FUTURE SECURITY CONFIDENCE FOR NUCLEAR FACILITIES ACHIEVED THROUGH DESIGN; PLANNING JOINTLY WITH KEY STAKEHOLDERS USING LESSONS LEARNED FROM THE 1979 TMI-2 ACCIDENT

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ABSTRACT

Following the 1979 watershed TMI-2 Accident, fundamental changes resulted in dramatic and beneficial transition for the commercial nuclear power industry. Materiel/personnel/public safety performance has improved along with the socioeconomic profile of the 103 operating US nuclear power plants. The security challenges faced by US DOE, DOD and chemical production and storage facilities following 9/11 can and should be faced squarely with the goal being a similar improvement in macro-ecosystem posture.

From 1979, the nuclear industry took steps to improve/modify the plants while building stronger training/emergency programs with close public involvement. All manner of stakeholders, including bill payers, evolved from the previous adversarial approach to develop a more participatory attitude-while recognizing progress and improvement. Awareness was beneficial - both perceived and actual safety trends improved.

Replicating the proactive approach taken since 1979, other vulnerable facilities can break out of the current malaise-worry caused by political and resource/market driven pressures by moving forward with more confidence. The cleanup of other sites post 9/11 can therefore improve using three key foundation actions: 1) promptly enact effective mandatory federal legislation; 2) implement prudent engineered solutions integrated with protective force objectives to optimize risk profile, and 3) open process/public involvement to the maximum extent practicable to ensure buy-in along the way.

INTRODUCTION

On March 28, 1979 a complex loss of coolant accident occurred at the Three Mile Island-2 nuclear power plant near Harrisburg, PA. Since that watershed event, many beneficial safety, operational and process improvements in policy/stakeholder communications have been implemented at the 103 operating US nuclear plants. Then, following the February 1993 World Trade Center attack and security breach/intrusion at TMI-1, in 1994 the US Nuclear Regulatory Commission (NRC) amended 10 CFR Part 73 "Physical Protection of Plant and Materials" to include assaults by a four-wheel drive land vehicle carrying personnel, and their hand-carried equipment, to the proximity of the 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 (9/11) dramatically changed this thinking; [1] outlines steps taken by the US NRC Chairman Richard A. Meserve to immediately assess the security condition at the US commercial nuclear plants. Steps are currently underway to upgrade physical security at US nuclear facilities with a sense of urgency that had not existed nine years ago. However, as much as we would like to do whatever it takes, limited resources must always constrain the response to the seemingly infinite magnitude and variety of physical threats.

This paper will demonstrate the current value of key TMI-2 stakeholders related Lessons Learned that can be directly applied to post 9/11 realities in many other types of vulnerable US facilities. Many years of evolution have been invested by the nuclear industry to develop, test and then implement/revise methods of stakeholder communication. The persistent interaction with stakeholders in an open effective manner has enabled development of a certain comfort level despite complex technical issues involved. The functional results achieved to date in both actual and perceived nuclear plant safety – operational efficiency/capacity factor and economic viability for US nuclear plants are impressive. Many plants are planning 20-year life extensions and for the first time in twenty years, there are serious discussions regarding the construction of new plants [2,3].

Other vulnerable US facilities can easily benefit from the hard-won advantages achieved by nuclear plants. Key attributes of success are based first upon strong regulations such as the US NRC 10CFR50 series, particularly 10CFR50 Appendix E. [4] These regulations require extensive and consistent investment in facilities, communication and cooperation with local authorities; also prescriptive emergency measures such as sirens, simulators and drills with established facilities/organizations. The second aspect of nuclear approach giving an advantage is the sound analytical/engineering culture, which can be integrated with an effective protective force to provide seamless protection – from physical structures to procedures/weapons/early warning systems. Finally, and most critically, is the direct involvement achieved with the various stakeholders, such as local people, community leaders, local emergency authorities (e.g., police/fire/EMT) and State regulators, who actually participate in hearings and quarterly emergency drills with established facilities/organizations. The nuclear plant stakeholders therefore remain involved with changes/or modifications to emergency security readiness.

DETAILED RESULTS: REGULATORY AND TECHNICAL LESSONS LEARNED

In the years following the TMI-2 accident, many safety and functional modifications were mandated by the US NRC to be implemented quickly at US commercial nuclear plants. The resulting improvements in plant performance, capacity factor and safety margins resulted in an actual and symbolic turning point for nuclear power. The deterministic flavor of these regulations, also included a helpful tone in the form of regulator guides that helped licensees smooth implementation and minimized ambiguity and misunderstanding.

