AUTOMATED WORK PACKAGE: CAPABILITIES OF THE FUTURE

Ahmad Al Rashdan, Johanna Oxstrand, Vivek Agarwal
Idaho National Laboratory
P.O. Box 1625, Idaho Falls
Idaho, 83415
ahmad.alrashdan@inl.gov; johanna.oxstrand@inl.gov; vivek.agarwal@inl.gov

ABSTRACT

As part of the ongoing efforts at the U.S. Department of Energy's Light Water Reactor Sustainability Program, Idaho National Laboratory (INL) is conducting several pilot projects in collaboration with the nuclear industry to improve the reliability, safety, and economics of the nuclear power industry, especially as the nuclear power plants extend their operating licenses to 80 years. One of these pilot projects is the automated work package (AWP) pilot project.

An AWP is an electronic intelligent and interactive work package. It uses plant condition, resources status, and user progress to adaptively drive the work process in a manner that increases efficiency while reducing human error. To achieve this mission, the AWP acquires information from various systems of a nuclear power plant and incorporates several advanced instrumentation and control technologies along with modern human factors techniques.

With the current rapid technological advancement, it is possible to envision several available or soon-to-be-available capabilities that can play a significant role in improving the work package process. In this pilot project, the researchers develop an AWP prototype of an expanding set of capabilities and evaluates them in an industrial environment. While some of the proposed capabilities are based on using technological advances in other applications, others are conceptual; thus, they require significant research and development to be applicable in an AWP. The scope of this paper is to introduce a set of envisioned capabilities, their need for the industry, and the industry difficulties they resolve.

Key Words: Work process automation; electronic work package

1 INTRODUCTION

Work processes in the nuclear power industry consist of a defined set of tasks that are executed in a fixed or flexible order, require specific resources, and meet overall work objectives. The tasks are highly dependent on procedures that guide field workers through the various work stages. These stages are compiled into typically large work packages that include work orders, forms, and reference documents. Work package development and compilation is performed by a procedure writer or planner. Procedures are written in accordance with an industry-specific standard [1]. Once a work package is compiled, the schedulers allocate plant resources to the work package and schedule its execution. The work package and resources are then executed by field workers with the support of other relevant plant organizations.

The use of work packages in nuclear power plants has been proven to succeed in terms of maintaining plant safety. However, the recent plan to extend a nuclear power plant's operating license to 80 years created a research and development need to explore new means to improve the reliability, economics, and safety of these plants. This need is being fulfilled by several projects under the U.S. Department of Energy's Light Water Reactor Sustainability Program.

The Light Water Reactor Sustainability Program is a research and development program that is sponsored by the U.S. Department of Energy and performed in close collaboration with industry. One of the key means of the program to achieve its objectives is to develop pilot projects for research and development and industrial evaluation. Automating parts of the work process is one of the aspects this pilot project is targeting in this effort [2].

The two means to improve the work process as part of this pilot project are by applying the science of human factors in the design of work packages and by using the advancements of instrumentation, information, and control (II&C) technologies in automating work package processes. Implementation of advanced human factors and II&C techniques in the design of a work process necessitated the evolution of conventional paper-based work packages to advanced electronic versions. This resulted in the guidelines developed in [3] and was reaffirmed by the business case study in [4].

Electronic work packages (eWPs) are work packages that rely, to various extents, on electronic data acquisition, processing, and presentation. The Electric Power Research Institute (EPRI) introduced several functions of this type of work package in [5]. Automated work packages (AWPs) are the logical evolution of eWPs. They are envisioned to incorporate the advanced automation technologies and innovations of the future and address the work process deficiencies that are not resolved by eWPs. This paper described an AWP by using the following stages of analysis:

1. Performing a deficiency or gaps analysis study on the current work processes.
2. Determining the gaps that are addressed by eWPs.
3. Determining the remaining gaps that are not resolved by eWPs.
4. Identifying new technologies or functions to address the remaining gaps.

Steps 1 and 2 have been investigated in earlier and ongoing efforts [5]; therefore, this paper is focused on Steps 3 and 4 to define future AWP capabilities in Section 2. The need and benefit of AWP capabilities was evaluated by an industry survey, which is presented in Section 3. The conclusion of this effort is presented in Section 4.

