IMPROVEMENT OF NUCLEAR POWER PLANT MANAGEMENT

APPLYING THE LESSONS LEARNED

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ABSTRACT

Active management participation is a common thread among nuclear power plants with superior performance. Plants that benefit from the hands-on attention of senior managers are typically more reliable and can be expected to have higher margins of safety.

There are numerous ways in which utilities are promoting management involvement in the day-to-day operations of their nuclear plants. The Institute of Nuclear Power Operations' (INPO) Plant Performance Indicator Program provides utilities with data in key performance areas, allowing management to monitor performance and concentrate on areas needing attention. Utilities are also setting ambitious short and long-term goals in several performance areas.

This increased management attention to nuclear plant operations is reflected in improved nuclear plant performance across the country. For instance, over the past five years, the number of significant events per unit has declined, unplanned automatic scrams have been reduced, equivalent availability is about the same (however, many units and the industry median has improved) and collective radiation exposure and volume of low-level waste shipped per unit are both showing a decreasing trend.

INTRODUCTION

The importance of management participation became apparent in the investigation of a nuclear accident in 1979. As a consequence of the accident at the Three Mile Island (TMI) nuclear plant, utilities also recognized the following:

- o the need to more than meet regulatory requirements in nuclear power plant operations
- o that they individually and collectively were responsible to achieve high standards of excellence in both construction and operation of their nuclear plants
- o that working smarter required integration of management attention at all levels and more comprehensive management tools. For example, an industrywide system of evaluation to highlight problem areas and share lessons learned and good practices was needed.

Overall, the period of introspection that followed the nuclear plant accident in Pennsylvania eight years ago had a positive effect in the U.S. nuclear industry. It brought about an industry dedicated to self-improvement through peer pressure and cooperation.

INPO

The Institute of Nuclear Power Operations, located in Atlanta, Georgia, is the result of that approach. A non-profit corporation sponsored primarily by the U.S. nuclear utility industry, INPO is dedicated to the safe and reliable operation of nuclear power plants.

In becoming a member, each utility in the United States opened its operation to careful scrutiny by an independent, non-governmental safety organization. The Institute's membership includes the 102 U.S. nuclear utilities and joint owner organizations (55 of which hold commercial operating licenses), 14 major supplier organizations from the United States and abroad and utility organizations representing 13 countries (as part of INPO's International Participant Program.)

The Institute's technical programs are designed to assist nuclear utility managers in achieving the highest standards of plant operations. INPO's "cornerstone" programs help utility management work smarter by focusing on four principal areas:

- plant and corporate support evaluations
- event analysis and information exchange
- training and accreditation
- various forms of assistance and technical exchange

Managing for Performance

Foremost among the management tools is the Plant Performance Indicator Program, which monitors key areas of plant operations, allowing trends to be tracked. INPO has worked on development and use of performance indicators with the U.S. nuclear industry and international participants. Three special review groups consisting of senior utility managers, a senior nuclear executive from each of the U.S. nuclear steam suppliers and a group of outside experts worked with INPO over a period of months to establish a set of overall performance indicators.

Considerable progress has been made in arriving at a common set of definitions for use, not only in the United States, but internationally as well. U.S. utilities are now using 10 overall indicators and 18 other performance parameters as an aid in monitoring nuclear plant operations. In addition, each U.S. utility with an operating unit has set challenging goals for most of the overall indicators, which include the following:

- equivalent availability factor
- safety system unavailability
- unplanned automatic reactor scrams while critical
- unplanned safety system actuations
- forced outage rate
- thermal performance
- fuel reliability
- collective radiation exposure
- volume of low-level solid radioactive waste
- industrial safety lost-time accident rate

The most important use of indicators is by utility managers in trending the performance of their nuclear units and identifying areas in which adjustments in priorities and resources are necessary. The performance indicators are, first and foremost, effective utility management tools for goal setting, development of necessary improvement programs and fostering healthy unit-to-unit and industrywide competition.

The following performance trend graphs are examples of the results that the U.S. nuclear industry has achieved in its quest for excellence in operation.

