EPRI / NEI Work Hours Task Force White Paper:

Managing Fatigue in the Nuclear Energy Industry: Challenges and Opportunities

Prepared for the NEI Work Hours Task Force by:

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May 6, 2002

EPRI Perspective: For many years, the energy industry has been concerned with the effects of fatigue on the quality of life, health, safety, and productivity of their employees. Since the early 1980s, the Nuclear Regulatory Commission Generic Letter 82-12 has provided work hour guidance for the nuclear industry. This guidance for work rules is under review by industry leaders and the U.S. Nuclear Regulatory Commission and a potential rulemaking process is underway (SECY 01-0113).

Changes to work hour guidance affect a host of physical, scheduling, and job-related factors in a complex way. Substantial gaps exist in scientific knowledge both of the effects of fatigue and on methodologies to effectively control or mitigate these effects. Research continues to address these gaps.

The Nuclear Energy Institute Task Force on Work Hours supports the current review of guidance and, on behalf of utility leaders, commissioned the attached white paper to capture current expert opinion on several aspects from the scientific and practical body of work on fatigue and its effects.

About Dr. Rosekind: Dr. Mark Rosekind is a Founder, President, and Chief Scientist of Alertness Solutions. From 1990 until 1997, Dr. Rosekind led the Fatigue Countermeasures Program at the NASA Ames Research Center. During the last two years of his tenure at NASA, Dr. Rosekind was also the Chief of the Aviation Operations Human Factors Branch. Prior to his NASA work, Dr. Rosekind directed the Center for Human Sleep Research at the Stanford University Sleep Disorders Center. His academic credentials include an undergraduate degree with honors from Stanford University, a Ph.D. from Yale University, and postdoctoral training at Brown University.

For more than 20 years, Dr. Rosekind's research, publications, presentations, and practical applications have led to significant changes in real-world settings. These accomplishments have been recognized with honors that include the NASA Exceptional Service Medal, a Flight Safety Foundation Presidential Citation for "Outstanding Achievement in Safety Leadership," and a NASA Group Achievement Award. In 1999 and 2000, Dr. Rosekind was a Fellow at the World Economic Forum in Davos, Switzerland.

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The nuclear energy industry has for many years assumed the challenge of addressing fatigue as a safety issue in its 24/7 operating environment. An extensive amount of work has been accomplished, documents generated, rulemaking options proposed, public comments evaluated, scientific reviews conducted, and stakeholder meetings held in an effort to identify effective actions to address fatigue. In the context of these many activities, this document will focus on providing a scientific perspective and pragmatic operational approach to three aspects of this issue: 1) fatigue is an operational safety risk, 2) reducing fatigue-related risks, and 3) opportunities to manage fatigue in the nuclear energy industry. This paper will not be an exhaustive scientific review or even attempt to cover the full complexity of fatigue in operational settings.

1. Fatigue is an operational safety risk.

"Fatigue," created by sleep loss and circadian factors, reduces alertness, performance, productivity, mood, and safety. The scientific evidence that establishes these findings is extensive and undeniable. There are thousands of peer-reviewed scientific papers from laboratories all over the world clearly demonstrating the negative effects of fatigue. This scientific literature includes field/workplace studies, accident investigations, and other data that demonstrate how fatigue is an operational safety risk in 24/7 settings.

However, there is no "blood test" for fatigue. This is one of the reasons that "fatigue" is difficult to regulate. When appropriate physiological factors related to fatigue are examined to determine whether it caused or contributed to errors, incidents or accidents, there is always an increase in the identified cases where fatigue had a role. Examples of this are cited in Nuclear Regulatory Commission (NRC) documents, including data from U.S. Coast Guard and National Transportation Safety Board (NTSB) studies. This issue about the base rate of risk posed by fatigue addresses the classic position that there is "little or no data actually showing that fatigue causes or contributes to accidents."

Recently, a group of experts estimated that 15-20% of all transportation accidents, across modes, were fatigue-related (1). The group determined that the role of fatigue surpassed that of alcohol and drugs and that official statistics underestimated the contribution of fatigue in transportation accidents.

So, there should be an interest in collecting more data specifically from the nuclear energy industry that examines the role of fatigue in errors, incidents, and accidents. Given the scientific and operational findings currently available, it would be remarkable to discover that fatigue could be dismissed as a safety issue. While these data will help to establish more accurately the risk represented by fatigue, they also would provide a baseline against which future data could be compared. Any planned interventions, whether through rulemaking, industry initiatives or other activities, should be empirically evaluated to determine their effectiveness. Collecting this data should not slow progress to reduce fatigue-related risks and it should be done in a manner that allows future comparisons to evaluate intervention outcomes.

