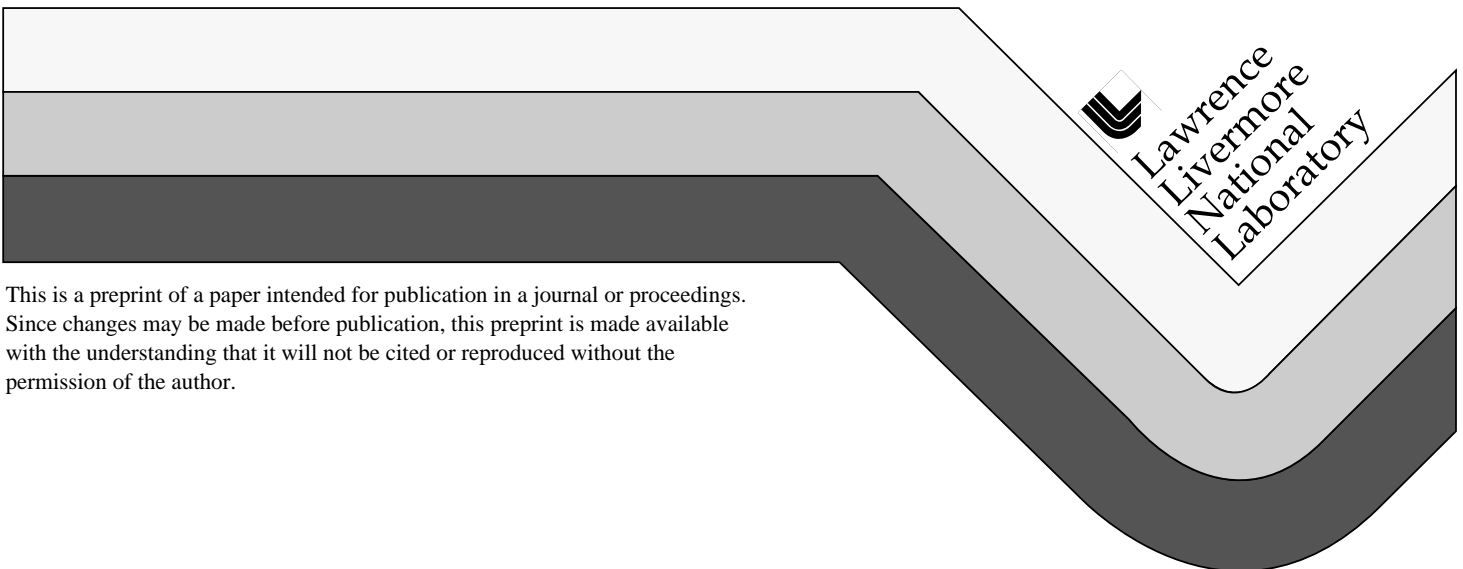


# Comparison of Radiation Safety and Nuclear Explosive Safety Disciplines

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# **Comparison of Radiation Safety and Nuclear Explosive Safety Disciplines**

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## **Introduction**

In August 1945, U.S. Navy Captain William Parsons served as the weaponeer aboard the Enola Gay for the mission to Hiroshima (Shelton 1988). In view of the fact that four B-29s had crashed and burned on takeoff from Tinian the night before, Captain Parsons made the decision to arm the gun-type weapon after takeoff for safety reasons (15 kilotons of TNT equivalent). Although he had no control over the success of the takeoff, he could prevent the possibility of a nuclear detonation on Tinian by controlling what we now call the nuclear explosive. As head of the Ordnance Division at Los Alamos and a former gunnery officer, Captain Parsons clearly understood the role of safety in his work. The advent of the pre-assembled implosion weapon where the high explosive and nuclear materials are always in an intimate configuration meant that nuclear explosive safety became a reality at a certain point in development and production not just at the time of delivery by the military. This is the only industry where nuclear materials are intentionally put in contact with high explosives. The agency of the U.S. Government responsible for development and production of U.S. nuclear weapons is the Department of Energy (DOE) (and its predecessor agencies). This paper will be limited to nuclear explosive safety as it is currently practiced within the DOE nuclear weapons complex.