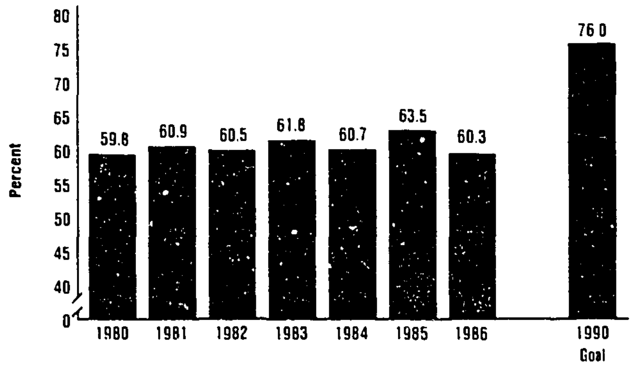

Figure 1. Industry Equivalent Availability

Equivalent availability [a](Figure 1) rose from 59.8 percent in 1980 to 63.5 percent in 1985. However, equivalent availability was 60.3 percent in 1986 due to the number of plants in an extended outage status. The industry goal for 1990 is 76 percent.

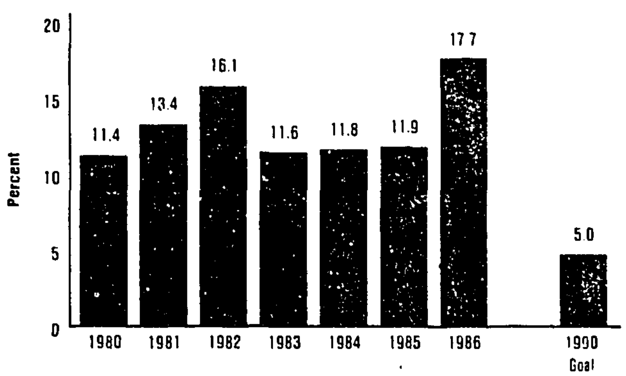

Figure 2. Industry Forced Outage Rate

The forced outage rate [a](Figure 2) declined by more than 26 percent between 1982 and 1985. Again, because of extended outages by several plants, the forced outage rate in 1986 of 17.7 percent does not compare favorably. The industry's 1990 goal of 5 percent represents a significant improvement.

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[a] If the seven U.S. plants that were in an extended outage since the beginning of 1986 were excluded from the data base, the 1986 industry value for equivalent availability factor would be 66.7 percent, and the forced outage rate would be 10.2 percent. Each of these would have represented continued, significant industrywide improvement.

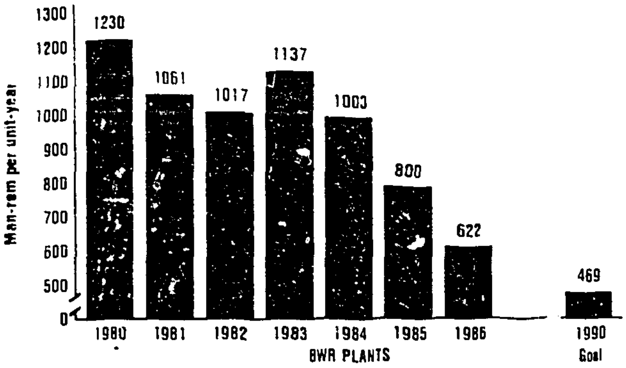

Figure 3. Collective Radiation Exposure per BWR Unit

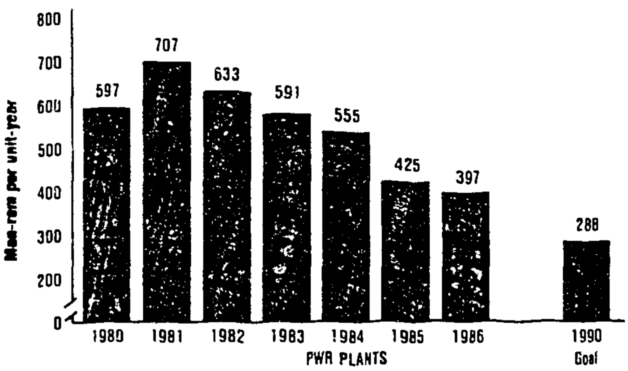

Figure 4. Collective Radiation Exposure per PWR Unit

Collective radiation exposure per boiling water reactor unit (Figure 3) decreased from 1230 manrem per unit year in 1980 to 622 in 1986, a decrease of more than 49 percent. For PWRs (Figure 4), this figure dropped from 597 in 1980 to 397 in 1986, a 33 percent decrease.