2 ENVISIONED AUTOMATED WORK PROCESS

The envisioned automated work process was developed by taking the current state of relevant technology advancements into consideration, in addition to projecting short-term achievable advancements. The approach followed was to fully automate the work process cycle from work request initiation to archiving. To ensure consistency with other efforts in the area of electronic work packages, the work package process description used in EPRI's eWP [5] will be used for introducing AWPs. The envisioned scenario assumes staff-assigned mobile devices equipped with an AWP platform that plays the role of being the worker's day-to-day mentor. This section discusses the work process stages in chronological order.

2.1 Initiation of Work Request

In addition to the manual and/or remote initiation of work requests, AWP incorporates an automatic initiation of work requests using plant equipment that tracks and reports the needed equipment maintenance. This type of smart equipment does exist in various industries today. As such, their benefit for predictive maintenance is being put into use. Equipping non-smart plant components with smart diagnostics and prognostics is being explored in ongoing efforts [6, 7]. Other maintenance prediction methods rely on smart plant state evaluation. This area of research is also advancing [8].

In AWPs, the initiation of work requests would rely on simplified and automatic template data population. All plant equipment would have its own list of potential work request initiation templates. The list would also be accompanied by a probability of occurrence of the various failure modes. The field worker would then need to select the applicable work request from a list and the rest of the information would be populated. This work process automation results in the following AWP functions:

Function 1: Automatic creation of a work request by systems, schedules, and current work packages.

Function 2: Integration of smart plant equipment that perform self-diagnosis and prognosis into the work request creation process.

Function 3: Integration of intelligent plant discrepancies identification systems into the work request creation process.

Function 4: Association of work requests with equipment failure modes and their associated probabilities of failure.

Function 5: Simplified and automatic template data population of work requests.

2.2 Screen Work Request

Once a work request is initialized, its information is instantaneously and automatically passed to operations and relevant plant organizations. Information such as priority and impact would be associated with the work request and evaluated against the current state and risk level of the plant. Operations and other relevant organizations are presented with a summary and detailed description of the feasibility of executing the work request, the needed requirements, and the ideal environment and time to execute the job. This work process automation results in the following AWP function:

Function 6: Automatic evaluation of the impact of work on the plant and plant risk estimation tools.

2.3 Work Package Creation and Scheduling

In the envisioned AWP, every work request template will be associated with a work package. The planner does not need to explicitly specify the list of materials, documents, tools, and other resources of a work package. This results in improved work package compilation quality and speed.

A smart-scheduling capability will evaluate the feasibility of performing the work in the current and future operational state by acquiring data from various plant information systems, including the plant enterprise asset management system and overall plant status as was performed in [9]. The optimal time for performing the work package will be decided based on plant status; request priority; logistical aspects, such as manpower, materials, and tools; and the impact of the work package on plant risk. Other less trivial factors—such as weather, time of day, and the field worker's stress factor—will also be evaluated to determine the best resources and time for performing the work. The schedule will continuously update based on the changes of the mentioned factors and work being executed. The allocation and release of resources will be driven by the AWP scheduler. This work process automation results in the following AWP functions:

Function 7: Automatic allocation of work packages to work requests.

Function 8: Automatic population of work package information and properties from the work package instructions.

Function 9: Automatic acquisition of plant information.

Function 10: Real-time plant risk models update based on current work package status.

Function 11: Comprehensive smart-scheduling capability to determine the optimal sequence of the execution of work package steps in the plant.

Function 12: Automatic allocation, reservation, and release of work package resources.

Function 13: Automatic verification and acquisition of documents.

2.4 Pre-Implementation Walk Down

The AWP will automatically decide on the need for a pre-implementation walk-down based on the work package and schedule the walk-down for all involved parties. The walk-down will guide the participants through every step of the process and advise them on key aspects to consider. The AWP will also brief the participants on the scheduled execution time. This work process automation results in the following AWP functions:

Function 14: Associating the need for a walk-down with the work package.

Function 15: Systematic instructions-based walk-down process incorporated in the work package.

