A Comparison of Commercial/Industry and Nuclear Weapons* Safety Concepts

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Abstract

In this paper we identify factors which influence the safety philosophy used in the U.S. commercial/industrial sector and compare them against those factors which influence nuclear weapons safety. Commercial/industrial safety is guided by private and public safety standards. Generally, private safety standards tend to emphasize product reliability issues while public (*i.e.*, government) safety standards tend to emphasize human factors issues. Safety in the nuclear weapons arena is driven by federal requirements and memoranda of understanding (MOUs) between the Departments of Defense and Energy. Safety is achieved through passive design features integrated into the nuclear weapon. Though the common strand between commercial/industrial and nuclear weapons safety is the minimization of risk posed to the general population (*i.e.*, public safety), we found that each sector tends to employ a different safety approach to view and resolve high-consequence safety issues.

1. Introduction

Assuring the public's safety has always been a top priority in the design, handling, and care of U.S. nuclear weapons. It is assured through a rigorous and vigilant nuclear weapons safety program which was initially implemented through a set of checks and balances between the War Department and the Atomic Energy Commission (AEC) and today is implemented through the coordinated efforts of the Department of Energy (DOE) and the Department of Defense (DoD) [1]. Federal requirements and memoranda of understanding (MOUs) between the two departments guide the implementation of nuclear weapons safety [*e.g.*, 2 and 3]. Nuclear weapons safety has evolved over time as technology has expanded and as experiences associated with over fifty years of operational deployment and maintaining the inventory have been continually assessed.

Because strict security classification encapsulates the nuclear weapons program it is not surprising to find that no comprehensive exchange of safety information has occurred between those involved with nuclear weapons safety and those associated with commercial/industry safety. The purpose of this paper is to identify and compare some of the conceptual approaches to safety used by the U.S. commercial industrial sector and the DOE nuclear weapons safety program. Such comparisons are useful for a number of reasons. From the perspective of the nuclear weapons safety expert these reasons include:

- the desire to broaden the scope of safety processes and safety technology by applying and combining a spectrum of safety approaches in new and enhanced ways and

* Nuclear weapons are used here to mean the weapons, themselves, without the delivery system.

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- the need to understand safety as it is applied in different technical, political, and economic arenas since, for example, DOE safety oversight processes are drawing on the expertise of safety experts outside the weapons complex as well as from inside.

Since safety builds on perspective, prospective, and experience, those involved with setting industrial/commercial safety standards in the private sector stand to gain from the concepts and technologies employed in the nuclear weapons safety program, too, resulting in enhanced safety for their product or operation.

In this paper we divide commercial/industrial safety into the public and private sector components. Public sector safety relates to government regulations that mandate safety in commercial/industrial products and services. Private sector safety relates to private organizations' self-regulating, safety process. In Section 2 characteristics of commercial/industrial and nuclear weapons safety are discussed. In Section 3 we contrast aspects of commercial/industrial and nuclear weapons safety for high-consequence operations.

2. Drivers of Safety

There are a number of factors which influence the implementation of safety in a design or process. These factors tend to differ for the private, public (*i.e.*, government), and nuclear weapons sectors and tend to shape the manner in which a safety problem is identified and solved. As will be discussed below, private-sector safety appears to link safety to the reliability of the product design. Public-sector safety appears to emphasize issues regarding human factors. Nuclear weapons safety relies on the concept of inherent safety to avoid issues of reliability and human intervention.

Following is a comparison of general characteristics associated with the two components of commercial/industrial safety and nuclear weapons safety. For each of the three categories we identify characteristics of the safety culture including the general focus of safety and influencing factors which drive the generation and implementation of safety standards. We realize that our descriptions of the public and private sector safety are not necessarily applicable to every instance of safety associated with commercial/industrial safety; however, they identify characteristics and trends which we understand to be generally attributable to each sector. Our observations are summarized in Table 1.