### **Definitions of radiation safety and nuclear explosive safety**

Radiation safety is the protection of people and the environment from unnecessary exposure to radiation (HPS 1997). Radiation safety deals with the reality of a radioactive environment. In

this sense, it has a probability of one and can be controlled to a low consequence (increase in exposure over normal background) or to a high consequence in terms of a lethal dose. Nuclear explosive safety is the application of positive measures to control or mitigate the possibility of unintended or unauthorized nuclear detonation, high-explosive detonation or deflagration, or fire in a nuclear explosive area (DOE Order 452.1A). A nuclear detonation is an energy release through a nuclear process, during a period of time on the order of one microsecond, in an amount equivalent to the energy released by detonating four or more pounds of trinitrotoluene (TNT). A high-explosive detonation is a violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure that proceeds through the reacted material toward the unreacted material at a supersonic velocity. A high-explosive deflagration is a rapid chemical reaction in which the output of heat is sufficient for the reaction to proceed and accelerate without input of heat from another source. Deflagration is a surface phenomenon, with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. A nuclear explosive is an assembly containing fissionable and/or fusionable materials and main charge high-explosive parts or propellants capable of producing a nuclear detonation (e.g., a nuclear weapon or test device). Main charge refers to the high explosive whose explosive energy implodes the fissile material. A nuclear explosive area is any area that contains a nuclear explosive or collocated fissile material and main charge high-explosive parts. Nuclear explosive safety has never had an accidental (unauthorized or unplanned) nuclear detonation or high-explosive detonation/deflagration involving a nuclear explosive. There have been several Department of Defense accidents with fire involved, but no high-explosive

detonation/deflagration or nuclear detonation. Thus, nuclear explosive safety deals with high consequence/low probability events.

### **Lifecycle of a nuclear weapon**

The lifecycle of a nuclear weapon can be described in several phases. These include development, production, operational, maintenance and retirement. In all phases, radiation safety and nuclear explosive safety are closely related when the nuclear explosive is present. While development and production involve the initial assembly of radioactive and high-explosive materials, maintenance activities may also involve removal and replacement of one or both in order to maintain the weapon in the stockpile. Retirement results in the dismantlement of the nuclear weapon and permanent separation of the main-charge high explosive and nuclear materials. The concerns throughout the lifecycle, however, revolve primarily around radiation safety and nuclear explosive safety. Radiation safety seeks to minimize the exposure of individuals to external radiation fields or contamination when performing intimate work with radioactive materials or sources while nuclear explosive safety ensures positive controls to avoid a serious accident involving the high explosive.

### **Radiation Safety versus Nuclear Explosive Safety**

Morgan and Turner (Morgan 1973) stated that, "...but for the most part the originators of health physics and those who joined with them in this early period had little knowledge, no formal training, and limited experience related to this work. Thus, by the process of trial and error, through extensive reading, ..." The same could be said for the early pioneers in nuclear explosive safety within the Atomic Energy Commission, one of the agencies to precede DOE. The need for nuclear explosive safety was recognized from the outset of the work at Los Alamos, but the

growth of a professional group of individuals evolved over many years. One of the early pioneers in nuclear explosive safety has documented\* an informal history of nuclear explosive safety at the Pantex Plant outside Amarillo, Texas. At that time, the plant was Pantex Ordnance Plant, owned and operated by the Army Ordnance Corps, and AEC accepted the final product. AEC Appendix 0560 established the Atomic Weapon Safety Program in the the early 1960's to maintain a positive, continuing program of nuclear weapon safety to minimize the possibility of the accidental or unauthorized production of a nuclear yield from nuclear weapons devices in the custody of the AEC. The personnel assurance program and the two-person concept, now considered positive controls, were not part of the original order. The formal nuclear explosive safety study process started in the early 1960's. Traditional safety guidance did not address activities permitted around nuclear explosives. The first studies identified concerns with electrical testing, and recommended the use of inert parts and the establishment of training facilities for production personnel. Although many programs exist to provide formal academic training in the field of radiation safety, training in nuclear explosive safety within DOE is limited to several courses to provide additional background in technical areas such as electrical equipment design and high-explosive safety. The group of people within the DOE and its contractors with direct nuclear explosive safety responsibilities numbers less than 50.