2.5 Supervisor Assigns Work Package to Craft

The AWP will evaluate worker qualifications with respect to work package scope in a manner similar to [10]. In the context of AWP, every instruction or process of the work package will be associated with certain qualifications. The qualifications will be used to automatically allocate the craft considering factors such as historical behavior of the field worker in performing certain instructions, stress factor of the field worker, training record and need, availability, hazards qualifications, impact, and criticality of the task. The automated decision-making of the best field worker for the job is presented to the supervisor to review, edit if needed, and confirm.

If training is needed, various forms of just-in-time training is used in the AWP. The training format can be audio, video, and/or augmented or virtual reality. If human-based training is a must, the AWP will allocate a suitable time slot for the training to occur. If the craft is qualified enough, but a similar task has not been performed for a while, a random set of task-specific questions will be automatically presented to refresh the craft's knowledge. This work process automation results in the following AWP functions:

Function 16: Automatic manpower allocation based on historical performance, field worker status, qualifications, training records, availability, hazards qualifications, impact, and criticality of the task.

Function 17: Training through audio, video, and augmented or virtual reality.

Function 18: Task-specific questions to validate and refresh field worker readiness.

2.6 Holds and Pre-Job Brief

Work package holds are automatically set by the AWP. The AWP automatically requests the supervisor to clear the hold after review. The AWP also decides and presents the key points that need to be mentioned in the pre-job briefing, such as the job execution plan, hazards, cautions, warnings, notes, historical issues, projected execution time and duration, and any specific comments the supervisor adds. The pre-job briefing could be presented in text, audio, video, augmented, or virtual reality format. Automation of this work process results in the following AWP functions:

Function 19: Automatic hold review and removal or notification for removal.

Function 20: Automatic determination of key points to mention in the pre-job briefing based on the work package scope.

Function 21: Pre-job briefing by means of video, augmented, or virtual reality.

Function 22: Tracking the historical common issues with work package activities.

Function 23: Using the historical execution time of all work package activities.

2.7 Measurement and Test Equipment, Tools, and Spare Parts

The measurement and test equipment (M&TE), tools, and spare parts used in the plant will be equipped with radio-frequency identification (RFID) tags that are linked to the AWP. The AWP will automatically allocate the appropriate M&TE, tools, or parts for the work package; make sure they are calibrated as the work requires; ensure the field worker does not forget them as the field worker heads to the work location; and ensure the field worker does not forget or misplace them in the plant as the field worker heads back from the work location. M&TE and tool tracking would also enable better utilization of the available resources. AWP will ensure the field worker has the needed safety gear by equipping the safety equipment with wireless detection capabilities, such as RFID. This work process automation results in the following AWP functions:

Function 24: Smart and RFID-enabled M&TE, tools, and spare parts.

Function 25: Automatic calibration tracking and assurance of proper M&TE use.

Function 26: Automated safety compliance and enforcement techniques.

Function 27: Tracked and optimized M&TE and tools use.

2.8 Walk-Down Clearance (Tag-Out) and Operations Permission to Start

Once the field worker heads toward the work activity location, AWP will use location detection capabilities to automatically proceed with tag-out and clearance requests. An electronic tagging system—including electronic tag-out status indication—will be implemented to manage the tag-out and tag-in processes. A database will automatically track all tagged-out and tagged-in equipment as work packages are executed and completed. Operations are automatically requested for a remote clearance after the AWP verifies plant conditions will allow the job to be performed. The AWP will also enable electronic hand-written signature and date for critical tasks. This work process automation results in the following AWP functions:

Function 28: Use of AWP device location tracking in scheduling and progress tracking.

Function 29: Use of plant equipment location definition in scheduling and progress tracking.

Function 30: Electronic tagging system displays.

Function 31: Automatic tag-out and tag-in.

Function 32: Automatic notification and clearance requests to supervisors, operations, and other relevant entities.

Function 33: Remote notification of permission to start.

2.9 Perform Work Activity

The AWP will use the device and equipment location ID to confirm that the field worker is working on the right equipment. A set of computer-based procedures will guide the operator through the work [11-14]. The procedures will use varying levels of detail, depending on the field worker's qualification and the criticality of the performed task. The time to complete each step will be tracked. If a certain step or task takes an abnormal time to complete, the field worker and supervisor are alerted, because this indicates a possible human error. Voice commands and instructions will be used to help the field worker utilize both hands if needed. In addition, all relevant plant entities will have full-view access to the field workers' progress. This includes video monitoring the task using a safety helmet-held camera or safety glasses equipped with cameras. The work execution will be recorded for quality assurance, peer inspections, training purposes, or supervisor review. Historical work package issues associated with similar equipment will be presented to the field worker as the worker approaches the step of their historical occurrence.

