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An Introduction to Risk with a Focus on Design Diversity in the Stockpile

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The maintenance and security of nuclear weapons in the stockpile involves decisions based on risk analysis and quantitative measures of risk. Risk is a factor in all decisions, a particularly important factor in decisions of a large scale. One example of high-risk decisions we will discuss is the risk involved in design diversity within the stockpile of nuclear weapons arsenal.

Risk is defined as "possibility of loss or injury" and the "degree of probability of such loss" (Kaplan and Garrick 12). To introduce the risk involved with maintaining the weapons stockpile we will draw a parallel to the design and maintenance of Southwest Airlines' fleet of Boeing 737 planes. The clear benefits for cost savings in maintenance of having a uniform fleet are what historically drove Southwest to have only Boeing 737s in their fleet. Less money and resources are need for maintenance, training, and materials. Naturally, risk accompanies those benefits. A defect in a part of the plane indicates a potential defect in that same part in all the planes of the fleet. As a result, safety, business, and credibility are at risk. How much variety or diversity does the fleet need to mitigate that risk? With that question in mind, a balance is needed to accommodate the different risks and benefits of the situation. In a similar way, risk is analyzed for the design and maintenance of nuclear weapons in the stockpile.

Before we discuss risk management specific to stockpile stewardship, we first discuss risk in general. Risk concerns "uncertainty + damage" or "hazard/safeguards" (Kaplan and Garrick, 1981). In other words, risk is lack of knowledge of the future and the potential damages that can occur. Also, risk is the potential hazards of a situation that are lessened with safeguards in order to reduce that risk. On the whole, risk is addressed with questions like "What will happen in the future given a specific event?" and "What is the probability that something bad will happen because of this event?" and "What are the consequences of that event?" (Kaplan and Garrick 13). If a student is faced with a situation where they must strike a balance of studying and sleep in order to do well on an exam, risk is analyzed. The event is taking the exam. The outcome of the test is uncertain, and that added to the damage of failing the exam equals the risk. The hazard of failing the exam is divided by a good night's sleep and adequate study, which lessens the chance of failing the exam. When they are faced with the risk of failing my exam and the decision to sleep or study, these basic tools of risk management and analysis are used. On a grander scale, the same kind of idea, plus more quantitative procedures, applies to maintaining the nuclear weapons stockpile.

There are obstacles and challenges involved in evaluating the risks of maintenance and design of the stockpile. Due to the Comprehensive Nuclear Test-Ban Treaty, full system tests of nuclear weapons are not permitted. Components of the weapons may be tested, but not the system as a whole. The mission of stockpile stewardship is to secure, maintain, and assure the reliability of the nuclear weapons stockpile without full system testing. An approach to mitigate risk in the stockpile is design diversity/type diversity. On its simplest level, design diversity is the method of mitigating risk and increasing reliability by incorporating independent and diverse designs into the weapons stockpile in order to prevent endogenous common cause failures. Endogenous common cause failures (CCF) are failures which "induce correlations between failures in otherwise independent components" (Collins, 2011). To create this design diversity in the stockpile, independent and diverse designs are used. The risk lies in the reliability of resources spread across a variety of designs such as quality control, testing, and inspecting. There is also the risk of CCF existing in different seemingly independent designs. Another risk is the cost of creating and maintaining all the different designs. Those risks are not as prominent when there is only one type of design.

The opposite of design diversity is keeping a consistent design within the stockpile. That method certainly reduces the resources needed to maintain a variety of designs. That's the chief benefit. But, a CCF will make a great impact on the reliability and security of the entire batch, as opposed to when a CCF is found in a diverse stockpile. Also, problems like CCFs become more noticeable and more prominent when the size of the stockpile is decreasing. Revisiting the Boeing 737 example, there have been highly publicized cases of a CCF destroying the credibility and safety of a whole fleet of the same design. Despite the benefits, a defect could cause more problems and risks than what would be expected with design diversity. That brings up the question: what is the safest, most economical, and reliable balance of design diversity?

