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# Fortifying Nuclear Security: Cultivating Vigilance Culture Among Personnel for Enhanced Prevention and Response

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## Abstract

A vigorous nuclear security culture is crucial in preventing the theft and sabotage of nuclear material. It requires vigilance from all employees because relying solely on closed-circuit television systems and security personnel is insufficient to deter potential threats. Employee attentiveness plays a vital role in recognizing and preventing suspicious activities. However, achieving a strong security culture is challenging because of the lack of incidents in some facilities, leading to employee complacency.

This paper highlights the pivotal role of personnel in the success of nuclear security measures, emphasizing the need for a proactive and vigilant mindset among staff. Through the analysis of case studies and real-world incidents, this study explored the effect of an enhanced vigilance culture on incident detection, response times, and overall security protocol effectiveness. The study delved into psychological and organizational factors influencing vigilance culture development, emphasizing leadership commitment, continuous training, and a sense of shared responsibility among security personnel. The proposed framework for promoting vigilance culture integrates practical strategies, including scenario-based training, regular debriefings, and leveraging technological advancements such as artificial intelligence for improved threat detection.

Contributing to the nuclear security discourse, this paper provides insights into the tangible benefits of a vigilance culture within nuclear facilities. The findings offer practical recommendations for security managers, policymakers, and training

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professionals to fortify security culture and mitigate potential risks in the ever-evolving landscape of nuclear security.

**Keywords:** Nuclear security culture, vigilance culture, scenario-based training

# 1. Introduction

The 2008 International Atomic Energy Agency (IAEA) model of nuclear security culture has 30 characteristics and lists 120 culture indicators that are assigned to each characteristic to illustrate their meaning. Vigilance has been listed as one of the characteristics under personnel behavior in this model. This model is designed to guide member states in planning and implementing programs to improve nuclear security culture, with a focus on the human factor and management leadership in nuclear security. It is a comprehensive framework that underscores the importance of individual and collective responsibility in maintaining a robust nuclear security posture [1]. Human factors play a critical role in enhancing security when personnel demonstrate strong motivation, vigilance, and high performance [2].

Vigilance culture and security culture, although related and overlapping in several areas, are distinct concepts within the context of organizational behavior and management. Vigilance culture focuses on the continuous and proactive observation and monitoring of potential threats and risks. It emphasizes the importance of being perpetually alert, prepared, and responsive to changes that could affect the organization's security posture. A culture of vigilance encourages employees and management to remain watchful for signs of problems or breaches, encouraging proactive measures rather than reactive responses [3].

Security culture, on the other hand, encompasses a broader set of practices, attitudes, and behaviors that are geared toward maintaining the overall security of an organization. It includes policies, procedures, training, and technologies that aim to protect an organization's assets, data, and people from various threats. Security culture is about creating an environment in which security is ingrained in every action and decision, promoting a comprehensive approach to safeguarding the organization.

Although vigilance culture is an essential component of a broader security culture, focusing specifically on awareness and alertness, security culture includes a wider range of elements such as technological defenses, physical security measures, policies and procedures, and compliance with regulations. Both are crucial for an effective security strategy, but they address different aspects of organizational security. Vigilance culture can be seen as a subset or a critical element within the larger framework of a security culture, contributing significantly to its effectiveness (Figure 1).

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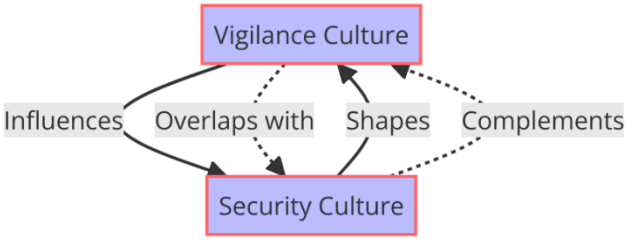


**Figure 1. Synergy between vigilance culture and security culture.**

Constant vigilance is a significant tool to eliminate nuclear threats, although the complete standard of vigilance is hardly possible to achieve. Because of the complacence of employees, most people believe that constant vigilance cannot ever happen, but it can because no security is perfect [4]. Constant vigilance and comprehensive security measures are the foundation of nuclear security [5].