Ahead-of-time notification of the need for any support will occur by the AWP scheduling capability. This will use a projection of task completion time based on the current and historical behavior of the work package parts. As the field worker completes any part of the work package, the worker will have the possibility to provide feedback or review any part of the work package including steps, documents, warnings, plant components, trainings, spare parts, tools, and M&TE at any stage of the work package. This work process automation results in the following AWP functions:

Function 34: Location-based verification of the equipment to perform the work on.

Function 35: Use of computer-based procedures.

Function 36: Adaptive level of the detail for instructions based on field worker qualification and task.

Function 37: Automatic tracking of work progress.

Function 38: Duration-based abnormality detection.

Function 39: Voice-enabled commands and voice instructions.

Function 40: Remote access of field worker progress to all involved entities.

Function 41: Remote video monitoring capability.

Function 42: Rapid and automated issue reporting during work execution.

Function 43: Automatic reporting of historical issues of all parts of the work package including steps and equipment, as well as reporting of historical information on how the issues were handled.

Function 44: Ahead-of-time notification of needed support.

Function 45: Real-time updates and optimization of the work package schedule according to current progress.

Function 46: Simplified and integrated feedback or review capability of steps, documents, warnings, plant components, trainings, spare parts, tools, and M&TE.

2.10 Sign-Off Clearance and Review

Once the work package procedure is complete, a clearance notification is sent to the supervisor for approval or acknowledgment. Instead of having to review the whole work package, the AWP will generate a summary of the key highlights for the supervisor's evaluation based on the task's progress, issues faced, field worker review, and the task's criticality. This work process automation results in the following AWP function:

Function 47: Automatic identification of key points to report to the supervisor for review.

2.11 Quality Assurance and Archiving

The feedback, review, and performance of all aspects of the work package will be stored to a quality assurance system that automatically detects patterns and identifies weaknesses in the work execution process for improvement. This will include a log of all actions performed in addition to video recording of the performed tasks. The data provided will be used to create areas of strength of individual field workers. The log and data of the work package will be electronically archived. This work process automation results in the following AWP functions:

Function 48: Automatic identification of pattern detection and weaknesses in the work package.

Function 49: Automatic development of field workers' areas of strength.

Function 50: Automatic archiving.

3 USER NEEDS SURVEY

A web-based survey was conducted by Idaho National Laboratory (INL) to determine which proposed functions would align best with industry needs. The survey also aimed to acquire feedback from industry regarding what works well in the current work package process and where in the process potential exists for efficiency gain improvements. A total of 12 individuals participated in the survey. The participants represented one European and five U.S. commercial nuclear utilities. Amongst the participants there were maintenance supervisors, planners, procedure coordinators, and information technology architects. The survey results are summarized in Figure 1 through Figure 3.

3.1 Results Discussion

As shown in Figure 1, initiating work requests is part of the current work package process that works well. Screening of work requests and conducting pre-job briefs were also identified as parts of the process that currently work well. Labor intensive tasks such as disassembling the work package, quality assurance records, and archiving were identified to have the highest potential for improvement.

Figure 2 shows that screening of work requests was identified as the only part of the process that could be removed. However, the overwhelming majority of the participants indicated that this part of the process should be kept in its current form; therefore, this result was deemed inconclusive. The participants agreed that the planning part of the process is not suited for automation, but that this needs to change.

Creating work packages is one part of the process that the majority of participants indicated as working well in Figure 1. However, it was also identified as a part of the process that should not be kept as is in Figure 2. The participants were split over whether this should be automated or just changed without automation. The participants identified two process parts that should be kept as is, which are the pre-job briefs and the walk-down clearances. The steps at the end of the work package execution were identified to have a high potential for automation.

The fact that the majority of the process parts scored low in the “keep as is” category can be viewed in two ways. The first is that the work package process has great potential for being improved. The second is that participants are very open to change. Both of these indicate the need to continue the AWP effort for the potential benefits to industry.

