DEVELOPMENT OF A FRAMEWORK OF HUMAN-CENTERED AUTOMATION FOR THE NUCLEAR INDUSTRY

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ABSTRACT

Introduction of automated systems into control rooms for advanced reactor designs is often justified on the basis of increased efficiency and reliability, without a detailed assessment of how the new technologies will influence the role of the operator. Such a "technology-centered" approach carries with it the risk that entirely new mechanisms for human error will be introduced, resulting in some unpleasant surprises when the plant goes into operation. The aviation industry has experienced some of these surprises since the introduction of automated systems into the cockpits of advanced technology aircraft. Pilot errors have actually been induced by automated systems, especially when the pilot doesn't fully understand what the automated systems are doing during all modes of operation. In order to structure the research program for investigating these problems, the National Aeronautics and Space Administration (NASA) has developed a framework for human-centered automation. This framework is described in the NASA document Human-Centered Aircraft Automation Philosophy by Charles Billings. It is the thesis of this paper that a corresponding framework of human-centered automation should be developed for the nuclear industry. Such a framework would serve to guide the design and regulation of automated systems for advanced reactor designs, and would help prevent some of the problems that have arisen in other applications that have followed a "technology-centered" approach.

I. INTRODUCTION

The National Aeronautics and Space Administration has developed a framework of human centered automation to provide guidance for the design of new automated systems for advanced technology aircraft and to help identify research issues. The development of such a framework was undertaken because of the problems that have surfaced following the wide-scale introduction of automation in so-called "glass-cockpit" aircraft. A number of studies have found that although automated systems have reduced workload and reduced certain types of errors, new types of error have surfaced. Specifically, it has been found that errors are occurring because pilots don't always understand what automated systems are doing, and react improperly or fail to react under such circumstances. In recognition of these problems and to hopefully forestall further problems, NASA has taken a proactive stance by undertaking the development of the framework for human centered automation.[1] We believe that the information contained in the Billings report has sufficient value that it could be recommended as "required reading" for those investigating advanced technology in the nuclear industry.

In comparison with the commercial airline industry, the commercial nuclear power industry is just on the threshold of the introduction of advanced technology in the control room. To date, many of the applications of digital technology in the control room have been a replacement of analog functions with digital equipment, with no change in the interaction of the operating crew with the control system. However, as time goes on, it is expected that digital systems will be implemented that change the functional roles of humans and control systems. In order to head off some of the problems that will result if these changes are made from a technology-centered perspective, we recommend that a framework of human-centered automation be developed by the nuclear industry. This framework would provide high-level guidelines and identification of research issues regarding the introduction of advanced technology in nuclear power plant control rooms. In addition, we recommend that methods be developed to identify and address potential automation induced errors during the design process for advanced systems, rather than waiting for problems to reveal themselves after the systems are in operation.

II. THE NASA FRAMEWORK OF HUMAN-CENTERED AUTOMATION

Human-centered automation, in its essence, means that automation should serve the human, not control the human. Automated systems should be designed to assist and support human performance rather than taking the human out of the loop. The NASA framework proposes some basic principles for human-centered automation:[1]

- Premise

  The pilot bears the ultimate responsibility for the safety of any flight operation.

- Axiom

  The human operator must be in command.

- Corollaries

  To command effectively, the human operator must be involved.

  To be involved, the human operator must be informed.

  The human operator must be able to monitor the automated systems.

  Automated systems must therefore be predictable.

  The automated systems must also be able to monitor the human operator.

  Each element of the system must have knowledge of the others' intent.

These basic principles are then elaborated into some more specific guidelines for the application of automation in the design of aircraft and air traffic control systems.

- Humans must remain in command of flight and air traffic operations.
  - Automation can assist by providing a range of management options.
- Human operators must remain involved.
  - Automation can assist by providing better and more timely information.
- Human operators must be better informed.
  - Automation can assist by providing explanations of its actions and intentions.
- Human operators must do a better job of anticipating problems.
  - Automation can assist by monitoring trends and providing decision support.
- Human operators must understand the automation provided to them.
  - Designers can assist by providing simpler, more intuitive automation.
- Human operators must manage all of their resources effectively.
  - Properly designed and used, automation can be their most useful resource.