Private Sector Safety

Safety standards set by the private sector are generated by four different types of organizations [4]:

- trade associations — such as the American Petroleum Institute (API);
  membership generally consists of participants associated with a single product; safety standards are usually financed directly by the membership;
- professional societies — such as the American Society of Automotive Engineers (ASAE);
  membership consists of participants from a broad spectrum of professions;
- general membership organizations — such as the American Society for Testing and Materials (ASTM) and the National Fire Protection Association (NFPA);
  membership is of a broad constituency often including participants from various professions and competing aspects of industry; income is derived from the sale of standards;

Table 1. Comparison of Characteristics of the U.S. Commercial/Industrial and Nuclear Weapons Sectors [2,4,5,6]

	Industrial/Commercial Safety		*Nuclear Weapon Safety*
	Private Sector Safety	*Public Sector Safety*	
Viewed as —	Market-based, may be seen as a form of self-regulation	Hierarchical and political	A rigorous and vigilant process to ensure comprehensive safety through independent assessment
Safety culture places emphasis on —	Product reliability	Human factors	Intrinsic safety (design and human factors)
Factors which influence the setting of safety standards	• PUBLIC SAFETY • professional ethics • desire to forestall government regulation • organizational self-interest • antitrust concerns • economics • liability • the media's portrayal of risk	• CONCERN FOR THE PUBLIC (*i.e.*, public safety) and concern by the public (*i.e.*, public pressure) • the media's portrayal of risk • potential of judicial review of regulatory decisions	• PUBLIC SAFETY • the aversion to the high-consequence risk associated with an accidental nuclear detonation • global responsibility • national security • societal ethics
Impetus of defining safety standards	Motivated by professional ethics, the desire for product credentials, and economics	Social response to a perceived risk.	Mandated by government policy and motivated by a fundamental intolerance of an unintended nuclear detonation. Influenced by national security considerations.
Implementation	Generally, implementation of private safety standards is voluntary	Implementation of public safety standards is required by law	Implementation of safety standards is driven by federal requirements and memoranda of understanding between the DOE and DoD

- third-party certifiers — such as Underwriters Laboratories (UL); generally nonprofit organizations which derive income from testing and certifying consumer products.

The safety standards that these four types of organizations set may be generally viewed as a form of self-regulation by the private commercial/industrial sector. Because they are set by private organizations they may be characterized as market-based and as reflecting a minimum common denominator of quality and performance across the spectrum of related business [4]. While this may initially imply "soft" safety, it should be noted that private-sector safety standards may at times be more stringent than public sector regulations applied to the same product or service. This may be motivated by a spectrum of reasons including on the one end of the spectrum, the desire to establish a degree of professional accountability into a product or service and on the other end, the desire to minimize the potential for litigation and future government regulation.

The focus of private-sector safety tends to be on product reliability. Safety guidelines, therefore, are set with the premise that the product will be operated within specified environments.[1] (It is incumbent on the user to operate the product within specified environments since the reliability of the product as well as the safety of the product is not necessarily assured outside these environments.) In stressing product reliability the private-sector safety culture fundamentally assumes that the consumer is literate, follows directions, and is generally not clumsy [4,7].

The process of defining safety standards in the private sector is usually done by "consensus" of knowledgeable participants and through "due process" [4,6,7]. Standards reflect a professional ethic by both the body writing the standard and the manufacturer implementing the standard. Setting and implementing safety standards are synergistic activities because standards provide value to the product or service resulting in some threshold of economic benefit to both the manufacturer and the certifying organization.

Not surprising, economics and organizational self-interest play a prominent role in defining private sector safety. Private industry realizes that the U.S. consumer demands safe products and services. Private industry also realizes that when given the option the consumer may be more inclined to purchase products that have been certified to some level of safety rather than those that have not. Industry also realizes the liability risks associated with products or services which result in injury to the public. They also realize the potential of the media to bias or accentuate a perceived risk. These factors influence the acceptance and implementation of private safety standards.

The features which help shape the prevailing philosophy underlying private safety standards include professional ethics and organizational self-interest [4]. Professional pride in the performance of a product is a strong driver in setting industrial/commercial safety standards in the private sector. It is a philosophy typical of the engineering profession which tends to predominate the composition of private-safety-standard organizations.

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[1] The private sector apparently avoids attempting to implement safety measures to account for misuse of a product for several reasons. First, the general philosophy is that standards cannot be written to control the consumer's behavior. Second, the private sector recognizes that the permutations of possible misuse may be too great to be captured by a set of safety measures. An attempt to address the issue of misuse may result in legal repercussions should the measures not provide safety for a particular scenario of misuse not considered [4,7]. There are, however, exceptions. Private sector safety does appear to address issues of human factors related to products for children and the elderly [4].

