March 3, 2022

Dr. James K. Olthoff
Director
National Institute of Standards and Technology
Gaithersburg, MD 20899

Dear Dr. Olthoff:

This is in response to your letter of August 16, 2021, requesting assistance in assessing the circumstances of the unplanned shutdown on February 3, 2021, of the National Institute of Standards and Technology (NIST) reactor at the NIST Center for Neutron Research (NCNR).

This assessment was based on a review of all documentation made available by the NCNR staff, a series of briefings on the event provided by NCNR and NIST staff, and a site visit to the NCNR on February 2, 2022. In addition, a review of all public documents related to the event under the NCNR docket on the U.S. Nuclear Regulatory Commission (NRC) web site was performed.

To understand the basis for my comments, my experience with the NIST reactor started in 1986 and spanned my career with the NRC including six years as the Chief of the Research and Test Reactor Licensing Branch overseeing licensing of the NCNR reactor. I also have experience in research reactor operations, engineering, and management from 12 years at the University of Buffalo research reactor.

1. An assessment of the conditions that allowed the February 3rd incident to occur.

The conditions contributing to the event can be placed into two major categories, administrative issues (management systems, requalification and training, procedures, and safety culture) and hardware issues (instruments, equipment, and tools). These weaknesses have been well documented in reports from the NCNR internal Technical Working Group and the Safety Evaluation Committee (SEC). The root causes of the weaknesses identified in these reports are important and need to be corrected. Like most significant events, this event was not caused by one particular failure, but was the result of many failures that together caused the event.

The primary condition that allowed the event to occur was the inability of NCNR management over a number of years to fully appreciate and adjust how the facility was operated to compensate for the of loss of experienced management and staff. My early interactions with the reactor staff were with persons who had been at the facility for years. This resulted in-depth knowledge of all aspects of the reactor design and operation. The level of formality (or more appropriately informality) in operation was commensurate with the knowledge and experience of the staff at the time. For example, this detailed level of operator knowledge and "skill-of-the-craft" resulted in procedures that lacked depth and precision, that were not reviewed before evolutions occurred and were not precisely followed. This occurred without significant impact on reactor safety.

Along with the loss of staff experience came the enhancement of the NCNR's mission. In discussions I was told that the increase in experimental capability that came with the construction of the neutron guide hall resulted in greater importance to maintain schedules and an increased operating tempo. The reactor staff was asked to do more while experiencing a loss in capability.

As new staff and management replaced long standing management and staff, significant increases to the formality of NCNR reactor operations did not follow. This can be seen in the root causes identified. Management structure remained relatively flat despite the need for a more robust management structure to oversee reactor operation given staff changes. Management oversight and training did not increase sufficiently to compensate for the diminished experience of the operations staff. Change management did not sufficiently address the turnover in management and staff. The training and requalification programs to develop and maintain proficiency did not evolve with the needs of the staff. Procedures were not updated to account for less experienced users.

The NCNR has a long history of excellent regulatory performance. This may have resulted in a false sense of security about the need to change what had been successful for many years. Complacency also appears to have taken hold without a strong desire for continuous improvement. This is not to say enhancements to operations were not made over time. Discussions with NCNR staff and management indicated an awareness of the need for improvements to aspects of operations before the event, but the event occurred before these improvements could be fully put in place.

Failure of a fuel element to latch onto the upper grid plate led to the element being damaged. This fuel element being unlatched during the start-up of February 3rd was the top-level root cause of the event. Discussions revealed that the cause of the failure is not exactly known. It is possible that there is a weakness in the initial design of the latching system that allowed the fuel element to become unlatched, but reviews have identified no design weaknesses. There could be wear to the grid plate that made the system more susceptible to becoming unlatched, but inspections have ruled out wear as is contributing factor. What remains is that over time, changes in the way the system was operated could have resulted in system operation not consistent with the intent of the designers. Whatever the cause, the reactor operator was not alerted that the fuel element was unlatched. The fact that a downward force on the top of a fuel element while checking height above the fuel element could unlatch the fuel element was a recent discovery that occurred while investigating the event. Discussions indicate that it is not clear if height checking was an operating procedure from the original design of the system. There is a possibility that trying to improve confirmation that a fuel element was latched introduced a procedure that unintentionally unlatched a fuel element.

Several changes to the process of confirming that a fuel element was properly seated and latched have occurred over the years (e.g., changes in performing checks with flow on or off). There appears to have been a partial loss of understanding over time as to how the system was initially designed to operate. It is unclear if fiducial marks existed on the index plate to help confirm refueling tool placement. There also appeared to have been alignment pins whose function was to assist in alignment of the reactor plug and upper and lower grid plates that were damaged and not replaced. Why these pins were not replaced is not known.