The essential elements that make personnel vigilant include the following. For nuclear security personnel to be vigilant, they must first believe that a real threat exists to the facility, and secondly, they believe that taking measures to promote nuclear security can help mitigate that threat. Vigilance entails understanding the red flags associated with a potential insider or external adversary and taking the appropriate action to respond to the threat [6]. Vigilance is very important for nuclear security personnel, and it relates directly to IAEA Fundamental Principles for when threats to nuclear security are credible and real. Vigilance includes looking for immediate threats (for example, attackers) as well as for things that could degrade the physical protection system (PPS) mission of detection, delay, and response—for example, vigilance in maintaining fences, vegetation lines, closed-circuit television (CCTV), and more [7]. Vigilance means that security personnel should be active, alert, and attentive during the protection of facilities to prevent unauthorized access, sabotage, and any malicious activity. They should be fully aware of the threat to respond to security breaches and security threats [8]. The definition of vigilance is an operator's ability to establish the focus of their attention and to remain alert over a longer period of time; a lack of vigilance can be dangerous when detecting critical signals or threats. The lack of vigilance in employees can also lead to an error in the detection of a signal or threat. Vigilance means detection, and it is defined as continuous surveillance or monitoring to offer a control parameter and recognition of changes [9].

Vigilance refers to two types recognized in this study; both are important for threat management and reducing threats [10]. The first type of vigilance, called "A," helps directly adaptive managers, and this type is known as searching for warnings and ensuring that the system is able to work. Strong knowledge of the organizational agenda is essential in this type of vigilance. For instance, an abnormal situation or breach of security would alarm personnel. If they are vigilant, they would be able to identify that security breach. Additionally, vigilant personnel would be able to recognize if alarms and cameras are working.

"B," or the second type of vigilance, is identified as when personnel do not know what they are searching for, such as unclear warnings, irregularities, misunderstood duties,

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and shocks. This type requires questioning capability when faced with unclear observation. For instance, if fellow personnel are not vigilantly fulfilling their duties, and vigilant personnel have noticed some irregularities and situations creating doubt (i.e., detected malicious insider activity), particularly when the fellow personnel seem confused about their duties or the vigilant personnel are confused by the fellow personnel's duties and actions, vigilant behavior would force the vigilant personnel to report and consult with a manager to secure the nuclear facility.

Complacency is the greatest threat to an effective nuclear security program. In many cases, facility personnel will become complacent over time and begin to choose convenience over security. Insider threats are low-likelihood, high-consequence events, meaning that they do not occur often but can result in devastating financial, reputational, and national security consequences. Therefore, security personnel must continue to stay vigilant over the long term. Lack of vigilance may cause security personnel to miss red flags that should warrant a response. Additionally, lack of vigilance may result in security personnel failing to institute or maintain preventive or protective measures. For example, overly complacent security personnel might fail to ensure that security equipment, such as cameras, is operating correctly and should carry out routine maintenance, particularly if maintenance efforts are time-consuming or expensive [6]. This study posits that the cultivation of artificial intelligence (AI)-based vigilance culture among nuclear security personnel will strengthen nuclear security. This paper discusses how vigilance of personnel can be enhanced to strengthen nuclear security. This study concludes that AI-based cultivation of vigilance culture can enhance threat prevention and response at nuclear facilities.

## 2. Research Gap and Methodology

The literature on nuclear culture and nuclear security is abundant, but the vigilance of nuclear security personnel has not been explored or discussed by experts and scholars much. Therefore, this study employed a qualitative review of existing literature on organizational behavior, security management, and psychological theories relevant to vigilance and security culture. The study synthesized findings from various other studies to identify key drivers of vigilance culture. Expert interviews were also conducted to substantiate the findings. Experts in the field can offer deep insights into the nuances of vigilance culture that are not readily available in published literature. Their experiences and knowledge enrich the understanding of factors influencing vigilance. Thus, interviews of three experts in nuclear security were conducted in this research. The following list shows a sampling of question that were asked to these three interviewees:

1. How do you define vigilance of nuclear security personnel?
2. What is the importance of vigilance of security personnel for nuclear security?
3. How can vigilance of security personnel be enhanced, and what factors can play a significant role in enhancing vigilance?
4. How does lack of vigilance affect prevention and response?

