RISK MANAGEMENT

Managing today's electronics engineering programs requires careful attention to risk. Inadequate attention to risk at the early stages of a program is often the reason behind cost overruns, schedule delays, and less-than-planned technical performance.

Risk is the chance of loss or injury. In a situation that includes favorable and unfavorable events, risk is the probability an unfavorable event occurs (1). Risk management is a collection of procedures focused on the identification and resolution of events unfavorable to a program. As such, it is indistinguishable from program management. Ideally, risk management is a formally structured process from which program risks are identified, analyzed, and mitigated (or reduced to a level acceptable to stakeholders).

Cost, schedule, and performance objectives of an end-item (e.g., an electronics system or an electronics component) typically define the domain of the risk management decision space. A characterization of this space is presented in Fig. 1, which illustrates how user expectations of cost, schedule, and performance are often at odds with what can be delivered. Risk is introduced when expectations in any of these dimensions push what is technically and/or economically feasible. Managing risk is managing the inherent contention that exists within each axis and across all three. The goal of risk management is to identify cost, schedule, and performance risks early, so that control on any axis is not lost and the impacts (or consequences) of risk and risk-mitigating actions on all three axes are well understood.

The process of managing risk varies widely in its complexity. Some program managers require very little structure or formality in their process. For others, a formal process for identifying, analyzing, and controlling risk is essential—particularly on many of today's highly complex and increasingly interoperable electronic systems.

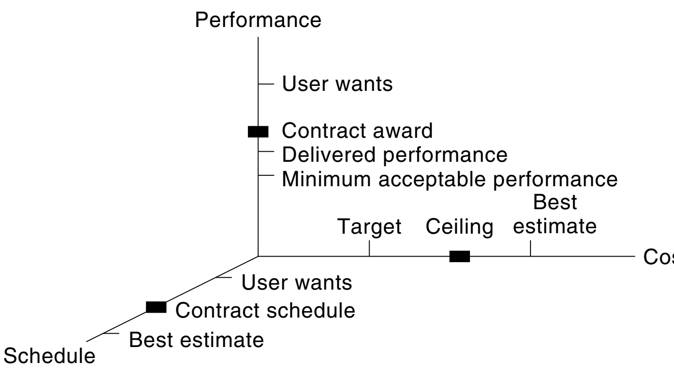

Figure 1. Risk management decision space.

A RISK MANAGEMENT PROCESS

A risk management process typically consists of the activities shown in Fig. 2. These activities are implemented by a cross-functional project risk-assessment team. Members of the team include people from the major engineering and program control areas of the project.

The steps illustrated in Fig. 2 are briefly described below.

Risk Identification. This first step involves the identification of key program risk areas by the risk assessment team. Risk areas are usually identified at the functional area of a program; an example might be *radar data processing.* Next, events within those risk areas whose occurrences would be unfavorable to the project are identified. These events are called risk events. For instance, in the risk area *radar data processing* a risk event might be "the proposed radar data processor may fail to achieve throughput requirements." Dependencies among risk events must also be identified, since the risk of failing to achieve one objective often impacts the ability to achieve other objectives. Risk event descriptions should be written with sufficient clarity to support assessments of their occurrence probabilities and degrees of dependency.

Impact Assessment. In this step, the team assesses the impact each risk event could have on the program. Typically, this includes how the event could affect the program's cost, schedule, or performance objectives (the following section of this article presents an approach for quantifying impact on the basis of multiple evaluation criteria). In addition, the team assesses the probability (chance) of each risk event. This often involves the use of subjective probability assessment techniques (3), particularly if circumstances preclude a direct evaluation of the probability by objective (i.e., engineering analysis) methods.

Risk Prioritization. At this step, the team reviews and analyzes the overall set of risk areas, risk events, impact assessments, and occurrence probabilities to set priorities for applying critical resources. These resources include the assignment of additional personnel and funding (if necessary) to focus on resolving the risks deemed most critical to the program.

Action. This step involves the development of action plans (or risk mitigation strategies) to eliminate the risk or reduce it to acceptable levels. Once an action plan is implemented, the team must continually monitor how well the plan is working and revise it as needed.

Throughout the process described above, it is critical to continually track and document progress. In addition, it is important to maintain a current listing of the various products (e.g., risk area list, the set of risk events) produced by the risk assessment team.

