportunity carry over, or should we be concerned about potential changes in the way we view the problem? Assuming there are new perspectives to bring to bear on this topic, what are they, and what principles might be discovered and applied to the enterprise to better deal with *opportunity and risk*? This paper offers some answers to these questions:

- There is duality in treating risks and opportunities.
- In ESE, be aggressive with opportunity and accepting of risk.
- The greatest enterprise risk may be in not pursuing enterprise opportunities.

## Introduction

In a recent book on opportunity management [Hillson, 2004] Hillson makes a rather convincing case that opportunities get "short shrift" in most programs. See, for example, Hillson's comments (on pp. iii, vii, and xvi): "There is … a systemic weakness in risk management as undertaken on most projects. The standard risk process is limited to dealing only with uncertainties that might have negative impact (threats). This means that risk management as currently practiced is failing to address around half of the potential uncertainties—the ones with positive impact (opportunities)." Furthermore, anecdotally, the author of this paper has noticed that many—if not most—risk and risk management documents, tools, processes, and websites, etc. do not even mention or discuss opportunities or opportunity management. Therefore, it seems to make sense to "appreciate" opportunity at the system scale.

Hillson views an "opportunity" as the opposite of a "threat" and adopts the position that these two factors together constitute risk. But, he also provides extensive evidence of the viewpoint that treats opportunity as the opposite of risk. In the present author's opinion, the latter view is more traditional and straightforward; though Hillson makes the case that the former is becoming more prevalent in academic and professional circles. Nonetheless, in this theoretical paper, opportunity is viewed as the opposite of risk. The author hypothesizes that in systems engineering at an enterprise scale the focus should be on opportunity, and that enterprise risk should be viewed more as something that threatens the pursuit of enterprise opportunities, as depicted in Fig. 1.

Fig. 1 is meant to suggest that the importance of opportunity management should increase qualitatively as one proceeds from system, to System of Systems (SoS), to enterprise scales. This is partially based on the premise, supported by historical fact and *ad hoc* observations, that risk management tends to dominate at a system scale. At an enterprise scale, the author tries (throughout this document) to develop the rationale for paying much more attention to opportunity management than risk management. It might then follow that opportunity management and risk management would be roughly co-equal at a SoS scale. Nevertheless, further testing of hypotheses concerning the greater importance of opportunity management at SoS and enterprise scales is appropriate as part of future work.

Mike Kuras observed that risk and opportunity can be thought of as assessable uncertainties. Clearly there exist un-assessable uncertainties and unknown uncertainties. So the topic of uncertainty management is more general than what is treated in this paper. This idea is merely acknowledged in Fig. 1, where there is no attempt to depict relative magnitudes of these other uncertainties at any of the three scales shown.

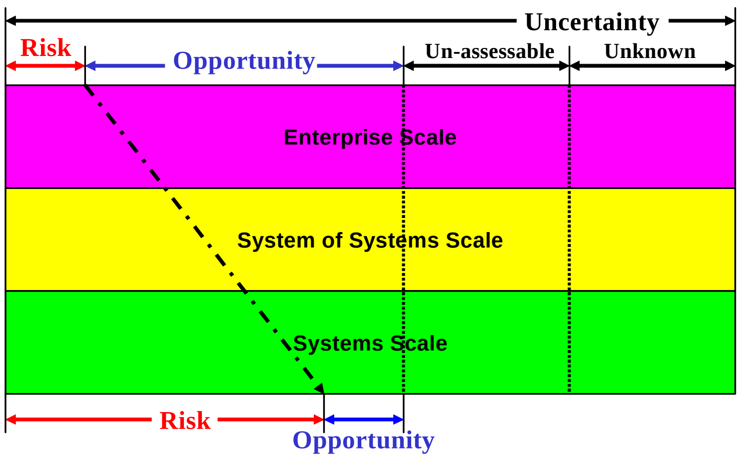

Figure 1. Relative Importance of Opportunity and Risk at Distinct Engineering Scales, Acknowledging Other Kinds of Uncertainty

A previous paper [Kuras and White, 2005] offered some definitions of system, SoS, and enterprise in the context of Complex-System Engineering (CSE). Three additional definitions of systems engineering (SE), Enterprise Systems Engineering (ESE) and CSE are offered to help clarify the use of these terms in this paper:

SE: An iterative and interdisciplinary management and development process that defines and transforms requirements into an operational system. Features: Typically this process involves environmental, economic, political, and social aspects. Activities include conceiving, researching, architecting, utilizing, designing, developing, fabricating, producing, integrating, testing, deploying, operating, sustaining, and retiring system elements.

ESE: A regimen for engineering (methodically conceiving and implementing solutions to real problems, with something that is meant to work) "successful" enterprises. Features: ESE is systems engineering but with an emphasis on that body of knowledge, tenets, principles, and precepts having to do with the analysis, design, implementation, operation, and performance of an enterprise. The enterprise systems engineer concentrates on the whole as distinct from the parts, and its design, application, and interaction with its environment. Some potentially detrimental aspects of Traditional Systems Engineering (TSE) are given up, i.e., not applied, in ESE. (See the Traditional Systems Engineering sub-section for more on a TSE definition.)

CSE: ESE but with additional conscious attempts to further open the enterprise to create a less stable equilibrium among many interdependent component systems. Features: In CSE, special attention is paid to emergent behavior, especially due to the openness quality, which can either be desirable or undesirable. One tries to instill the deliberate and accelerated management of the natural processes that shape the development of complex systems.

# Traditional View of Risk and Opportunity

The following definitions are introduced:

$P_o$ = Probability of Occurrence

$C_f$ = Consequence of Failure

$A_r = \{P_o, C_f\}$ = Risk Assessment

Consider a person who might have a heart attack. Assessment of risk is the joint view of probability of occurrence, $P_o$, and consequence of failure, $C_f$, i.e., $A_r = \{P_o, C_f\}$. $P_o$ is estimated based on heredity, height/weight, fitness, stress, blood pressure, cholesterol, HDL/LDL levels, etc. $C_f$ is evaluated by contemplating sickness, disability, death, with associated losses and anguish of the family.

$P_o$ can be reduced with risk prevention (or avoidance), e.g., by getting new parents ☺, increasing one's willpower to properly exercise, finding and sticking to a better diet, having more regular and thorough checkups with the right doctors, getting counseling, and changing jobs to reduce stress.