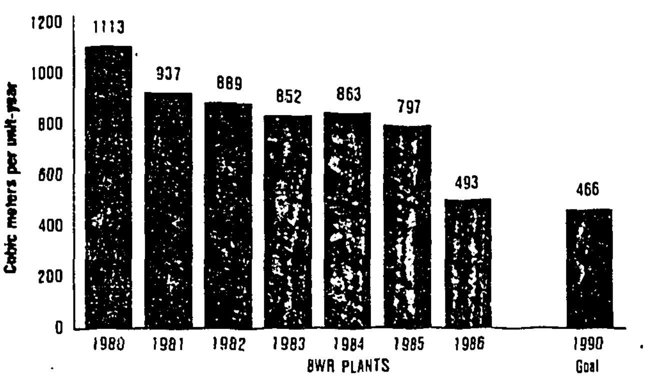

Figure 5. Low-level Solid Radioactive Waste per BWR Unit

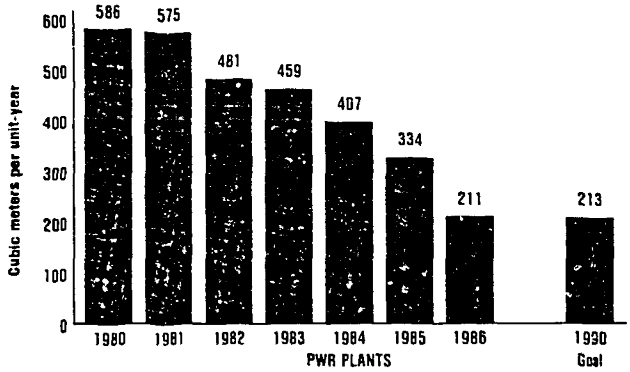

Figure 6. Low-level Solid Radioactive Waste per PWR Unit

Low-level, solid radioactive waste shipped per BWR unit (Figure 5) dropped from 1113 cubic meters per unit-year in 1980 to 493 in 1986, a 56 percent decrease. For PWRs (Figure 6), this figure dropped from 586 in 1980 to 211 in 1986, a 63 percent decrease.

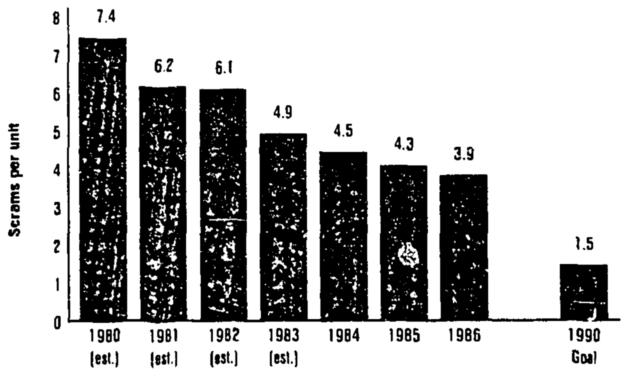

Figure 7. Unplanned Automatic Scrams

Unplanned automatic reactor scrams (Figure 7) dropped by more than 47 percent between 1980 and 1986. As you can see, the 1990 goal represents an additional substantial reduction.

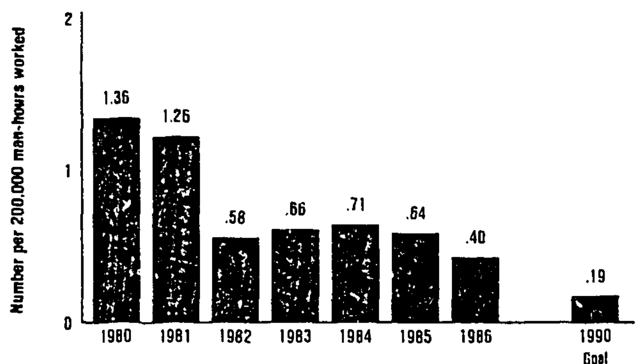

Figure 8. Lost-time Accident Rate

Utility initiatives in worker safety (Figure 8) have reduced lost-time accident rates at nuclear plants by about 70 percent between 1980 and 1986. The goal is to reduce the lost-time accident rate by a factor of two during the next four years.