Isolating Critical Risks

A major result of the risk management process is resolving where to apply engineering resources to deal effectively with the most critical program risks. To reach this result requires a method that isolates the most critical risks among all those identified. Such a method involves quantifying the impacts these risks might have on a program, along with their occurrence probabilities, through the application of utility theory techniques.

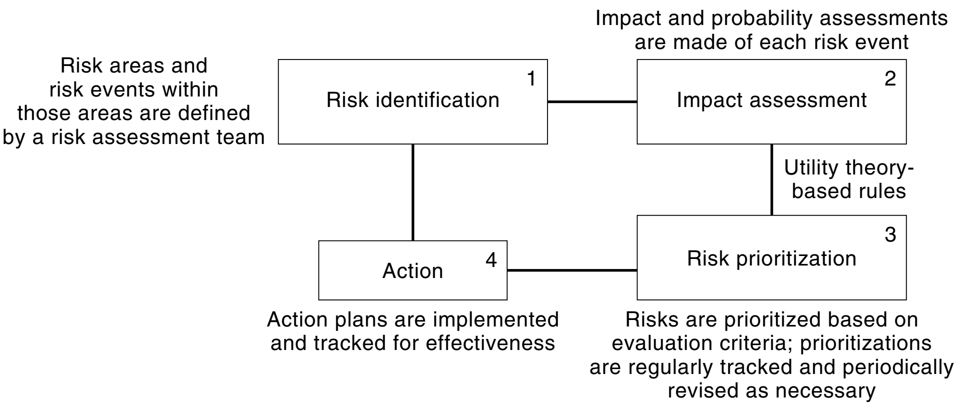

Figure 2. A risk management process (2).

An important product of the method is a "situation display," illustrated in Fig. 3, which shows a relative prioritization of risks according to their impacts and occurrence probabilities. The points denote specific risk events. Each event falls into one of three risk classification regions: high, medium, or low. The boundary curves separating these regions are not arbitrary; they reflect an actual consensus derived from a group of systems engineers who have implemented the utility-theoretic method described in this article.

Measuring Impact and Assessing Probability. Risk is evaluated in two dimensions—impact and occurrence probability. Although the criteria of cost, schedule, and technical performance reflect the traditional set, criteria specific to a program can and should be defined. The following formulation illustrates an approach for measuring the impact a risk may have on a program. The approach produces a measure referred to as "impact intensity" in Fig. 3.

An Impact Intensity Measure. Before introducing a rule to measure a risk event's impact intensity, we discuss some important notation. Let x_{if} represent a qualitative rating assessed for risk event X_i in evaluation criterion (or factor) f.

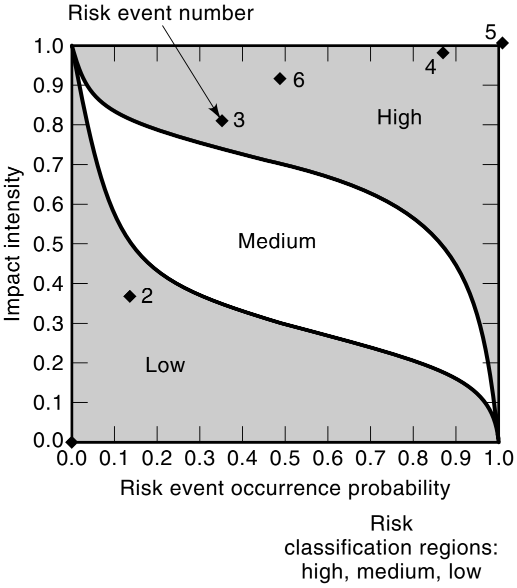

Figure 3. A program's risk picture—an illustrative situation display.

Define u_f as a function that maps x_{if} to an equivalent numerical value. This value is denoted by $u_f(x_{if})$, where $u_f(x_{if})$ is defined to range between zero and one. A set of illustrative values for $u_f(x_{if})$ is shown in Fig. 4.