$C_f$ can be reduced by taking mitigating actions through risk minimization (or contingency), e.g., by making better investments, buying more health/life insurance to protect the family, keeping legal/financial affairs in order, updating one's will and estate plan, and deciding about life support systems. Clearly, both avoidance and contingency actions should be planned and acted on in advance. Here, one cannot wait until death (or even until one is sick) to buy life (health) insurance, for example. Then it's too late. This model should be kept in mind when evaluating program/project risks.

Note that risk assessment can be either quantitative or qualitative. Being quantitative has obvious advantages if the quantities involved are sufficiently accurate; given that, precision helps minimize error propagation with further calculation. Nevertheless, much can be gained in terms of making risk management more effective through purely qualitative analysis, sometimes based mostly on heuristics and "gut" feel; this approach, though often simpler, depends on common sense, however, and must stand up to scrutiny by knowledgeable experts and experienced practitioners.

## *What Is Risk?* [Garvey, 2005]

"A *risk* is a potential event that, if it occurs, will adversely affect the ability of the system to perform its mission. Thus risk is a probabilistic event. In contrast, an *issue* is an adverse event that has already occurred or will occur with certainty." Issues need to be tracked, even though, technically, they are not risks. The limited resources (in most cases) for mitigation need to be balanced to address both issues and risks with a proper holistic allocation, considering both at the same time.

Fig. 2 [Garvey, 2005] illustrates risk in a human-made system. It shows that consequences are expressed as undesirable events that, for instance, degrade the performance or capability of a system or SoS (or enterprise). Once the "leaves" of the "tree" are expressed and understood, one will likely attack the underlying condition to mitigate the risk.

There is <u>no risk</u> if something (see Fig. 3):

- <u>Never</u> happens, no matter <u>what</u> the consequence.
- Happens with <u>no</u> consequence.
- <u>Surely</u> happens. (This is subtler, implying an <u>issue</u> and maybe a consequence.)

How can something undesirable that will surely happen not be a risk? Program planning must eliminate such an eventual occurrence from being relevant. If not, that part of the program

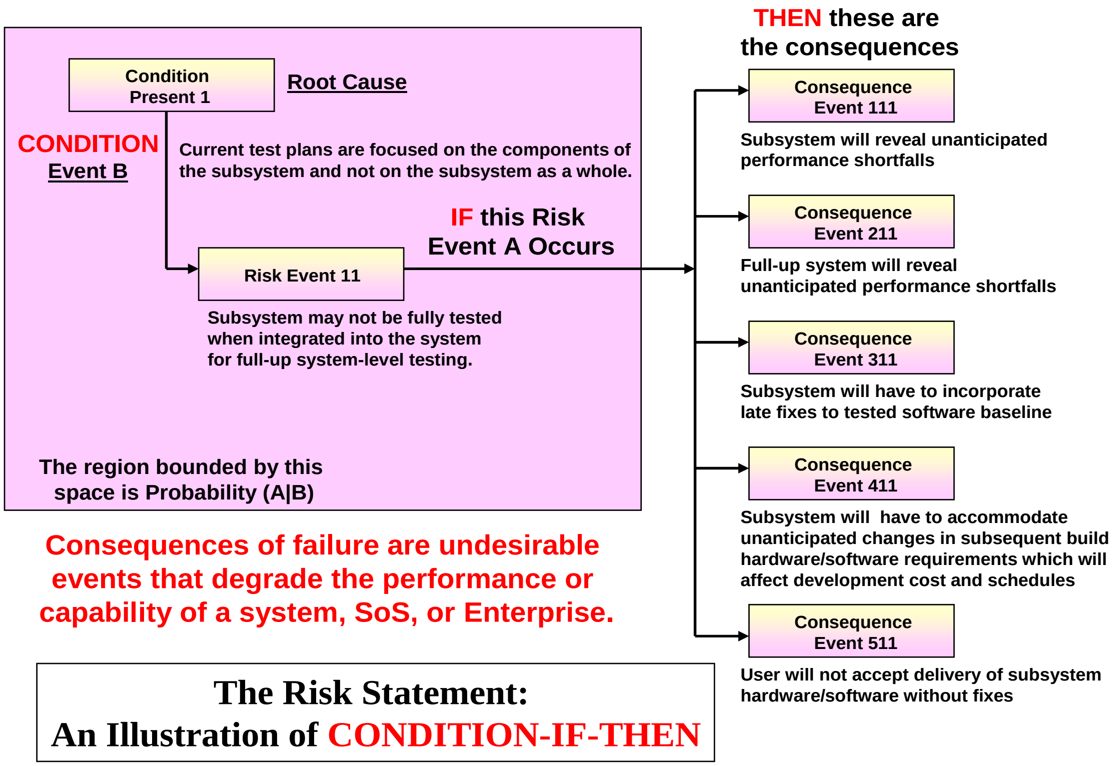


Figure 2. The Consequences of Failure

should be halted, re-planned, and restarted. In other words, undesirable certainties are put "outside the box." This is a situation when it is good to stay inside the box or redefine one's box to be smaller to eliminate the unfortunate certainty. Recognize, however, that what might happen with this program redefinition is the creation of a new risk (with a probability between 0 and 1). It also has been pointed out to the author that the "no risk" treatment above is idealized. If one applies sensitivity analysis to risk, in practice, there really are no 0 or 1 probabilities. (The author agrees!) Also, do not be too confused by Fig. 3; as Paul Garvey pointed out, the range of the consequence variable, $C_f$, is often taken to be [0, 1]; in such as case, $C_f = \infty$ is moot.

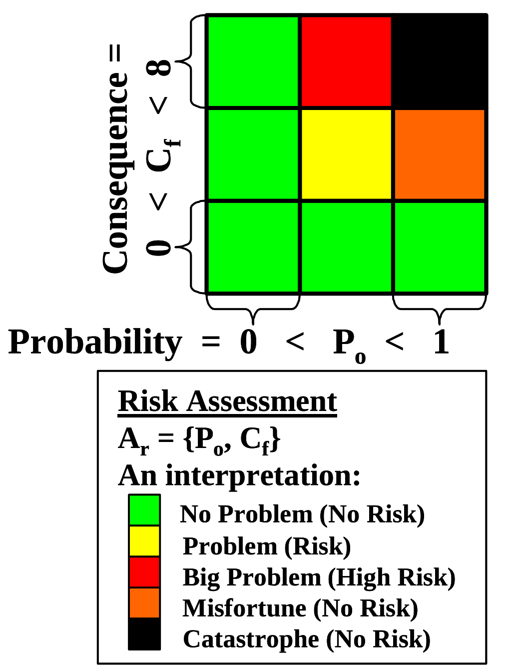


Figure 3. Perspectives on Risk Assessment

In qualitative risk management, probabilities typically are estimated with only 5%–10% accuracy, and consequences are rated with only 3–5 categories. Many organizations use quantitative risk management. In commercial engineering, it is not uncommon to know the probabilities of failure to a high level of accuracy based on tests or models, and to know the impact in dollars to two-place accuracy. Furthermore, impact is often defined on a continuous scale rather than just heaping effects into 3–5 categories.