2. Reducing fatigue-related risks.

The majority of nuclear energy industry efforts have focused on a regulatory or policy approach that limits work hours. Several other activities have been suggested, including some educational recommendations and some related to sleep disorders. This section will focus on interventions, what can be done to effectively reduce fatigue-related risks.

a. Semantics are important.

A starting point for all of the stakeholders would be to develop a common language to describe objectives, intended actions, etc. For example, in several documents a primary policy objective is to "ensure, to the extent practicable, that personnel are not assigned to shift duties while in a fatigued condition." Given the complexity of fatigue as experienced in real-world operations, this objective, as stated, probably can not be attained. An objective that can be operationalized and measured is critical. If an objective was to reduce fatigue-related risks, this should be followed by measurable criteria, such as: 1) by allowing an appropriate sleep opportunity, 2) limiting consecutive work hours per day, 3) allowing appropriate recovery opportunities, 4) utilizing effective alertness strategies, etc.

Also, the words used to describe the effects of fatigue on performance and safety also should be tightened. There can be a wide range of changes described by a performance or safety reduction versus impairment. The connotations of these descriptors can be used and interpreted in a variety of ways.

b. The classic fatigue intervention: limit work hours.

The classic, standard approach to addressing workplace fatigue is to limit the number of hours worked. All modes of transportation and some work environments have regulations or policies intended to reduce or eliminate fatigue by limiting an individual's hours on the job. Unfortunately, while it is important and necessary to address work hours, it's not that easy, and it is not sufficient to effectively reduce fatigue-related risks.

A review of federal regulations related to hours of service or duty limitations in actual practice would show it is difficult to find an effective model currently in place. Consider that many of the transportation modes have regulations established in the 1930s and do not reflect the current state of scientific knowledge related to fatigue. The Federal Aviation Administration (FAA) published a Notice for Proposed Rulemaking (NPRM) in the mid-1990s and received almost 2,000 comments on the proposal. No definitive rulemaking has followed. The Federal Highway Administration (FHWA) organized an expert panel, conducted a variety of research projects, and developed a proposal for commercial truck driver duty and driving limitations. After many comments, and some years, no definitive rulemaking has emerged. The Federal Rail Administration (FRA) has requested that Congress address hours of service issues for train engineers (under congressional mandate, not FRA control) during the past several sessions with no specific proposals emerging. Recently medical interns and residents have petitioned the Occupational Safety and Health Administration (OSHA) and supported the introduction of congressional legislation to limit house staff work hours.

The challenges of addressing fatigue within the complexity of real-world operational settings are exemplified by the attempts of all of these Federal regulatory agencies to revise and update their hours of service rules. One example of a transportation regulation that represents a functioning rule is the United Kingdom's CAP 371, which establishes flight/duty time limitations for commercial airline, pilots. However, even this rule is under review with the intent of revising and updating it.

A review of the comparison tables provided in the NRC documents further illustrates the complexity faced by regulatory agencies addressing this issue. While the tables identify some variables for comparison, further examination illustrates the significant inconsistencies across these operational environments. For example, in commercial aviation there is an 8-hour flight time limitation; there is no specified duty limit. However, there is an 8-hour off-duty requirement in each 24-hour period, effectively (through simple subtraction) creating a 16-hour duty limit. In rail, there is a 12-hour duty limit but no limit to the number of consecutive duties. As pointed out, in some modes there are monthly or annual duty limits and not in others. There also are inconsistencies in the off-duty time required. In some modes, like aviation, there are different regulations for different flight operations (e.g., Part 121 Vs Part 135 Vs Part 91).

c. Start with sleep and consider the complexity.

Unfortunately, the focus on limiting work hours does not acknowledge some of the most important scientific data that do exist or the complexity of translating the science into real-world operational settings. First, the strongest and most extensive data demonstrate that **sleep** is a critical factor in promoting alertness and performance in *subsequent* wakefulness. Data clearly show that acute and cumulative sleep loss degrade subsequent alertness and performance. Therefore, any "hours of service" policy should emphasize the provision of an appropriate sleep opportunity prior to duty. This is perhaps so obvious that it gets lost in discussions focused on limiting work hours. If individuals are not fully rested prior to starting a work period, then their performance will likely be reduced while awake. The subsequent number of work hours can only further degrade an already reduced performance potential. While there is a strong physiological basis for addressing this sleep issue first, in real-world operations it also raises other difficult areas. For example, how individuals utilize their time off when intended to provide a sleep opportunity.