Here, $u_f(x_{if})$ acts as a measure of the individual impact intensity that risk event X_i has on evaluation criterion f. For instance, suppose $f = 1$ denotes the technical performance evaluation factor; a value associated with $u_1(x_{11})$ would reflect the impact intensity measure of risk event X_1 on the system's technical performance. Likewise, values for $u_2(x_{12})$ and $u_3(x_{13})$ could denote the impact intensity measures of risk event X_1 on the system's cost (e.g., $f = 2$) and schedule (e.g., $f = 3$), respectively. Illustrative values for $u_1(x_{11})$ are presented in Fig. 5.

One rule for measuring the impact intensity is given by Eq. (1). Equation (1) measures the impact intensity $I_A(X_i)$ of risk event X_i as a weighted average of $u_f(x_{if})$.

$$I_A(X_i) = \frac{1}{W} \sum_f w_f u_f(x_{if}) \tag{1}$$

In the expression above, w_f is a positive weight associated with the fth evaluation criterion. In Fig. 4, there are three evaluation criteria: cost, schedule, and technical performance. The sum of these weights is given by W (i.e., $W = \sum_f w_f$). In this formulation, observe that $0 \le I_A(X_i) \le 1$. A value of $I_A(X_i)$ close to unity indicates risk event X_i will have a serious impact on the program if it occurs. A value of $I_A(X_i)$ close to zero indicates risk event X_i, even if it occurs, will have little (or no) impact on the program. It is important to note that

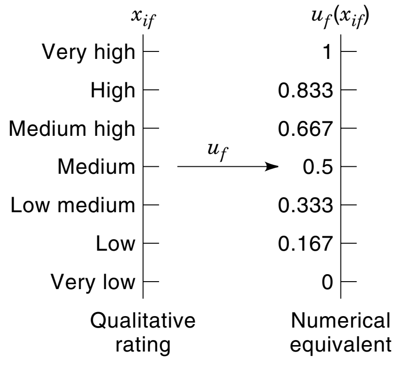

Figure 4. Illustrative values of $u_f(x_{if})$ for evaluation criterion f.

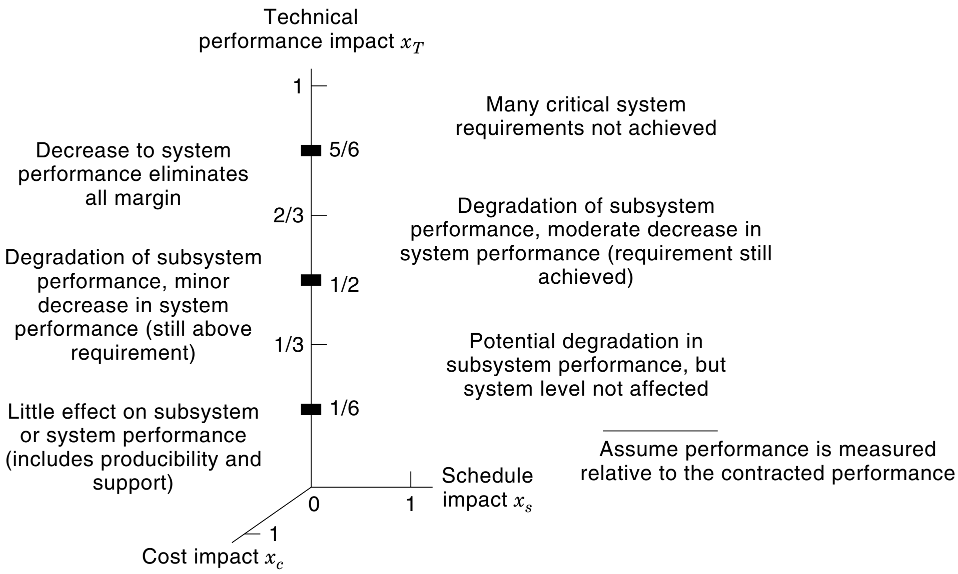

Figure 5. Illustrative values for $u_1(x_{11})$.

$I_A(X_i)$ by itself takes no account of the probability that X_i will occur.