All manner of federal jurisdictional issues are addressed from basic licensing rules (Part 2) through strong provisions to prevent false disclosure (Part 21) through specific power plant license, (Part 50) disposal of radioactive waste (Part 60) packing and transport of radioactive waste (Part 71) and physical protestation of plants and material (Part 73). Without these strong regulatory foundation points, much of the progress achieved to <u>reduce</u> <u>risk</u> – both actual and perceived would have either been slower or not been realized at all.

The US PMI® Project Management Body of Knowledge [5] defines risk as “an *uncertain* event or set of circumstances that, should it occur, will have an effect on [the project’s] time, cost or quality/performance *objectives.* Nuclear plants are, after all, very large projects that take vast amounts of time and resource to implement with billions of dollars spent over a plan-build-operate-decommission-lifecycle that involves many decades of time. Therefore, planning so far into the future carries a substantial potential for risk, primarily revolving around achievement of expectations from a complex set of ‘stakeholders’ (over several human generations). These requirements boil down to a mandate for absolutely safe operation, with key metrics established for performance in the arena of product delivery. Metrics can be shorthanded as the 3 E's…environmental, economics and electricity as needed {always with reliability-high quality}. Likely stakeholders who may have authority or exert influence regarding the nuclear reactor lifecycle decisions are typically:

- Regulators…nuclear, environmental, industrial safety
- Investment Partners and Owner/operators
- Scientists, Engineers, Project Managers, and Construction contractors
- Various hands on professionals, union workers and technicians
- Local and government politicians
- Community people and organizations-businesses, home-landowners, farmers
- Environmental action groups-(greens) and other professional groups
- International Nuclear and standards groups//utilities//OEM's//other suppliers
- Energy users...public/private/government firms and homeowners.

The lesson to be drawn from the successful experience of the US Nuclear industry is that swift, effective and consistent progress can be achieved within the USA political system using proper regulation. Other vulnerable facilities such as chemical plants are <u>not</u> subject to extensive regulation but, rather to "voluntary" measures [6]. Recent reports have uncovered substantial risk associated with these chemical facilities. Also, despite assurances offered by programs such as the US Treasury Risk Insurance Program [7], commercial insurance coverages are under intense scrutiny for industrial – market driven production facilities. Uncertainty drives up this insurance cost, whereas proper capital investment to reduce risk, could be, at least in part, used to reduce real and perceived risk and therefore cost less for insurance cover. In contrast, US DOD actions have naturally intensified with extensive efforts underway to substantially improve specific requirements – an example being [8] US Navy Atlantic Fleet Design guidance for entry/access to facilities. The lesson, therefore, seems to be clear – develop strong regulation that helps define proper requirements and fairly yet firmly specifies capital expenditures**.** This shift away from the unstable extreme of pure market driven mandate toward a regulated arena appears to be necessary for other industries.

TECHNICAL AND ENGINEERING APPROACH: DEFENSE IN DEPTH

The effective protection of vital assets is a common objective no matter which industry. Therefore, the US nuclear industry provides a valuable lesson in that much of the post-1979 TMI-2 accident effort has been directed to improve risk posture using an integrated approach where human behavior is enhanced with education, certification and training. This has taken place with thorough engineering analysis, assessments and evaluation remain a strong cultural cornerstone.

The classic nuclear culture/approach has always been regarded as defense in depth from the 'inside-out' perspective i.e., lines of functional defense 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 1979 Three Mile Island accident, when the last line (the Reactor Building) performed to protect the public. Full-spectrum risk management also involves an evaluation of SWOT-Strengths, Weaknesses, Opportunities and Threats [9]. 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 area of risk has been on the fear drivers, W and T of the SWOT formula, which had resulted in the existence of an overall negative flavor.

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 [10]) while a more positive/confident approach is evident in 21st Century nuclear – with much more emphasis on the S&O of SWOT… well over 16 years beyond such negative events demonstrated on the world stage with dramatic accidents at Three Mile Island & Chernobyl. Of course, since the events of 9/11, renewed concerns exist (which are emotionally charged by the media – [11] in the month before 9/11 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 defense in depth from the OUTSIDE IN.

RAISING EXPECTATIONS – POST 9/11; REDEFINING THE STANDARD FOR SECURITY AT VULNERABLE FACILITIES

We have examined the legislative and technical aspects of Lessons Learned from the 1979 TMI-2 accident. The following illustrates a suggestion to move up to a higher standard, which may be applied to more accurately protect other vulnerable facilities in the US from terrorist actions.

