SAND96-1427C
CONF-960647--10

An Examination of the Consequences in High Consequence Operations

S. D. Spray
J. A. Cooper
Sandia National Laboratories
Albuquerque, NM USA 87185-0490

Abstract

Traditional definitions of risk partition concern into the probability of occurrence and the consequence of the event. Most safety analyses focus on probabilistic assessment of an occurrence and the amount of some measurable result of the event, but the real meaning of the "consequence" partition is usually afforded less attention. In particular, acceptable social consequence (consequence accepted by the public) frequently differs significantly from the metrics commonly proposed by risk analysts. This paper addresses some of the important system development issues associated with consequences, focusing on "high consequence operations safety."

1. Introduction

In assessing risk, it is traditional to partition the areas of concern into the probability of occurrence and the consequence of the event. Most safety analyses focus on probabilistic assessment of an occurrence and the amount of some measurable result of the event, but the real meaning of the "consequence" partition is usually afforded less attention. In particular, acceptable social consequence (consequence accepted by the public) frequently differs significantly from the metrics commonly proposed by risk analysts. In developing systems for high consequence operations, it is of considerable importance to explore the factors that contribute to determining the degree of consequence. Although some are measurable quantitatively, some are highly qualitative. Consequence assessment must therefore address both quantitative and qualitative contributions. It is also important that the acceptable social consequence of high consequence systems not be mis-read. Public backpressure can create considerable tension with technical feasibility. Frequently, technical feasibility is subservient to social acceptance.

* This work was supported by the United States Department of Energy under Contract DE-AC04-94AL85000.

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

2. High Consequence Operations Consequences

Some of the most useful factors in determining high consequence losses include large monetary loss, loss of large numbers of human lives, the effect of disasters on the human emotional acceptance level (including the "dread" factor), serious environmental effects (short term or long term), organizational health (and survival) impacts, political effects that are widely detrimental, and the status of national defense posture as a protective entity. In this section, each of these will be explored in detail. Then their integration into a comprehensive measure of consequence will be addressed.

2.1 Monetary Loss

Monetary loss is commonly measured directly by the expense originally required to build the facility or system lost, or the expense to rebuild. Some people are also willing to put monetary value on human lives, based on the potential for legal judgments. Many factors combine to make this approach less meaningful than one might at first expect. For example, it is also important to consider resource limitations that can make rebuilding a facility or system impossible or undesirable. Time may be extensive in securing rebuilding funds, whether or not losses are insured. A collective will to restore lost entities is also necessary. There is typically psychological damage to all concerned when a dramatic loss occurs, even if available funds make recovery feasible. Legal judgments due to various losses are a factor. Human lives lost in a disaster have impact that transcends monetary value, as addressed next.

2.2 Loss of Human Life

Although the "value" of human life is difficult to specify (beyond legal judgment statistics), it is tempting to measure the impact of loss of life in numbers. One advantage of doing so is that such a measure is independent of what monetary value might be placed on a life. While this metric may give some insight into the magnitude of a particular loss, other factors are at least as important. For example, the loss of 168 people in the April 19, 1995 bombing in Oklahoma City was of grave concern to most people in the U.S., while on the same day, almost as many people died in automobile accidents on U.S. highways with little attention beyond the family or community impact (a very small fraction of the U.S. population).

Many factors contribute to this, such as the emotional factor (discussed subsequently) about the horrors of an explosion, the fear of the terrorist threat being made real to a population relatively unexposed to it, the concern over those known or thought to be trapped alive but injured in the rubble, the inability of anyone to control their own exposure to such an event, and the sudden loss of so many at the same time in the same location. Furthermore, mere numbers can be misleading. For example, the loss of a single U.S.

President by assassination in 1963 continues to engender discomfort to this day. For these reasons, the loss of life consequence is one of the most complex factors in judging consequence. Any metric proposed should consider at least all of the above factors.