*Quantifying Risk*

What simple mathematical expression can express risk?

- Suppose risk, R, were defined as $R = P_o \times C_f$

Then R would not match our definition of risk and assessment interpretation of Fig. 3, i.e., when $P_o = 1$, there would be no risk, but $R = C_f$ could be > 0. This would be questionable for two reasons. More important, this can only make sense if $C_f$ assumes a cardinal (quantitative), not ordinal (qualitative), position in a series of values.

Instead of quantifying risk, an event, why not express the estimated disruption, $D_e$, one would face considering risk?

- Let $D_e = P_o \times C_f$. (Note: This is the same as the expected consequence.)

– "Estimated" comes from uncertainty, i.e., $P_o$.
– "Disruption" measures aggravation to the program or mission.
– This definition is consistent with our definition of risk and our interpretation of assessment, e.g.,
    - $D_e = 0$, when there is no problem.
    - $D_e = \infty$, when there is a big problem or catastrophe.
    - $D_e > 0$ (and $< \infty$), when there is a problem or misfortune.

Do not lose the perspective that risk has two components. Think about both probability of occurrence, $P_o$, and consequence of failure, $C_f$. One can worry about all kinds of eventualities, but if the probability is very small, time should not be wasted on the risk event unless the consequence is very bad. If the probability is very large and the consequence is significant, one should think hard about restructuring the program/project to help ensure or at least salvage the possibility of overall mission success. Also, events that were risks (with $P_o > 0$) should continue to be tracked (to show the basis of past decisions) even after they have been mitigated to yield a 0 probability.

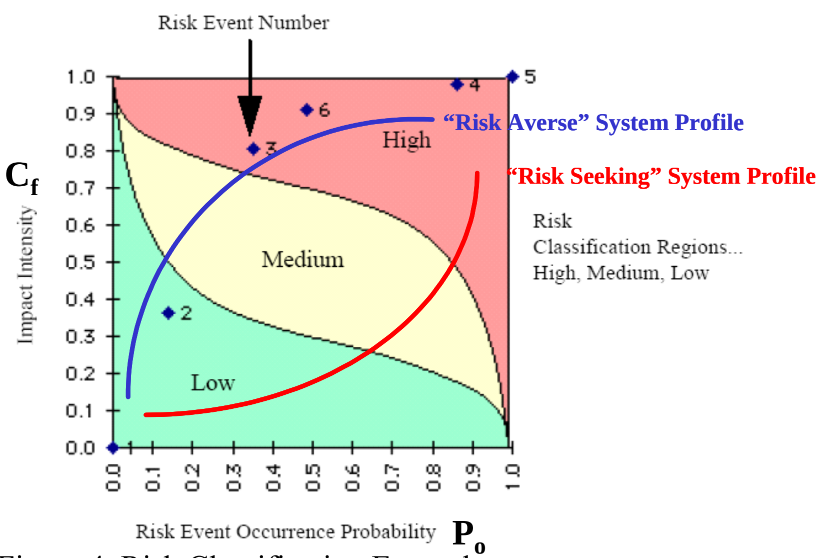


Figure 4. Risk Classification Example

This explanation is an almost trivial way of thinking quantitatively about risk management problems. However, when this topic is treated in more depth, the mathematical treatment and the formula(s) used in risk models are slightly more sophisticated. In general, one can plot $C_f$ vs. $P_o$ to express a nonlinear relationship (see Fig. 4, Paul Garvey). Mathematical modeling and correctness are nice, but the more important point is to understand the concept of how the two factors, $P_o$ and $C_f$ work together to impact one's risk management plans and operation. Suppose $C_f$ is defined as a real number in the range [0, 1] and is called "impact intensity," for example. Then low, medium, and high risks, respectively, could be defined as in the green, yellow, and red areas. The boundaries are drawn arbitrarily to depict hypothetical value judgments of the risk manager based upon his/her assessments of the risk probability and consequence pairings $A_r = \{P_o, C_f\}$. Here the probability of risk event occurrence is identical to $P_o$. One could draw any single-valued curve in this space as a given instance of the risk assessment (relationship) between occurrence probability and impact intensity, $A_r = \{P_o, C_f\}$. A "risk averse" system would be represented by a convex up curve, as shown, because the larger the increase in probability, the lesser the increase in consequence.

As an example of a risk averse system profile, consider again the person who might have a heart attack. As the health of this breadwinner, say, with a significant heart problem gradually degrades with increasing age, the probability, $P_o$, of a heart attack increases. One would first try to reduce this probability and help him/her by medical intervention. Then, compared to doing little to mitigate the significant consequences of a heart attack when $P_o < 0.2$, for example, for $P_o > 0.3$, say, his/her family might continually escalate efforts to protect themselves by buying more life insurance. $C_f$ may still increase with the associated increase in $P_o$, but the impact on the family is not as great. The extra insurance would help, but it might not cover the now greater loss in expected future earning power.

A "risk seeking" system (like an enterprise, as will be seen) would be represented by a convex down curve, as shown, because the larger the increase in probability the greater the increase in consequence.

A straight line in the square of Fig. 4, from (0, 0) to (1, 1), would be labeled "risk neutral." In this case, one could prioritize risk by the product, $D_e = P_o \times C_f$.

### *What Is Opportunity?*

- Opportunities are events or occurrences that <u>assist</u> a program in achieving its cost, schedule, or technical performance objectives.
- In the larger sense, <u>explored</u> opportunities can enhance or accomplish the <u>entire mission</u>.
- Opportunity also is associated with <u>uncertainty</u> <u>and</u> <u>impact</u>.
- There is a duality or parallelism to risk that can be applied.
- For an opportunity, let $Q_o$ be the probability of occurrence, and $B_s$, the benefit of success
- Similarly, to estimated disruption, we can pose the simple formula $M_e = Q_o \times B_s$, the <u>estimated mitigation</u> or <u>expected benefit.</u> Fig. 5 is the "dual" of Fig. 3. Again, do not be confused by Fig. 5. As Paul Garvey pointed out, the range of the benefit variable, $B_s$, could be taken to be [0, 1]; in such a case, $B_s = \infty$ is moot.