These principles provide a guiding philosophy for the design of automated systems for commercial transport aircraft. The development of similar principles of human-centered automation for advanced reactor designs would provide a unifying framework to make design and regulatory decisions for instrumentation and control systems, and to structure a research program to investigate the issues of human performance in advanced control rooms.

III. HUMAN-CENTERED AUTOMATION FOR THE NUCLEAR INDUSTRY

There is much ongoing work that is relevant to the assessment of the role of advanced technology in nuclear power plant operations. The development of a human-centered automation framework would help integrate the lessons learned from these studies, and provide guidance for identification of additional research that is needed.

We are currently conducting a project entitled "Risk Impact of New Technologies" for the Nuclear Regulatory Commission (NRC) to identify the influences of advanced systems on operator tasks, and to assess the potential impacts on plant risk. The results from this project will be directly applicable to the assessment of operator roles in advanced nuclear power plants.

We have also performed a task for the National Aeronautics and Space Administration (NASA) to study pilot errors that result from the use of automated systems in advanced technology ("glass cockpit") aircraft.[2] The methods used in this study and the insights gained are directly applicable to the nuclear industry. It would be beneficial to apply the lessons learned in the aviation industry to research aimed at advanced nuclear power plants. We believe that such concepts would provide a useful framework for the study of the operator's role in nuclear power plants, and that the application of lessons learned from NASA research would be very beneficial to the nuclear industry.

Research programs such as these are providing valuable information regarding potential impacts resulting from the use of advanced technology in nuclear power plants. However, these studies are providing only a part of the picture, and it will be difficult to combine the results of the separate studies into an integrated whole. A framework of human-centered automation can provide the structure for integrating and interpreting the results from the different studies. This can lead to the development of specific guidelines for the application of automation in the reactor control room, that will be applicable both for the design and regulation of advanced systems.

The development of a framework of human-centered automation would provide a unifying concept to tie together research, the development of human-machine interface guidelines, and regulatory reviews that relate to a multitude of issues regarding the use of advanced technology. The

framework could be developed in a cost-effective fashion by incorporating the lessons learned in other industries. We would suggest that the development of the framework include the survey of experience gained in other industries such as petrochemical. Ongoing activities to survey users of advanced technology in process control rooms can be extended to obtain this information. In addition, we propose that aviation experience with glass cockpit aircraft and the background for the NASA human-centered automation philosophy should be incorporated as well.

The following is a proposed outline of tasks for the development of a framework of human-centered automation for the nuclear industry.

1. Perform a review of experience in petrochemical and other advanced industrial plants regarding the effects of advanced technology on the role of the operator.

2. Perform a review of aviation experience with automated systems and the background behind the development of the NASA philosophy of human-centered automation. NASA research using the human-centered automation philosophy and research from the Aviation Safety/Automation Program should be reviewed.

3. International research on the role of the operator using advanced systems should be reviewed to determine applicability to the development of the framework. Particular emphasis should be given to research and experience gained in France, Canada, Japan, and from experiments at the OECD Halden Reactor Project in Norway.

4. Research programs conducted to date by the NRC and other U.S. organizations regarding the operator's role with advanced technology should be reviewed to identify unresolved issues.

5. A framework of human centered automation for the nuclear industry should be formulated, with a focus on defining and integrating research needed to resolve the issues identified in 4 above, to provide a technical basis for design and regulatory decisions regarding the role of the operator in advanced design plants.

6. A final report should be prepared describing the lessons learned from petrochemical, aviation, and international nuclear experience; the framework of human-centered automation that was developed; high-level guidelines for the use of advanced automated systems in nuclear power plants; description of unresolved research issues; and recommendations for a research program to resolve design and regulatory issues related to the role of the operator for advanced design nuclear power plants.

We believe that the development of a concept of human-centered automation would provide the nuclear industry with a mechanism to integrate research and regulation of issues pertaining to the role of the operating crew in nuclear power plants of advanced design. Such a framework could be developed either by regulatory bodies such as the U.S. Nuclear Regulatory Commission or by commercial organizations such as the Electric Power Research Institute. Perhaps the most value would be obtained if regulatory and commercial interests collaborated to perform the development of the framework.

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