According to all interviewees and primary data, vigilance of security personnel is significant for nuclear security, and complacency is a threat to nuclear security.

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Increased vigilance in nuclear security personnel can play an important role in enhancing threat prevention and response at nuclear facilities.

## 3. Personnel's Crucial Role in Vigilance Culture

The IAEA emphasizes the importance of an effective nuclear security culture, which depends on the commitment of individuals at all levels, from policymakers to the general public [11]. Vigilance plays a critical role in managing unexpected and abnormal situations by enhancing decision-making accuracy. Elevating the levels of vigilance and professional commitment among all employees is crucial for developing a strong nuclear security culture because it prevents employees from engaging in malicious activities. The vigilance of employees is key to reducing the need for inspection and enforcement actions, and it fosters improved relationships between stakeholders and the public. Employees who recognize their significance and contributions to nuclear security tend to work more diligently than those in environments with a weaker security culture.

Heads and managers in information technology are tasked with identifying security weaknesses and taking proactive steps to prevent and deter threats. Each stakeholder should possess a documented policy that outlines personal commitments to adhere to these policies. Such policies and expectations mandate the protection of sensitive materials and data by identifying threats and security concerns through vigilance, thereby fulfilling nuclear security duties. Additionally, reporting any abnormal activities to prevent future threats is essential. Employees should also be required to monitor visitors and their passes during visits to important areas, ensuring that all visitor processes are properly followed.

To ensure employee vigilance, managers must conduct walkthroughs to observe security personnel's interest in their jobs and instill a sense of importance for their positions. Employees should be encouraged to participate in trainings, exercises, and healthy competitions to promote diligent performance of their responsibilities. To induct vigilance, managers must establish a culture in which employees can give confidential suggestions to improve nuclear security [2]. Education, training programs, educating personnel regarding technologies, technological developments, and their proper usage play an imperative role in enhancing vigilance. Personnel should be supported mentally, financially, and emotionally for a sense of belonging because these elements of support would make personnel more vigilant. Lack of vigilance and complacency would lead to security breaches, and personnel would not be able to detect, prevent, and respond on time. They would not be able to identify the threats and would be unable to take countermeasures. Lack of vigilance would affect the performance of all technological equipment because nuclear security requires up-to-date technological equipment, which would result in late detection, late response, late prevention, or no prevention at all [8].

Some key factors of a lack of vigilance include attention fatigue (staring too much at CCTV) and poor routine, especially if a site's PPS leads to a high rate of false alarms and nuisance alarms. Nuisance alarms are different from false alarms because the PPS has correctly detected something (rather than a false alarm) but what has been

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detected is not important—for example, animals at a fence line are triggering sensors. If too many of these alarms occur, then operators will form a habit of assuming alarms are not relevant. Varying routine and roles can help keep people active, as well as introducing the better incentives that keep people interested (during quiet times and relating performance to duties), good shift patterns (e.g., 8-hour instead of 12-hour shifts) and having a PPS system that reduces operator stress and fatigue. Training will also help, as will external evaluation—for example, live-fire exercises [7].

Personnel should be motivated to ensure nuclear security, and they should know the consequences of their behavior should they not ensure security and need to embrace a sensible approach to their security obligations. Effectiveness of nuclear security culture requires personnel compliance with rules and regulations as well as constant vigilance and a questioning approach. Additionally, teamwork and cooperation among all personnel are necessary for strong nuclear security. Personnel must know how important their contribution is for nuclear security. A high level of security requires the proper enforcement of nuclear security cultures by making personnel more vigilant. The role of the state, organizations, managers, personnel, the public, and the international community is very important to enforce nuclear security culture [12]. Nuclear security culture starts at the top. The best way to increase vigilance is to ensure a commitment exists from leadership to promote nuclear security as a top priority within the workforce. Other measures, such as requiring annual training and increasing the accessibility or convenience of reporting security incidents, can help to decrease complacency over time [6].