Public Sector Safety
Public sector safety standards are set by government established agencies. Government agencies such as the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), Federal Aviation Administration (FAA), and Nuclear Regulatory Commission (NRC) create regulations (including safety regulations) which are mandated into law. Because of the government bureaucracy associated with the process of generating safety regulations, public-sector safety standards are generally cast as hierarchical and political [4].

The government is in the business of addressing social issues of which assuring public safety is one. It is, therefore, not surprising that the process of setting government safety regulations is sensitive to public pressure and to the media's portrayal of risk. We note that in the aftermath of a high-consequence accident the government response is usually immediate in order to restore public confidence and/or reduce the potential of a similar accident. In lower-consequence events, public safety regulations may take years to be defined and may be subjected to the delays associated with bureaucratic wrangling and the legal requirement of benefit/cost analyses.

Like the private sector, public-sector safety is concerned that a product is designed to operate safely. However, the primary focus of public-sector safety appears to be related to issues of human factors. Safety issues related to potential mis-use are commonly addressed leading to regulations which attempt to direct human behavior [4]. In some instances public safety standards take the flavor of commercial/industrial housekeeping.

Nuclear Weapons Safety
The nuclear weapons safety program is a rigorous and vigilant government effort implemented to protect the public health and safety. It is motivated by the profound aversion to an unintended nuclear detonation.

The U.S. nuclear weapon safety program is mandated by government policy. Federal requirements, such as the DOE Orders [2], define the weapon safety program and responsibilities. The process requires the DOE and DoD to continually review the design, handling, and care of U.S. nuclear weapons systems and to address concerns on an expeditious basis. The process is formalized in the Nuclear Weapon Safety Study Groups (NWSSGs) with input from these studies and other assessments forming the basis of the yearly surety report to the President. The safety process also includes stockpile surveillance activities which encompass periodic selections of weapons from the inventory for inspection and non-nuclear testing.

The safety of the nuclear weapon is provided by safety features designed into the weapon. As will be discussed in Section 3, these features are passive in that they do not require detect and react actions to provide safety. The nuclear weapon is "inherently safe" to the spectrum of environments.

3. Contrasts Between Commercial/Industrial and Nuclear Weapons Safety for High-Consequence Operations

Definitions
Safety can be interpreted differently by different safety professionals and for the different sectors of safety (private and public). The differences in interpretation are manifested in how a safety problem is viewed and solved. We chose here to compare the definitions of passive and active safety as used in nuclear weapons safety and automotive safety. We note ahead of time that the definitions used by both sectors differ, but we intentionally

make this comparison to highlight the fact that safety is tailored to some degree by product. We feel that understanding this is important if, for example, future exchanges of safety-related technologies and approaches are to take place. We begin by stating that conceptually *'safety'* encompasses those measures which reduce the magnitude of the perceived risk to acceptable limits.

In the nuclear weapons safety arena only passive safety measures are implemented into the weapon safety theme. Passive safety features are those which provide some level of safety just by their presence in the system design — the features are not required to "mechanically operate" to provide safety. A structural barrier made of a material which by its physical properties alone provides protection to a specified level may be an example of passive safety feature. The passive safety features result in an inherently safe weapon -- no action, no detection, or no change of state is required in order for the weapon to be in a safe configuration regardless of the environment.

Though not implemented into the weapon design, active safety features are defined to be those which provide some level of safety *after* they mechanically operate (*i.e.*, some action is required in order for safety to be provided). We note that active safety is predicated on the timely detection of a "danger" threshold *and* on the successful operation of the safety measure. A circuit breaker is an example of an active safety measure. We reiterate again, nuclear weapons are designed to be inherently safe; therefore, the safety features in the weapon are passive.

Passive and active safety is defined differently in the U.S. automobile industry. Active safety measures are defined to be those measures which mitigate the dynamic environment of the vehicle. Therefore, brakes are defined as an active safety measure. A passive safety measure is one that protects the occupant of the vehicle. Therefore, air bags, reinforcing steel in the door panels, and seat belts are examples of automotive passive-safety measures [8].

