INL/CON-12-25716
PREPRINT

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May 2012

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Abstract.[1] Human error is a significant factor in the cause and/or complication of events that occur in the commercial nuclear industry. In recent years, great gains have been made using Human Performance (HU) tools focused on targeting individual behaviors. However, the cost of improving HU is growing and resistance to add yet another HU tool certainly exists, particularly for those tools that increase the paperwork for operations. Improvements in HU that are the result of leveraging existing technology, such as hand-held mobile technologies, have the potential to reduce human error in controlling system configurations, safety tag-outs, and other verifications. Operator rounds, valve line-up verifications, containment closure verifications, safety & equipment protection, and system tagging can be supported by field-deployable wireless technologies. These devices can also support the availability of critical component data in the main control room and other locations. This research pilot project reviewing wireless hand-held technology is part of the Light Water Reactor Sustainability Program (LWRSP), a research and development (R&D) program sponsored by the U. S. Department of Energy (DOE). The project is being performed in close collaboration with industry R&D programs to provide the technical foundations for licensing, and managing the long-term, safe, and economical operation of current nuclear power plants. The LWRSP vision is to develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of the current nuclear reactor fleet.[i]

Key Words. Human Performance, human error, hand-held mobile devices, nuclear power plants

1. Introduction

Over the past decade, the commercial nuclear utilities have placed a strong emphasis on Human Performance (HU) initiatives, which has resulted in the development of HU tools. HU tools are process tools (job-aids) intended to mitigate human error during or prior to task execution. Since the introduction of these tools, there has been a marked reduction in the mispositioning of components, wrong unit operations, wrong train operations, plant transients, and plant trips.[1] Despite over a decade of employing these error reduction tools, the nuclear utilities continue to be heavily impacted by human error, resulting in plant transients, nuclear safety challenges, and equipment damage. While consequential errors are relatively low (typically measured in the range of 10^{-4} consequential errors on a base of 10K hours worked), the sheer number of work hours accumulated by plant staff over time means that errors impacting plant safety and reliability still occur too frequently. These errors can create unique and costly challenges regardless of whether the error leads to an event. These costs arise in the form of retraining, procedural changes, event investigation, and intangible costs, such as reduced public trust. In 2010, analysis of a series of events occurring at NPPs within the commercial industry determined that poor human performance (human error) significantly contributed to these events.[2]

Despite significant gains in the reduction of errors, a number of unacceptable errors still occur too frequently with no new prevention solutions presented. It appears that adding more job-aids increases the complexity of each task and subtask, thereby increasing workload and causing lack of task focus. Managers and workers alike have expressed frustration with the added burden of "more of the same," and overall results show minimal improvement in error reduction. There appears to be a consensus by industry leaders, managers, and workers that a saturation point has been reached with job aids. Implementing a new approach is critical to avoid reaching the limits of human reliability in preventing errors.

[1] Two series of demonstrations were conducted under the auspices of Duke Services at the Catawba Nuclear Power Plant (NPP) in August 2011 and February 2012 and we wish to thank them for their support.

One possible solution to augmenting the use of HU tools is to utilize latest off-the-shelf hand-held wireless technology. This technology is extremely reliable and can be easily adopted to improve task execution, verification, and validation, thus making it easier for the performer to focus on the task at hand. This technology can also easily identify whether or not the worker is using the correct component, the correct train, or is even working in the correct plant. In addition, the technology has the potential to directly reduce the mental workload of plant workers by integrating many of the currently available job aid functions into the software and hardware.

The rapid development of wireless technology and hand-held devices (i.e., Personal Digital Assistants [PDAs], tablets, smart phones, etc.) has opened the door to new opportunities for advanced work practices, computer-based procedures (CBPs), and real-time information flow to and from the field. The nuclear industry has yet to fully utilize the potential of these technologies with few exceptions. Since such devices are relatively new, little experience or research has occurred in utilizing them in the commercial nuclear industry. However, these initial studies have indicated the potential benefit of access to real-time data with a focus on improved communication between the control room, supervisors, and remote field workers (i.e., Nuclear Equipment Operators [NEOs] and Maintenance Technicians).[3]

1.1 Situational Awareness

One of the more important aspects of operator performance is situational awareness (SA), which has been described as both an end-state and a process, consisting of the operators state of knowledge or comprehension as to where the system is now based upon perception (what is there), comprehension (what this means), and the ability to predict future systems states and/or performance requirements. SA also contains a spatial representation and temporal representation that can be updated by new informational elements as sequences of events become available (for a more thorough review of SA concepts, see Endsley[2] and Wickens[3]). Distributed SA for teams has been proposed as a global concept where the definition has been broadened to conceptualize SA as an emergent feature produced by interaction of the members of that system with their technology.[4] That is, technology has a role, and depending upon context almost a partnership role in providing and sustaining SA.