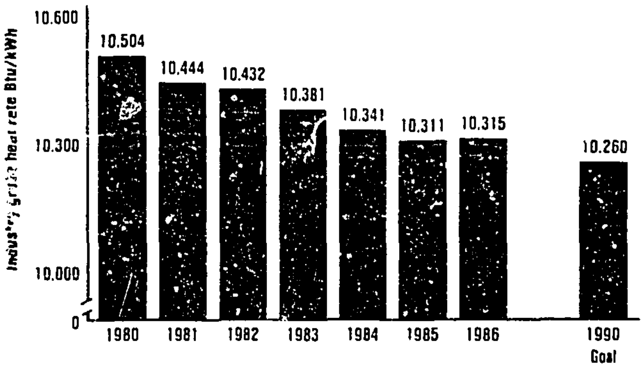

Figure 9. Thermal Performance

The U.S. industry's thermal performance (Figure 9) decreased from 10,504 Btu/kWh in 1980 to 10,315 in 1986. This drop in heat rates shows increased attention to thermal efficiency.

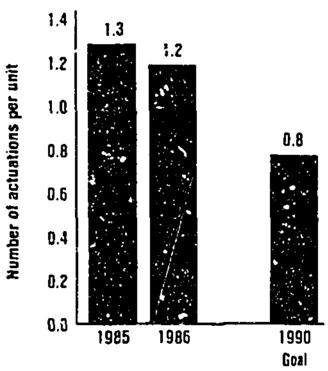

Figure 10. Unplanned Safety System Actuations

Finally, the goal for the number of safety system actuations per unit-year (Figure 10) represents a reduction of nearly 38 percent by 1990, down to 0.8 per unit-year from 1.3 per unit-year in 1985 when data collection on this indicator began.

Maintenance

The performance indicator trends show that a maturing nuclear industry is realizing its self-improvement potential. Certainly, the operational goals U.S. utilities have set for 1990 are tough and challenging and an additional step in that direction.

In the face of these challenges, INPO has directed resources, some of them focused formerly on plant construction activities, toward such operational areas as maintenance, outage management and configuration control.

On the average, 70 percent of a plant's non-capital budget involves maintenance expenditures. Better maintenance results in improved performance, such as higher unit availabilities, reduced number of reactor scrams and reduced numbers and lengths of forced outages.

As part of the performance indicator program, INPO monitors 11 maintenance-related parameters that focus on such operational items as maintenance backlogs, preventive maintenance activities and radiation exposure and industrial safety for maintenance workers. For example, these have shown steady improvement in the following areas:

- The number of unplanned automatic scrams while critical as a result of maintenance activities was reduced by more than 26 percent, down to 2.5 scrams per unit[b] in 1986 from 3.4 per unit in 1984.
- The industry average for preventive maintenance items overdue dropped from 10.8 percent in 1984 to 9.2 percent[b] in 1986, a reduction of nearly 15 percent.
- The industry average of maintenance overtime worked dropped more than 7 percent, down to 20.9 percent[b] in 1986 from 22.5 percent in 1984.
- The industry average for ratio of highest priority maintenance work requests (MWRs) to total MWRs completed dropped from 8.7 percent in 1985 to 6.5 percent[b] in 1986, a decrease of more than 25 percent.

The Institute responded to the industry's maintenance-related needs by developing an Outage Management Assistance Program aimed at helping utilities improve both the quality of work performed and unit availability. This assistance effort involves team visits to plants during the planning stage two to four months before the outage and again while the outage is in progress.

[b] These maintenance indicator figures for 1986 are based on data available at the time the article was written (three quarters actual and one quarter projected).

INPO also operates and manages the Nuclear Plant Reliability Data System (NPRDS), which supplies industrywide data on the performance of nuclear plant systems and components. INPO receives design characteristics reports and component performance information from members. Both the Institute and member utilities use this information to identify significant failure patterns or unusual component failure modes.

Ongoing NPRDS improvements are enhancing the retrieval of assessment of component performance data. Regular screening of NPRDS information by the Institute's Equipment Reliability Analysis Program and the Component Failure Analysis System is helping to pinpoint trends and identify equipment performance improvements opportunities.

SEE-IN

Among the management tools recommended during the TMI accident analysis was a program for systematic gathering, review, analysis and communication of plant operational experience. INPO reports on operational events received from U.S. utilities and international participants through a program called the Significant Event Evaluation and Information Network (SEE-IN).

