PROTECTION OF NUCLEAR PLANTS AGAINST VEHICULAR BOMBS VIA FULL SPECTRUM RISK ASSESSMENT

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ABSTRACT

A more urgent need now exists since 9/11 to protect vital assets at nuclear plants from physical security threats. Any approach to successful defence must result in the best possible risk profile, while also performing this defence against credible threats within the context of limited personnel and materiel resources. Engineered solutions need to be well thought out, and take advantage of each plant's available organic strengths and opportunities. A robust, well trained/equipped highly motivated protective force will help reduce concerns where there are weaknesses making the plant vulnerable to threats. A thorough risk assessment takes into account the proper combination of both deterministic and probabilistic application of resources as a most advantageous approach; this is postulated to be development of integrated protection methods and plans, which blend solid engineering design with the highest calibre of protection forces. By setting a clear and ambitious objective to shield the nuclear assets with this type of dynamic full spectrum defence in depth, the risk of harm-breach or likelihood of any opponent’s threat being realized should be reduced to the lowest practicable levels.

INTRODUCTION

In 1994 the US Nuclear Regulatory Commission (NRC) amended 10 CFR Part 73 "Physical Protection of Plant and Materials" to include the use of a four wheel drive land vehicle, by adversaries, for transporting personnel, and their hand-carried equipment, to the proximity of safe shutdown equipment and structures, and to include a land vehicle bomb. At the time, this new ruling was generally viewed as having gone 'overboard' by personnel at all levels in the nuclear industry. The terrorist attacks of September 11, 2001 dramatically changed this thinking. Steps are currently underway to upgrade physical security at US nuclear facilities with a sense of urgency that had not existed seven years ago. However, as much as we would like to do whatever it takes, the realization of limited resources, threats of seemingly almost infinite magnitude and variety and physical constraints quickly materializes. A risk-based approach that achieves the greatest protection within these constraints is described in this paper. Emphasis is placed on an integrated, balanced approach to protection against large vehicular bombs. Although other types of threats certainly require attention, the vehicular bomb threat is selected as a template since it is a common denominator for all plants. The optimal risk reduction premise is based upon a well designed, deterministic engineering foundation, which reduces the usual emotive reactive response. This approach relies upon the use of dynamic, adaptable application of personnel and hardware assets coupled with details of protection being sufficiently variable and evolutionary such that little if any openings ever become or remain available for opponents. A full spectrum proactive analysis is suggested, which takes into account Strengths, Weaknesses, Opportunities and Threats SWOT (Ref 1-Hillowson-PMP Services-2000) for each particular site as the most responsible manner to achieve the optimal risk profile. Otherwise, a less balanced situation will be exploited by terrorists because, with careful study, it is most probable that their limited resources would dictate exploitation of weaknesses in the defensive-deterministic arena. A calculated risk can target this weak area in such a manner that they also achieve a reasonable probability of avoidance of opponent personnel. It can thus be shown that this combined-functionally integrated engineering approach complements a very robust site protection force and results in the most advantageous integrated risk profile for US nuclear plants.
RISK BASED CONCEPT

Defence in Depth

The classic nuclear culture/approach has always been regarded as defence in depth from the ‘inside-out’ perspective; i.e. lines of functional defence to protect the public with layers moving outward from DI (nuclear fuel cladding) to DII (reactor coolant) to DIII (reactor vessel and systems) to DIV (robust containment building). This as illustrated in the classic Three Mile Island accident, when the last line (the Reactor Building) held and performed to protect the public. Full-spectrum risk management also involves an evaluation of SWOT- Strengths, Weaknesses, Opportunities and Threats (Ref 1). These are defined as follows: Strengths (risk resistors) - good points; Weaknesses (risk sources) - areas of vulnerability; Opportunities (upside risks) - positive improvements not currently planned; Threats (downside risks) - anything that might go wrong. In the past, the primary focus with regard to nuclear plants in the arena of risk has been on the fear driven W and T of the SWOT formula, which had resulted in the existence of an overall negative flavour. Ever since the 1950s, there have always been people who are extremely doubtful about - indeed, often hostile towards - nuclear power. Actual safety performance and perception have both improved [actual safety by a factor of 100 since 1978 (Ref 6-Sailor, Bodansky et.al-2000)]; while a more positive/confident approach is evident in 21st Century Nuclear- with much more emphasis on the S&O of SWOT… well over 14 years beyond such negative events demonstrated on the world stage with dramatic accidents at Three Mile Island, & Chernobyl (Ref 7-NEI-2000/2002). Of course, since the events of September 11, renewed concerns exist (which are emotionally charged by the media- e.g. per Ref. 5 (Curtis 2001) in the month before September 11 events, there were 57 stories world-wide about nuclear terrorism; the following month there were 1106). Therefore, the new approach depends even more than ever on exploitation of S&O aspects to deal more effectively with terrorist threats – even those such as media manipulation where psychological warfare becomes a real factor. Now, we must therefore reorient examination of security defence in depth from the OUTSIDE IN.

