Assessment of NCNR and NIST Related to the February 3, 2021 Incident

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The Importance of NCNR

As documented in numerous publications, neutrons are valuable tools in advancing the frontiers of science and for meeting industrial needs. This importance has been recognized by the many scientifically advanced countries that have in recent decades invested in state-of-the-art neutron research facilities. The U.S. has retreated from its once-commanding position in neutron science. The situation is particularly dire for U.S. research reactor capabilities. More than 50 years after its commissioning, NCNR is the "newest" of the nation's high performance research reactors. It has become a highly valued and oversubscribed workhorse for neutron scattering/cold neutron science in the U.S., providing some 40% of all U.S. neutron science productivity, including over 3000 research participants and over 50 companies per year. The loss of this capability for over a year has thus had a significant deleterious impact on the U.S.-based science that depends on neutron scattering. The fields of soft and biological materials have been particularly hard-hit, although other fields have felt the impact, as well. **The importance of neutrons for research in important forefront areas of scientific inquiry, coupled with the dearth of other capacity for these experiments elsewhere in the U.S. makes it imperative to restart NCNR as soon as it is safe to do so.** U.S. competitiveness in scientific areas important for emerging technologies depends on the availability of this facility.

The NIST-NCNR Relationship

NIST should take great pride in NCNR and the capabilities it provides for the U.S. neutron community in industry and academia. Instead, there seems to be a rather arm's-length relationship between NIST and NCNR. While elaborated in some instances in addressing the charge, other areas where this became apparent include:

- NIST services (e.g., HR) do not seem to fully understand some of the differences in the environment in which NCNR operates relative to the rest of NIST. The fact that other federal entities (e.g., NRC) can compensate potential reactor operators at a much higher rate than NCNR can (due to differences in job classification, I believe) suggests that creativity and possibly advocacy on the part of HR may be required to address some of the most serious issues surrounding the restart and continued safe operation of NCNR. NCNR management cannot address this issue on its own: support from the highest levels of NIST will be required for a successful resolution.

Addressing the Charge

The conditions that allowed the February 3rd incident to occur: The circumstances that led to the February 3, 2021 incident accumulated over time, making an incident of some sort inevitable. Specific issues, most of which have been identified in the exhaustive root cause analysis included:

- Staffing:
    - Historical dependence on expert-based operations: For much of the life of the NCNR, the reactor operators have been a close-knit, long-serving team, with extensive experience in reactor operations. Such staffing enabled the development of and reliance on expert-based operations depending on deep knowledge and "feel" rather than written procedures. In fact, the culture developed an antipathy to use of written procedures, which was communicated to newly hired operators who received the message that reliance on written procedures was, in effect, a sign of weakness. Questions from newer operators were frequently derided, leading to a decrease in their inclination to ask questions.
    - High percentage of new (to NCNR) operators: There has been significant turnover in the ranks of reactor operators. While the newer operators, in general, have reactor operations experience, it has not been at NCNR. Many are not yet qualified, an issue exacerbated by the pandemic, which not only slowed the qualification process but also led to infrequent operations, so that operators could become rusty. The newer operators have found the culture promulgated by the "old timers" not supportive of a written procedure-based operating system. They also found that the procedures in existence at the time of the incident were inadequate in detail, outdated, and, in some instances, wrong.
    - Inadequate staffing: Reactor operators staffing is woefully inadequate. Almost all crews are short-staffed in terms of licensed operators. And the number of highly experienced reactor operators at NCNR is dropping quickly.
- Culture of Complacency
    - Previous "near misses" and other anomalies: There were, over the decades, circumstances that mirrored those leading up to the February 3 incident that were caught before they affected reactor operations. They were not sufficiently examined to determine the root cause and correct the issue(s). Had that occurred, NCNR would likely be operating today.
    - "Sliding" of various requirements: Perhaps the most glaring example of "sliding" requirements is found in the changing dimensions of refueling tools, with different generations of tools having measurably different dimensions, thus requiring "expert judgment" and "feel" rather than objective measurement to determine proper placement. The absence of various fiduciary marks (not reflected in the procedures is another example of sliding requirements without regard to potential consequences. The breakdown of communication between reactor operators and the engineering organization became apparent in these instances.
    - Reactor Qualification: Historically, reactor qualification has been done by relying on the certification of a supervisor that an operator is qualified to do the work. This process has not involved quantifiable metrics or other objective measures of operator capability.
    - Requalification: Operator requalification has been required every two years and is done as a "en masse". Furthermore, the requalification requirements have, to a significant extent, depended on the judgment of the individual overseeing the requalification. This has meant that not all aspects of operation are necessarily covered in the level of detail needed to ensure truly qualified operations. There is no "mid-term" requalification

process to ensure that reactor operators stay sharp, nor has there been requalification if an operator has not performed a process for a long period of time.