The reactor was started in 1981 and 1993 with a fuel element unlatched. Fortunately, power fluctuations indicative of reactivity changes in the reactor core alerted the reactor operator and led to shutdown of the reactor before damage could occur. However these fluctuations were not identified at the time as being caused by boiling in the fuel element cooling channels which may have impacted the scope of corrective actions. There were also occasions where pre-start checks detected fuel elements that were not latched. These near misses did not receive sufficient investigation and while changes were made in latching confirmation procedures, the event shows that effective corrective actions were not developed. While there were power

fluctuations during the start up that led to the event, they were not considered significant enough to abort the start-up. This lack of a questioning attitude and not determining a root cause of event precursors are also conditions that led to the event.

The importance of the safety review committee to reactor safety is a long-standing facet of research reactor regulation. One of the purposes of this committee is to bring expertise that a facility may not have and to see trends that may not be visible to reactor management due to their closeness to the facility. That the SEC was unable to identify the challenges related to declining staff expertise or help ensure that corrective actions in response to the precursor incidents to the February 3rd event were comprehensive contributed to the event.

Much discussion focused on safety culture at the NCNR. While there are no direct NRC regulations requiring a safety culture program, it has been shown that a strong safety culture at a facility helps focus facility activities on outcomes supportive of safety and helps prevent NRC violations. While the nuclear power industry has fully embraced safety culture and have clearly shown its advantages, only a few of the larger research reactors have safety culture programs. While it is difficult to say with certainty if weak safety culture allowed the event to occur, a strong safety culture would have increased the probability of identifying many of the root causes of the event.

2. An assessment of the NCNR's emergency response to the event.

Generally, the NCNR's emergency response to the event was acceptable as discussed in the NRC inspection report on this subject. One of the purposes of emergency planning is to respond to events that were not fully considered in the evaluation of the facility, in other words, to respond to unknowns. While event classification and determination of the impact to the public appeared adequate, some aspects of the response reveled weaknesses. Surprising to me was that an emergency event that resulted in evacuation of the confinement was not the subject of emergency drills. This was evidenced by the reactor operators not having a checklist for leaving confinement under emergency conditions and not having procedures for reentry. Apparently, an event that would force evacuation of confinement was considered beyond even the realm of emergency planning. The failure to secure carbon dioxide flow when evacuating and the buildup of carbon dioxide within the confinement building was a much greater threat to health than the event itself. There have been positive steps to address these weaknesses. Event scenarios that appear unrealistic should be developed and exercised. Insights into improving response actions can result. Addition crew training time should be devoted to emergency planning response.

3. The NIST organizational response to the incident.

The interface between NIST and the NCNR during response to the event and afterwards appeared acceptable. NIST public affairs provided valuable expertise in interactions with the public. NIST should be prepared for additional public interaction when the final NRC response to the event becomes public. NRC public affairs would probably give NIST advanced warning of any press release.

The discussion with NIST staff about institutional risk management was surprising in that NCNR regulatory risk was not seen as a NIST institutional risk. However, loss of neutron research was seen as a NIST institutional risk. The reason regulatory risk was not considered is that the calculated accident doses at the NIST fence line from accidents are well within regulatory limits. While this was shown by the measured doses at the NIST boundary from this event, regulatory

risk consists of more than radiation doses. As was seen, the impacts of the event are more than just the loss of neutron research. Impacts include the expenditure of significant resources for recovery and permanent improvements, significant interaction with the NRC including the need for NRC permission for reactor restart, the possible negative view of NIST by the public, local, and state government, and the reactions of NIST's Federal overseers.

Adding reactor regulatory risk to the NIST institutional risk management program should be carefully considered.

4. The efficacy and completeness of the proposed corrective actions.

Generally, the corrective actions were well considered. As is the case with any event, the NRC will be concerned with the corrective actions, especially why the corrective actions will prevent reoccurrence of the event. The NRC will also be interested if the corrective actions took a broad view of the event to help ensure that the potential for future events of all kinds are reduced.

The discussions of the physical steps of cleaning debris from the reactor and preparing the reactor for restart appear reasonable. The addition of confirmation of fuel element latching by video confirmation is in a positive step and should significantly reduce the possibility of a reoccurrence of the event.

NCNR engineering should continue to investigate the latch system to determine if a redesign would be warranted. The difficulty of making changes to the grid plate is recognized, therefore changes may need to be made to the fuel element instead. The impact of unintended consequences on reactor safety of any redesign effort should be carefully considered. The role of index marks on the index plate and the use of alignment pins should also be evaluated.

Power fluctuations during the startup that led to the event were not considered significant enough to abort the start-up. It appears that the fluctuations were attributed to control rod system maintenance that had occurred. From a review of power traces during the event startup and normal startups, clear differences could be seen. The development of a complex approach towards determining what level of power fluctuations during startup is acceptable is being considered. There are many examples of power traces during normal startups. Power fluctuations beyond normal are an indication of a problem that should not be allowed. There are too many uncertainties to determine a safe level of power fluctuations beyond normal. Training should emphasize proper reactor response during startup and immediate steps to take if this is not the case. While this may result in some startups being terminated and evaluated, the consequence of being wrong could lead to a repeat of the event.