The Idaho National Laboratory's (INL) Human Factors Group has been working with its industry partner, Duke Energy, to deploy new technology to improve Human Performance in Plant Status Control (e.g., the process of maintaining plant components in the correct position for the given plant condition) at the Catawba Nuclear Station in York, South Carolina. Our approach has been to find new technologies, which will maximize the collective SA of the entire nuclear station team, including interaction with their technology in order to improve accuracy in positioning plant components,[5] executing work processes, and supporting decision-making. The real time presentation of this rich data (i.e., the electronic forms, text, video, photos, and voice) has the potential to maximize success in monitoring the plant status control process by making the right information available to the people who need it in a timely fashion. Leveraging these recent technological breakthroughs should improve current controls while enhancing SA, thus leading to a reduction in human error.

1.2 Current Constraints

Much NPP fieldwork involves reliance upon a paper-based system. All NPP work processes follow strict quality and technical standards. The current process provides this information in paper form, which at times can be difficult to follow and execute without an in-depth expert knowledge of the process. Using such a paper-based system has very limited capabilities for communicating information to stakeholders and back in real-time. The written word allows for individual interpretation and therefore introduces variance in individual decision-making during task performance. Hand-held wireless technologies available today present an endless set of possibilities for consistent and reliable information flow, data gathering, and communication, thus eliminating the need for paper in the field.

1.3 Availability and capability of wireless

In the world of rapidly changing technology, many hand-held devices have the capabilities necessary to address NPP operations and maintenance activities. The number of devices commercially available is growing on a daily basis, introducing additional functionality and capability while eliminating the need to carry multiple devices to the field. Common to most commercial devices is the ability to scan barcodes; perform audio, video, still camera, and computing functions; data storage; and wireless data transmission.[6] These functions have the potential to connect field workers to one another remotely while providing actual plant status, and ultimately, increased SA. Field-rugged devices have already been developed for a variety of work environments (e.g., medical, petro-chemical) with challenges similar to those present in NPPs, thus eliminating the need to produce special one-of-a-kind devices specifically designed for the nuclear industry.

2. Method

2.1. Subjects

Based upon discussions with industry leaders, plant personnel, operators, and field workers, it became clear that NPP field workers are the workgroup most likely to benefit from portable devices and wireless technology. During the course of this research, 14 nuclear power plant field workers participated as subjects in the present study.

2.2. Scenarios

Participants worked though seven scenarios (five operational and two maintenance) either as independent parties or paired participants during the demonstrations. INL researchers observed the participants, captured specific comments made about the demonstration and the technology used as they worked through the scenario(s), and recorded potential usability issues with the technology hardware and software. Researchers noted common errors or deviations from the process occurring within each scenario type and recorded comments from scenario observers – either those who had already completed the scenario or were waiting for their turn in the immediate area. INL researchers video-recorded each of the scenarios for later analysis.

2.2.1. Mobile Technologies for Nuclear Power Plant Field Workers

A primary concern in using mobile technology is the ability of the technology to function fully under the environmental conditions that are present in an NPP. Today's field workers need mobility and tools that can withstand the difficult work conditions (e.g., tight areas, climbing ladders, high noise, high temperature, radiation fields, etc.) that are often encountered. In addition, to achieve real-time data, a wireless network is needed to support these devices. To date, few NPPs have invested in the necessary wireless backbone infrastructure needed for real-time data streaming.

The Motion Tablet J3500 and the Motorola MC75A (see Figs 1 and 2) were selected for device testing in these scenarios.

FIGS. 1 and 2. Research Models.

Our approach consisted of the seven steps identified by the CDC and adopted for use in the present study and are listed below.[7]

The basic approach included the following:

Step 1: Gap Analysis
Step 2: Research Questions Development
Step 3: Data Collection Methods
Step 4: Instrument(s) Development
Step 5: Demonstration (Case Study) Participants

Step 6: Data Collection
Step 7: Data Analysis and Reporting

2.2.2. Review of existing data sources

Discussions with plant management identified multiple data sources utilized by the research team to assess the current "as is" state of human performance and PSC. The following data sources in Table I were used for this evaluation.

