The Current State of New Technology in Civilian Nuclear Applications

As part of its task, the Transformation Team was directed to consider several particular new technologies. The current state of these technologies is discussed below.

a. Digital Instrumentation and Control

Digital instrumentation and control (DI&C) is not a new technology. Such systems have been in use for more than three decades in a variety of applications both within and outside the nuclear industry. New nuclear power plants are being designed with integrated DI&C systems. However, use in operating power plants requires retrofitting of analog control and monitoring systems. Upgrades to operating plants have included the introduction of different types of digital systems, including field-programmable gate arrays, as well as upgrades of hardware systems that now include embedded digital devices.

The U.S. Nuclear Regulatory Commission (NRC) has had the current regulatory structure for DI&C in place since the 1990s, when the agency first issued a regulation incorporating Institute of Electrical and Electronics Engineers (IEEE) 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," by reference into Title 10 of the Code of Federal Regulations (10 CFR) 50.55a(h) and revised the Standard Review Plan, NUREG-0800, "Review of Safety Analysis Reports for Nuclear Power Plants," to include reviews of digital systems. Since then, two updated versions of IEEE 603 have been issued without revisions to the regulation. In addition, the footprint of the guidance documents for DI&C has grown significantly as several other digital-specific industry standards were endorsed for safety-related systems to govern aspects of digital systems, including software development processes.

DI&C technology has rapidly evolved over this timeframe, which hastens the obsolescence of technology-specific endorsed standards. Outside the U.S. nuclear market, many additional DI&C standards have emerged over the intervening decades for other safety applications such as medical technologies, aircraft, space applications, and naval reactors. Although both internal and external NRC stakeholders widely accept that IEEE 603 is adequate to assess safety systems, the current regulatory approach may not provide the desired flexibility for new DI&C systems that could enhance safety for operating and advanced reactors.

The current regulatory structure for DI&C, including evaluation of systems against IEEE 603 using the current standard review plan and interim staff guidance, is overly prescriptive and an impediment to the implementation of DI&C. The voluminous and prescriptive nature of the regulatory structure present challenges to applying the standards or alternatives to new and novel DI&C in a risk-informed way. In the current review approach, all safety-related instrumentation and control (I&C) systems are in general treated equally regardless of whether they are of low safety significance, and the risk significance of non-safety-related I&C systems (e.g., Risk–Informed Safety Class-2 per the provisions of 10 CFR 50.69) may not be a consideration in the review. As a result, industry's application of DI&C has generally been limited to nonsafety retrofits (where the endorsed standards do not apply) pursued without prior NRC approval under 10 CFR 50.59, "Changes, Test, and Experiments," or retrofits that support power uprate license amendments (where there is a return on investment). The regulatory structure applicable to safety systems has contributed to industry's reluctance to pursue safety system retrofits to proactively address obsolescence issues and otherwise generally improve safety.

The Commission has recognized the need for flexibility in assessing the safety of DI&C systems within the regulatory structure. In 2015, the Commission directed that NRC requirements and guidance should not pose unnecessary impediments to advances in nuclear applications of digital technology, that any new or revised requirements should be performance-based rather than prescriptive, and that DI&C requirements should be technology neutral—with specific guidance developed as needed—and should apply equally to new and operating reactors.[1] The staff has initiated a DI&C plan that addresses several challenges posed by the existing regulatory structure and has made progress in implementing the Commission's direction to support technologies being considered for use in the near-term. However, substantive changes to the underlying regulatory structure have not yet materialized. Transformation of the regulatory structure for DI&C is needed for the NRC to be agile when addressing new technologies in the coming years. The main paper provides an overview of the staff's recommendations for transformation related to DI&C, and Enclosure 5 gives more details on these recommendations.

b. "Big Data"

"Big Data" is the continuous collection of data that presents a source for ongoing discovery and analysis. The data can be comprised of structured data traditionally found in databases and spreadsheets, text-heavy unstructured information such as documents and e-mails, or data collected using other mechanisms. Governments and businesses worldwide are using Big Data in areas such as customer relations and knowledge management to further their missions and increase efficiencies. Advances in data analytics and predictive analytics using Big Data tools have made it possible for organizations to mine data more precisely and to better refine searches and uncover relationships, correlations, and trends. Both the NRC and industry are beginning to leverage these tools as discussed further in Enclosure 8, and the NRC staff has begun positioning itself to use Big Data to enhance staff effectiveness and to address the potential future regulatory impacts of Big Data usage by industry.