- Training: Training for refueling, the operation that led to the February 3 incident, is done on a set-up that does not closely mimic the actual refueling in important ways. As a result, a trainee who may be proficient in the operation on the training apparatus may encounter difficulties when doing an actual refueling operation.
- Loss of Institutional Memory:
    - Operations and Maintenance: Some aspects of reactor operations and maintenance have historically been the responsibility of a single operator. Some of these individuals have left NCNR without thoroughly documenting their responsibilities, leaving their successors to try to recreate previous procedures and practices.
    - Culture: On the positive side, the almost complete turnover of reactor operators in recent years offers an opportunity to set a new culture for the future – one that embraces thoughtful adherence to thorough and up-to-date written procedures and that values continuous learning and a questioning attitude.

NCNR's emergency response to the incident: Many aspects of NCNR's emergency response to the incident were handled very well. The response in the immediate aftermath of the incident (as opposed to the issues that arose several days later upon reentry to the facility) was handled primarily by NCNR, with appropriate notification and engagement of other NIST resources as required. The interactions with the community were handled in an exemplary manner and should be captured as a best practice, not only for NIST, but for other facilities, as well. In terms of the immediate response to the incident itself, relatively small issues appeared that deserve attention for the future:

- While there had been drills for emergency response, none of them mimicked important aspects of the actual occurrence, for example, the short time to evacuate the facility or the long time (days) before the facility could be reentered. A wider range of potential scenarios should be included in the drills. Further, the conditions of a particular drill should not be revealed to those participating before the drill takes place (if that is not done already).

The issues surrounding the reentry into the facility the day after the initial incident are more concerning and revealed the need for more in-depth consideration of all aspects of incident response. While responsibility for the first part of the incident response on February 3 clearly rested with NCNR and was, in general, dealt with effectively, the "near miss" during the reentry revealed a number of missteps and missed connections including:

- Individuals in NCNR noted various unusual conditions prior to reentry such as the fact that the CO_2 had not been turned off and the change in the pH of the water. These were not communicated in a way that was "heard" by those who needed to consider these conditions when planning for the reentry.
- The building reentry quickly became an industrial emergency (as opposed to the February 3 rad emergency) when it became apparent that the building was unsafe. This put primary responsibility for the episode under the control of NIST, not NCNR. The lack of a good handoff between the NCNR rad response and the NIST industrial safety response reflects lack of communication and systems thinking. It is a symptom of the somewhat arm's length

relationship between the two organizations. The fact that no one was injured or killed in this incident is attributable only to the care and keen observations of the crew entering the building.

NIST's organizational response to the incident: NIST's response to the incident went through several phases. The immediate response to the incident on February 3 was outstanding. All critical stakeholders were notified and kept informed, and the engagement with the community was outstanding, based on the community response. The response to the follow-up episode of building reentry, showing fault lines between nuclear safety (owned by NCNR) and industrial safety (owned by NIST) reflected the rather loose connection between NCNR and the rest of NIST as already discussed. The issue runs deeper, however, since safety and operations of the reactor are NCNR's responsibility, while the condition of the building in which the work is done is the responsibility of NIST. This situation posed the potential for significant finger-pointing, and there is at least some evidence that there are at tensions along these lines. In short, the NCNR Director has the responsibility for the safe operation of NCNR but lacks the authority and resources to implement some actions required to ensure safe operations.

NIST's engagement in the Safety Evaluation Committee has been good and has contributed to a good outcome of the committee in terms of root cause and corrective action determination. The major issue going forward is the lack of substantive engagement by NIST, as opposed to NCNR, on the risks associated with NCNR, which also pose risks for NIST writ large. It is commendable that NCNR is recognized as a high consequence/low probability operation in NIST's risk management system, but it was apparent from our meetings that evaluating the various aspects of the risk and the detailed evaluation of mitigation and/or acceptance options has not been done at the leadership level.

The efficacy and completeness of the proposed corrective actions: The root cause analysis has been well done, and the proposed corrective actions will contribute significantly to ensuring safe operations going forward. The most important items in the corrective action plan as articulated, as well as some other thoughts for consideration, include:

- The need for additional staff – enough to fully staff the existing four shifts, and a fifth shift. If this is not done, there is a high likelihood of additional issues (although almost certainly not the fuel latching issue). Resolving the staffing issue requires the full attention of NCNR management and true help and support for the NIST HR organization, as reflected in creative thinking and actions about ways to attract qualified staff to positions that offer competitive compensation relative to related jobs elsewhere in the federal government.
- Leadership engagement – the current NCNR leadership clearly recognizes the importance of engaging more deeply in the day-to-day operations. The challenge will be to make sure this commitment continues as the leadership changes and as other (non-safety) challenges arise that demand leadership time.
- Resources to implement corrective actions on a continuing basis – The corrective actions require resources, some of which have already been mentioned. Both NIST and NCNR leadership must deliver those resources to develop and maintain credibility with the NCNR staff and demonstrate their commitment to creating a safe and productive working environment.
- Culture – Going forward, it is insufficient merely to develop a culture that is not complacent. The culture must encourage questioning and critical thinking, it must value asking questions and outside perspectives. And a means must be developed not only to develop these new norms

but to maintain them far into the future, long after everyone who was present for the February 3 incident is no longer at NCNR. The staff turnover among the reactor operators is an outstanding opportunity to reset the culture to embrace these attributes, since most if not all of the previous employees who did not embrace them have left. Still, growing, nurturing, and maintaining this type of culture is difficult, and requires continuous attention and "check-ins".