## 4. Realization the Importance of Vigilance Culture

The lack of incidents in the workplace can lead to a dangerous state of complacency, in which the absence of adverse events creates a false sense of security among workers and management. This state can significantly increase the risk of accidents and injuries. Complacency is often a result of routine and repetitive tasks that do not require active problem-solving, leading individuals to operate on autopilot. For organizations, complacency may stem from a belief that existing safety measures are sufficient, alongside prioritizing productivity and efficiency over continuous safety improvements. Key indicators of complacency include a lack of engagement from workers, diminished problem-solving efforts, and a general disinterest in taking initiative for their tasks. These signs point to an environment in which employees are physically present but mentally disengaged from their work [13]. Instances such as the Deep Water Horizon disaster and NASA shuttle explosions highlight the catastrophic outcomes of organizational complacency, underscoring the critical need for vigilance in safety practices. Preventing complacency clearly requires a multifaceted approach, involving continuous education, engagement, and a proactive stance on safety and risk management.

Combatting complacency involves continuous vigilance and active engagement from both workers and management. Solutions include promoting a culture that embraces enterprise-wide risk management and integrating risk assessment into all levels of planning and operations. Furthermore, breaking the cycle of routine and encouraging

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constant awareness of potential hazards are crucial steps. This awareness can be achieved through frequent safety training, informal toolbox talks, and fostering an environment in which safety discussions are a regular part of the workflow [14].

Because of a lack of vigilance culture, in 1979, theft occurred of low-enriched uranium (LEU) from the GE Wilmington fuel fabrication facility. Although the LEU was recovered after some days, a lack of vigilance from the security guards made the theft of LEU possible. In this incident, a laboratory technician exploited the security system for illegal goals after identifying weaknesses in the security system. The theft happened because security guards did not notice on entry that the presented security card of David Learned Dale was not an authorized access area card but was instead his driver's license with a blue background similar to the badges of permanent personnel and employees at the facility. This event underscores the critical importance of a vigilant security culture within sensitive facilities, in which every layer of security, including personnel checks and physical barriers, plays a vital role in preventing unauthorized access and potential threats to public safety.

Other events include the Koeberg attack, which happened in South Africa in 1982 because of a lack of vigilance from the employees. In this incident, an insider smuggled limpet mines into plant. This incident affected the plant financially and halted its commissioning by 18 months. In 2012 at Y-12 National Security Complex in the United States, an incident occurred in which three anti-nuclear weapons protestors gained access to the most sensitive nuclear site at Y-12 National Security Complex because of the complacency in their nuclear security culture. The US used to spend $10 million annually on the integration of advanced detection systems for armed responses [14].

Lack of vigilance has direct and indirect effects. Direct impacts of reduced vigilance—for example, if a site is attacked—increases adversary times and fields of action but also reduces the defender's ability to respond. The same occurs with cyberattacks, where a malicious actor can be on a server for months before being detected. A cyberattack can implant all kinds of malware that may have a direct impact on response. Indirectly, poor vigilance can lead to poor maintenance of equipment, which will affect the ability to detect and respond incidents. Poor maintenance also affects working culture because people will not work hard if they feel neglected. Investing in people and equipment helps instill prestige and purpose. A facility where people do not feel valued or invested in will struggle to maintain standards [7].

## 5. Attributes of Vigilance Culture

Once the importance of the vigilance culture is realized, the next step in strategy adopted in this paper on enhancing the vigilance culture is to identify the attributes of the vigilance culture which contribute to the continuing evolution of vigilance culture throughout the nuclear industry. Many vigilance culture attributes, described as organizational factors or characteristics of vigilance culture are listed by researchers, utilities, and regulators in their discussions of vigilance culture. Sometimes they are essentially describing the same attribute, just with different wording; in many cases they are just very closely related. The attributes were reduced to a list of the most important

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based on the frequency with which they were cited and also mentioned by expert in interviews.