In this author's opinion, based on personal observation of several program managers, a natural tendency for military officers in the acquisition field is to be aggressive in minimizing downside risk and conservative in maximizing upside opportunities. However, at least one class member felt that such colonels would tend to be aggressive with opportunities and conservative with risks, just the opposite of what a typical systems engineer might do. This is an area worthy of further study.

As with the discussion on risk, remember that opportunity has two components: <u>both</u> the probability of occurrence, $Q_o$, and the benefit of success, $B_s$. One can get excited about all kinds of eventualities, but if $Q_o$ is very small, one should not waste time pursuing this opportunity event unless $B_s$ is very good. If $Q_o$ is very large and the $B_s$ is significant, one should think hard about restructuring a program/project to help ensure the possibility of enhancing the overall mission. As before, this formula for estimated mitigation makes sense if $B_s$ assumes cardinal (quantitative) values, but not if $B_s$ has an ordinal (qualitative) position in a series of values.

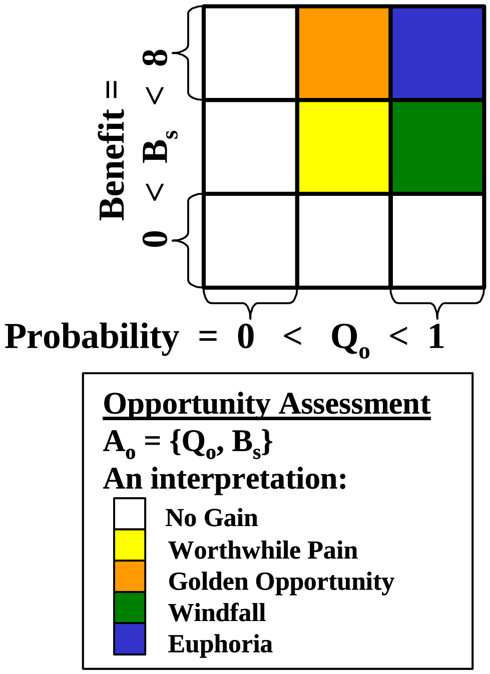


Figure 5. Perspectives on Opportunity Assessment

Again, this is an almost trivial way of thinking quantitatively about opportunity management situations. However, were the topic treated in more depth, the mathematical treatment and the formula(s) used in the opportunity models would be more sophisticated. In general, one can plot $B_s$ vs. $Q_o$ to express a nonlinear relationship (see Fig. 6). Mathematical modeling and correctness are nice, but it is more important to understand how $Q_o$ and $B_s$ work together to impact one's opportunity management plans and operation. Suppose $B_s$ is a real number in the range [0, 1] and is called "impact intensity." Then low, medium, and high opportunities, respectively, could be defined as in the green, yellow, and red areas. The boundaries are drawn arbitrarily to depict hypothetical value judgments of the opportunity manager based on his/her assessments of the opportunity probability and benefit pairings $A_o = \{Q_o, B_s\}$. Here the probability of occurrence of a risk event is identical to $Q_o$. One could draw any single-valued curve in this space as a given instance of the opportunity assessment (relationship) between probability of occurrence and impact intensity, $A_o = \{Q_o, B_s\}$. An "opportunity averse" system would be represented by a convex up-curve, as shown, because the larger the increase in probability, the lesser the increase in benefit.

As an example of an opportunity seeking system profile, suppose that, as the "quality" of a joint software upgrade program gradually degrades with time because it becomes increasingly difficult to integrate the results from the existing set of contractors into the operational system, the probability of failure, $P_o$, increases, but the opportunity to do something about this, i.e., $Q_o$, increases. MITRE's Kenneth Brayer suggests Brooks' Law [Brooks, 1995]. To paraphrase: Adding more people to a late software project usually implies an initial penalty but might pay off in the long run. Compared to doing little to encourage the marginal benefits of integration when $Q_o < 0.2$, for example, for $Q_o > 0.3$, suppose program office policy is to add other contractors to the mix while permitting additional opportunities to learn what works best by engineering the operational system. $B_s$ may increase with the associated increase in $Q_o$—but by even more, say, than at smaller values of $Q_o$. The extra involvement with the users helps focus the

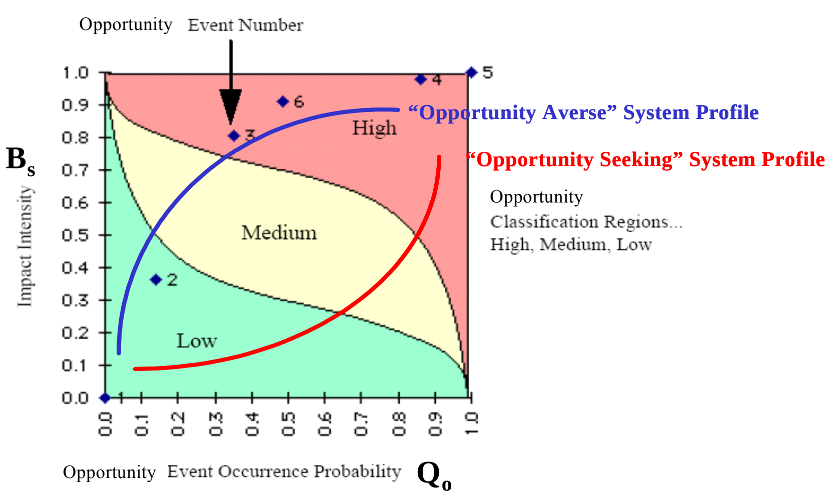


Figure 6. Opportunity Classification Example

integration effort while effectively shaping the composition of the productive contractors.

An "opportunity seeking" system (like an enterprise) would be represented by a convex down-curve, as shown, because the larger the increase in probability, the greater the increase in benefit. Again, a straight line from (0, 0) to (1, 1) in Fig. 6 would be labeled "opportunity neutral." Here one could prioritize opportunity by the product, $M_e = Q_o \times B_s$.