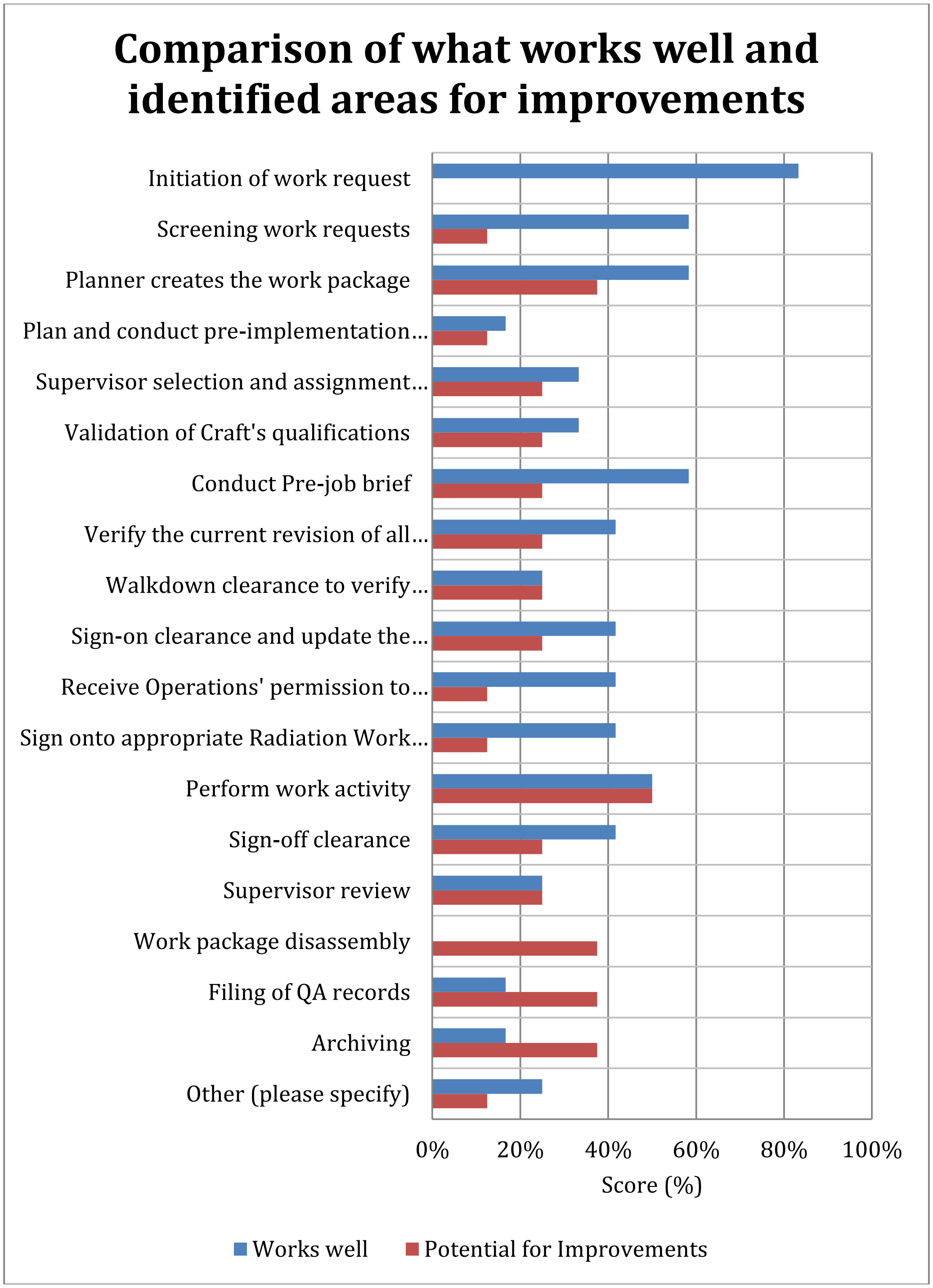

Figure 1. Comparison of what works well in the work package process and identified areas for improvement.