Resources Versus Threats

Primary resource considerations include costs, time and information. As the planning process unfolds it is quickly realised that many excellent ideas for counter terrorism measures are simply impractical to implement due to limitations of one or more of these resources. Conceiving effective counter terrorism measures is not rocket science; it requires careful thought and planning. The challenge is to maximise the effectiveness to cost ratio. On the other hand, relatively low tech, inexpensive means of carrying out threats have the potential to cause tremendous destruction and havoc. Ongoing reassessments of resources are necessary to maintain the balance of resources versus threats in our favour.

Asset Identification

Asset identification for commercial nuclear power facilities has traditionally given primary consideration to equipment and certain response activities, such as communications. This deterministic approach works well when dealing with accidents involving inanimate plant components. It is now widely recognised, however, that certain personnel may represent indispensable assets for thwarting terrorist attacks. This human element has been largely ignored in past by relying on engineered systems.

GENERAL THREAT DEFINITION

Overview

Providing protection against terrorist attack is not new for US nuclear power generating facilities. However, the types, level of sophistication and potential destructive forces have increased over the years and there is little reason to doubt that threats will increase following the events of September 11. In the past, attack by land vehicle has been the primary focus as the mode of delivery for a large bomb. It is now clear that other types of threats require consideration.
Land Threats

The common denominator of threats for all plants, which has been recognised and protected against for many years, is an attack with a large land vehicle bomb. What many individuals, even security personnel, find surprising is the relatively small size truck required to deliver a bomb with large destructive potential. Consider, for example, the 1995 bombing of the A. P. Murrah Federal Building in Oklahoma City in which a mid-sized rental truck packed enough explosives to literally destroy the 9 story reinforced concrete building. Land vehicle threats should consider that obstacles to ordinary passenger cars such as speed bumps, curbs, shallow ditches, … etc. offer no deterrence to the terrorist intent on an attack.

Water Threats

At least two terrorist attacks against US assets by watercraft have occurred in recent times. Most noteworthy of these events is the attack against the USS Cole in Yemen on October 12, 2000. Seventeen sailors were killed when the small watercraft delivered a powerful bomb close to the hull. It is reported Ref. 11 (US Armed Services Committee Report – USS Cole – May 2001) that a shaped charge was used to enhance the destructiveness of the bomb. Ten months prior to this attack an attempted attack against the USS Sullivans, also in Yemen, was foiled because the terrorists overloaded the boat and it sank before it could reach the target. Apparently, they learned from their mistake.

Air Threats

The reality of a terrorist attack by aircraft should no longer be debatable after September 11. As well can be imagined, a fully loaded jetliner impacting at cruising speed presents a formidable hazard to even the most robust power plant structures. Besides the impact force and penetration of structural barriers, effects of a subsequent fire should be considered.

Organic Threats

Organic threats are those which result from within the plant community; an insider intent on facilitating or carrying out an attack against the plant. These threats are in some ways more difficult to define due to the fact that the perpetrator is blending in with co-workers while studying plant weaknesses, perhaps over a very long period of time.
ENGINEERED COUNTER TERRORISM MEASURES

Natural Features

In the context of malevolent vehicle attack, effective counter measures may include a variety of natural features for preventing attack vehicles from approaching too close to the facility. Natural features include ditches, waterways, woodlands and other impassable features. Some empirical-based technical guidance for assessing the effectiveness of natural features exists. However, the natural variability of the features counted on to foil attackers, such as the slope and depth of a ditch, places a large burden on the assessor who must pass judgement on barrier's effectiveness. Of course, the primary advantage of natural features is that they are essentially free.

Man-made Barriers/Deterrent Measures

Man-made barriers can be classified as being active, such as gates, or passive, such as cable and bollard systems or concrete inertia barriers. A typical, utilitarian, engineered inertia barrier is depicted in Figure 2. One significant feature clearly seen in this photo is that the barrier is unanchored; it is merely placed on top of the ground surface. This particular barrier is designed to stop the forward motion of the terrorist vehicle on high-speed impact within a prescribed distance. The vehicle may travel beyond the barrier but its drive mechanism will no longer be usable. Having these barriers installed without requiring excavation saved significant costs and avoided potential interference with underground services.

