U.S. DEPARTMENT OF ENERGY | Nuclear Energy

## Nuclear Energy Enabling Technologies (NEET)

# Advanced Sensors and Instrumentation (ASI) Annual Project Review

## Digital Technology Qualification

Richard Wood, ORNL
Ken Thomas, INL

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# Project Overview

## Goal

Resolve impediments to qualification of digital technology for nuclear power application to enable more extensive utilization of modern equipment in the full range of I&C systems at nuclear power plants

## Objectives

- Provide objective, scientific basis for determining *necessary and sufficient* mitigation of common-cause failure (CCF) vulnerabilities [ORNL]
- Establish suitability of digital alternatives for adoption in place of legacy analog components [INL]
- Demonstrate the application of equipment, strategies, and methodologies to enable more extensive digital technology usage [Case studies & Pilot projects – ORNL, INL, Industry partners]

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# Project Overview

- **Participants**
  - Digital Technology Qualification – ORNL
    - Richard Wood (PI)
    - Laura Pullum, Cyrus Smith
  - Digital Technology Qualification – INL
    - Ken Thomas (PI)
    - Ted Quinn (Technology Resources)

- **DOE-NE R&D Programs that benefit from this work are**
  - Light Water Reactor Sustainability (LWRS) Program
  - Next Generation Nuclear Plant (NGNP) Program
  - Small Modular Reactor (SMR) Program
    - SMR Licensing and Technical Support (LTS)
    - Advanced SMR (AdvSMR) R&D
  - Advanced Reactor Concepts (ARC) Program

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# Technology Impact

## Current Status – CCF Mitigation

- All licensees are required to analyze CCF vulnerability and implement mitigation (e.g., diversity) strategies within their defense-in-depth infrastructure
- The determination of adequate CCF mitigation is highly subjective and leads to considerable regulatory uncertainty (and licensing risk)
- Experience has shown the result to be complex I&C architectures, licensing delays, increased costs and greater maintenance burdens

## Expected Impact

- A systematic, comprehensive science-based method will be developed and demonstrated for evaluating CCF mitigation strategies
- Availability of quantifiable measures and objective criteria for CCF mitigation in place of the current ad hoc assessment and subjective criteria can greatly reduce regulatory uncertainty
- Optimal I&C architecture designs can be achieved to provide a well-defined safety basis, less imposed complexity, and, potentially, reduced cost

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# Technology Impact

## Current Status – Sensor & Actuator Technology

- New plant designs are continuing the use of legacy analog technology to minimize licensing risk and up-front costs
- Legacy technology has been shown to be problematic in two significant areas for which modern technology provides improved characteristics
  - reliable, accurate performance
  - maintenance burden (i.e., effort and cost)

## Expected Impact

- Identification of legacy sensor and actuator technologies being propagated into new plant designs and determination of the associated burdens
- Identification and demonstration of digital technologies that are suitable to replace legacy analog technology to achieve improved characteristics
  - accuracy
  - reliability
  - availability
  - maintainability
- Determination of the operational benefits and qualification basis for implementing digital replacements to legacy analog components

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# Research Plan

## Digital Technology Qualification – CCF Mitigation

- FY 2012 – $225K
  - Identify state of the practice for CCF mitigation (including non-nuclear industries) and perform gap analysis
- FY 2013 – $260K
  - Develop a taxonomy to characterize the nature of CCF vulnerabilities and mitigation approaches and identify key digital system characteristics
- FY 2014 – $200K
  - Investigate measures of key characteristics and CCF modeling approaches
- FY 2015 – $400K
  - Develop models and metrics to quantify the impact of mitigation approaches and establish mitigation strategies
- FY 2016-17 – $850K
  - Conduct case studies to test models and metrics with experiments to demonstrate mitigation strategies
- FY 2018-20 – $1125K
  - Demonstration and benchmarking of systematic CCF mitigation approach

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# Research Plan

## Digital Technology Qualification – Sensor & Actuator Technology

- FY 2012, $95K
  - Identify legacy sensor/actuator technologies that are being incorporated in new plant designs and thus warrant evaluation
- FY 2013, $139K
  - Investigate experience with legacy sensor technologies to capture and characterize unfavorable behavior, identify candidate alternate digital technologies and evaluate suitability to meet qualification requirements
- FY2014, $200K
  - Investigate experience with legacy actuator technologies to capture and characterize unfavorable behavior, identify candidate alternate digital technologies and evaluate suitability to meet qualification requirements
- FY2015-2017, $1,100K
  - Conduct and evaluate pilot projects for selected sets of digital equipment to prove suitability for NPP sense and execute applications
- FY2018-2020, $1,250K
  - Partner in modernization demonstration to qualify digital sensors and actuators for implementation in a nuclear power plant