Therefore, the first emphasis should be to provide an appropriate sleep opportunity that supports alertness and performance during work. This addresses the issue of minimizing acute sleep loss. The second emphasis should be to provide appropriate sleep recovery opportunities. That is, if a cumulative sleep debt should accrue, there are identified opportunities to recover. Again, a focus on minimizing acute and cumulative sleep loss provides a well-rested individual prior to beginning a work period.

While the available scientific data establish sleep as a foundational factor for any work hour limitation structure, the full complexity of addressing "hours of service" should be acknowledged. For example, the acute and cumulative work hours need to be addressed. The acute situation involves a single work period, while the cumulative considerations include double-shifts, overtime, and consecutive workdays. Both the sleep and work hours (continuous hours of wakefulness) are affected by a third physiological factor: circadian rhythms. The circadian timing of both work and sleep will affect the quantity and quality of sleep and waking performance and alertness levels. Hence, the structure for hours of service limits begins to become complex. In an attempt to further address cumulative issues (both sleep and wake) consider weekly, monthly or annual limits. Though in this arena, data to guide specific policy limitations are essentially non-existent.

While addressing sleep and the hours of continuous wakefulness as core physiological considerations in any work hour limitation policy, circadian effects and interactions with these factors should not be underestimated. Adding a "circadian" aspect to work hour limitations only furthers the complexity of any hours of service structure.

d. The science: an extensive foundation with critical gaps.

As stated in Section 1 of this document, an extensive foundation of scientific data clearly establishes that "fatigue" reduces alertness, performance, productivity, mood, and safety. However, the current operational need is to identify and implement very specific policies or regulations intended to reduce these fatigue-related risks. Unfortunately, there are some critical gaps in the available scientific literature that do not provide the specificity needed for establishing real-world regulatory policies. These policies require a specific number: for off-duty periods, for work hour limitations on a 24-hour basis, for extended work periods, for recovery opportunities, etc.

Generally, policymakers and expert scientific panels have relied on generalization, extrapolation, and interpretation to take the available scientific data and translate it into specific regulatory structures and numbers. A review of the scientific literature typically cited to support regulatory policies will show that no study exists that was designed or conducted to specifically establish work hour limitations, in any industry. This is critical because it demonstrates how scientific studies, not specifically designed to address work hour issues, have been used post-hoc to suggest or even establish limitations.

Recently, often-cited examples of this are two studies that compared performance under conditions of continuous wakefulness and alcohol. These studies provide results that clearly fit under Section 1 of this document. That is, sleep loss and extended periods of continuous wakefulness can show performance decrements similar to the effects of alcohol. An important concept that supports the premise that fatigue can reduce performance. However, neither of these often-cited studies was designed to establish a regulatory duty limitation.

Though a full scientific review of these studies is beyond the scope of this document, some brief points illustrate the limitations of generalizing their findings too broadly. For example, even a cursory examination of the wake vs alcohol performance curves from these studies shows a distinct circadian pattern. This represents a classic confounding methodological issue in sleep loss studies: how to differentiate the effects of sleep loss and prolonged wakefulness from those of the circadian clock. Though subjects are performing during periods of prolonged wakefulness, they are also performing at well-documented circadian periods of reduced performance. So, how much of the observed effects are due to sleep loss and being awake and how much to the effects of the circadian clock? Can the performance tests used as outcome measures in these studies be directly extrapolated to flying an airplane, driving a truck or the control room of a nuclear power plant? Real-world operations are much more complex. Even further, how should the laboratory-based performance tasks be translated into operational performance or specific safety risks?

Again, these studies show that prolonged wakefulness can reduce performance comparable to alcohol. It is questionable how appropriate it is to extrapolate beyond this general finding to the creation of a very specific regulatory limitation and the associated safety implications.

e. Quantifying "safe" can be challenging.

A critical area that requires explicit operational definition is establishing what is "safe." Too often, in many discussions (especially in human factors domains) "safety" is never explicitly defined. Unfortunately, this can reduce safety discussions to personal anecdote or the generalization of one occurrence to standard practice. As previously stated, a specific and clear statement of attainable objectives must be established. These safety objectives should be operationally defined and amenable to measurement.

This issue is related to the scientific design and methodology used in studies that become generalized to establish work hour limitations. Rarely when citing study findings for support of a specific work hour limitation is there any discussion of the measures or design used in the study. However, there are key questions about relevance and generalization that should be raised. For example, how are the study measures related to operational performance in a particular setting? Are there comparisons that can quantify the lab-based measures and outcomes in terms of operational safety?