2.3 The Emotional Effect

Emotion (including the "dread" factor) enters into consequence in a variety of ways. For example, any effect of inadvertent exposure to nuclear radiation is feared by most people, even where the levels involved are much smaller than natural radiation. In an apparent contradiction, people show little fear of medial or dental x-rays, which also may produce a significantly higher level of exposure than that feared. Part of the reason for this phenomenon is the discomfort people have about the "real" levels they might accidentally be exposed to, in contrast to the levels specified by experts, whom at least some of the public may regard with suspicion. However, a major contributor to these types of fears is emotion and dread. Radiation not carefully controlled is thought to have potentially horrible effects, it is largely an "unknown" entity, and there is no warning of its effects until it is too late.

Many people drive comfortably, but fear airplane travel, which is statistically much safer than automobile travel. Part of the reason for this is that people tend to feel more in control of their safety in an automobile, confident (whether warranted or not) that they can safely control their destiny. The dread effect is a strong contributor because of the potential terror of falling from possibly high altitude for possibly minutes of sheer terror.

Perception also plays a role. A person speeding down the highway at 70 mph has a comfortable perception, because the seemingly robust surroundings of the automobile chassis and even the relatively motionless air surrounding the person mitigate the feeling of potential danger. If the same person were placed in the same seat, and moved down the highway at 70 mph with no other surrounding protection, the perception of danger would be much different.

Many people fear swimming in the ocean because of the potential for shark attacks, even though statistically they are much more likely to accidentally drown in their bathtub. Some feel that the statistics are misleading, because safety from shark attack is statistically biased by large numbers of people that never swim in the ocean or who swim only in areas known to be essentially "shark-free." There is some merit to this argument, and certainly anyone would feel uncomfortable swimming knowingly where schools of sharks were being sighted. However, the emotional dread factor is again probably more significant. Almost everyone has seen movies or television images of shark feeding, and it is hard to imagine a more terrifying personal experience.

The impact of an aircraft crash where hundreds of people may be killed all at once touches a public sense of alarm. One of the concerns that has been expressed about proposals to build 800 (or more) passenger commercial airplanes is the impact that the loss of so many lives in one accident would have on society. Would a disaster of such magnitude be accepted by the public, or would there be protests against creating a high consequence system with the potential for such losses?

Similarly, proposals to build skyscrapers with hundreds of stories come under scrutiny because of the potential loss is a disaster such as the World Trade Center bombing were to occur. We could possibly attribute this to the loss of life metric, were it not for the comparable loss of life in automobile accidents. Possibly humans just don't feel emotionally comfortable with large numbers of loss of lives all at once in one place. It is likely that the dread factor enters the equation. People think that they easily could have been part of such a disaster, and they fear the possibility. These illustrations shed some light on emotional effects, but whenever personal feelings overwhelm logic and statistics, one should just note that whether or not these fears appear reasonable, they are part of human makeup. For this reason, the emotional factor exemplifies a public sense that must be accounted for in determining consequences of building the systems that are technically feasible.

2.4 Environmental Effects

Environmental effects receive special scrutiny in today's society. An occurrence like the Exxon Valdes oil release illustrates the destruction that can take place to plant and animal life, ecosystems, and pristine beauty that are treasured by most of us. In addition to immediate or short term effects, we are becoming more concerned about long term effects that transcend our lifetimes. We are protective of species that might become extinct. We are more willing than ever before to sacrifice (e.g., through recycling efforts) for the overall good of society and its future. These factors enter into consideration of how serious the consequences of a high consequence disaster might be.

2.5 Organizational Health

The viability of an organization can be seriously affected by a high consequence disaster. An illustration is the Challenger accident, which resulted in a waning of congressional support for NASA's space programs. Another example is the Three Mile Island nuclear reactor accident, which had a significant role in stifling the nuclear power industry development. A 1988 terrorist attack on a Pan American airliner was instrumental in the collapse of the company. In all of these cases, human psychology must be accounted for. A subtle form of blame for these disasters is associated with the support system behind each of these programs. Obviously, this is a factor in establishing a degree of consequence.