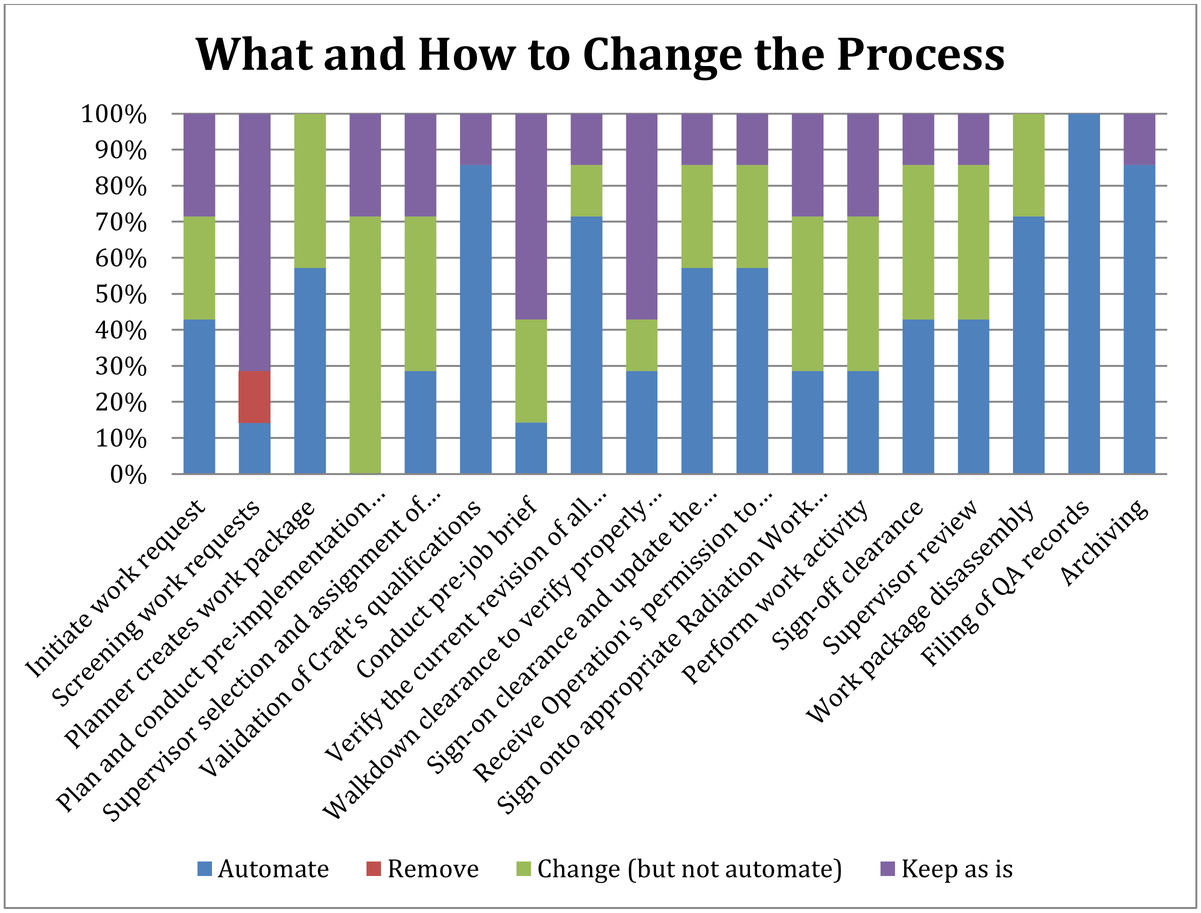

Figure 2. What and how to change the process.

The last scope of the survey targeted identifying capabilities to increase the efficiency of the work package process from the envisioned scenario of the previous section. As illustrated with an orange bar in Figure 3, the function that all participants identified as useful for increasing efficiency is automatic tracking of task progress. An overwhelming part of the participants (i.e., 86%) identified several other functions as having a great impact on efficiency gains, including the following functions:

1. Integration of enterprise asset management system and/or work management system.
2. Automatic population of work package information including assigned craft, tools, spare-parts, equipment, and documents.
3. Automatic integration of plant risk information during planning.
4. Automatic notifications to supervisors, operations, and other relevant entities as required.
5. Voice assisted instructions (e.g., talk-to-text).
6. Remote access of task progress to all involved entities.
7. Automatic notification to resources for QA and other validations.
8. Automatic tool recall for calibration or disqualification.