## a. Definition of Selected Attributes

Central to the establishment of such a culture is the unwavering commitment of leadership. The study elaborates on the indispensable role of leaders who not only prioritize security within their organizational ethos but also actively engage in promoting and embodying behaviors indicative of vigilance. This top-down support is fundamental, setting a precedent for the entire organization's approach to security. Nine attributes (Figure 2) have been identified by the authors based on interviews as factors contributing to vigilance culture.


**Figure 2. Attributes of vigilance culture.**

**Leadership commitment** is a cornerstone in cultivating a culture of vigilance within organizations, especially in sectors in which safety and security are paramount. This commitment is not merely a formalistic endorsement but a comprehensive strategy that involves visible leadership actions, strategic allocation of resources toward safety initiatives, and consistent and clear communication emphasizing the importance of vigilance at all levels of the organization.

**Continuous training** is as another pivotal element. This analysis accentuated the necessity for ongoing training initiatives that focus on skill development and the execution of scenario-based drills. These measures are instrumental in equipping personnel with the capabilities to identify and effectively counteract security threats. The provision of such training is a critical component in sustaining heightened levels of vigilance among employees. To combat complacency, continuous improvement and

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regular reassessment of security measures are essential. This improvement includes updating training programs, conducting drills, and refreshing security protocols [11].

**Shared responsibility** also significantly contributes to the development of a vigilance culture. The study underscores the importance of engendering a collective sense of commitment toward security across all levels of staff. By fostering inclusivity in security dialogues, organizations can ensure a comprehensive engagement, thereby enhancing the overall vigilance.

**Organizational culture**, particularly the efficacy of communication channels and the establishment of trust, plays a crucial role in nurturing a vigilant environment. Open lines of communication and a foundation of trust encourage individuals to report suspicious activities, thereby strengthening the organization's security posture.

**Recognition and rewards** for vigilant behavior have been identified as effective strategies for reinforcing the desired security mindset. Acknowledging and incentivizing vigilant actions motivate employees to maintain a high level of alertness continually.

The present study further explored the effect of **psychological factors**, such as the perception of threat levels and cognitive load, on vigilance. The study posited that addressing issues contributing to cognitive overload is essential for ensuring that individuals remain vigilant.

**Incident experience**, particularly learning from past security incidents and near misses, is crucial for reinforcing the significance of vigilance. The study highlighted the necessity of addressing complacency to maintain a proactive approach toward security.

**Technological integration**, including the adoption of advanced security systems such as AI and modern surveillance technologies, is shown to complement human vigilance effectively, thereby enhancing overall security measures.

**Regulatory compliance** also plays a significant role in shaping vigilance culture. Adhering to industry standards and regulations sets a baseline for security practices, influencing the organizational approach to vigilance.

Throughout this study, examples and case studies were referenced to illustrate how these determinants have been applied in real-world scenarios, further substantiating the findings. For instance, the incorporation of advanced surveillance technologies in airport security protocols has significantly improved threat detection rates [15]. Similarly, the implementation of comprehensive training programs reducing vulnerabilities by enhancing personnel readiness is key in preventing threats [16]. These examples serve to underscore the multifaceted approach required to cultivate and sustain a culture of vigilance within organizations, highlighting the interplay between leadership, training, shared responsibility, technological integration, and organizational support in achieving this goal.

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## 6. Framework of Promoting Vigilance Culture

Vigilance culture is a comprehensive approach emphasizing the importance of constant vigilance within the realm of nuclear security. It revolves around the principle of continuous observation and monitoring, in which individuals and organizations adopt an ever-watchful eye toward identifying and addressing potential security threats and risks. This culture is rooted in a proactive rather than reactive stance, advocating for preemptive actions to forestall security breaches before they can occur. Key to this approach is a heightened responsiveness to changing circumstances, ensuring that security measures are flexible and adaptable to evolving threats. The ultimate goal of vigilance culture is to avert acts of sabotage and prevent the malicious exploitation of radioactive materials, thereby safeguarding a secure environment against emerging challenges.

