The Journal of Space Safety Engineering 4 (2017) 22–28

Contents lists available at ScienceDirect

The Journal of Space Safety Engineering

journal homepage: www.elsevier.com/locate/jsse

Launch and reentry safety objectives

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ARTICLE INFO

Article history:
Received 11 January 2017
Available online 5 April 2017

ABSTRACT

The primary objective of U.S. Government safety organizations for space vehicle activities has always been the protection of people. The earliest protection objectives focused exclusively on protection against fatalities. The initial risk measure employed was the probability the most exposed individual would be killed. Over time, the protection objectives have broadened. Many facilities now protect against multiple levels of injury (typically, severe injury or casualties, and fatalities). Most facilities have established some maximum tolerable societal, or collective, risk that is considered tolerable. Some facilities have placed limits on tolerable catastrophic risk as measured by the probability that large numbers of people may be simultaneously injured.

The 2010 publication of the Range Commanders Council guidance document, RCC 321, broadened protection objectives by defining the basis for protecting critical assets that are a part of the launch complex. These criteria ensured that the chance of damaging the critical infrastructure required for continued operations of the launch complex and the facilities required for emergency response to a mishap were sufficiently small.

For commercial launches the United States Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) has promulgated financial responsibility standards based on the Maximum Probable Loss (MPL) that will result from launch operations. The MPL is a combined measure of potential damage and injury that may occur from events with extremely remote likelihood.

Individual ranges have imposed a variety of protection standards to protect unique resources including environmentally sensitive assets.

As launch operations become more common, once isolated launch complexes are surrounded by industry and communities they support. Zoning regulations rarely consider the constraints these developments may impose on launch operations. Moreover, current safety regulations are confined to protecting these communities from injuries resulting from launch operations.

This paper explores the issues of

- What should be protected?
- Why should protection be provided?
- Potential risk measures for assessing compatibility between launch operations and surrounding communities.
- The need for ranges/launch complexes to have a voice in land use decisions for the regions surrounding them.

The purpose of this paper is to stimulate discussion so that the International Launch Safety Community addresses these issues before circumstances produce a *de facto* resolution.

1. Introduction

As a result of a number of spectacular missteps, society has developed concerns for balancing adverse consequences of new technology against the benefits to be derived from the technology. In many cases, when dealing with new technology significant segments of the public desire to avoid any risk. The safety community must discover the proper balance between protection objectives and technology development.

In the early years, the Range Commander and the range safety organization at each range set protection standards with no accountability to outside agencies nor even the need to communicate the standards. Over time, many local, regional and national agencies[1] have published regulations to limit adverse consequences of

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[1] Relevant Federal agencies in the United States include the Environmental Protection Agency, Consumer Product Safety Commission, Federal Communications

http://dx.doi.org/10.1016/j.jsse.2017.03.006

human activities. While the focus of these agencies has typically not been launch and re-entry activities, their actions have set important precedents.

Agencies have a variety of protection objectives ranging from environmental protection and nuisance avoidance to protection of property and protecting people from injuries or fatalities.

2. What should be protected?

Launch and reentry operations are relatively unique activities: They can place people at risk on land, at sea and in the air. A single operation may potentially hazard people and property on land, at sea, in the air and in orbit. Moreover, the regions at risk may have characteristic dimensions on the order of many hundreds to thousands of miles.

2.1. Protection of life

While it is generally accepted that protecting human life is the highest priority, there is a divergence of opinion and practice regarding other protection objectives. Arguments in favour of only protecting against loss of life have included:

- It is a common metric of protection used internationally for a broad class of activities.
- It has been used as a measure of weapons effectiveness (lethality).
- Death is an unambiguous state.
- Death is so much more onerous than lesser injuries, let alone nuisance or "mere damage" to the environment or property.
- Many believe that characterizing other adverse consequences has too much uncertainty.