Figure 3 demonstrates that though the participants were in disagreement regarding the extent to automate the process in the earlier survey part of Figure 2, there was a significant change of standing towards automation when the participants were introduced with automated solutions, described by the functions of the previous section.

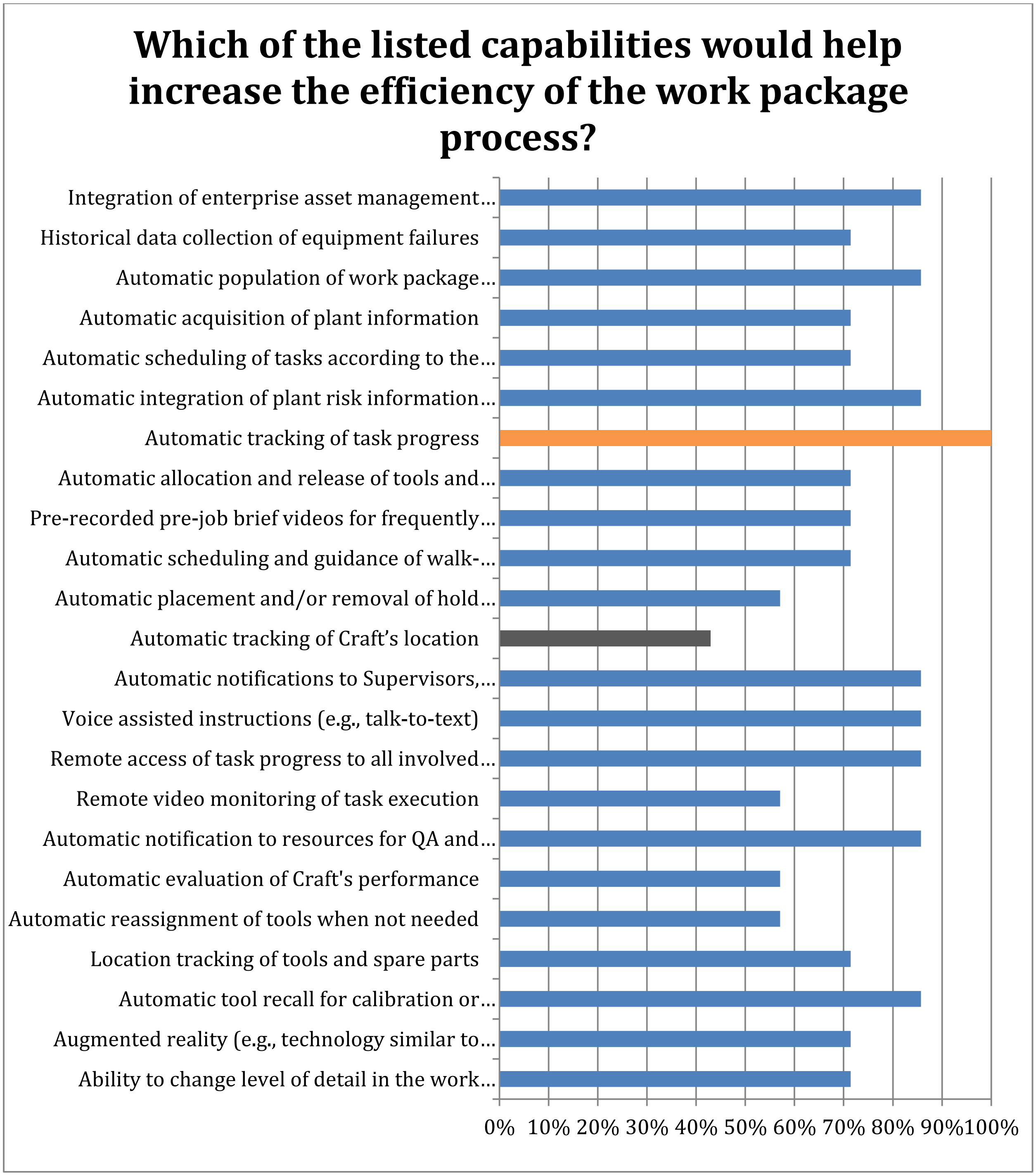

Figure 3. Functions to help increase efficiency in the work package process.