The definitions for passive and active safety associated with vehicular safety and nuclear weapons safety are not the same. As a matter of fact, if one applies the nuclear weapon safety definitions to modern automobile seat beats and air bags, seat belts and air bags are active safety measures. This is because for the seat belt to provide some level of safety a latching mechanism must engage to restrain the occupant, and for the air bag to provide safety it must inflate.

Approaches to safety for high-consequence operations

For a number of commercial/industrial operations safety measures are integrated into the system in anticipation of a high-consequence accident. These safety measures provide a prescribed and acceptable level of safety given that the accident has occurred. We observe that many of these safety measures are active and may require human intervention to initiate operation. The nuclear power industry, for example, relies on human intervention or active sensors to address abnormal conditions. Safety measures must then function reliably and actively to provide an assure level of safety. The same basic detect and react approach exists in the automotive industry. Safety measures, such as seat belts and air bags, are integrated into the automobile to provide some level of assured safety given that an accident has occurred. However, these features, too, depend on an active detection scheme and must operate with a high degree of reliability to provide safety.

In contrast, the safety features of a nuclear weapon are passive in that they require no detect and react mechanism(s) to reach a state of safety. We note that there are no reliability issues which could compromise the safety of the weapon.

Attaining an assured level of safety versus attaining an acceptable level of risk
In the commercial/industrial sector the potential negative repercussions of a high-consequence operation is defined as risk. The goal of safety, of course, is to identify the level of accepted risk and operate below it. To do so two factors must be considered -- the magnitude of an accident and the response of the system to that accident. The relationship among these terms is:

(Accident) x (Response) → (Level of Accepted Risk)

The level of risk is generally defined by societal acceptance of risk and economic considerations. This level of risk is a constant for a particular high-consequence operation but may differ for different high-consequence operations. The response of the system is determined by the integrity of the safety features. We note that if the safety features provide active safety then the response of the system is limited by the reliability of the feature to operate in the accident environment. We note that there are numerous examples of active safety features used in industrial/commercial high-consequence operations. Based on the accident-response relationship, as long as safety is provided by active features then the maximum accident scenario that may be considered is limited.

In nuclear weapons safety there is no acceptable level of risk for an unintended nuclear detonation. To account for this the accident-response relationship is not written in terms of the risk, but in terms of the level of assured safety. This level implies "no unintended nuclear detonation." The relationship among the terms is:

(Response) x (Accident) → (Level of Assured Safety).

We note that since there is no tolerance for an unintended nuclear detonation, safety must be maintained even under the worst case accident scenario. In order to obtain this absolute level of assured safety for any accident, the response of the system (*i.e.*, the response of the safety features) must not have a limit beyond which safety is not assured. To attain this the features must be passive (as defined in nuclear weapon safety). By implementing passive safety into the weapon the weapon is inherently safe to any accident condition. We note that the expectation that the weapon remains safe even under "worst" case conditions is a significantly more rigorous requirement than that posed on high-consequence operations in the commercial/industrial sector.

4. Conclusion

Safety philosophy is the product of culture, mission, and technology. The factors associated with each of these three areas tend to shape the manner in which a safety problem is identified and solved. In this paper we address issues of safety culture and identify and compare some of the conceptual approaches to safety used by the U.S. commercial industrial sector (both the public and private components) and the DOE nuclear weapons safety program. We draw the following conclusions.

- Safety in the private and public components of commercial industry and the nuclear weapons safety program focus on the same goal -- that is, assuring public safety by reducing the risks to an acceptable level.

- The safety focus is different in the private and public sectors of commercial industry and in the nuclear weapons safety program. Generally, the private-sector safety places emphasis on product reliability. Public-sector safety appears to place emphasis

on product operation (as well as "mis-operation"). Nuclear weapon safety places emphasis on the implementation of passive safety features in the weapons for inherent safety.

- Nuclear weapons are designed to be inherently safe to the "worst" case scenario and do not rely on human intervention to attain safety.

- The difference in the rigor levied on nuclear weapon safety as compared to high-consequence commercial/industrial safety is due to society's complete aversion to an unintended nuclear detonation, the repercussions, and the national security implications.

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