![Figure 2 - Man-Made Concrete Inertia Barrier](image)

Another desirable feature of surface mounted vehicle barriers such as these is the ability to relocate selected units with relative ease. Temporary barrier relocations may be necessary to facilitate plant operations or simply as part of a plan to confuse the adversary.

Deterrent type barriers may be used effectively in some applications. A typical deterrent barrier for land vehicles is the so-called "Jersey" barrier that is widely used for highway construction projects as a safety barrier. Although these inexpensive, precast concrete barriers are designed for glancing vehicle impacts, they do possess some limited capacity for preventing vehicle penetration for head-on impact conditions. An example of a deterrent type barrier for watercraft is shown in Figure 3.
New Technologies

Numerous methodologies for conducting engineering blast assessments of structures have been practised for several decades and are well documented. However, as threat levels have increased, so has the need to develop better assessment tools. An example of a state-of-the-art application of a numerical analysis for prediction of blast pressure leakage into an industrial building and subsequent propagation through a complex interior geometry is depicted in Figure 4. Such analytical tools are especially useful for those situations where handbook type solutions are not directly applicable and the need to reduce excess conservatism in the blast load prediction exists.
Figure 4 - Numerical Solution for a Complex Interior Blast Propagation

DYNAMIC DEFENCE STRATEGY

Re-examination of the Concept of ‘Dynamic Defence in Depth’ Nuclear Core vs. Physical Security

Use of the concept ‘dynamic defence in depth’ is postulated which has, as its core element, these optimal human factored engineering enhancements to result in true uncertainty for any opponents. A postulated ‘success formula’ is: SUCCESSFUL DEFENCE = (DESIGN) + (ENGINEERED/MATERIEL ASSETS) + (METHODS/PROCEDURES) + (HIGHLY QUALIFIED PERSONNEL ASSETS). A security force must therefore be an integral part of the defence, making use of these design enhancements- not only their ‘guns’ or weapons. This concept also relies on both systematic discipline and variable real time deployment of physical engineered assets, examples can be seen in previous sections, published via Ref.2 (Sawruk, et al April 1995); Ref. 3 (Barriers Certified by USNRC/USACE – 1995); and Ref 9 (Potter-Nimitz USNA Text 2001) data on mobile concrete inertia barriers, and the use of natural terrain like burmmed dry laid rock walls, and large rocks, which are already in use around US Nuclear Plants. We should, however go one step beyond and suggest more proactive-aggressive use of these types of assets in a manner like ships use random zigzag patterns when in transit through dangerous waters, so as to not be totally predictable for submarine launched torpedoes (Ref 9). A more familiar SWOT methodology should be examined as a means of inserting rigour that is consistent with Nuclear culture.

Thorough functional analysis with tools such as SWOT has therefore already been suggested as a steel thread woven through the nuclear fabric to a large extent. This is outlined in Ref. 4 (McDowell, Lemer 1991) with useful suggestions regarding application of rational risk assessments, and as ‘vital asset within an asset’ as consistent with the nuclear plant design culture. The perspective must be shifted from the classic-[STATIC-FIXED DESIGN] nuclear core ‘Defence in Depth’ to a [DYNAMIC-FLEXIBLE] security/vital asset protection mode. Also, we suggest moving to the next step, this being using a robust combination of deterministic and probabilistic philosophy. Your deterministic strategy asserts that some attack will happen, just a matter of when. This while your probabilistic tactics optimise using a full bag of tricks from one end of the spectrum to the other; ranging from overwhelming protective force application through to designed/engineered physical measures, with seamless operational application. This is ‘Dynamic Full Spectrum Defence in Depth’ theory as it applies to protection of a nuclear power plant from any threat to physical security. This would include threats originating from either external or internal-organic opponents-events; thus relying heavily on the integrity and reliability of all personnel on site. Obviously in a zero sum game of resource allocation, you must also perform constant optimisation to balance actions and take this tactic in order to match resources with proper protection of vital assets. The USACE (Ref 8) outlines practical operational fundamentals to guide design and application of forces to protect a vital asset –using the 4 D’s…(in order) D1-Detect, D2-Delay, D3-Deflect, D4- Defeat. Done properly, this should be consistent with best value for money. Also, the way a US Navy Aircraft carrier [Vital Asset] is protected by various interlinked rings of surface/subsurface warships and aircraft gives an interesting dynamic example -Ref (9), which is very consistent in mindset used with Nuclear Plant physical security Nuclear Defence in Depth. Each ring functions to detect and defeat threats; whilst the outer ring also perform a deflect and delay function. The lesson here, is to deploy this fundamental combination of engineered measures along with flexible force – ever changing/moving, increasing in intensity – strength closer to the vital asset. The use of a well designed, thoroughly tested, highly organized/trained an well [material] – equipped team of defenders is the heart of the matter; because, only if you have a proper security force can you enable these organic engineered security assets to work like a Swiss watch.