2.6 Political Effects

Political repercussions from high consequence accidents can be far reaching. The Oklahoma City bombing resulted in immediate effects. For example, restrictions on personal travel freedom in the U.S. was brought up in Congress, and this and some more minor incidents contributed to establishing barricades to block traffic from proceeding on Pennsylvania Avenue past the White House. The promptness and quality of federal disaster response regularly becomes a political issue following major hurricane-spawned disasters. Since political decisions influence how we all live, this is an important contributor to the consequence equation.

2.7 National Defense Capabilities

National defense posture can be affected by some types of high consequence accidents. For example, an accidental detonation of a nuclear weapon would certainly encourage opponents of nuclear weapons programs, and would probably contribute to a tendency to place additional restrictions on the nuclear weapon program, or even possibly to decommission all nuclear weapons. Any of these moves would reduce the effectiveness of national defense. It is unlikely that such effects would be limited to the country responsible for the accident. Since national defense is an important factor in any society, the consequences associated with this effect are important.

3. On Measuring Consequences

It would be attractive to have a direct quantitative metric to describe the consequences of high consequence operations losses. Furthermore, surveying the consequence effects above, it is clear that the complexity of the issue precludes direct quantification of consequences. The partitioning utilized above is not exclusive; there are many mixed effects and interactions between the factors, especially at the emotional level. Nevertheless, it seems appropriate to establish some metric that combines what quantitative information is available with qualitative assessments of the complete spectrum of factors. There are a variety of methods to accomplish this aim; one illustration is given here.

The approach illustrated is to use data where available, but to depend largely on expert opinion to develop estimates. There are two important points to be made here. One is that even the most quantifiable considerations (e.g., basic monetary loss, basic human life loss expectations) require expert opinion inputs along with calculable quantities. The second is that "expert opinion" does not always mean physical scientists or even necessarily those with any scientific background. In areas such as judging the dread factor, the "experts" may be chosen from a cross-section of society in general. The main point is that the best data possible is to be elicited, and each factor should be individually evaluated for identifying the best expert inputs.

Another important consideration has to do with uncertainty measures provided along with any data produced. Pure subjective uncertainty necessarily is based on opinion, and so this fits well with the approach suggested. One approach that we have investigated seems promising for this application. It incorporates a weighted sum applied to numeric ratings (including the uncertainty associated with the ratings) of each of the factors and used to produce a consequence metric (see example below). Here, the factors are all contributory variables, normalized to have minimum value of zero and maximum value of one. Weighting functions can also be normalized to be between zero and one. Furthermore, if the weighting functions are a partition of the number one (that is, if they are constrained to add to one) the result is normalized on a scale of zero to one (one indicating highest possible consequence).

In the example illustration, we will use the symbols below to indicate the factors outlined in this paper. The type of high consequence operation is not defined, since the example is merely illustrative.

m = monetary loss (weight f_m)
l = loss of lives (weight f_l)
d = the emotional/dread effect (weight f_d)
e = environmental effects (weight f_e)
h = organizational health (weight f_h)
p = political effects (weight f_p)
n = national defense effects (weight f_n)

$$C = \text{overall consequence} = f_m m + f_l l + f_d d + f_e e + f_h h + f_p p + f_n n \qquad (1)$$

The inputs are listed below, with each weight given first, followed by the loss potential of the factor. (The numbers are given with no uncertainty in order to simplify the example.)

m: 0.1; 0.2
l : 0.2; 0.7
d: 0.2; 0.3
e: 0.1; 0.1
h: 0.1; 0.2
p: 0.1; 0.5
n: 0.2; 0.5

C = 0.4

The illustrated consequence is therefore a little below average.

4. Conclusions

The development of high consequence operations systems and the assessment of their safety involves much more than technical feasibility. Social acceptance is a complex issue that warrants considerable attention. Social attitudes transcend the hard metrics that ordinarily come naturally to designers and safety analysts, and present a new and complex challenge. Public acceptance may become ever more important as more complex high consequence operations become technically feasible.