The challenge is: should the lab produce weapons that are modernized and high-margin warheads or produce life-extended Cold War weapons? This problem has been said to be, "Arguably one of the more important issues to be resolved and ultimately may be one of the hardest to address." (Jaeger and Pedicini, 2005). This is due to the nature of the United States' nuclear deterrent. There are a few options that exist (or have existed) that attempt to mitigate the risk involved in maintaining the stockpile. There are incremental life extension programs (iLEP) that maintains the Cold War stockpile incrementally. On the other hand, there were Reliable Replacement Warheads (RRW), which were intended to increase safety and security by modern replacements. A possible middle ground between those two methods would be an extensive reuse life extension program (erLEP) because it extends the life of Cold War warheads but still adds new elements to the weapons (Goodwin and Mara). It is an attempt to balance the pay-offs of resources and design diversity.

There is a distinct balance in creating the optimum economical, reliable, and secure stockpile. But how does one find that fine balance? Quantitative measures must be used. There's an old saying, "You can't manage what you can't measure". You can't claim to measure risk completely and effectively without numbers to support your conclusions. Many individuals and companies create ordinal scales to measure risk. In reality, those methods can help but they are more subjective. They will not be as accurate or effective as quantitative measures (Hubbard and Evans). Sometimes, a mix of subjective opinions and quantitative data must be used in order to fully acknowledge uncertainty and risk. Hubbard says, "At its root, the objective measure of risk management should be based on the whether and how much risk was actually reduced or whether risk was acceptable for a given payoff. In order to do that, the risk management method should have an approach for properly assessing the risks. In order to measure the effectiveness of risk management, we have to measure risk itself" (Hubbard 42). The root of measuring risk is the probabilistic methods.

In order to measure risk itself, we must realize the uncertainty that exists in situations in which risk exists. On top of that, there are different types of uncertainties. Aleatory uncertainties are more easily realized and more easily calculated in models than epistemic uncertainty. The reason is that aleatory uncertainties come from variation in samples and randomness and large data sets. Using information from data and samples is an easier way to predict risks rather than instances without the opportunity of having large data set. Epistemic uncertainties come from incomplete knowledge where there isn't a large sample or there are unknown outcomes. Although probability based on frequency of large, experimental samples is easier, other high-consequence situations with less data inevitably must be considered. Many times, risk must be measured and managed for situations that the outcome is unknown, possibly has never happened before. The challenge is being able to use probability to manage those high-risk situations (Pate-Cornell, 1996). Probability stems from frequency, a standard in calculating probability because it is a measurable number coming from real, repeated trials. Probability is "a numerical measure of a state of knowledge, a degree of belief, a state of confidence" (Kaplan and Garrick, 1981). We convert a frequency distribution to a probability model to make predictions about future observations. A simple example of this point is a coin toss. When a coin is tossed many times, the frequency of heads will be roughly fifty percent. To predict that a head will show on a coin toss, we use the frequency and say the probability that a head will occur is .5. When it comes to finding risk, simply using the mean of a probability and consequence graph is not accurate. Risk must be described with not just the mean but the whole curve, and not even just one curve, but many.

Hubbard says that there are four methods of determining effectiveness in risk management; "statistical inferences based on large samples, direct evidence of cause and effect, component testing of risk management, a "check of completeness"" (Hubbard, 2009). In summary, it's important to have a large sample of data in order to come to accurate conclusions. Basing risk management analysis off only a few select incidents or cases is not effective. It's also important that cause and effect is analyzed in a controlled way. That way, risk management methods directly control the risk they're meant to; no hidden risks are solved by chance. Component testing does not analyze the whole method of risk management, but each of the parts of risk management. Each part, such as scoring methods, expert opinion, or computer simulations must be tested. Lastly, the check of completeness is checking to make sure that all risk is analyzed, not just the risks of what the business is doing itself. For example, risk involving baggage, worker safety, and other aspects of airline services must be accounted for in addition to risks involving the actual plane itself. With this management effectiveness checklist in mind, risk can be more effectively and thoroughly evaluated and controlled.

In conclusion, risk must be as low as possible when it comes to the nuclear weapons stockpile. Design and care to keep the stockpile healthy involves all aspects of risk management. Design diversity is a method that helps to mitigate risk, and to help balance options in stockpile stewardship.

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