Table I. Data sources used to support the study objectives.

Fleet Operations Center of Excellence Plant Status Control (PSC) & Tagging GAP Action Plan Update
MNS Final Plant Status Control Project Plan
Common Cause Assessment of Causal Evaluations Involving Plant Status Control for the Period Jan 2009 – May 2010 (Conger & Elsea)
Performance & Plant Status Control Metrics (KPI & Nuclear Performance Measures Data)
Plant Status Control Area for Improvement Benchmark of North Anna and Surry Observation Program Focused Self Assessment
2010 Nuclear Mispositioning & Plant Status Control event PIPs, Cat 1, 2, & 3

Discussions with plant experts and INL staff concluded that relying on similar, additional tools would unlikely reduce the current error rate or reduce the probability of PSC events given the current processes and job aids.

Process Mapping to Promote Understanding. A detailed process mapping was conducted in order to better understand the current work process at the utility and identify areas that could be improved by utilizing technical solutions. Both INL and Catawba team members participated in the mapping process, which focused on the identification of standard work execution during operations and maintenance activities. Additionally, the process maps were used as the basis for scenario development and concept demonstration at the nuclear station. The process mapping succeeded in highlighting two specific types of tasks: (1) labor-intensive tasks, performed in large numbers at utilities that were prone to error and privy to producing plant misconfigurations, thereby manifesting in safety-significant challenges; and (2) tasks that were representative of the kind described and develop work execution scenarios with which an evaluation of a number of properties of the candidate OTS work execution technologies could be conducted in a status quo condition. [8]

Confirmation of HU Saturation. Workers pointed to a multitude of cards hanging from their security badge lanyards. They expressed that the situation was at "saturation," with escalating levels of frustration directed at implementation of additional similar job aids. In place of HU aids, field workers expressed a desire to have tools that would allow them to refocus on the tasks critical to their jobs. One example of this frustration was requirements calling for second and third checkers to independently validate the work of the first field worker.

2.2.3. Research Questions Development

INL researchers sought to answer three significant questions regarding improvements achievable through the use of hand-held mobile devices:

1. Would modern wireless hand-held technology with embedded error prevention tools increase efficiency, performance, and decision-making, while reducing human error?
2. Would the use of the hand-held device grant field workers the ability to focus on the task with error prevention mitigated by such devices?
3. What impact would hand-held wireless technology have on plant status control?

2.2.4 Data collection methods

Data collection methods were limited to field-based case studies (scenarios) in the Catawba Training Flow Loop relying on a limited number of research participants, field workers, and others. The data collection methods used were recorded observation and audio/visual data capture during scenario runs, post-demonstration participant questionnaire, and post-demonstration focus group discussion via recorded observation and audio/visual data capture.\

2.2.5. Hardware Selection Criteria

All devices selected were commercial off-the-shelf (COTS) products. The following hardware selection criteria were employed:

- Usability
- Cost
- Ability to integrate other wireless forms
- Speed
- Functionality
- Size: The relative size of the hand-held device for portability and user interface
- Display Screen: The display size was selected to minimize the "key-hole" effect
- Ruggedness

Software development elements. The software had to conform to the following:

- Meeting human performance and human design guidelines, as available in NUREG 0700[9] and other sources
- Every operator action was followed by some type of feedback or acknowledgment (see IEEE-STD-1786[10] for computer-based procedures)
- Action monitoring of the operator's actions (e.g., check for out-of-range data values, alerts in wrong component barcode scanning)
- Simple enough to reduce the learning curve from the current process to the computer-based procedures displayed on the selected hand-held devices
- Considerations were given for the detail level of the contextual information being presented both in the field and the information control center (ICC)
- The software had to be capable of guiding the operator through the CBP process flow procedure (e.g., choosing the appropriate next step for "if/then" statements, understanding that cautions and notes must be read prior to associated steps, etc.)