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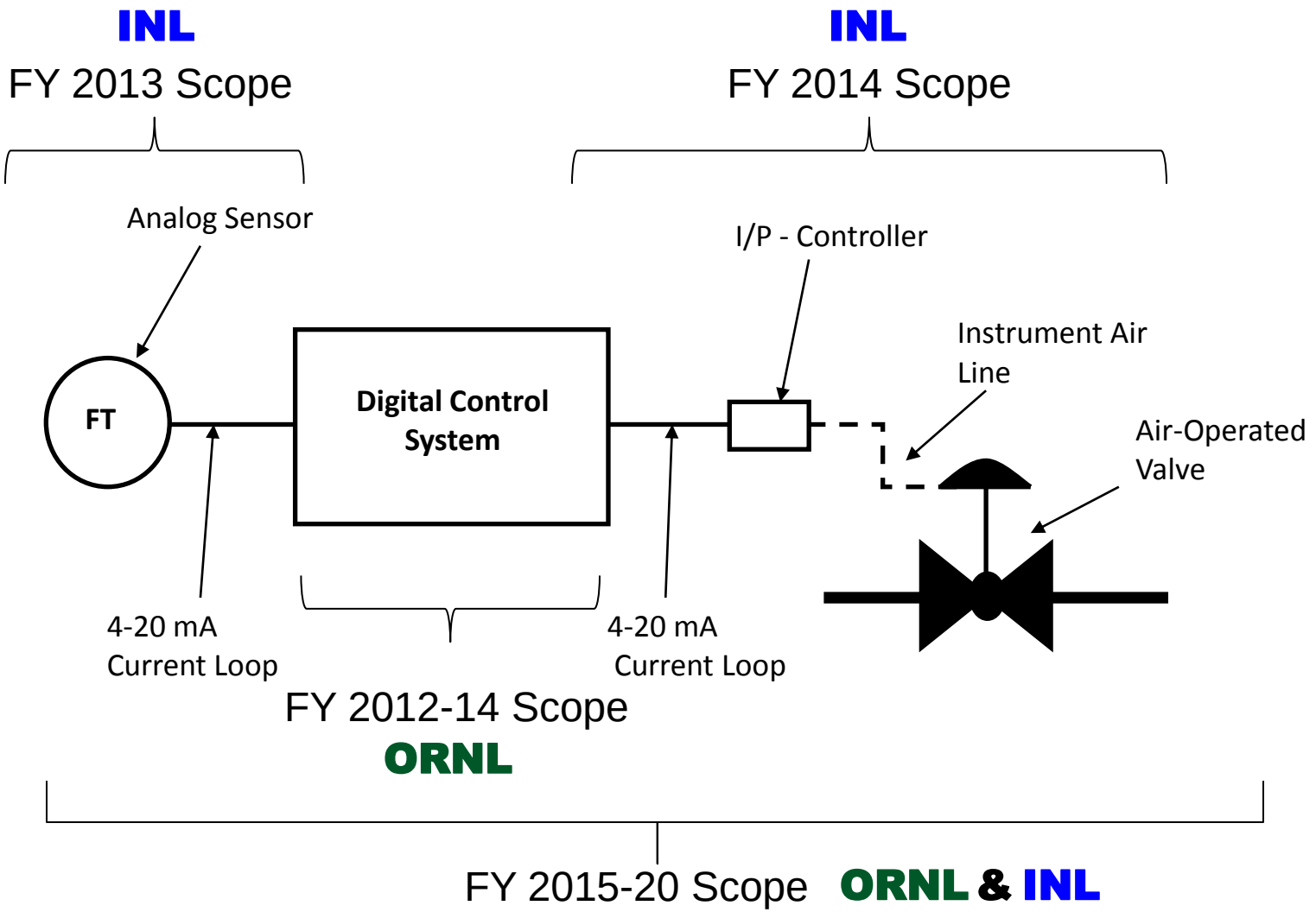
# Research Plan