### **Basic problems in the safety disciplines**

The basic problems in radiation safety may be described (Morgan 1973) as: (1) understanding the mechanisms of radiation damage; (2) establishment of appropriate levels of maximum permissible exposure; and (3) intelligent enforcement of these levels. The basic problems in

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\* Pierce, K. An informal history of nuclear explosive safety at the Pantex plant; 1993.

nuclear explosive safety may be described as: (1) understanding the mechanisms that will potentially detonate a high explosive; (2) establish appropriate procedures that will minimize potential for detonation; and (3) intelligent enforcement of these procedures. It is the area of intelligent enforcement that leads to the many methodologies associated with these disciplines.

## **Methodologies**

### ***Radiation safety***

In radiation safety, the health physicist (Cember 1983) is responsible for the safety aspects in the design of processes, equipment, and facilities utilizing radiation sources, to minimize radiation exposure within acceptable limits; and he must keep personnel and the environment under constant surveillance to ascertain that his designs are indeed effective. If control measures are found to be ineffective, or if they break down, he must be able to evaluate the degree of hazard, and to make recommendations regarding remedial action.

### ***Nuclear explosive safety standards***

In nuclear explosive safety, the safety professional is required to evaluate the adequacy of positive measures (controls) to meet the following safety standards (DOE Order 452.1A): (1) minimize the possibility of accidents, inadvertent acts, or authorized activities that could lead to fire, high-explosive deflagration, or unintended high-explosive detonation; (2) minimize the possibility of fire, high-explosive deflagration, or high-explosive detonation, given accidents or inadvertent acts; and (3) minimize the possibility of deliberate unauthorized acts that could lead to high-explosive deflagration or high-explosive detonation. In other words, the burden in nuclear explosive safety is not the solution but the evaluation of the operation to meet this unique set of standards. If the nuclear explosive safety professional is involved in developing the solution, he

is not authorized to formally evaluate the operation that incorporates the solution. In the process of evaluation, however, the nuclear explosive safety professional is challenged in the same multi-disciplinary manner as the radiation safety expert.

### ***Process evaluation***

In fact, the processes, equipment (including tooling) and facilities are looked at very closely for different reasons. In the case of a lifting technique which includes a tool attached to a crane, nuclear explosive safety concerns would relate to tool design and techniques for attachment that would minimize any potential for insult to the nuclear explosive such as drops or impacts. On the other hand, radiation safety concerns would relate to the potential for external radiation exposure and stay-time. The efficiency sought by radiation safety concerns may run counter to the safety desired by nuclear explosive safety. At the same time, it is important to recognize that nuclear explosive safety concerns do not exist in a vacuum. In today's regulatory environment, any loss of containment of radioactive material or unplanned exposure of personnel to radiation fields can result in shutdown operations for an extended period of time and present problems dependent on the configuration of the nuclear explosive. It is, therefore, in the best interest of the nuclear explosive safety expert to understand the concerns and requirements of the radiation safety expert.

### ***Organizational support***

Of equal concern to both disciplines is the organizational support in the areas of administration, program management, personnel, and training. Although approval of the operation may be the final goal of program management, an integrated approach is required to ensure that milestones are reviewed in an effort to avoid untimely delays or rework of items at a later time. This may



be especially true in nuclear explosive safety where the operation cannot begin until the following items have been approved or certified: (1) facility safety analysis; (2) operation hazard analysis report; (3) technical safety requirements and operational safety controls; (4) nuclear explosive operation readiness review; (5) facility readiness reviews; (6) nuclear explosive safety study report which assures the DOE decision maker/authorizing official that the nuclear explosive surety standards are met. The quality of personnel and training requirements for both disciplines are very similar. Individuals with work experience, education in science or engineering, and interests in the multi-disciplinary requirements of the job are essential.