The effectiveness of the hand-held mobile devices current to demonstrate the following was assessed:

- The use of bar codes to:
  - prevent wrong component, wrong train, and wrong plant errors;
  - update electronic plant diagrams and thereby improve plant status control.
- The use of video and audio data to:
  - improve communication, data collection, and decision making.
- The use of HHMD integration to:
  - reduce human error
  - provide a reviewable information repository
  - eliminate individual work-arounds
  - support just-in-time transfer knowledge
  - reduce man power requirements
  - deliver training.

Technology Selection. Early in the research process, it was decided that COTS technology would be used whenever possible along with proof of concepts, rather than development of a field deployable product (software or hardware). One tablet device was selected and one small hand-held device (see Figs 1 and 2).

Just-in-Time Training. Just-in-Time training was developed by INL staff to support participants in the use of these hand-held devices in the form of hands-on demonstration and coaching prior to the operations and maintenance demonstrations. The initial participants (two Nuclear Equipment Operators [NEO] and Maintenance Technicians) provided additional training to subsequent participants. Thereafter, each participant was asked to train the next group of participants as well. INL researchers observed the ease of this subsequent training as well as the knowledge transfer on the embedded error prevention tools provided by the software.

Scenario Development. Two scenarios (one for operations and one for maintenance) were designed by INL researchers and Catawba NPP Operations trainers to create a foundation for this study. These process flow (maps) diagrams, along with written operations and maintenance instructions, allowed the research team to focus on real world challenges faced by field workers. In addition, the process maps created a physical diagram that could be used by the software developer to incorporate needed elements of the research project. As previously mentioned, the technology employed COTS software along with additional software developed by INL to ensure use in proofing concepts explored in the initial phase of the project. The scenarios developed were chosen on the following bases:

- A commonly occurring process with possibility of finding an emergent issue
- Involved communication between the field worker in the field and the supervisor or other plant personnel
- Normal operating and maintenance procedure usage
- Provided opportunity were the current work process could be addressed with wireless hand-held technical solution
- Would show a stark contrast between the current processes (as is state) and the possible futuristic processes ("to be" state)

Operations Scenario. The operational scenario was designed around a system valve lineup, pump startup, and system shutdown. Operators used an electronic procedure and barcode component validation throughout the scenario. The supervisor (role-played by an INL researcher) conducted RCV in the ICC and watched video data streamed via a mobile camera mounted on the operator's hardhat. The scenarios are briefly described in the following steps:

1. An operator performs a procedure that requires him to manipulate valves, start a pump and adjust flow in order to put the flow loop in an operational configuration.
2. RCV is performed using RealityVision software to stream video back to the ICC operator, who then visually concurs that the correct component manipulation occurs.
3. The operator performs a procedure, which starts a subsystem in a similar manner that is designed to maintain a constant tank level within that subsystem.
4. The operator performs a procedure to secure the subsystem.
5. The operator performs a procedure to secure the flow loop.

Maintenance Scenario.
1. A maintenance technician verifies they are performing work on the correct component.
2. Technicians remove a diesel cylinder head cover.
3. Technicians perform a number of inspections of the diesel head internals that include taking photographs, annotating the photos, and attaching notes:
   a. These items become embedded into the procedure and are transmitted in real- time back to the ICC for further distribution to stakeholders.
4. Technicians review OE (Lessons Learned) which has been embedded into the procedure (annotated digital photographs of past problems to watch for).
5. During the inspection, the technicians find an emergent (simulated) issue—in this case, a cracked valve spring inside the diesel head.
6. Technicians establish communication with the ICC via video streaming using the Reality Vision software.
7. The information concerning the cracked valve spring is conveyed to management personnel (e.g., Main Control Room [MCR], supervisors, engineers, planners) in order for parallel decision-making to occur:
   a. With all stakeholders receiving information in real-time, parallel decisions are easier to obtain versus the current process of series decision-making (i.e., personnel inform superiors of problem sequentially).
   b. Using this method opens the lines of communication and increases the availability of information based on experience, expertise, and updated knowledge to help plant personnel make effective decisions.

IRB. Prior to the initiation of the scenario, each participant received a Human Subjects Research Informed Consent Form from an INL researcher. Participants were asked to read through the consent form for information regarding the scenario and instructed that if they agreed to participate in the research, they were granting the research team permission to privately analyze any data gathered.

Post-Demonstration Questionnaire. A paper-based questionnaire was developed and administered to participants immediately following the completion of each scenario run. The questionnaire was designed to capture both qualitative and quantitative data provided by the demonstration participants. The questions captured data regarding current work processes used for everyday work and current work processes in comparison to the technology-enhanced process. Fourteen participants completed the Post-Demonstration Questionnaire.