Fig. 7 is another way to evaluate where to pay attention (e.g., concentrate on the triangular-shaped "Attention Arrow" area), especially with limited resources. Obviously, emphasis should be placed on the higher probability, higher impact squares. Inspired by a figure in Hillson's book, the diagram has been modified to be consistent with the present author's choice of the treating risk and opportunity as dual entities, as well as the terminology used in this paper.

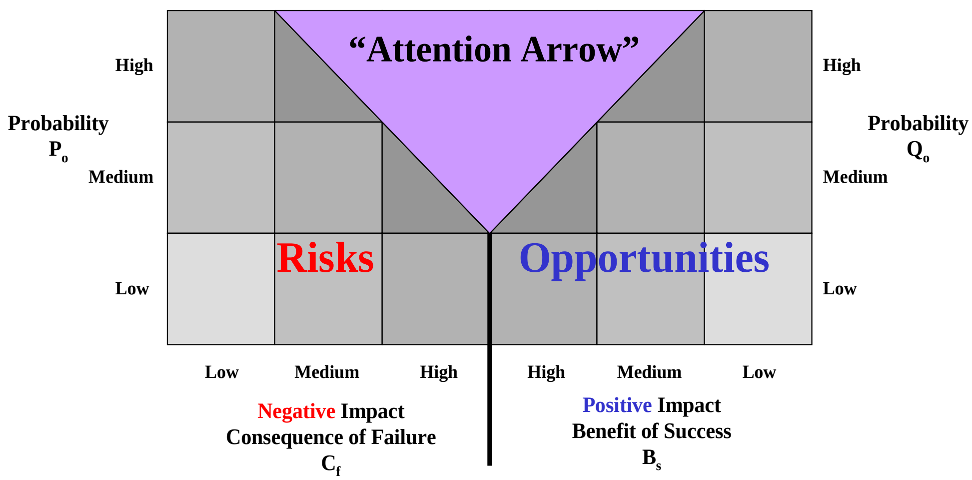


Figure 7. Risk/Opportunity Representation on Probability/Impact Grid (after [Hillson, 2004, p. 126])

A related point of MITRE's Joe DeRosa: Another aspect of duality between risk and opportunity is the number of risks and opportunities vs. the analysis of a single risk or opportunity. It is advisable to have few risks in a program and to perform risk analysis and mitigation. In our opinion it is also desirable to have many opportunities. Good ESE (and CSE) should therefore create an environment that decreases the number of risks and increases the number of opportunities, besides mitigating each single risk and stimulating each single opportunity.

## System and Systems of Systems Risk Management

Paul Garvey's color scheme (Fig. 8) can be used for either risk or opportunity management, although he did not consider opportunity management nor enterprise-scale risk management, which this paper addresses later. Fig. 9 shows his assessment of risk management for SoS compared to TSE. His work is independent of this examination of opportunity and risk.

The present work attempts to "break new ground" in the corresponding distinctions for opportunity, not only between TSE and SoS, but also between SoS and ESE. These will be treated after reviewing TSE, SoS engineering, and ESE.

### *Traditional Systems Engineering*

Arguably, TSE's underpinnings derive from classical linear system analysis, where much can be formulated, predicted, formulated, predicted, repeated, and explained. The central concept of superposition, i.e., the well-behaved output summation of separate inputs, works well and leads to the notions of system decomposition and hierarchical composition of separately engineered subsystems.

Unfortunately this approach does not always work well in nonlinear—let alone complex—system environments. TSE addresses a solution's form, fit, and function in two steps: functionality and implementation. It typically starts with "specifications" (predictions engineered to come true).

| | G | Y | R |
|---|---|---|---|
| **Process** | In a SoS, this action step requires a **similar** effort and scope as compared to a TSE environment | In a SoS, this action step requires a **modest increase** effort and scope as compared to a TSE environment | In a SoS, this action step requires a **significant increase** effort and scope as compared to a TSE environment |
| | **or** | **or** | **or** |
| **Tools/ Constructs** | In a SoS environment, **similar** tools and/or analytical constructs can be used with few (if any) modification as they are applied in a TSE environment. | In a SoS environment, tools and/or analytical constructs similar to those applied in TSE environments can be used; however, they require **modest changes to their designs or modest extensions to their underlying logic** to be properly applied in an SoS environment. | In a SoS environment, tools and/or analytical constructs similar to those applied in TSE environments can be used; however, they require **significant changes to their designs or significant extensions to their underlying logic** to be properly applied in an SoS environment. In some areas, new tools and/or analytical constructs may also be needed. |

Figure 8. Qualitative Distinctions Between TSE and SoS Risk Management

| | |
|---|---|
| Yellow | **Step 1 Prepare** |
| G: Action 1 | Commit Resources |
| Y: Action 2 | Form the Team |
| Y: Action 3 | Know the Mission |
| R: Action 4 | Think Risks |
| Yellow | **Step 2 Identify the Risks** |
| Y: Action 1 | Establish Team |
| G: Action 2 | Develop Understanding |
| Y: Action 3 | Identify Risks |
| G: Action 4 | Classify Risks |
| G: Action 5 | Write Risk Statements |
| R: Action 6 | Correlate Related Risks |
| Yellow | **Step 3 Assess and Prioritize Risks** |
| Y: Action 1 | Impact Assessment |
| G: Action 2 | Probability Assessment |
| R: Action 3 | Timeframe Assessment |
| Y: Action 4 | Reassess Risks |
| Y: Action 5 | Rank Risks |
| G: Action 6 | Coarse Sort; Identify Handling Bands |
| Green | **Step 4 Decide on Handling Options** |
| G: Action 1 | Identify Options within Each Risk Band |
| G: Action 2 | Easy Risks |
| G: Action 3 | Hard Risks |
| G: Action 4 | Assign OPRs |
| G: Action 5 | Update Risk Database |
| Yellow | **Step 5 Establish Handling Plans** |
| Y: Action 1 | Develop Plans and Estimates |
| Y: Action 2 | Review and Approve |
| Y: Action 3 | Fund, Direct, Integrate |
| Green | **Step 6 Implement Risk Handling** |
| Y: Action 1 | Finalize Risk Management Plan |
| G: Action 2 | Provide Mechanisms to Monitor |
| G: Action 3 | Implement Handling Plans |
| G: Action 4 | Monitor Progress |
| Green | **Step 7 Monitor Handling Plans** |
| G: Action 1 | Periodically Review Handling Plans |
| G: Action 2 | Modify or Stop, If Required |
| G: Action 3 | Retire Risks |

G = green
Y = yellow
R = red

Figure 9. SoS vs. TSE Risk Management Assessment Summary

Predictions (as plans, roadmaps, etc.) carry much weight; systems are built to "stand alone." Developmental tests often disregard implementation. If there's divergence from the plan during development, a big effort is made to get back on track to restore the predictions' validity. But, in complex environments, the approach may miss potentially superior solutions.