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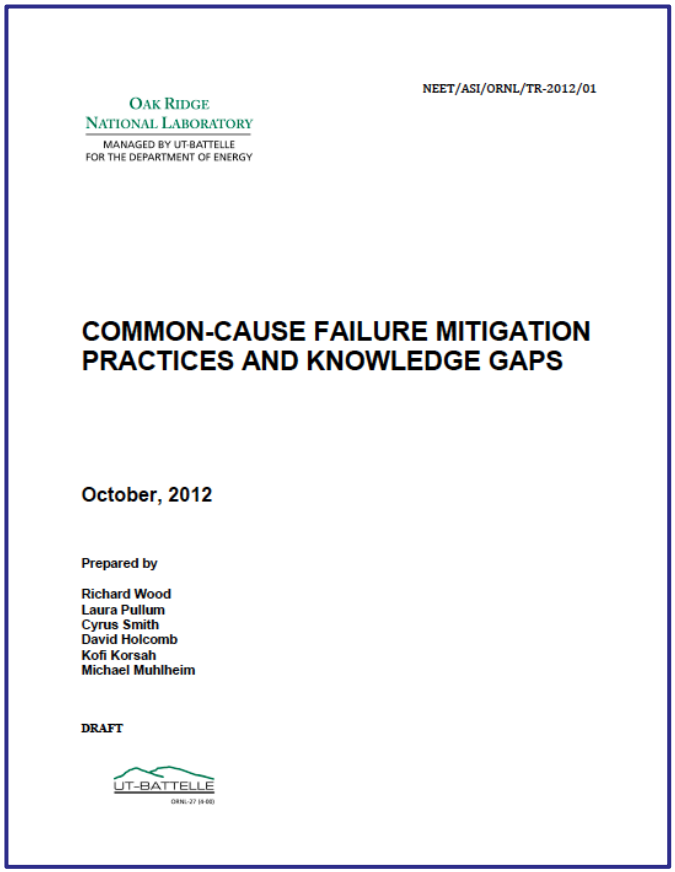
# FY 2012 Accomplishments

- **Common-Cause Failure Mitigation Practices and Knowledge Gaps (NEET/ASI/ORNL/TR-2012/01)**
  - Identified experience with common-cause failure
  - Reviewed existing guidance on addressing CCF vulnerability
  - Investigated mitigation approaches in the nuclear and non-nuclear industries
  - Summarized prior nuclear industry research regarding CCF
  - Identified knowledge gaps in the treatment of CCF vulnerabilities


NEET/ASI/ORNL/TR-2012/01

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

COMMON-CAUSE FAILURE MITIGATION PRACTICES AND KNOWLEDGE GAPS

October, 2012

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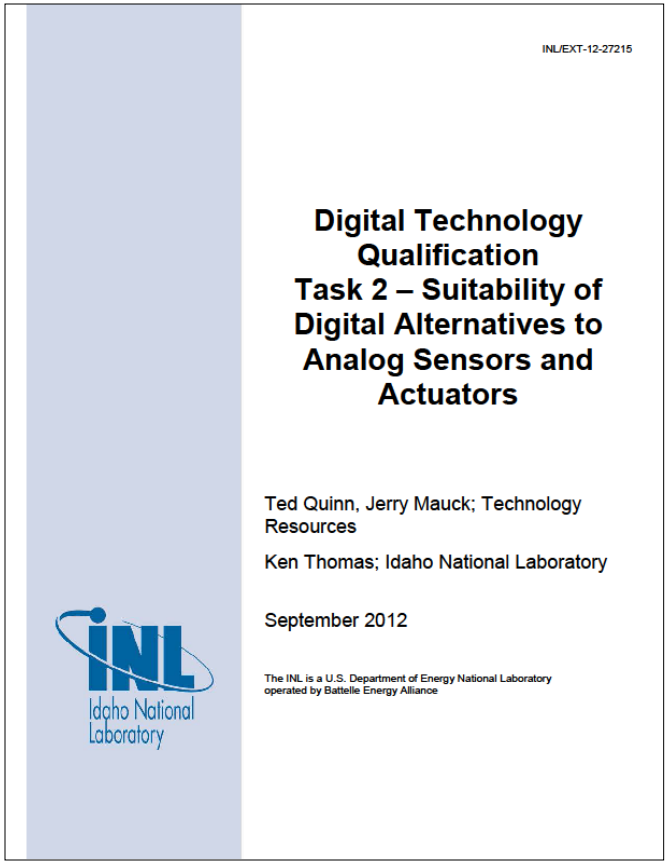
# FY 2012 Accomplishments

- **Digital Technology Qualification Task 2 – Suitability of Digital Alternatives to Analog Sensors and Actuators (INL/EXT-12-27215)**
  - Identified legacy sensor/actuator technologies that are being incorporated into new plant designs and thus warrant evaluation
  - Investigated major reasons why more advanced technologies are not being incorporated into new plant designs
  - Identified the attributes of these legacy technologies that make them less desirable than potential digital alternatives