Because Eq. (1) reflects a weighted average of a risk event's impacts across each evaluation criterion, a high value in one criterion [e.g., $u_1(x_{11})$] does not necessarily imply a high value for $I_A(X_i)$. In particular, an evaluation criterion of X_i at its maximum possible value, $u_1(x_{11}) = 1$, does not guarantee $I_A(X_i)$ will reach its maximum possible value. A measurement rule that guarantees the overall impact intensity reaches its maximum possible value whenever any one evaluation criterion of X_i is at its maximum possible value is given by Eq. (2).

$$I_M(X_i) = 1 - \prod_f [1 - u_f(x_{if})]^{v_f} \tag{2}$$

where $v_f = (w_f/\mathrm{Max}\{w_f\})$. In this formulation, observe that $0 \le I_M(X_i) \le 1$. Equation (2) is similar to the well-known Keeney–Raiffa multiplicative multiattribute utility function (4). Note that if any evaluation criterion in Eq. (2) has a value equal to unity, then $I_M(X_i) = 1$. This is true regardless of the weight associated with the criterion. Such a property is desirable for risk management. It allows a risk event to be signaled (flagged) for further consideration when just one evaluation criterion is at its extreme. To guarantee that $I_M(X_i)$ takes a high value whenever an evaluation criterion X_i has a high value, define $v_f = (w_f/\mathrm{Min}\{w_f\})$. The multiplicative rule [given by Eq. (2)] will always produce impact intensity values higher than those generated by the additive rule [given by Eq. (1)]; that is, $0 \le I_A(X_i) \le I_M(X_i) \le 1$. This result follows from the facts that $e^{-y} \le 1 - y$ and $\log(1 - u) \le -u$, $0 \le u \le 1$. In practice, program managers and decision makers often prefer to generate the display shown in Fig. 3 on the basis of the weighted average rule for measuring a risk event's impact intensity. This provides a point-of-departure for examining how these impact measures might change upon invoking the $I_M(X_i)$ rule, instead of the rule given by $I_A(X_i)$.

Assessing Probability. Once each risk event's impact intensity has been determined, the risk assessment team evaluates, or assigns, the event's occurrence probability. In practice, this is almost always a subjective probability. Usually time (or information) precludes the development of such probabilities through objective engineering (or scientific) analyses. There is a large body of literature on techniques for eliciting subjective probabilities (5). An illustrative scheme is offered in Table 1 for translating qualitative assessments of an event's likelihood of occurrence into probability values.

SUMMARY

Isolating critical risks among a program's set of risk events can now be accomplished on the basis of an event's assessed occurrence probability and impact intensity measure. Shown in Fig. 3, those events with a high probability of occurrence and a high impact intensity are readily visible and are the prime candidates for direct management action.

Program managers sometimes look for a single measure that represents an overall "risk value" associated with each risk event. This single measure is typically of the form given by Eq. (3)

$$E[I(X_i)] = P(X_i)I(X_i) \tag{3}$$

Equation 3 is the *expected impact intensity* of risk event X_i. Although there is nothing technically wrong with combining

Table 1. An Illustrative Probability Assessment Scheme

Qualitative Assessment of Risk Event X_i Occurring	Quantitative Translation $P(X_i)$
Sure to occur	1
Almost sure to occur	0.9
Very likely to occur	0.8
Likely to occur	0.7
Somewhat greater than an even chance	0.6
An even chance to occur	0.5
Somewhat less than an even chance	0.4
Not very likely to occur	0.3
Not likely to occur	0.2
Almost sure not to occur	0.1
Sure not to occur	0

an event's occurrence probability with its impact intensity measure in such a manner, it could mislead the program's management if this were the only measure presented. A risk event with high impact intensity and low occurrence probability and another event with low impact intensity and high occurrence probability can produce comparable values for $E[I(X_i)]$. However, these events may require different levels of management attention and different risk mitigation strategies. In program risk management, it is usually more desirable and/or cost-effective to focus the risk mitigation effort on reducing events with high impact intensities and high occurrence probabilities. This can best be seen when such information is presented to management in a form shown in Fig. 3.

This article presented an introduction to risk management and some structured analytical techniques for identifying which risks among those identified are most critical to a program. Implementing a risk management process is a core program management activity. The benefits gained include: the early identification of risk events so mitigation strategies can be developed in a timely manner; the establishment of a common set of project-specific cost, schedule, and technical performance scales on which to map risk event impacts; and the creation of a structured environment within the systems engineering process for monitoring and documenting changes in risk events and their prioritizations over time. In the spirit of T. Gilb, risk management is a process essential toward "actively attacking risks before they actively attack you" (6).

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