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Capturing Risk in Solution Prioritization

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Introduction

The intent of the Chief of Staff of the Air Force-directed Comprehensive Assessment of Nuclear Sustainment (CANS) was to identify and provide solutions for any systemic problems within the nuclear sustainment enterprise. During the study, strategic-level findings were prioritized using a multi-objective optimization approach. As with any system, there is risk associated with maintaining the status quo when problems are identified. However, as it was assumed that the risk associated with not addressing the strategic-level findings was sufficiently high such that all findings would eventually be addressed, this risk was not included in the prioritization problem formulation. This is not to say that risk was not considered at all, but rather that the consideration of risk was limited to that of the solutions themselves—risk that the solution may have unintended consequences that actually make the problem worse. Though sufficient and appropriate for the initial study, the inclusion of risk in the prioritization formulation may provide a more complete picture for decisionmakers. The remainder of this article presents a generic methodology to incorporate a measure of risk into a multi-objective solution prioritization problem like the one in the CANS study. Such a methodology may be useful in follow-on efforts of CANS. (For a detailed description of the CANS methodology, see the previous *Air Force Journal of Logistics* article entitled "Using AFSO21: The Problem is Big, Time is Short, and Visibility is Enormous."[1])

Original Problem Formulation

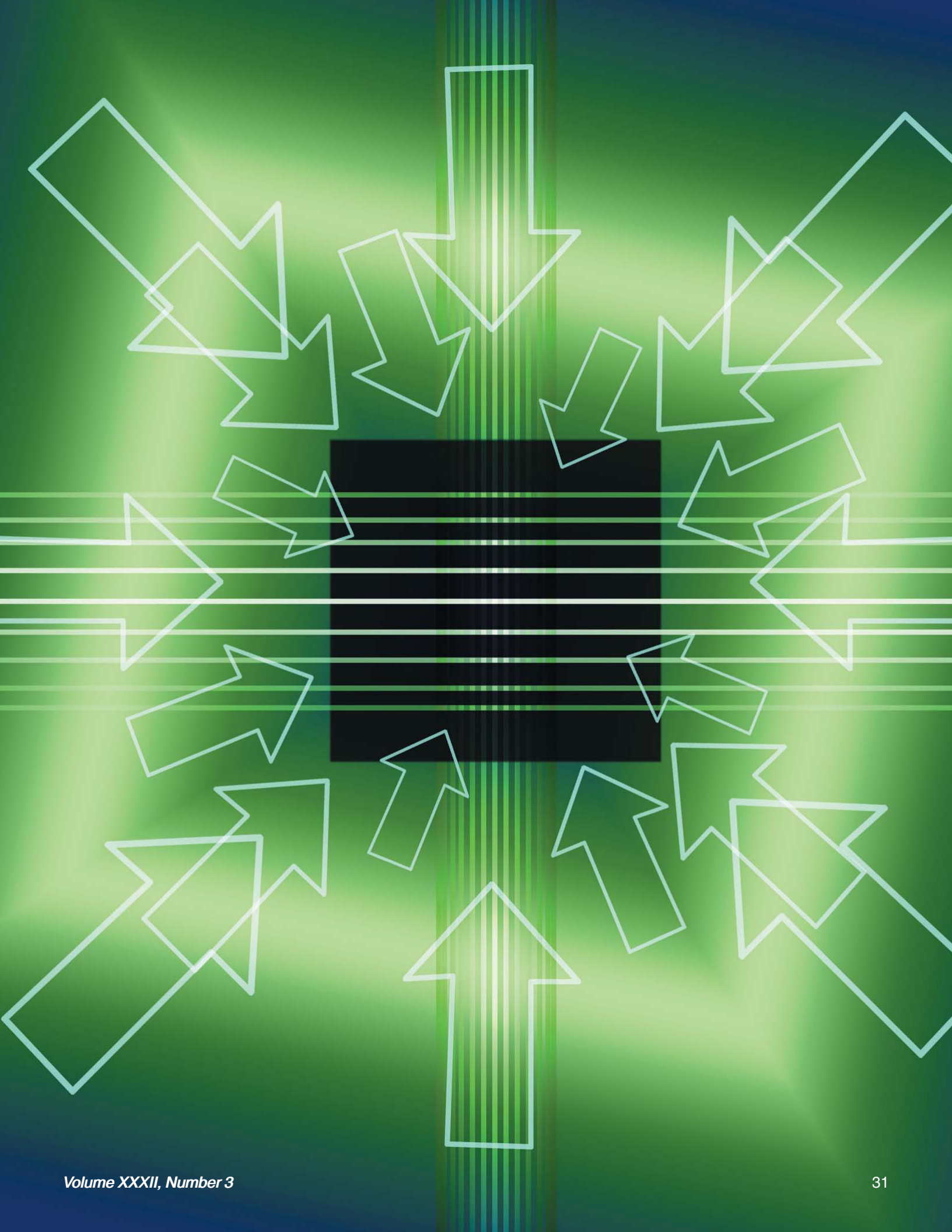
The original prioritization portion of CANS attempted to prioritize strategic level findings of the study. To accomplish this, subject matter experts (SME) scored the impact of each strategic level finding, if solved, on the five key mission areas (see Figure 1). The result was then formulated as the following multi-objective optimization problem:

$$\max F(x)$$

subject to

$$x \in \Omega = \{x \in \{0,1\}^n : g_i(x) \leq 0,\ i = 1,2,...,M\}$$

where $F : \Omega \rightarrow R^J$. In this formulation, the five key mission areas represent the competing objectives and the selection of particular strategic findings for resolution represents the decision variables. The resulting problem was then solved using a weighted-sum-of-the-objective-functions (WSOTOF) method[2] in which weights were determined by surveying senior Air Force leaders.



	Training	Policy	Culture	Resources	OS/Control
Finding 1	1	3	1	1	9
Finding 2	1	3	1	9	1
Finding 3	9	1	9	1	1
Finding 4	3	9	1	3	9
Finding 5	3	1	9	3	9
Finding 6	3	1	3	1	1
Finding 7	9	9	9	3	1
Finding 8	1	1	3	1	9
Finding 9	3	3	1	9	1
Finding 10	1	9	3	1	9

Figure 1. Impact of Solving Strategic-Level Findings on the Five Key Mission Areas

Modeling Risk

Risk analysis[3] and mitigation related to performance, cost, and schedule can be modeled or approximately quantified for each finding using a modified version of the Develop and Sustain Warfighting Systems (D&SWS) core process working group[3] Active Risk Management (ARM) process model as follows: SMEs use brainstorming to identify and explicitly define potential consequences associated with not correcting the strategic level findings. The SMEs then score the identified consequences, via a Delphi voting method, using life cycle risk management likelihood and severity ratings (a numerical score from 1 to 5) as defined in the D&SWS ARM process model[4] and shown in Figure 2. These scores then provide a quantifiable measure of risk to be included in the prioritization.

Addition of Risk in the Problem Formulation

Consider the following formulation. Let

$$F(x) = \sum_{j=1}^{J} w_j f_j(x) + w_{J+1}\, \xi\,(x)$$

where $f_j : \Omega \rightarrow \mathrm{R}$, $j = 1, 2,...,J$ are the impact on the original key mission areas and $\xi(x)$ represents the risk associated with finding x.

Article Acronyms

AFSO 21 – Air Force Smart Operations for the 21st Century
ARM – Active Risk Management
CANS – Comprehensive Assessment of Nuclear Sustainment
D&SWS – Develop and Sustain Warfighting System
SME – Subject Matter Experts

The question then becomes: What function $\xi(x)$ best describes the risk determined and quantified using the ARM process model?

The risk scores can be divided into three areas (see Figure 2). The green squares represent a safe area where there is little likelihood of a risk occurring and low impact to the system if it does. The yellow and red squares represent medium- and high-risk areas, respectively. The function chosen to represent the risk in the prioritization formulation should be similarly scaled (be smaller for risks in the green area, somewhat larger for those in the yellow area, and larger again for those in the red area). As shown superimposed over Figure 2, a simple product of the severity and likelihood ratings would meet this criterion.