GENERAL THREAT DEFINITION – A STRONG LESSON: TO RELY ON PHYSICAL PROTECTION

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 9/11. More rigor has been applied to general facility security post 1979 TMI-2 accident, gradually as a matter of functional evolution. 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. Based upon a risk-based, integrated, balanced approach to achieve 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. Recent informational use of extensive suicide truck/car bombs, seem to re-enforce this as the terrorists weapon of choice. The optimal risk reduction premise is based upon a well-designed, deterministic engineering foundation, which helps balance the usual emotive reactive 'gun toter' 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) 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/cost effective integrated risk profile for any vulnerable US facility.

Resources Versus Threats

Primary resource considerations include costs, time and information. As the planning process unfolds, it is quickly realized 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 maximize 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 favor of the asset owner.

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 recognized, however, that certain personnel may represent indispensable assets for thwarting terrorist attacks. This human element has been largely downplayed in past by relying on engineered systems.

Land Threats

The common denominator of threats for all plants, which has been recognized 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 with enough explosives to literally destroy the nine-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 persistent 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 [13] 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, the terrorists quickly learned from their mistake.

Fig. 1 Blast damage to *USS Cole* by Watercraft bomb

Air Threats

The reality of a terrorist attack by aircraft should no longer be debatable after 9/11. 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 are a major hazard.

Organic Threats

Organic threats are those that 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. Personnel reliability programs should deter this possibility.

ENGINEERED COUNTER TERRORISM MEASURES - DESIGNED TO ENSURE PROPER FUNCTION AND PROTECTION.

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 judgment 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.

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.

Fig. 2 Man-made concrete inertia barrier

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 practiced 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 now possible with 21st Century analytical tools. 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.

Fig. 3 Representative Watercraft deterrent barrier

DYNAMIC DEFENSE STRATEGY - A 21ST CENTURY NECESSITY NO MATTER WHICH TYPE OF VULNERABLE FACILITY

Re-examination of the Concept of 'Dynamic Defense in Depth' Nuclear Core vs. Physical Security.

Use of the concept 'dynamic defense in depth' has, as its core element, these optimal human factored engineering enhancements to result in true uncertainty for any opponents. A postulated 'success formula' is the: SUCCESSFUL DEFENSE = (DESIGN) + (ENGINEERED/MATERIEL ASSETS) + (METHODS/PROCEDURES) + (HIGHLY QUALIFIED PERSONNEL ASSETS). A security force must therefore be an integral part of the defense, 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 [13,14,]; 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 15]. A more familiar SWOT methodology should be examined as a means of inserting rigor that is consistent with Nuclear culture.

Security Defense in Depth: Functional Analysis and Integration with a Robust Protective Force.

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 [16] with useful suggestions regards 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 'Defense 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 optimize 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 Defense 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 optimization to balance actions and take this tactic in order to match resources with proper protection of vital assets. The US Army Corps of Engineers [17] 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 , which is very consistent in mindset used with Nuclear Plant physical security Nuclear Defense in Depth. Each ring functions to detect and defeat threats; while 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, [18] is an excellent summary of why organizations like the US Marine Corps are generally successful in an uncertain and hostile arena. This book helps to illustrate the missing essential ingredient for many nuclear facilities; that is the ever-vigilant proactive-aggressive spirit/attitude at the heart of EVERY good US Marine. The basic business of the Marines 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. This concept 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, which could also serve to set a standard for other vulnerable facilities.

Bottom Line – A Favorable Risk Profile.

Using the Dynamic Full Spectrum Defense 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 tuned for optimal performance, 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 AND INTEGRATED APPROACH TO REALIZE ADVANTAGE FROM 1979 TMI-2 LESSONS LEARNED

The current national push for much improved security posture Post 9/11 needs to ensure optimal protection of many diverse yet vulnerable “government” and “commercial” facilities. Various market and regulatory/political forces can and will mix to present a potential challenge – which could result in stalemate and exposure to terrorist threats due to delay.

Development since 1979 has been characterized by a firm yet **open process** used by the nuclear industry that includes enactment of strong legislation by the US Congress (which is also properly supported by state and local legislatures). Participation by stakeholders in developmental and licensing hearings, emergency procedures, including regular quarterly drills is the primary lesson learned here. Keeping an open process viable using solid communication ensures adaptability and buy in by influential stakeholders/billpayers giving the best chance for prompt, cost efficient and effective success.
Integration of engineered measures along with development for high-quality/purpose fit and well-planned protective force and physical protection measures will also help improve the **precision and value/accuracy** of $$ spent on physical protection. **Resources expended vs. risk profile must be both perceived and actually be favorable** to allow sponsoring firms to survive in the business market otherwise the terrorists can and will claim victory.

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