In the formulation of a framework to foster a culture of vigilance within nuclear facilities, the genuine threats these establishments face must be acknowledged. The foundation of a robust nuclear security culture rests on universal acceptance among organizational members that credible threats exist. Without this fundamental acknowledgment, the motivation to counter potential threats diminishes because complacency stands as a formidable opponent to vigilance. Therefore, security personnel must recognize the perpetual presence of threats because adversaries persistently seek to identify and exploit vulnerabilities within every nuclear facility's defenses [14].

To mitigate such risks, fostering open communication channels between senior management and staff regarding security issues is essential. These discussions should encompass a range of topics including emerging threats, the importance of vigilance, personal accountability, adherence to procedures, and strategies for enhancing teamwork and cooperation. Various methods to facilitate this open communication can significantly contribute to bolstering vigilance, including the following:

1. **Open meetings** with personnel, allowing for a direct exchange of ideas and concerns;
2. **"Learning on lunch" discussions**, which informalize the sharing of knowledge and experiences;
3. **Regular communication** through emails, ensuring that all members are updated on the latest security information and guidelines;
4. Implementation of an **award program** to recognize and incentivize adherence to security practices; and
5. **Briefings for section heads** to disseminate information through leadership channels [17].

These mechanisms serve as vital sources of open communication, playing a pivotal role in enhancing vigilance within the organization.

Additionally, diversity of resources in security-related awareness-raising and training is critical. To prevent content from becoming outdated or monotonous, maintaining a variety of resources and regularly refreshing them are essential. Materials that are

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easily understandable, encourage critical thinking, and include interactive components, such as quizzes and scenario-based discussions, are particularly valuable. These approaches not only facilitate engagement but also reinforce the practical application of security concepts in various contexts.

Benchmarking the nuclear security culture within an organization is also of paramount importance. Regular assessment of the current security measures against a spectrum of threats is necessary to evaluate their effectiveness. Furthermore, such evaluations aid in the strategic planning of future initiatives aimed at cultivating a security culture. This process ensures that security systems remain robust and adaptable in the face of evolving threats.

Incorporating AI into nuclear security frameworks represents a paradigm shift in enhancing threat detection, surveillance, and incident response capabilities within nuclear facilities. Leveraging AI technologies can significantly augment the efficacy of nuclear security measures by offering advanced solutions to detect, analyze, and respond to potential security threats swiftly and accurately. AI has revolutionized threat intelligence by automating the collection, analysis, and synthesis of security-related data. AI contributes the following:

- Automated data processing—AI algorithms sift through vast amounts of information, identifying patterns and anomalies that might elude human analysts.
- Predictive capabilities—Machine learning models predict potential threats based on historical data, enabling proactive measures.
- Focus on complex threats—By handling routine tasks, AI frees up analysts to concentrate on sophisticated threats that demand human expertise.

However, AI technology could also increase the threat; as technology automates tasks, human vigilance may decrease. Relying solely on automated systems can lead to complacency. Technology also floods personnel with information. Filtering relevant signals from noise becomes critical for maintaining vigilance. Although technology enhances vigilance, it also introduces new threats (e.g., cyberattacks, data breaches).

As AI continues to evolve, integrating it into our security practices is not just an option—it is a necessity. By fostering a vigilant mindset, embracing AI, and addressing its challenges, organizations can stay ahead in the ongoing battle against cyber threats. The diagram in Figure 3 is a mind map designed to illustrate the steps organizations must take to fully harness AI for threat detection, which consists of three strategies: train and educate, human–AI collaboration, and continuous learning. *Train and educate* is different from *continuous learning* because *train and educate* should not be limited to workshops and training programs, but the need exists to integrate a *continuous learning* habit in personnel, which is a significant part of the cultivation of vigilance culture.