Dynamic Implementation- the vital key is a high standard-especially for your security force.

To set this high standard, here come the US Marines Ref. 10 (Freedman-2000); This is an excellent summary of why organisations like the US Marine Corps are generally successful as designed to operate in an uncertain and hostile arena. This book helps to illustrate the missing key for many nuclear facilities, which I believe is an essential ingredient; that is the ever-vigilant proactive-aggressive spirit/attitude at the heart of EVERY good US Marine. The basic business or trade arena of Marine is to function in hostile, uncertain territory, against unfavorable odds; examples being landing on a beach to take over territory against resistance, or to protect an embassy in the midst of a foreign country-threats. They always remain keen and alert – vigilant; never complacent. Table V-1 below illustrates the essence of this spirit/attitude as an excellent bridge between business and military ways of thinking, which should help guide/shape-achieve the optimal risk profile with any physical security business planning process at Nuclear Plants:
Table I: Key US Marine Corps Management Principles (As listed in Ref 10, these are the 9 most relevant to physical security operations of the 30 total).

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<th>Principle</th>
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<td>1</td>
<td>Aim for the 70%-solution - it’s better to decide quickly on an imperfect plan than to roll out a perfect plan when it’s too late.</td>
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<td>2</td>
<td>Find the essence - when it comes time to act, even the most complex situations and missions must be perceived in simple terms.</td>
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<td>3</td>
<td>Orient to speed and complexity - the ability to react quickly and effectively in chaotic environments usually trumps other competencies.</td>
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<td>4</td>
<td>Focus on the small team - most of the organization’s critical tasks are accomplished by the lowest-level managers and their subordinates, so anything done to make them more effective will have a large payoff.</td>
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<td>5</td>
<td>Surprise and disorient the opposition - confused and off-balance competitor can be routed with fewer resources.</td>
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<td>6</td>
<td>Make tempo a weapon - controlling the pace of competition can exhaust and demoralise the competition.</td>
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<td>7</td>
<td>Keep plans simple and flexible - it’s better to have a few options that can be easily adapted to changing situations than to try to make specific plans for every contingency.</td>
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<td>8</td>
<td>Experiment obsessively - even the most successful organisation will eventually stop winning if it doesn’t explore radically different approaches.</td>
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<td>9</td>
<td>Don’t depend on technology - train to be effective regardless of which technologies are available.</td>
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Bottom Line – A Favourable Risk Profile.

Using the Dynamic Full Spectrum Defence in Depth Theory means the best chance for success in protection of vital assets at a Nuclear Plant will be achieved over time and under all reasonable scenarios. The proper Nuclear Plant Security Plan has therefore, by design, optimized the integrated functional risk profile. The bottom line is achievement of a sustained and well tuned organic performance based upon deployment of the proper physical engineered assets, combined with training-readiness of a highly motivated and properly trained security force; both elements integrated, 100% of the time, so when needed they act to ensure that the Right Result happens at the Right Time in the Right Way for the Right Reasons- and the opponent rarely, if ever, comes close to penetrating the protective shield.

CONCLUSIONS

Post 9/11-Renewed Threat Focus

Following the events of 9/11, the importance of physical security enhancements at US nuclear plants has increased dramatically.

Engineered Features-A Steel Thread Throughout

A thorough, well designed combination of engineered protection features are needed from both the inside out and outside in perspective in to defend integrity of nuclear assets.

Security Forces-High Standards Apply

Properly equipped, well-trained and highly motivated security force personnel are the essential ‘glue’ which hold together any protective plan.
A Much Improved Risk Profile Is Achievable

Dynamic full spectrum Defence in Depth allows optimisation-application of limited resources with flexible/hard to predict combinations of both top notch people and well designed/engineered methods-materiel to achieve the best result protecting vital nuclear assets.

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