It will be important to evaluate the relevance and appropriateness of measures (e.g., performance) and findings from laboratories and other industries for application in the nuclear energy industry. There may be instances where there is a direct relation and in other areas results may not be appropriate to generalize.

This issue is particularly relevant when considering safety. The nuclear energy industry has well-defined and established safety layers that are intended to prevent errors or stop one from evolving to a critical stage. These safety assets of the nuclear energy industry should be analyzed to determine how they create an environment different from other operational settings. These safety procedures may change the profile of fatigue risks in the nuclear energy industry and provide a mechanism for addressing these issues within an existing framework.

f. Fatigue monitoring technology.

Since there is no "blood test" for fatigue, a variety of operational environments have focused on technology as a method for detecting fatigue. These technologies take the form of fatigue or alertness monitors, or are characterized under the areas of readiness to perform or fitness for duty. There are an estimated 100 to 150 of these "devices" in development or being marketed. A variety of considerations have been outlined that should be evaluated before implementing a technological solution (2). While there are many claims and tremendous optimism about these technologies, an objective and empirical position should be the basis of evaluating their potential. The first and only laboratory-based study to evaluate and compare six different devices found that only one significantly correlated to performance measures validated as sensitive to sleep loss and circadian factors (3). Ongoing development and research of varied technologies should be encouraged. Their future implementation should be based on objective scientific data establishing their effectiveness in operational settings. Also, the policy and legal ramifications of these devices should be fully explored prior to widespread implementation.

g. Acknowledge the economics.

Two significant barriers to change related to fatigue include history and economics. History characterizes the cultural attitudes and operational practices that can represent significant impediments to change. Economics plays a central role in maintaining the status quo and as a barrier to change. The economics of managing fatigue can range from corporate costs related to staffing, to the cost of meeting regulatory requirements, to the costs associated with an accident, to individual operators' incomes due to overtime. While the safety issue should be the primary focus of any activity, it is naïve not to directly acknowledge the economic consequences of recommendations and actual interventions. At a minimum, the economic aspects should be explicitly identified, discussed, and overtly acknowledged. Without this type of direct acknowledgment, economic issues can subvert any attempt to implement change.

h. Focusing on work hours to the exclusion of other important factors.

While necessary, work hour limitations (broadly defined) are not sufficient to fully address the complexity of fatigue in real-world operational settings. Unfortunately, the almost exclusive focus on work hours often ignores other effective avenues for addressing fatigue. A variety of opportunities available to reduce fatigue-related risks are described in the next section. Many of these opportunities are easier, more straightforward, and could be implemented faster than a purely work hours approach. For example, increasing education and information about fatigue within the industry would allow an even more structured and consistent approach to reduce related risks.

3. Opportunities to manage fatigue in the nuclear energy industry.

a. The need for a comprehensive fatigue management approach.

Operational requirements are varied, there are differences among individuals, and the physiology of fatigue is complex and therefore, a simple, single or one-size-fits-all approach to addressing fatigue will not be effective. Add to these factors history and economic barriers and the need for a comprehensive approach emerges. The components and outline of a comprehensive fatigue or alertness management program have been described elsewhere (4,5). Program components include education and training, alertness strategies, scheduling, and healthy sleep. This approach to managing fatigue is currently underway in a variety of operational settings in different countries. The NRC documents describe this approach and identify its potential. It is also pointed out that there is little or no published data about the effectiveness of this fatigue management approach. Similarly, there is little or no published data about the effectiveness of any hours of service or work hour limitations scheme to address fatigue. Rather than review the components of a program, specific recommendations based on a fatigue management approach will be presented.

b. Institute education and training activities.

Across industries and all modes of transportation, the single element agreed upon by all parties is the need for a foundation of education and training related to fatigue and effective alertness strategies. Given the amount of training provided, and required for, operators across settings, there is an obvious gap in the information provided about fatigue. This is in spite of the requirement that operators be alert and awake while on station/duty.

The nuclear energy industry should identify educational opportunities to introduce fatigue training and develop curriculum and standards for these educational activities. A multi-year program should be developed so that fatigue education does not become the "safety issue of the month" but rather an ongoing part of training. Industry stakeholders should decide if there should be requirements for education and training or whether these activities can be "voluntary." These educational activities should extend to all personnel in the industry, including operators, management, and regulators.

c. Identify and implement personal and organizational alertness strategies.

There are a variety of scientifically validated strategies shown to improve alertness and performance, such as planned naps and strategic caffeine. Strategies appropriate for the nuclear energy industry should be identified and policies developed for their implementation. Individual operators may use some of these strategies but appropriate organizational support and policies should complement them.

d. Scheduling principles and guidelines.