## *Characterizing One's Systems Engineering Environment*

Fig. 10 is useful to characterize one's systems engineering (SE) environment. A marker is placed in each of the eight sectors to indicate the perception of how difficult the environment is with respect to that dimension. The closer it is to the center, the more the situation is judged to be similar to a TSE environment. The closer it is to the outer edge, the more difficult the situation is presumed to be. The yellow (middle) annulus can be thought of as akin to SoS engineering, and the orange (outer) annulus to ESE. A "spider diagram" is formed by connecting the markers. This diagram is a visual model of how difficult the environment appears. It is also useful to compare and contrast templates among those engaged in different enterprises to see how much they have in common and how much they differ.

# System, System of Systems, and Enterprise Opportunity Management

## *The Regimen*

MITRE's Mike Kuras has developed a "regimen" for CSE [Kuras and White, 2005] that consists of eight interrelated activities (explained in the cited paper):

- Emphasize the Developmental Environment
- Shape Development During Operations
- Identifying Outcome Spaces
- Establishing Rewards (and Penalties)
- Judge Actual Results
- Apply Developmental Stimulants
- Characterize Continuously
- Enforce Safety Regulations

To some extent, all these activities relate to opportunities and risks, but two (discussed next) relate explicitly: Establishing Rewards and Characterize Continuously.

Opportunities and Risks in "Establish Rewards"

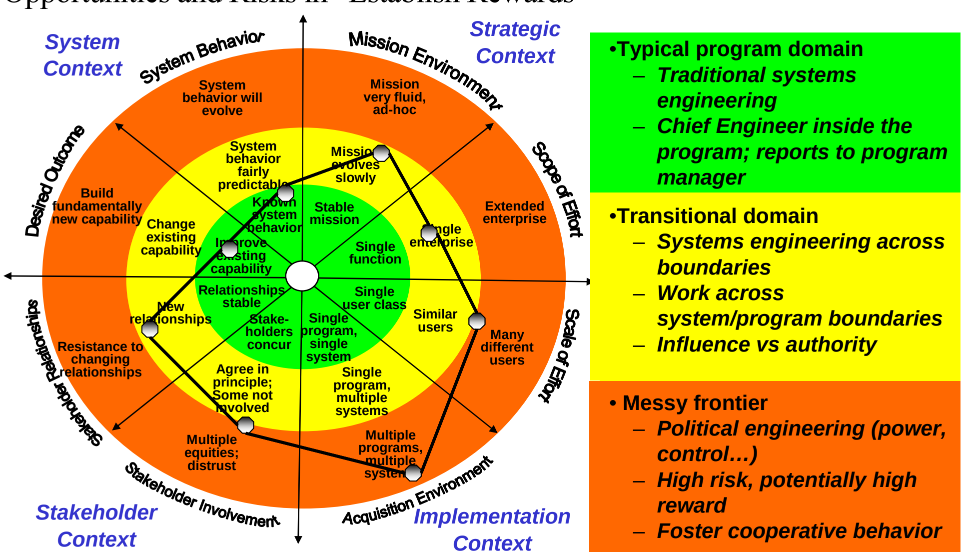


Figure 10. ESE Environment Characterization Template [MITRE's Renée Stevens]

Imagine that a suitable outcome space has been identified and (although not necessary) communicated to a complex system's autonomous agents who must develop specific outcomes that fit in this space. In doing so, they take advantage of any *opportunities* that appear or that they can uncover. At the same time, they face the *risks* of developing products that may not be classified as outcomes, or that are less desirable outcomes. These *risks* are either not rewarded or are less rewarded than more desirable outcomes.

Because some reward is granted to many outcomes fitting the space, agents would likely pursue *opportunities* to achieve outcomes more aggressively rather than mitigate the *risks* of not achieving an outcome. *Risk* mitigation might be reduced to ordering outcomes according to their perceived rewards. Presumably this ordering would be pursued with other autonomous agents because only targeted populations of agents, not individual agents, are offered rewards. This is an example of cooperation among autonomous agents.

Despite the apparent logic of this hypothesis—that *opportunities* would be treated more aggressively than *risks*—validation from actual case studies should be sought.

Opportunities in "Characterize Continuously"

This CSE activity is the continual generation and refinement of complex-system characterizations. Characterization is crucial for autonomous agents to independently develop metrics to guide their local decision making to be congruent. The specific outcomes used to judge actual results should be characterized, as should the rationale that eventually explains the subsequent judging decisions.

Rewards (and perhaps Outcome Spaces) initially should be characterized with succinct "bumper-sticker" labels (e.g., the U.S. Army's visionary slogan, "Own the Night"). Pithiness encourages a greater variety of *opportunities* for good and bad outcomes. Initially, at least, it is probably better to have a very open outcome space with the potential for great rewards. But this implies a greater inconsistency in how Rewards (and Outcome Spaces) may be interpreted.

To the extent that consistency matters, a complex system benefits from continually developing and espousing more detailed and complete characterizations. Still, in complex-system evolution, characterizations cannot be too refined. New Outcome Spaces may need to be added and characterized to encourage new possibilities that otherwise might not be explored.

### *Further Thoughts About Opportunity and Risk Concerning TSE, SoS Engineering, and ESE*

Moving from TSE to SoS engineering, and ESE (and CSE), one should consider opportunity/risk with respect to a complex system's environment as well as (creating potential program contingencies in) the system. There may be many more opportunities to pursue in a system's environment compared to the system itself due to: the environment's larger scope (which contains the system's scope) and the relative freedom from apparent (from the system's view) constraints, compared to what the system experiences as "stress" from its own environment. Vigorously pursuing opportunities in the system's environment can reduce the stress and may lead to system solutions that are not only better, but even easier to implement.

Environmental risks seem less important than these opportunities. As more open systems are fielded, opportunity management will become more main-stream. Today, as MITRE's Mike Bloom points out, a good deal of opportunity management is going on at the enterprise scale in the U.S. Department of Defense (DoD). However, these activities are mainly associated with competing for huge fixed pots of money; there is lots of inertia in big systems' multi-year funding profiles. One could view opportunity (and its associated risk) philosophically ("nothing ventured, nothing gained"). Downside risk would be more concerned with not incurring "damage" to the system's environment that might stifle the aforementioned opportunities. This would, in effect, hinder potential progress in obtaining mission-critical capabilities from the environment's developing systems.