Focus Group Discussions. After each scenario run, all demonstration attendants also participated in a focus group discussion led by the research team. INL researchers posed a series of questions to those in attendance and recorded key pieces of information within the discussion in notes. The debriefing discussions were recorded via audio/video equipment as well.

3. Findings

The following findings from interview data were obtained during the four days of tests:

- Participants in the scenarios noted that the technology allowed them to follow the procedure precisely and carefully one step at a time.
- Participants reported that it allowed them to focus solely on the task at hand rather than hurrying to the next step.
- The ability to communicate with other departments and receive real-time input from outside sources, along with rich reference data such as photos and video, was well received.
- Component verification was positive, ensuring and actually forcing field workers to be 100% sure they were working on the correct component.
- Participants felt that status control was greatly improved.
- There was a reduction in mispositioning errors of all types.

Additionally, those surveyed indicated that the following potential improvements could be made:

- The technology should be designed to accommodate the demands of personnel climbing ladders and performing containment activities, that is, designed to be hands free, rugged or durable, and sized accordingly.
- A single device should contain a tablet, camera, flashlight and barcode scanner in one piece of equipment.
- It was suggested that gloves with conductive fingertips (capacitance device) for use with touch screen electronic devices be worn to carry out tasks in utilities.
- The technology should be customizable to accommodate different levels of expertise and visual differences due to age as well as personal preferences in viewing options were critical and valuable design options.

One of the more striking findings was that the utilization of the MHHD was observed to eliminate the need for 3-Part Communication and Peer Checks were a second field operator is required to watch the first operator touch the component identification tag while reading out loud using an alphanumeric tool (e.g., CB-132, Charlie-Bravo-One-Three-Two). Tag and barcode recognition reduced this need while preventing wrong component wrong train errors.

Another positive findings was that software updating of an electronic schematic could be observed on the large screen displays in the ICC by supervisory personnel. Additional efficiency gains were realized by the demonstration of a Remote Concurrent Verification (RCV) tool that could be used in lieu of an additional field prior to start of maintenance work activities or component manipulation required for some activities.

Additionally, rich data using RealityVision™ software were used to illustrate increased communication capabilities. The efficiency gains were shown by allowing remote decision-making by stakeholders who could observe work activities or emergent issues without having to be at the actual job site. See Fig 3 for a detailed view of one screen shot of the CBP.

FIG. 3. Hand-held display and CBP example.

Other improvements included improved Operating Experience (OE) collection by capturing rich data (e.g., video, voice, and annotated pictures) for later inclusion in job briefs and or later use for any number of knowledge management needs such as meetings (embedded HU Tool). Also demonstrated was the utilization of lessons learned by inclusion of OE in the CBP (rich data must be viewed prior to the procedure step, e.g., annotated picture of inspection points) to improve the accuracy of work without an over reliance on memory by the field worker (embedded HU Tool).

4. Conclusion and Discussion

Little research has been carried out to assess the impact of hand-held devices in the increase of collective situational awareness within the commercial nuclear industry. The ubiquitous presence of wireless technology and hand-held devices in the form of Personal Digital Assistants, tablets, and smart phones, etc. provides an abundance of novel opportunities for advanced work practices, CBPs, and information flow in real-time. Notable benefits of these hand-held devices are portability, advanced communication capabilities, information display, and specifically the ability to provide field workers with an instant access to real-time or near-time plant data. Integrating this type of technology into the field offers significant potential gains in HU improvement and reliability, reductions in human error and human variability, as well as refined validation methodologies.

This research developed and demonstrated concepts great potential to produce positive gains in human performance, efficiency and safety from the use of wireless hand-held devices. A mix of hardware and software capabilities were developed aimed at reducing the mental workload of field workers (integrated requirements and operator aids into the software), increasing overall field work efficiency (RCV, rich data availability, and improved audio/visual communications), improving plant status control (electronic schematics updated in real-time), and incorporating or replacing the need for the current mix of HU Tools (electronic validation of components-barcode scanning, embedded OE, and CBP forces procedural adherence).

In order to take advantage of these technologies, we need to think past our current methods; step back and evaluate current processes, benchmark other industries, deploy small scale demonstrations to get the industry’s buy-in, and in the long-term, standardize and scale up.