c. Accident Tolerant Fuels

The NRC has more than 40 years of experience in regulating nuclear fuels. This experience with fuel design is nearly entirely with uranium dioxide (UO_2) fuel and zirconium (Zr) cladding. As a result, the agency has a good understanding of the behavior of UO_2-Zr fuel as a function of burnup (irradiation level) and in various accident scenarios. However, several fuel vendors, in coordination with the U.S. Department of Energy (DOE), have announced plans to develop and seek approval for various fuel designs with enhanced accident tolerance (i.e., fuels with longer coping times during loss of cooling conditions) which use either a type of cladding other than Zr or a different fuel type. As explained further in Enclosure 8, in response to feedback from industry on the NRC's process and regulatory framework for licensing accident tolerant fuel (ATF), the NRC staff has undertaken a number of ongoing initiatives for the efficient and effective licensing of ATF. The feedback received during the transformation initiative generally indicated that these activities, in combination with the approaches in the staff's recommended licensing strategy to appropriately focus on more safety significant issues and use existing information, will ensure that the NRC is prepared to review applications for the use of ATF in a

[1] Staff Requirements Memorandum to SECY-15-0106, "Staff Requirements—SECY-15-106—Proposed Rule: Incorporation by Reference of Institute of Electrical and Electronics Engineers Standard 603-2009, 'IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations,'" dated February 25, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16056A614).

timeframe that supports the industry's current timelines for development of the fuel. Accordingly, the staff plans to continue the current activities and does not recommend any changes to the regulatory framework or approach in this area.

d. New Materials and Manufacturing Methods

Industry is interested in pursuing emerging advanced manufacturing methods, including additive manufacturing (or, three dimensional printing), as opposed to traditional casting or machining methods, to produce nuclear power plant components. In addition, industry is interested in developing new high-temperature materials for advanced reactor designs. As explained further in Enclosure 8, the staff is developing an advanced manufacturing action plan and is also engaging early with ongoing industry research and development of codes and standards that support the use of new materials and manufacturing methods while ensuring the safety of these techniques. Accordingly, the staff plans to continue the current activities in this area as well as those identified in the advanced manufacturing action plan under development, and does not recommend any changes to the regulatory framework or approach in this area.

e. Advanced Reactors

Most of the NRC's reactor licensing and oversight experience relates to light- water reactors (LWRs), but the NRC does have some experience with non-LWR regulation. Fort St. Vrain Nuclear Generating Station, the last commercial non-LWR, had been licensed by the Atomic Energy Commission, and stopped operating in 1989. The NRC has also reviewed a variety of preliminary designs for non-LWRs at varying levels of detail, including a preliminary safety evaluation for the Power Reactor Innovative Small Module reactor, and policy issues identified during the Next Generation Nuclear Plant project. More recently, in February 2016 the NRC reviewed and approved a construction permit, submitted by SHINE Medical Technologies, Inc., for a new and innovative medical isotope production facility. Although not an advanced reactor, this project demonstrates that the NRC is capable of reviewing innovative facility designs within the current framework and in a timely manner. However, this capability is possible only through exemptions and individualized adjustments to existing processes.

Meanwhile, interest in non-LWR designs from industry and other parts of the Government such as DOE has varied. Recently, DOE has supported research initiatives to encourage the development of non-LWR designs and has a goal of having at least two non-LWR designs reviewed by the NRC and ready for construction by the early 2030s at the latest. Industry, including advanced reactor vendors, has indicated it supports DOE's proposed timeline but may engage in pre-licensing activities on a shorter timeline.

To be better prepared to review and regulate non-LWRs, the staff developed and issued a vision and strategy document, including activities related to fuel cycles and waste forms. The NRC issued, "NRC Vision and Strategy: Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness," in December 2016 (ADAMS Accession No. ML16356A670). To achieve the goals and objectives stated in this document, the NRC also developed implementation action plans (IAPs). The IAPs identify specific activities that the NRC plans to conduct in the near term (within 5 years), midterm (5–10 years), and long term (beyond 10 years). The plans and strategies have created a platform for systematic enhancements to the NRC's regulatory structure for non-LWR reviews. The advanced reactor activities are prioritized within the current budget and consider input from stakeholders on their needs. In the area of advanced reactors, the staff is recommending that builds on and leverages the current

IAPs and Regulatory Roadmap document, as discussed in more detail in the main paper and Enclosure 5. In addition, several current staff initiatives are encouraging engagement with the industry in the area of advanced reactors. The staff plans to continue these activities, as described in Enclosure 8.