Operational reports are screened for significance and classified for priority of evaluation immediately upon receipt. For those classified as significant, either a significant event report (SER) is transmitted on NUCLEAR NETWORK as quickly as reliable information can be processed or the industry is notified that the event is significant and is adequately described in another document.

Similar events that have occurred relatively frequently or single events of high impact are analyzed further. These are published in a detailed significant operating experience report (SOER) with recommendations to be accomplished at applicable plants to prevent recurrence of the event. SOERs are classified by their importance: red for immediate attention and yellow for prompt attention. Utilities use SOER recommendations to develop corrective action plans to prevent future occurrence of similar events in their plants.

Typically, between 7,000 and 10,000 operational reports are screened annually. For example, INPO received a total of 7,665 reports for SEE-IN screening in 1986. Seventy-nine events, or about 1 percent, were judged to be significant. As a result, INPO issued 40 SERs, and three SOERs providing 13 recommendations in the areas of design, operation, maintenance and training.

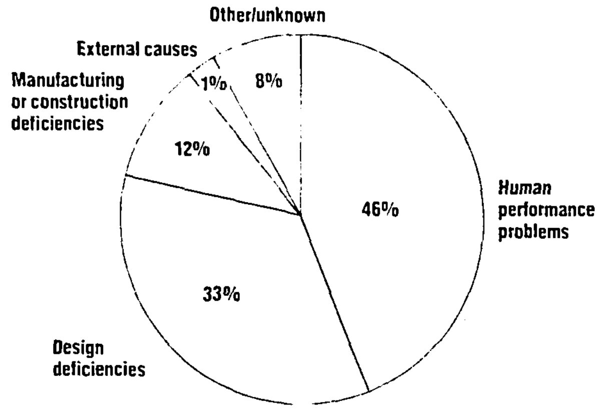

Figure 11. Major Root Cause Categories

Analysis of the root causes associated with these significant events can be used by the industry to effectively focus preventative action. For example, human performance problems were the reason for 46 percent of the 120 root causes involved with the 111 significant events identified in 1985 (Figure 11). The remainder found their roots in design deficiencies (33 percent), manufacturing deficiencies (12 percent) and unknown or other causes (9 percent).

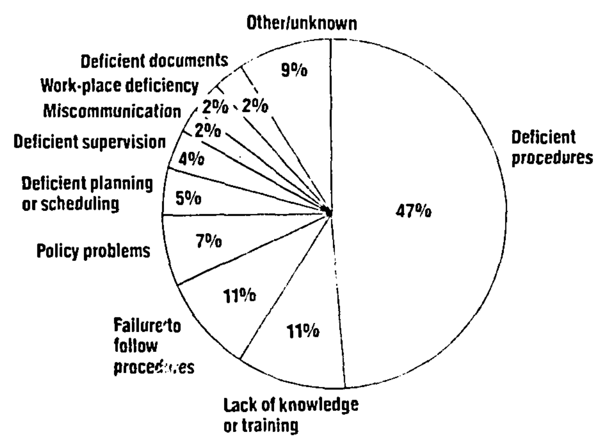

Figure 12. Human Performance Root Cause Categories

Most of the events with a human performance root cause (Figure 12) were associated with deficient procedures (47 percent), lack of knowledge or training and failure to follow procedures (11 percent, respectively) and policy problems (7 percent). In nearly 80 percent of these cases, the employees involved were licensed operators, instrument and control technicians or maintenance personnel. The analysis supports the following conclusions:

- Incomplete procedures were the principal problems.

- Approximately one-half to two-thirds were influenced by circumstances beyond the immediate control of those personnel involved at the time.

- About one-third of all human performance root causes involved misoperation of components by personnel.

These patterns of human performance indicate that efforts toward improvement in plant operations should focus on the following areas:

- Procedures (especially for testing) should be revised as necessary to include all the steps required to perform the activity properly. This effort should focus primarily on the return to service (completion) portion of testing procedures and on the performance portion (action steps) of all procedures.

- Procedures should associate appropriate cautions with steps that may have adverse effects if performed under certain conditions.

- Plant personnel should be encouraged to submit requests for procedure revision when they find deficiencies such as incompleteness or lack of clarity.