Several calculations were reviewed concerning heat transfer in fuel element coolant channels containing a foreign object (debris from the event). The purpose of these calculations appears to be laying a foundation to present a case for returning to operation fuel elements that may have debris from the event in the flow channels. If there are fuel elements in this condition, their return to operation should be very carefully considered given the potential unknowns and unintended consequences. If a decision is made to move in this direction, the NRC should be clearly aware of the NCNR's plans and should agree.

Observations during the site visit showed a commitment to improving safety culture at all levels of NCNR management and staff. Safety culture cannot be established by edict or procedure. It cannot appear overnight. The commitment and involvement of management must be clear and

continuous. Attributes such as continuous improvement, resisting complacency, and a questioning attitude must become second nature. This effort must continue.

The importance of the safety review committee to reactor safety is a long-standing aspect of research reactor regulation. The safety committee should have the freedom and expertise to help reactor management understand issues that may be difficult to see given the day-to-day responsibility of running a facility. The NCNR is unusual in having two review committees, the SEC and the Safety Assessment Committee (SAC). While the SAC is a wholly external committee of very knowledgeable members their time on site has been limited to a week or less per year with a phone briefing about six months after their site visit. While their contribution to reactor safety is very important and needs to continue, they are only seeing snapshots of facility activities and primarily are looking at past activities. Additional engagement of the SAC may be warranted leading to reactor restart.

There needs to be enhanced SEC oversight leading up to restart. NCNR management should consider changes in the operation of the SEC by performing a top to bottom review of SEC activities. Because of the complexity of NCNR operations, the significance of the event, and the importance of maintaining corrective actions moving forward, the SEC should have the ability to review all aspects of NCNR activities. Technical Specification (TS) 6.2 states that the SEC exists to provide an independent review of reactor operations. Given the event, consideration should be given to expanding the review function to engineering and management activities. The review and audit functions in TS 6.2.3. and 6.2.4 are very narrow. Consideration should be given to the SEC performing activities beyond those in the TSs. TS 6.2 states the committee is independent. It is difficult to see this independence when TS 6.2.1 states that the membership will consist of no less than 4 members with two members from the NCNR and one from Health Physics. The committee membership should be revised to be independent so that the majority of a voting quorum consists of members without organizational ties to the NCNR. This independence is also consistent with the American Nuclear Society TS standard (ANSI/ANS-15.1)

The SEC should have a leading role in reviewing NCNR activities moving forward to confirm that corrective actions have been properly and fully implemented. Also, the SEC needs to take a leading role in continuing to audit NCNR activities to help confirm that backsliding towards the root causes that contributed to the event do not reoccur. The SEC may need to have an increased presence at the NCNR until all corrective actions are in place. This may require a change to the SEC charter and additional SEC resources.

The NCNR is unique among NRC regulated research and test reactors as the only operating test reactor. Opening and maintaining lines of communication with similar reactors would allow for the exchange of ideas. A better understanding of events elsewhere could result in potential lessons learned for the NCNR staff and would be consistent with a strong safety culture. Potential candidates for these exchanges could be Department of Energy test reactors or reactors overseas such as the Open Pool Australian Light-Water (OPAL) Reactor operated by the Australian Nuclear Technology Organization or Petten High Flux Reactor (HFR) in the Netherlands. Discussions I have had with other test reactors reveal that preventing complacency, maintaining continuous improvement, and supporting a strong safety culture are not issues unique to the NCNR.

Placing the corrective actions in place will involve significant resources. It will also involve a continuing resource commitment to maintain the corrective actions. From discussions with staff, an additional operating shift is key to putting into place and maintaining improvements in training

and qualification, procedural adherence, and safety culture. However, there is a large level of skepticism if resources will be made available to make the needed changes and if resources to maintain the corrective actions into the future will be made available. The message that the corrective actions must and will be fully put in place and maintained needs to be reinforced. There is also a clear expectation from the NRC that a licensee will make resources available to safely operate the facility.

NCNR management should consider adding important corrective actions to the TSs. This would show a clear commitment to the corrective actions and would allow a clear articulation to NRC why the corrective actions are important to safety. This would also require a clear justification to NRC to relax or discontinue corrective actions if that decision is made in the future. While having any action in the TSs does not guarantee it will be carried out successfully, having an action as a TS will result in additional focus on carrying the action out. It also means that the corrective actions added to the TSs will be subject to NRC inspection activity, allowing an additional evaluation of its effectiveness.

While the corrective actions will significantly reduce the possibility of a repeat of this event, NCNR management and staff should carefully review all aspects of reactor operations to help ensure that the conditions for a different future event do not exist.

In closing, from my experience, the value of the mission of the NCNR supporting neutron research cannot be understated. The reactor should be returned to operation and the corrective actions maintained.

I would like to acknowledge the cooperation shown by the NCNR management and staff which contributed to my understanding of the event and the corrective actions. The candor of the discussions I had with NCNR management and staff was commendable. Please do not hesitate to contact me if there are any questions about my observations.

Sincerely,

Alexander Adams Jr.

cc: R. Dimeo, NCNR