As a property of complex systems and thus of enterprises, “openness” suggests a predisposition for opportunities (and risks). In creating new, potentially attractive solutions (desired outcomes in targeted outcome spaces), one should try to open the system further to create more opportunities for emergent behavior (alternative outcomes) while paying close attention to emerging risks. One has a “license” to more aggressively identify, explore, and develop opportunities in an enterprise than in TSE.

Enterprise risks can be mitigated by creating a management process with the adaptive built-in abilities to: quickly assess whether the emergent behavior is desirable; encourage desirable behavior; eventually eliminate (or reduce) undesirable behavior; and be more accepting of risks to prevent returning to preconceived notions that might lock out ultimately desirable emerging capabilities.

Per Renee Stevens (Fig. 10), the “messy frontier” is characterized by political engineering with the promised personal benefits of power and control, for example. There are both potentially high risks and correspondingly high rewards. Cooperative behavior must be fostered to counterbalance continual competition. At the SoS and enterprise scales, several program managers (PMs) usually need to be taken into account—not just one. Thus a risk and opportunity management integrated product team (IPT), for example, would have to interface with several PMs and their supporting functional areas. Remember that what may be an opportunity for the enterprise might be a risk for a particular program/PM.

Mike Kuras has suggested that research should be performed on what economists do about opportunity and risk at multi-scales of analysis, i.e., macroeconomics and microeconomics. Perhaps they have done more than anyone in the enterprise opportunity/risk arena.

Consider Fig. 11, in which the X-axis and Y-axis labels of Resolution and Field of View of an earlier chart [Kuras and White, 2005] have been replaced by Risk Avoidance and Opportunity Pursuit, respectively. As before, the axes represent arbitrary scales indicating low to high values of the two variables. The accessible region comprises combinations of the Risk Avoidance and Opportunity Pursuit pair, where humans can comprehend a vision of the underlying reality. Humans are incapable of attaining any visualization in the inaccessible region. The boundary between these two complementary regions exists but is not necessarily known or quantifiable. The preceding discussion suggests these hypotheses:

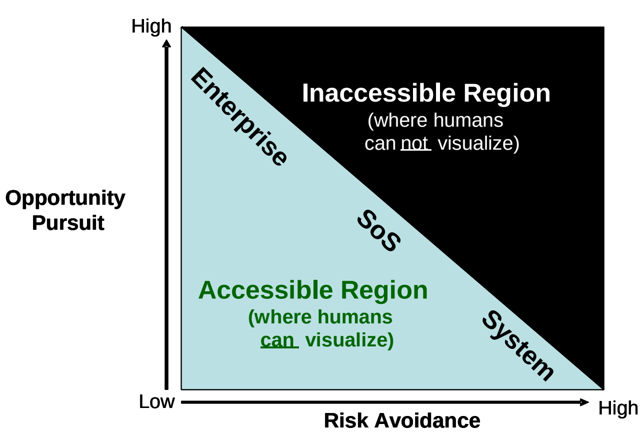

Figure 11. Multi-Scale Hypotheses for Opportunity and Risk

- At a given System scale, one typically focuses more on avoiding risk than on pursuing opportunity.
- At a SoS scale, more attention is paid to opportunities and less to risk.
- At an Enterprise scale, the emphasis should be on opportunity, not risk.
- Further evidence to support or refute these hypotheses is needed.

Thus the opportunities for intervening in an enterprise environment to accelerate the natural processes of evolution are great. The greatest enterprise risk may be in allowing this process to atrophy.

## *Qualitative Distinctions Between TSE, and SoS and ESE Opportunity Management*

For now this author has decided not to change the color descriptions when contemplating enterprise opportunity (or risk) management. This decision is tentative because enterprises are generally more complex than SoSs and require a different scale of analysis. The discussion is now concluded with summary red(R)-yellow(Y)-green(G) characterizations of opportunity management for SoS and ESE (similar to Fig. 9). Fig. 12 shows some preliminary results. (Note there is much less green here.)

Compared to TSE environments, resources in SoS and (especially) enterprise environments are deemed harder to control because many independent organizations are usually involved. This may be particularly true for opportunities as they seem to receive less focus than risks in traditional environments. Similarly, it would be more difficult to assemble a high-performance team in SoS and enterprise environments. Both these statements follow from the entries in the Stakeholder Involvement and Relationships sectors of the ESE environmental characterization template (Fig. 10).

Paradoxically, understanding the mission at the enterprise scale may be easier than at the SoS or program scale because the vision and mission statements for the enterprise scale must be kept rather general (and thus easier to understand) compared to those for the SoS or program scale, which might become more involved (and thus harder to understand).