There will be a need for the commercial nuclear industry to invest in the necessary infrastructure to support hand-held wireless technology. Data collection is critical once the technology is deployed in the actual work environment to evaluate commercial nuclear industry metrics such as plant status control, reduced human error rate, improved procedure use and adherence, mispositioning index, and plant operations endorsement. Additionally, it is imperative that research be extended to the multitude of technologies available in the form of heads up (hands free), mixed reality and virtual reality. The INL Human Factor research organization hopes to gather preliminary data from initial deployment in order to pave the way for valuable contributions to the development and deployment of wireless technology in the commercial nuclear industry.

Benefits:

1. Improved plant status control - key process information can be updated in real-time, providing control room and field workers with overall view of the actual state of the plant
2. Reduction in mispositioning of components through bar code use
3. Reduction in wrong component/train selection through bar code use
4. Improved situational awareness (Sa) by all plant personnel – the use of CBP providing field workers rich data and real-time system status, along with real-time system status to ICC
5. Improved decision-making – with improved Sa (actual plant status)
6. Improved communication with the supervisor and other stakeholders – audio/video to and from field
7. Lowered mental workload - the field worker has access to the necessary information, including requirements, that is seamlessly integrated into the CBPs to perform the task at hand (task focus vs. process focus)
8. Reduced interruptions - with task status being updated on a regular basis in ICC, stakeholders can receive updates without disrupting work activities
9. Improved procedure use and adherence - CBPs prevents casual use of procedures, must follow procedure as presented on hand-held
10. Current copy of procedure in use – updated procedures can be uploaded when hand-held device is put in service
11. Improved individual accountability – by preventing individual behaviors/decisions outside scope of predefined work packages or procedures (enabled by using CBP)
12. Improved information flow - information could flow from the field to the control room or
13. ICC such that control room and ICC operators are easily aware of the equipment manipulated by the field workers
14. Improved safety - through continuous oversight or supervision for field workers via remote observation of field activities (live video/audio feed from field) 14. Improved OE collection - by capturing rich data for later inclusion in meetings, job briefs, and/or CBPs
15. Improved utilization of lessons learned - by inclusion of OE in the CBP (rich data must be viewed prior to the procedure step, for example an annotated picture of inspection points)
16. Improved system analysis - through immediate validation of data, system can alert the field worker and/or control room of suspicious data. The suspicious data could prevent the operators from continuing without independent resolution (data points that are out of tolerance or specification)
17. Improved emergent issue resolution - through real-time problem identification, remote collaboration and decision making

Potential Benefits:

Focus group discussions and individual discussions indicated potential for many possibilities based on the demonstrations observed. The current COTS technology can provide the following additional benefits with a constant stream of new possibilities in of development.

1. Improved safety - reduction of mental workload, allowing field workers to focus on the task and potential hazards
2. Improved data collection – non-consequential error points that occur in the field during the process of executing the task can be identified through data collection (i.e., bar code scanning the wrong component) allowing for process improvements
3. Improved system response analysis - Field operators performing actions resulting in system alarms can view alarm on the hand-held device and take immediate mitigating actions without unnecessary delay
4. Minimizing transposing errors by blue tooth connection to calibrated tools (e.g., remote monitors, electronic meters, torque wrenches). In addition, the procedure knows when a suspicious value (torque readings) have been recorded and thus could alert operations and engineering along with the field worker
5. Improved work planning and coordination - providing various stakeholder with 21 information such as task completion, task progress and task or subtask time estimates, enabling better work planning in real time (i.e.

procedures can coordinate work efforts by alerting individuals or shops such as QA when they will be needed at the work site)

6. Remote system operations can be realized - field workers can perform tasks directly without needing to verbally request permission from the MCR
7. Improved accident/incident construction post event - error points and other data collected and time stamped
8. Reduction in work-arounds - the technology and software prevent individual work-around without supervisor acknowledgement and consent
9. Improved risk management - as a result of procedural and process adherence to requirements
10. Improved mode sensitivity - building in mode sensitivity that could be used to flag operations restricted in certain operational modes could prevent unwanted actions which place the plant in a limiting condition
11. Reduced radiation exposure - Improved communication capabilities could enable remote decision-making (As Low As Reasonably Achievable – ALARA could be greatly improved)

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