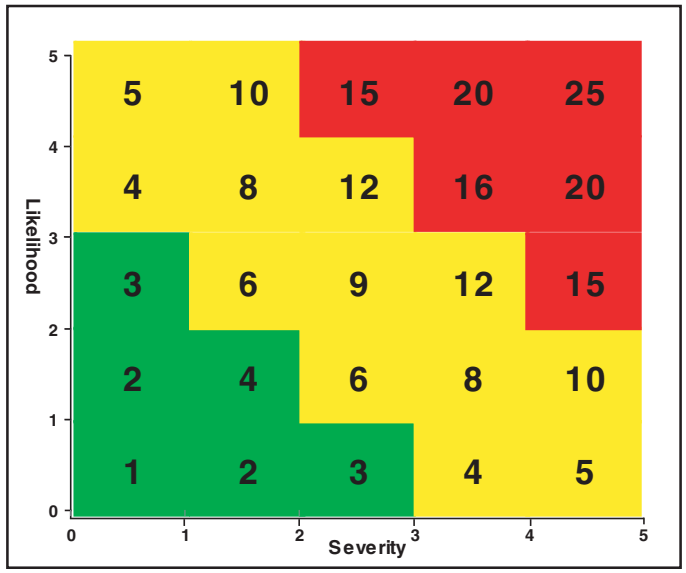


Figure 2. Risk Function Diagram

Therefore, consider the inclusion of the aforementioned risk function as follows. Let

$$\xi(x) = \max_{i=0}^{I_x} \xi_i(x)$$

where the function $\xi : \Omega \rightarrow R$ is a measure of the risk associated with consequence i of not addressing finding x, Ix is the total number of identified consequences associated with not addressing finding x and $\xi_i(x)$ = (Severity x Likelihood). Thus, the final formulation then becomes

$$\max \mathrm{F}(x)$$

subject to

$$x \in \Omega = \{x \in \{0,1\}^{\mathrm{n}} : g_i(x) \leq 0,\ i = 1,2,...,\mathrm{M}\},$$

where $F(x) = \sum_{j=1}^{J} w_j f_j(x) + w_{J+1} \max_{i=0}^{I_x} \xi_i(x)$

Conclusion

This article presents a simple method to quantify risk so that it can be included as an additional objective in a multi-objective solution prioritization problem like the one in the CANS study. The ability to capture risk in the prioritization method may

provide a more complete picture for decisionmakers and could be useful in future studies.

Notes

1. J. Walston, "Using AFSO21: The Problem is Big, Time is Short, and Visibility is Enormous," *Air Force Journal of Logistics*, XXXII, No 2, 56.
2. M. Ehrgott, *Multicriteria Optimization,* second edition, Berlin, Germany: Springer, 2005.
3. J. Jackson and M. Hailston, "D&SWS Life Cycle Risk Management (LCRM) Update," briefing, D&SWS Core Process Working Group, 27 June 2008.
4. J. Kindinger and J. Darby, "Risk Factor Analysis—A New Qualitative Risk Management Tool," *Proceedings of the Project Management Institute Annual Seminars & Symposium*, Houston TX, 7-16 September 2000.

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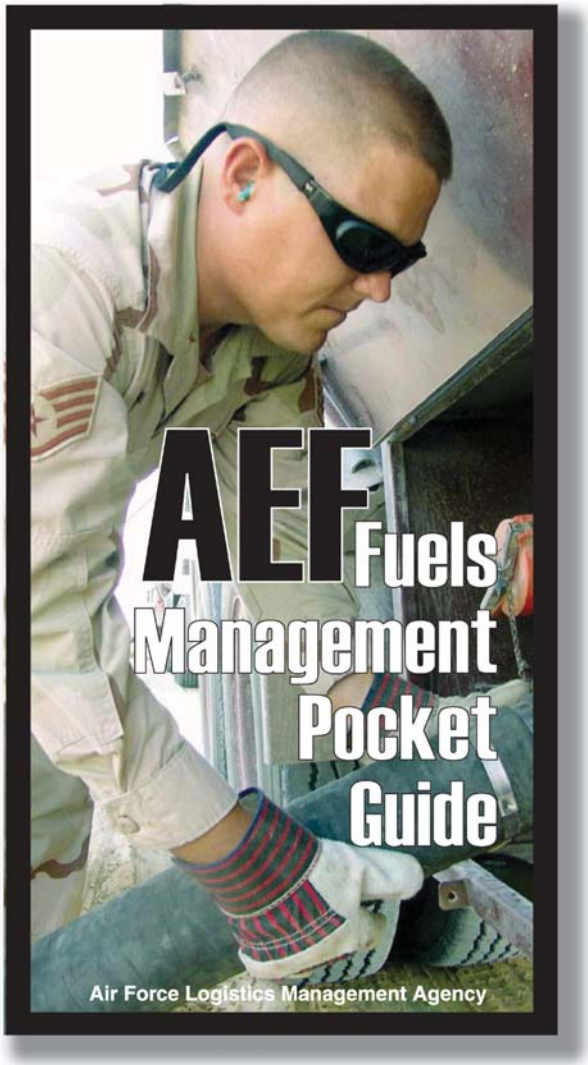

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