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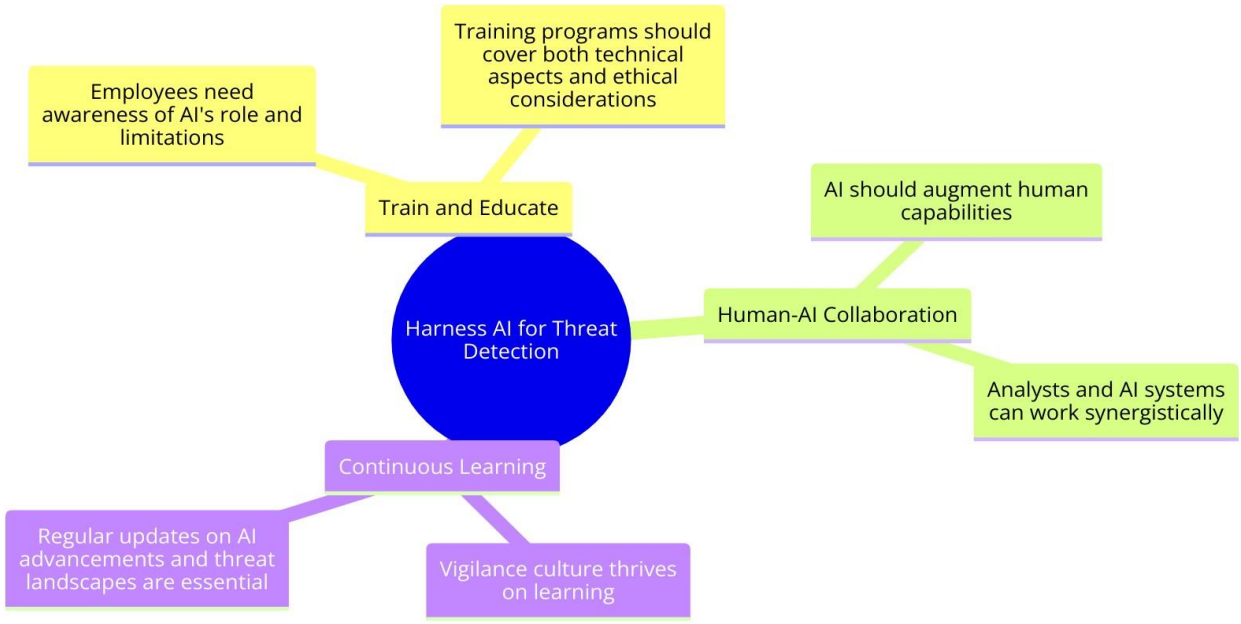


**Figure 3. Proposed framework to cultivate vigilant culture using AI.**

Vigilance culture involves a proactive approach to nuclear security, emphasizing continuous observation and preemptive actions to prevent security breaches. It prioritizes adaptability in response to changing circumstances. In summary, promoting a vigilance culture within nuclear facilities requires a multifaceted approach, encompassing the recognition of threats, open communication, diverse and engaging training resources, and ongoing assessment of security practices. Through these strategies, a proactive and resilient security culture can be established, effectively safeguarding against potential vulnerabilities.

## 7. Conclusion

In conclusion, this study emphasized the irreplaceable role of personnel in nuclear security and the imperative of cultivating a vigilant mindset. By examining real-world incidents and proposing a comprehensive framework, this study contributes valuable knowledge to enhance security measures. Because nuclear security remains a global priority, fostering a strong vigilance culture stands as a proactive strategy to safeguard against potential threats.

Three main points were identified in this paper. First, a prolonged period without incidents can create a false sense of security among personnel, leading to relaxed vigilance and adherence to protocols [14]. Second, real-life case studies show that human factors can undermine nuclear security systems. Complacency can result from routine and the perception that security measures are overly robust or unnecessary [1]. Third, a lack of incidents may mask potential insider threats because individuals with malicious intent can exploit the relaxed security environment created by complacency [18].

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This paper presented a qualitative review; future studies could involve quantitative measures of vigilance culture. Researchers could develop and validate an instrument for measuring the elements of vigilance culture among nuclear facility personnel. Future studies could involve creating a survey based on the nine attributes of vigilance culture outlined in this paper and assessing their prevalence and effect on security outcomes.

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