### **Operations and procedures**

In both disciplines, the operations and associated procedures and facilities are comprehensively reviewed and evaluated to identify hazards and potential accidents and to establish design, construction, and operational means to protect the public and worker health and safety and the environment. While radiation safety may rely on measurable parameters and surveillance activities to determine if the design and controls are effective, the nuclear explosive safety expert is often required to subjectively evaluate proposed changes to the process for their potential impact on nuclear explosive safety. The nuclear explosive safety study referred to in the above paragraph is formalized in DOE-STD-3015-97. Key elements of such a study include evaluations of the adequacy of written procedures for the safe conduct of the operation, the threat to nuclear explosive safety from human error, potential threats to nuclear explosive safety from security operations, and the safety of the equipment and procedures for transporting nuclear explosives. On a periodic basis, the entire process is reevaluated to ensure that it continues to meet the safety standards.

## **Philosophies**

In radiation safety, a measure of success for the operation may be that there was no significant radiation exposure. In nuclear explosive safety, the concept of one-point safety in the design of nuclear weapons serves to ensure that any loss of life is limited only to those closest to the weapon and minimize damage to the surrounding area. One-point safety (DOE Order 452.1A) is defined as the probability of achieving a nuclear yield greater than four pounds of trinitrotoluene (TNT) equivalent in the event of a one-point initiation of the weapon's high explosive shall not exceed one in a million ( $1E-06$ ) in an accident or abnormal environment. Although the origin of one-point safety is classified information, it serves as a constant reminder that the business is a deadly serious one.

### ***ALARA and graded approach***

The concepts of ALARA for radiation safety and Graded Approach in nuclear explosive safety are very similar. Based upon the assumption that there is no radiation dose that is absolutely safe, the NCRP (NCRP 1987) has recommended that radiation doses shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account. Graded approach (DOE Order 452.2A) is a process by which the level of analysis, documentation, and actions necessary to comply with a requirement are commensurate with the relative importance to safety and the magnitude of any hazard involved.

### **Facility design and construction**

Workplaces in radiation safety may be referred to by various classifications such as Type I, II or III (Schleien 1992) with increasing activity limits. Typical radiation concerns in facility design and construction to support the desired workplace include ventilation, containment, shielding,

washing facilities and accommodations for the storage and transfer of radioactive material.

Nuclear explosive safety concerns in facility design and construction involves high explosive enclosed in metal (cased) or bare high explosive (uncased) and activities authorized in designated bays, cells and staging areas. Specific concerns for nuclear explosive safety include lightning and fire protection, seismic tiedowns, electrostatic discharge and facility grounding. The facility safety and operation hazard analyses referred to above under organization support are part of the safety basis requirements that provide a layer of defense that ensures nuclear explosive operations and associated activities are performed only in facilities designed, built, and maintained in a manner that recognizes and controls the hazards associated with the operations (DOE/AL 5610.11A). In general, radiation safety concerns do not conflict with nuclear explosive safety concerns. In fact, they may complement one another by providing a safer workplace to perform the required work.

## **Discussion**

The disciplines of radiation safety and nuclear explosive safety may represent opposite poles in the safety environment. Efficiency, stay-time and occupational safety are of little concern in nuclear explosive safety compared with radiation safety. While processes planned to minimize radiation exposure may be found satisfactory during the review by nuclear explosive safety, the actual exposures for the operation cannot be determined until after the processes have been approved for use. At that point, any changes made to accommodate radiation safety would then be reviewed by nuclear explosive safety personnel to ensure that the approved operation continues to meet the nuclear explosive safety standards. The broad range of concerns for both disciplines seems to vary only in focus not depth. While nuclear explosive safety looks at the

reliability of the tool and its ability to produce results without insult to the nuclear explosive, radiation safety may design and require the use of a local exhaust system or special handling procedures to control potential contamination or reduce time to perform the operation. Radiation safety may be hands-on to design and evaluate the solution to a problem. Nuclear explosive safety does not offer the solution but evaluates the safety case offered by management to determine if it provides positive controls and minimizes the threat to nuclear explosive safety.

### **Conclusion**

The fields of radiation safety and nuclear explosive safety are related but different. In some cases, radiation safety concerns pick up where nuclear explosive safety concerns end. At other times, it is just the opposite. Intelligent enforcement of procedures in both disciplines dictates ALARA or Graded Approach to evaluate the real safety level of the operation and find it satisfactory.

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