The full range of "hours of service" issues needs to be identified and addressed. A comprehensive list of factors (e.g., minimum rest, duty length, recovery requirements, consecutive days, circadian considerations, and more) would allow the creation of a system that provides appropriate balance between these factors. Potentially, a document identifying scheduling principles and guidelines on their application within the nuclear energy industry could be created. Examples of this approach exist in the aviation industry (6,7). A hallmark of this approach is the clear identification of scientific scheduling principles. The application of these principles can be diverse and requirements met by innovative scheduling practices.

e. Develop industry policies to address sleep disorders.
Sleep disorders are prevalent and some (e.g., sleep apnea) have clearly been linked to car accidents and significant performance decrements. However, addressing sleep disorders is a complicated issue that touches medical concerns, confidentiality, treatment effectiveness, insurance needs, liability questions, and more. The nuclear energy industry should establish a task force to examine these many different issues and recommend policies to address this component of a comprehensive fatigue management approach.

f. Identify and pursue important operational research.
While there is a tremendous scientific foundation to address many fatigue-related issues, as previously identified, there also are gaps. Therefore, the industry could identify operationally relevant fatigue issues that could be addressed through specific research projects. These should be well-defined studies that have a clearly identified operational question that will be answered from the results. Studies focused on industry-specific issues and situations could provide objective, empirical data upon which to base decisions. Appropriate stakeholder support should be used to move findings into operational practice.

g. Create pilot programs and mechanisms for change.
Most hours of service policies were written and implemented decades ago. Many stakeholders are hesitant to implement new changes given how long these policies generally stay in place. Therefore, stakeholders should define the elements of pilot programs that could be implemented in short timeframes, evaluated, and changes made within a reasonable time. If deemed effective, through empirical metrics, then pilot programs could be expanded rapidly throughout the industry. If needed, changes could be made prior to expanding activities. Also, if ineffective, programs could be ended without long-term consequences, costs, etc.

At the very least, newly instituted activities, whether work hour policies or educational, should have a defined timeline for objective evaluation and clear mechanisms to make changes in a timely manner.

h. Address the overtime issue.
The industry should undertake a full analysis of overtime issues, especially their relationship to true operational demand. Overtime can be related to extended hours of wakefulness and may represent a fatigue-related risk that requires explicit policies to address. However, these policies should be developed within the context of a comprehensive understanding of this issue.

i. Create preventive industry scenarios for operational deviations.
The NRC documents identified a variety of situations that created operational deviations that required schedules beyond standard policies. Specific industry scenarios that have already occurred and others that could occur should be identified. These scenarios should represent a range of potential operational deviations. Given these defined scenarios, fatigue-related interventions and policies should be developed to address these circumstances. Like other

preventive scenario exercises, these fatigue-related ones could establish industry-sanctioned approaches to manage known and projected operational deviations.

j. Need to maintain safety and operational flexibility.
An essential element to any approach that addresses fatigue must include appropriate provisions for operational flexibility. Real-world operations can be affected by many different variables and opportunities must exist for responding to these potentially unknown circumstances. This operational flexibility should be provided within the overall context of safety.

k. Some guiding principles.
Whenever possible, there should be a scientific foundation for fatigue management activities. This empirical approach allows many complex and contentious issues to be bridged through the application of objective scientific data. Where gaps exist, it should be explicitly stated when policies or activities are based on other than scientific findings.

Managing fatigue-related risks in any 24/7 operational setting is a shared responsibility among all stakeholders. Unfortunately, addressing fatigue often involves a lot of "finger pointing" at "others" that are responsible. However, the issues involve everyone and are too complex for simple solutions. Therefore, it is critical to fully engage all stakeholders and require balanced commitment that fatigue is a shared responsibility among all parties.

l. Innovate and consider options.
Perhaps the most significant opportunity for change resides in the possibility of innovation. Many individuals will identify "what doesn't work." However, the challenge of addressing these complex fatigue issues also presents many opportunities. For example, perhaps a prescribed work hours limitation policy could be identified. Also, a comprehensive fatigue management approach also could be outlined within the context of the many elements identified here. Perhaps organizations could have options to either utilize a specified work hours limitation structure or pursue a clearly defined fatigue management approach (that included scheduling policies).

The nuclear energy industry has made significant progress to address this complex issue. The industry faces challenges similar to those experienced in transportation and other safety-sensitive 24/7 operating environments. This document is intended to address some of the scientific issues currently under discussion and to provoke consideration and discussion beyond the current proposals.

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