- Benchmarking and External Review: Other owners of high consequence operations have developed best practices for staying safe and, literally, not hurting or killing people. Who are "best in class" in these operations? What do they do? What would they see if the observed the NCNR operation? It would be well worth the time and effort to invite such experts to visit and observe. Some should be from nuclear operations, but individuals from other walks, e.g., the chemical industry could also have valuable insights. It may be appropriate to add some of these individuals to the SEC as it becomes a more independent body.
- Regular demonstration of proficiency is critical, with regular expiration of qualification, either on a set schedule or after an extended period of not performing the action. And it is a good idea to make proficiency demonstration not overly predictable so that the individual must exercise critical thinking. In addition, proficiency demonstration and requalification should be rigorous (not "rote") and objective (not evaluated subjectively by a single individual). In short, failure should be a possible outcome.
- A best practice being instituted in NCNR is engaging worker-level staff in writing the procedures (with mentoring when appropriate). This helps ensure that the staff own the procedures.
- The need to develop and institute training on placing fuel elements in the reactor that more nearly mimics the actual operation is recognized and is important.
- A weak interface between operations and engineering was a sign of complacency and contributed to the incident. Rigorous implementation of actions to address this deficiency will be critical.
- All current NCNR personnel are clearly committed to implementing the corrective actions that have been identified. What is less clear how effectively implementation will continue once the pressures of running an operating research reactor surface. Life will be much more challenging once operations begin and personnel have to balance their current (increased) responsibilities with operating the reactor safely and supporting the user program. Potential budgetary challenges brought on by the increased costs associated with the more rigorous operating environment may also exert pressure to cut corners. It will be important to monitor for signs of stress and "corner cutting" as operations ramp up. Updating job descriptions to include all responsibilities (including the new ones) and periodic checks to make sure that each job is do-able at the level required for safe and effective operations is important.
- As with any significant cultural change, the NCNR leadership must continue to be clear about the cultural values of the organization. Any violations of those values must be dealt with swiftly and firmly. It may be challenging, due to privacy issues, to communicate that action has been taken, but the values need to be communicated continuously, and reporting of issues needs to be strongly encouraged.

Concluding Thoughts

The vessel clean-up and return to operations are critical aspects of a "return to a new normalcy" for NCNR. The vessel clean-up offers an opportunity to exercise the new cultural norms that have been articulated. And, of course, operating the reactor requires those norms to be lived on a daily basis, but under differently stressful conditions than have been present during the shutdown. Leadership needs to be vigilant to ensure that everyone exercises critical thinking and is driven by what is the RIGHT thing to do, not what is easier or "good enough". This will become more challenging under the stresses of a daily grind in which there are time and financial constraints.

There are issues that remain to be addressed that are outside the control of the NCNR organization. These include:

- Ensuring that the responsibility for all aspects of the NCNR operations and infrastructure is appropriately assigned and that the entity with responsibility for a given area also has the authority to address it fully and safely.
- The challenges associated with attracting, retaining, and appropriately compensating the staff needed to operate the reactor and the facility, especially reactor operators. The NIST HR organization, with the support of the highest levels of leadership at NIST must engage constructively and creatively to address this challenge. Failure to succeed will affect the availability and safe operations of the NCNR.

The NIST leadership can control other issues remaining to be addressed:

- Continued vigilance, including for evidence of deferred maintenance and other conditions that could impact safety of operations and/or indicate "relaxation" of the new culture.
- Show by doing that management can deliver the promised resources and actions.

I conclude with a final suggestion: It became apparent during the site visit that the staff of NCNR consider themselves a "family." Families have their stories – episodes, sayings, memories of unforgettable family members and the like. Similarly, NCNR has a proud history with many impressive accomplishments that deserve to be remembered. While the February 3, 2021 incident is not a source of pride, the response to it, the resilience of the organization in its aftermath, and the changes that brought about in the culture and operations of the facility are both inspiring and instructive. NIST and NCNR should capture the episode and lessons learned in the voices of those who were present during this time in the history of NCNR, both for the archives and, equally important, to share the story for NCNR staff for decades to come.

I would like to express my appreciation to all who met with the individuals reviewing the February 3 incident either virtually or in person. I benefitted greatly from their knowledge and remarkable openness and candor.