INL/EXT-12-27215

Digital Technology Qualification
Task 2 – Suitability of Digital Alternatives to Analog Sensors and Actuators

Ted Quinn, Jerry Mauck; Technology Resources

Ken Thomas; Idaho National Laboratory

September 2012

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

INL Idaho National Laboratory

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# FY2013 Activities

- **Digital Technology Qualification – CCF Mitigation**
  - Capture terminology for CCF mitigation (academia, industry, standards)
  - Assess characterization of CCF vulnerabilities
  - Develop common, consistent taxonomy for CCF mitigation
  - Identify potential measures of key digital I&C system characteristics
- **Digital Technology Qualification – Sensor & Actuator Technology**
  - Evaluate analog sensor performance limitations (accuracy, reliability, availability, and maintainability)
  - Evaluate improved performance of candidate digital sensor replacements
  - Identify current gaps in available digital sensor technologies
  - Identify qualification and regulatory issues related to digital sensor replacements

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# Planned Accomplishments

- **FY 2013:**
  - Establishment of a Comprehensive Taxonomy for CCF Mitigation in Nuclear Power Plants
  - Candidate Alternate Digital Sensor Technologies: Evaluation of Suitability to Meet Qualification Requirements
- **FY 2014:**
  - Investigation of Measures for Digital System Characteristics and Approaches to CCF Modeling
  - Candidate Alternate Digital Actuator Technologies: Evaluation of Suitability to Meet Qualification Requirements
- **FY 2015:**
  - Development of Baseline CCF Models and CCF Mitigation Metrics
  - Pilot Projects: Applications of Digital Sensor Technology

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# Planned Accomplishments

- **FY 2016-17:**
  - Case Studies: Experimental Assessment of CCF Models and Mitigation Measures
  - Pilot Projects:  Applications of Digital Actuator Technology
- **FY 2018-20**
  - Benchmark Demonstration: Systematic CCF Mitigation Approaches
  - Pilot Projects: Application of Digital Sense and Execute Technology for NPP Modernization

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# Crosscutting Benefits

- **The nuclear power industry and DOE-NE reactor programs will benefit from resolution of key inhibiting factors to the transition to digital technology**
  - Improved reliability, enhanced performance, greater automation and operational flexibility, and sustainability available through digital technology
  - Impasse in I&C system modernization can be alleviated (LWRS)
  - Propagation of burdensome legacy technologies to new and advanced plants can be minimized (NGNP, SMR)
  - Imposition of complicated, inefficient architectural approaches can be eliminated, allowing increased automation and decreased O&M costs (NGNP, SMR, ARC)
- **Research outcomes apply to all reactor types**
  - Provision of a systematic, objective basis for determining adequate CCF mitigation enables reduced regulatory risk and optimal I&C architectures
  - Demonstrated qualification of modern technology for application in nuclear power plant environments reduces obsolescence concerns, performance deficiencies, and maintenance burdens

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# Transition to Competitive Research

- **Near-term interim research products include methods, models and metrics to define appropriate CCF mitigation and determination of candidate digital sensor and actuator equipment**
- **Case studies and pilot projects can be defined to experimentally validate and demonstrate digital technology qualification approaches for CCF mitigation and equipment suitability**
- **Laboratories, universities, and/or industry can collaborate to develop individual or integrated applications to demonstrate tools, techniques, and equipment**
  - Quantification of the resilience against CCF arising from diversity, defensive design measures and/or other diversity-seeking life-cycle decisions
  - Benchmarking of comprehensive CCF mitigation strategies
  - Evaluation of equipment suitability based on qualification criteria (e.g., quality, reliability, environmental compatibility)
  - Implementation and testing of digital field devices in representative environments or in pilot applications at nuclear power plant partners

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# Conclusion

**Digital Technology Qualification Research**

- **Advances the state of the practice to contribute to resolving impediments to qualification of digital technology for nuclear power applications**
  - Addresses regulatory uncertainty
  - Reduces burden of dated technology with limited capabilities
- **Provides the basis for the more extensive adoption of modern digital technologies at operating LWRs and in new reactor designs, including SMRs and advanced reactor concepts**
  - Systematic, objective approach to establishing adequate CCF mitigation
  - Suitable digital alternatives to legacy analog technology
- **Applies to the full range of reactor types and supports the goals of the DOE-NE reactor technology programs**
  - Enhances the sustainability of existing plants
  - Promotes competitiveness, safety, and efficiency of advanced concepts