By contrast, the National Ranges in the United States and the Federal Aviation Administration's Office of Commercial Transportation have been moving in the direction of increasingly broader protection concerns. The Air Force Ranges were among the first to recognize the importance of addressing lesser injuries to people. The ranges added the consequence of casualty, serious injury or worse, as the primary consequence metric for several reasons including the following [8]:

- Using casualties as the criteria avoids the uncertainty associated with the promptness and effectiveness of medical treatment that can prevent serious injuries from becoming fatal.
- Casualty measures are necessary to provide a reasonable level of protection from all launch vehicle hazards, particularly toxic exposure.
- Serious injuries are onerous.

Supplemental criteria have been needed to address lesser injuries from toxic hazards to be consistent with the concerns of other regulatory agencies. Accidents with toxic releases may subject very large numbers of people to relatively low exposure levels. Although a single person subjected to such levels might be regarded as tolerable and the medical consequences may range from benign to minor irritation, adverse public reaction from affecting many people may significantly impact the ability to perform future launch operations.

In the United States the prevailing standard has become that launch facility operators must protect against casualties and may need to consider lesser injuries when large numbers of people can be affected from a single incident. At that point it was evident that protecting people from severe injuries was essential. The question was "Is that sufficient?"

By contrast, there are agencies around the world who still base their protection criteria on fatalities exclusively.

2.2. Catastrophic risks

The baseline for protection described in the previous section was ensuring the maximally exposed individual would be protected against unacceptable probabilities of incurring the adverse outcome and that collectively the societal risk, as measured by the number of people who, statistically, might be subjected to the adverse outcome was limited. The discussion about large numbers of people sustaining lesser levels of injury from a single event raised a new question: What further limitations needed to be imposed on adverse consequences to many people from the same event?

While the question arose from considering toxic injuries from a launch and the international reaction to the disaster in Bhopal [2], the Range Safety community quickly realized that there were other classes of accidents that could produce multiple severe injuries or deaths. Examples of such accidents include a spent stage striking a ship, large debris striking an aircraft, and explosive debris falling in a public gathering, such as a stadium.

Bhopal caused the range safety community to recognize the need to address "High Consequence Events". These events may include outcomes that have a significant impact on continued range or launch operations, significant environmental impacts, impacts on relationships with other countries, and other long term or irreversible consequences. Signal events have a major impact on society as a result of a combination of **dread** and **lack of visibility and understanding** by the general public. Some examples of potential high consequence events include:

- Events that may produce significant dollar damage or large numbers of casualties,
- Events that damage critical assets or cultural treasures or natural wonders,
- Events that create a public perception of irresponsible action on the part of the range – whether or not any damage or injuries resulted,
- Events that damage the local economy, such as creating an atmosphere of fear in a tourist dependent community,
- Events that violate or appear to violate the rights of foreign nationals

These factors are addressed in the remaining narrative of this section. Both the US and the international community are more ambiguous with respect to catastrophic loss potential. These communities acknowledge the potential for high consequence events; they agree that catastrophic risk is a special concern. The community has not yet agreed upon what constitutes a catastrophe nor what actions are appropriate for protecting against high consequence events. Risk profiles and F-N curves have been employed by some to compute and display catastrophic potential property damage and injuries. Reference [1] (Section 5.5) summarizes some of the most pertinent work related to catastrophe aversion to injury; many of these are illustrated in Fig. 1.

An accident resulting in downing an aircraft or sinking a ship is clearly catastrophic and a feared outcome. Concerns about simultaneously injuring large numbers of people has resulted in criteria to protect against sinking a ship or downing an aircraft and catastrophe averse criteria such as displayed in Fig. 1. The most prominent examples of criteria to protect people from mishaps induced by launch and reentry failures are the RCC 321 provisional criteria for protecting occupants of ships and aircraft.

Commission, Federal Trade Commission, Nuclear Regulatory Commission, and Occupational Safety and Health Administration, Natural Resources Conservation Service, Federal Energy Regulatory Commission, Office of Infrastructure Protection, Bureau of Land Management, Bureau of Alcohol, Tobacco, Firearms and Explosives among others. Numerous such agencies also exist at the state, regional and local levels.