- Qualification requirements for individuals performing an activity should include not only fundamental and technical knowledge and appropriate experience, but also specific training in the special precautions that may be necessary under certain plant or system conditions.

- The importance of "thinking through" procedures and being aware of the consequences of specific actions should be instilled in plant personnel.

INPO was able to draw the following conclusions from causal analysis in the area of plant design. About half of the root causes involved system or component configuration problems and another one-third involved specification of design reviews, but the remainder were not found until they resulted in a significant event during plant operations.

These root cause patterns indicate that management effort to reduce significant events in the area of plant design should focus on the following areas:

- Plant personnel should be encouraged to report equipment performance problems encountered during various plant activities. These problems may help identify design deficiencies or predict component failures before they result in significant events.

- Plants should review industry operating experience for applicable design deficiencies that have caused (or could have caused) significant events elsewhere. Special inspections or tests can be conducted to determine the presence of similar deficiencies. Appropriate corrective action will minimize the recurrence of events due to design similarities.

- When establishing the configuration of systems or components, all possible operating modes or conditions should be anticipated to ensure appropriate performance and avoid improper responses. This emphasis is especially important in the configuration of instrument and control system logic and control functions.

- When specifying components or materials, available performance information about that component or material should be taken into account. Since it is often not possible to anticipate all operating effects or material behavior, industry experience with similar applications should be carefully considered.

Virtually, every step of the Institute's SEE-IN program can assist in preventing significant events, and there are indications of its effectiveness.

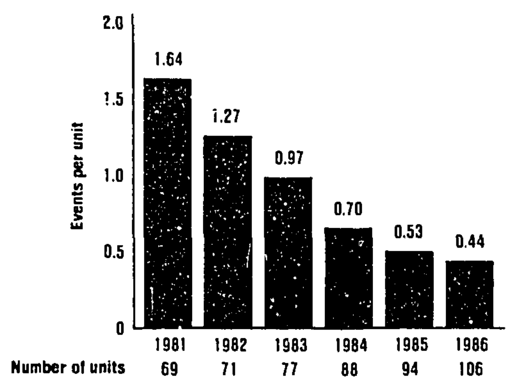

Figure 13. Significant Events per Unit

The number of significant events is tracked in a fashion similar to other performance indicators.

While determination of event significance is somewhat subjective, there has been a threefold reduction in the number of these events since 1981. In fact, the number of significant events per domestic operating reactor (Figure 13) had dropped to 0.44 per year in 1986, down from 1.64 per reactor in 1981, representing a decrease of more than 73 percent. The declining number of significant events occurring each year at U.S. plants indicates that the industry is learning from experience and should expect fewer mishaps.

Management commitment and involvement in plant operations can be seen in the industry's response to SOERs. INPO tracks satisfactory completion of recommendations provided in SOERs. Through 1986, 85 percent of all SOER recommendations had been completed in all U.S. plants.

The Institute has taken additional steps to promote industry efforts to incorporate, implement and retain operating experience in all facets of plant operation. During 1986, INPO conducted an in-depth review of SOER recommendations to determine the lasting effectiveness of utility response and identify the lessons learned from 1980 to 1985 that have continuing applicability.

In February 1987, INPO issued INPO 86-033, Selected Significant Operating Experience Report (SOER) Recommendations (1980-1985), identifying 62 SOER recommendations of long-term importance for nuclear utility management. Effective implementation of these recommendations will be evaluated on a continuing basis. Other SOER recommendations are evaluated only until initially closed, unless a subsequent performance problem occurs. This effort should concentrate management attention on essential lessons learned and, at the same time, help address the substantial accumulation of significant industry operating experience.

Summary

Providing the tools to keep management attention at all levels focused on the operation of their nuclear plants is the key to improved performance. Programs developed for the industry highlight areas in need of attention and enhance decision making on commitment or resources.

As seen by the reduction of significant events, the industry is using operating experience to prevent mishaps. And, the positive trends in performance shown by the indicators is testimony to the benefit of better management tools.

The U.S. nuclear industry took the initiative in 1979 to establish an organization that promotes excellence. While progress has been made in the eight years since INPO was formed, room for improvement continues. Certainly, nuclear industry management is receiving and developing the tools to achieve higher levels of safety and reliability.