| SoS Opportunity Management | | Enterprise Opportunity Management | |
|---|---|---|---|
| **Assessment** | **Action Steps and Substeps** | **Assessment** | **Action Steps and Substeps** |
| Yellow | Step 1 Prepare | Red | Step 1 Prepare |
| Y: Action 1 | Commit Resources | R: Action 1 | Commit Resources |
| Y: Action 2 | Form the Team | R: Action 2 | Form the Team |
| Y: Action 3 | Know the Mission | R: Action 3 | Know the Mission |
| R: Action 4 | Think Opportunities | Y: Action 4 | Think Opportunities |
| | | | |
| Yellow | Step 2 Identify the Opportunities | Yellow | Step 2 Identify the Opportunities |
| Y: Action 1 | Establish Team | R: Action 1 | Establish Team |
| Y: Action 2 | Develop Understanding | R: Action 2 | Develop Understanding |
| Y: Action 3 | Identify Opportunities | Y: Action 3 | Identify Opportunities |
| G: Action 4 | Classify Opportunities | G: Action 4 | Classify Opportunities |
| G: Action 5 | Write Opportunity Statements | G: Action 5 | Write Opportunity Statements |
| R: Action 6 | Correlate Related Opportunities | Y: Action 6 | Correlate Related Opportunities |
| | | | |
| Yellow | Step 3 Assess and Prioritize Opportunities | Red | Step 3 Assess and Prioritize Opportunities |
| Y: Action 1 | Impact Assessment | R: Action 1 | Impact Assessment |
| G: Action 2 | Probability Assessment | Y: Action 2 | Probability Assessment |
| R: Action 3 | Timeframe Assessment | R: Action 3 | Timeframe Assessment |
| Y: Action 4 | Reassess Opportunities | R: Action 4 | Reassess Opportunities |
| Y: Action 5 | Rank Opportunities | R: Action 5 | Rank Opportunities |
| G: Action 6 | Coarse Sort; Identify Handling Bands | Y: Action 6 | Coarse Sort; Identify Handling Bands |
| | | | |
| Green | Step 4 Decide on Handling Options | Yellow | Step 4 Decide on Handling Options |
| G: Action 1 | Identify Options within Each Opportunity Band | Y: Action 1 | Identify Options within Each Opportunity Band |
| G: Action 2 | Easy Opportunities | Y: Action 2 | Easy Opportunities |
| Y: Action 3 | Hard Opportunities | R: Action 3 | Hard Opportunities |
| Y: Action 4 | Assign OPRsG | R: Action 4 | Assign OPRsG |
| G: Action 5 | Update Opportunity Database | G: Action 5 | Update Opportunity Database |
| | | | |
| Yellow | Step 5 Establish Handling Plans | Red | Step 5 Establish Handling Plans |
| Y: Action 1 | Develop Plans and Estimates | R: Action 1 | Develop Plans and Estimates |
| R: Action 2 | Review and Approve | R: Action 2 | Review and Approve |
| Y: Action 3 | Fund, Direct, Integrate | R: Action 3 | Fund, Direct, Integrate |
| | | | |
| Yellow | Step 6 Implement Opportunity Handling | Red | Step 6 Implement Opportunity Handling |
| Y: Action 1 | Finalize Opportunity Management Plan | R: Action 1 | Finalize Opportunity Management Plan |
| Y: Action 2 | Provide Mechanisms to Monitor | Y: Action 2 | Provide Mechanisms to Monitor |
| Y: Action 3 | Implement Handling Plans | R: Action 3 | Implement Handling Plans |
| Y: Action 4 | Monitor Progress | Y: Action 4 | Monitor Progress |
| | | | |
| Green | Step 7 Monitor Handling Plans | Yellow | Step 7 Monitor Handling Plans |
| G: Action 1 | Periodically Review Handling Plans | Y: Action 1 | Periodically Review Handling Plans |
| Y: Action 2 | Modify or Stop, If Required | R: Action 2 | Modify or Stop, If Required |
| G: Action 3 | Retire Opportunities | Y: Action 3 | Retire Opportunities |

**G = green**
**Y = yellow**
**R = red**

Figure 12. ESE vs. SoS Opportunity Management Assessment Summary

With the regimen for complex-system engineering mind-set, it may be easier to think of and try to apply opportunities for managing the enterprise environment at the enterprise scale. The SoS scale may present more constraints for the communities of interest (COIs) that have worked longer at this scale than at the enterprise scale.

This chart's colors are selected according to a rationale similar to that of Fig. 8. The colors tend to complement those of Fig. 9's comparative risk colors. Note that these initial qualitative assessments of opportunity management could change as more is learned about SoS engineering, ESE, and CSE.

# Concluding Remarks

The greatest enterprise risk may be in not pursuing enterprise opportunities. Enterprise risk, *per se*, is mainly concerned with keeping an enterprise "healthy", i.e., open to future possibilities for change. There is duality in treating risks and opportunities among systems, SoS, and enterprises. As the scales and associated emerging patterns change from systems to enterprises, it is asserted that opportunities become more important. See Fig. 1.

Opportunity and risk management are "team sports." Everyone should be sensitive to what is happening and participate in altering course, as appropriate. This is more challenging in enterprise environments. ESE is the "big leagues" in opportunity management. Keep in mind there are unknowns and unknowables. Be rather humble when confronting the complexities of an enterprise.

Opportunities in ESE abound. Be open to them in creative ways, while being mindful of the need to monitor results carefully to protect against stagnation or even chaos. Qualitative assessments of opportunity management tend to be more difficult for enterprises than for SoS or systems. These assessments might easily change when more is understood about ESE.

Proposed rule of thumb: In ESE, be aggressive with opportunity and accept risk. This is just the opposite of what one might think of as a corresponding TSE tenet. Nevertheless, additional hypothetical examples and—better yet—validation from actual case studies should be sought.

# Suggestions for Future Work

Future work could include the exploration of "Real Options to give weight to upside opportunities associated with uncertainty, in addition to the traditional concern with downside losses and risks." [Haberfellner-de Weck, 2005] Other suggestions include:

- Provide more examples to illustrate benefits of pursuing (especially enterprise) opportunities to strengthen validation of thesis of emphasizing opportunities at enterprise engineering scales.
- Further explore and evaluate appropriateness of enterprise opportunity (vs. risk) emphasis in example enterprise environments [suggested by Prof. Olivier de Weck of MIT-ESD during the author's talk on the CSE Regimen at the 5 Oct 05 meeting of INCOSE's New England Chapter].
- Do most military program managers (colonels) focus on risks or on opportunities?
- Update Fig. 12 based on results of above work.
- Create business case for pursuit of (especially enterprise) opportunities.
- Questions paraphrased from suggestions by MITRE's Michele Steinbach:
  - To what extent does preoccupation with risk lead to a shorter list of options?

- How can lost opportunities be quantified and included in risk management cost?
- What is easier, recognizing risks or recognizing opportunities?
- How does one measure consequence?
- How much correlation is there between risk averse (seeking) and opportunity averse (seeking) individuals or organizations?
- How does one determine where organizational culture is between risk adverse and opportunity seeking? Under what circumstances does that motivate change, and what changes should be made, and how should they be accomplished?
- Further investigate risks and opportunities from broader viewpoint to gain more insight from interdependencies. Use parallel, multi-scale analysis in considering system and enterprise hierarchies.

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# Biography

Brian E. White received Ph.D. and M.S. degrees in Computer Sciences from the University of Wisconsin, and S.M. and S.B. degrees in Electrical Engineering from M.I.T. He served as an Air Force Intelligence Officer, and for 8 years was at M.I.T.'s Lincoln Laboratory. Dr. White spent 5 years as a principal engineering manager at Signatron, Inc. In his 24 years at The MITRE Corporation, he has held a variety of senior technical staff and project/resource management positions. He is presently Director of MITRE's Systems Engineering Process Office.

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