The Plant Modernization Pathway and industry collaborators are developing a Nuclear Digital Transformation Strategy to minimize nuclear power plant total cost of ownership. This strategy will allow nuclear utilities to:

- Replace the “like-for-like” replacement approach for obsolete electronic equipment, holistically leverage the modern capabilities of digital platforms, and reduce human workload and equipment costs.
- Plan for foundational digital platforms to be implemented with lifecycle support strategies already in place. This allows technology investments to be executed, maintained, and refreshed continuously and deliberately; retains intellectual property investments; manages digital obsolescence; and lowers lifecycle costs.

The Advanced Concept of Operations Model shown in Figure 3 establishes requirements and constraints for all plant and work function modernization efforts ensuring strategic business objectives are achieved. Nuclear power plant budgets are created using a market-based electricity price point to derive total operating, maintenance, and support costs to support this price (top-down). Work is also analyzed for opportunities to aggressively focus workload on essential functions that can be resourced within budget (bottom-up). Work functions are then configured into the operating model. Process innovations and enabling Plant Modernization Pathway research technologies are then applied as an integrated set by using Systems and Human Factors Engineering. This promotes a business-driven Digital Transformation Strategy that reformulates the traditional labor-centric model to one that is technology-centric. This transformation lends itself to fewer on-site staff that are focused on daily operations, with maintenance and support functions centralized or outsourced to on-demand service models.

The Digital Transformation is realized by the tiered digital system infrastructure depicted in Figure 4. The integrated infrastructure shown in Figure 4 supports the Advanced Concept of Operations in its full range of activities to directly operate and support nuclear power plants in the following ways:

**Instrumentation and Control (I&C) Systems Category**

Current plant I&C functions are transformed by: (1) transitioning current safety-related I&C functions to one digital, safety-related platform, (2) transitioning current non-safety/balance-of-plant I&C functions to one digital, non-safety-related platform, and (3) implementing a fully digital Main Control Room and eliminating remote operating stations.

Together, these changes minimize investment costs.
while still complying with all technical and regulatory requirements. The digital transformation simplifies maintenance and engineering support, and reduces operations workload and operator training requirements by using only two I&C platforms (i.e., safety-related and non-safety-related). The coordinated design of these foundational elements vastly improves digital upgrades performed individually, following a “bottom-up” approach.

The same control and human interface (HMI) software developed for plant use are directly leveraged as shown in Figure 5. No separate design effort is needed. This improves simulator performance for training and enables simulator use as a design tool for developing control system changes, HMI changes, and procedures. It also allows validation of final system software and HMI designs prior to plant installation.

**Data Systems Category**

Data capture and analytics for plant support are transformed by: (1) capturing vast quantities of digital plant data directly from the safety and non-safety I&C platforms, (2) adding non-process control sensors to the data systems to fill I&C systems data gaps for plant health monitoring, (3) reducing maintenance workload through condition-based maintenance and predictive maintenance, and (4) performing condition-based maintenance and predictive maintenance analysis in a non-I&C environment, enabling monitoring, diagnosis and maintenance tracking in remote facilities.

Total costs are further reduced through work process optimization, achieved by coupling the condition-based maintenance and predictive maintenance functions with data systems technology. Such technologies include automatic generation and scheduling of electronic work packages and use of mobile technologies to promote correct and timely maintenance.

These data capture and data analytics tools enhance decision-making. I&C operating display facsimiles are provided across the data systems. Multi-disciplined performance dashboards are also created at the plant, site, and/or fleet level. These improve the understanding of the operating status of a plant across the enterprise and improve operational and emergency response decision-making by management.

The modern digital infrastructure shown in Figure 4 does more than enable like-for-like upgrade of obsolete analog I&C and other electronic system replacements. This sustainable, technology-centric solution delivers an approach that drastically reduces total cost of ownership while improving plant operation and maintenance capabilities.

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**Figure 4. Digital Transformation System Infrastructure.**

**Figure 5. “Digital twin” of I&C systems in a nuclear power plant control room glassstop simulator.**