4 CONCLUSIONS

The scenario development performed in this study identified 50 advanced functions that could impact the current work process. These functions encourage relying on II&C technologies that have not yet been utilized. Since the vast majority of these functions can be developed with current or near-future technological advancement, the envisioned AWP described in this paper is achievable in the near future. However, there is a need for an organization to drive this evolution, which is the role INL is playing through this project. The actual impact in terms of efficiency, cost savings, and human error remains unknown; however, the survey conducted as a part of this study clearly demonstrated the desire for industry to apply advanced technologies and move forward. To the research team, the survey indicated that the AWP mission of enhanced process automation aligns with industry need. The future plan for the AWP project will develop and evaluate an initial set of the functions along with an industrial collaborator.

5 ACKNOWLEDGMENTS

The authors would like to acknowledge the Department of Energy's Office of Nuclear Energy for funding this effort as part of the Light Water Sustainability Program.

This paper was prepared as an account of work sponsored by an agency of the U.S. Government under Contract DE-AC07-051D14517. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the U.S. government or any agency thereof.

6 REFERENCES

1. Procedure Professionals Association, 2011, *Procedure Writer's Manual*, PPA AP-907-005 Rev 1. Procedure Professionals Association.
2. Hallbert, B., Thomas, K., 2015, *Advanced Instrumentation, Information, and Control System Technologies - Technical Program Plan for FY 16*, INL/EXT-13-28055, Rev 5, Idaho National Laboratory.
3. Farris, R. K., Medema, H., 2012, *Guidance for Deployment of Mobile Technologies for Nuclear Power Plant Field Workers*, INL/EXT-12-27094, Idaho National Laboratory.
4. Thomas, K., Lawrie, S., 2015, *Pilot Project Technology Business Case: Mobile Work Packages*, INL/EXT-15-35327, Idaho National Laboratory.
5. EPRI, 2015, *Improving the Execution and Productivity of Maintenance with Electronic Work Packages: A Mobile Work Management Initiative*, 3002005363, Electric Power Research Institute.
6. Agarwal, V., Lybeck, N., Pham, B., Rusaw, R., and Bickford, R, 2014, "Development of Asset Fault Signatures for Prognostic and Health Management in the Nuclear Industry," *IEEE International Conference on Prognostics and Health Management*, pp. 1-7.
7. Agarwal, V., Lybeck, N., Pham, B., Rusaw, R., and Bickford, R, 2015, "Prognostic and Health Management of Active Assets in Nuclear Power Plants," *International Journal of Prognostics and Health Management*, *Special Issue on Nuclear Energy PHM*, **Vol. 6**, pp. 1-17.
8. Cetiner, S., Kisner, R., Muhlheim, M., and Fugate, D., 2015, *Development of a First-of-a-Kind Deterministic Decision-Making Tool for Supervisory Control System*, ORNL/TM-2015/373, Oak Ridge National Laboratory.
9. Oxstrand, J., Al Rashdan, A., Le Blanc, K., Bly, A., and Agarwal, V., 2015. *Automated Work Package Prototype: Initial Design, Development, and Evaluation*, INL/EXT-15-35825, Idaho National Laboratory.

10. EPRI, 2014, *Nuclear Maintenance Applications Center: Applying Skill of the Craft to Maintenance Planning*, Electrical Power Research Institute, Palo Alto, California, 3002003194, Electric Power Research Institute.

11. Oxstrand, J., Le Blanc, K., and Bly, A., 2014, *Computer-Based Procedures for Field Activities: Results from Three Evaluations at Nuclear Power Plants*, INL/EXT-14-33011, Idaho National Laboratory.

12. Oxstrand, J., Le Blanc, K., 2015, *Computer-Based Procedures for Field Workers – Identified Benefits*, INL/EXT-14-33212, Idaho National Laboratory.

13. Oxstrand, J., Le Blanc, K., Bly, A., Medema, H., and Hill, W., 2015, *Computer-Based Procedures for Field Workers - Result and Insights from Three Usability and Interface Design Evaluations*, INL/EXT-15-36658, Idaho National Laboratory.

14. Oxstrand, J., Le Blanc, K., 2016, "Supporting the Future Nuclear Workforce with Computer-Based Procedures," *Nuclear Future - The Official Journal of the Nuclear Institute*, **Vol 12(1)**, pp. 34-39.