Development of Risk-Based Performance Indicators: Program Overview

March 2000

Executive Summary

The purpose of this document is to provide an overview of the current effort to develop risk-based performance indicators (RBPIs). The development of RBPIs is being undertaken as a possible enhancement to the Revised Reactor Oversight Process. However, at the present time, no decision has been made in that regard pending further development and evaluation. This work will be coordinated with the concurrent efforts to risk-inform 10 CFR Part 50.

In developing RBPIs, "performance" refers to those activities in design, procurement, construction, operation and maintenance that support achievement of the objectives of the cornerstones of safety in the Reactor Oversight Process.

SECY 99-007, "Recommendations for Reactor Oversight Process Improvements," Attachment 2, "Technical Framework for Licensee Performance Assessment," lists the key attributes of performance within each cornerstone. RBPIs provide performance measures that are related as explicitly as practical to the risk-significant elements of these key attributes.

Collectively, the RBPIs will have the following characteristics:

- The RBPIs should be compatible with, and complementary to, the risk-informed inspection activities of the oversight process.
- The RBPIs should cover all modes of plant operation.
- Within each mode, the RBPIs should cover risk-important SSCs to the extent practical.
- The RBPIs should be capable of implementation without excessive burdens to licensees or NRC in the areas of data collection and quantification.
- To the extent practical, the RBPIs should identify declining performance before performance becomes unacceptable, without incorrectly identifying normal variations as degradations (i.e., avoid false-positive indications and false-negative indications).
- The RBPIs should be amenable to establishment of plant-specific thresholds consistent with the Revised Reactor Oversight Process.

Risk-significant changes in performance areas such as maintenance, testing, training, and quality assurance are expected to manifest themselves as changes in the values of the RBPIs. Some risk-significant performance areas cannot be measured by the RBPIs and will be covered through the risk-informed inspections outlined in the Revised Reactor Oversight Process. Design issues relating to performance under the cornerstone objectives will be reflected in individual RBPIs (such as system unavailability) and/or through the Significance Determination Process that will be applied to inspection findings. Both the RBPIs and the risk-informed inspection findings provide performance indications that can be evaluated in a consistent and risk-informed process to assess licensee performance.

The RBPIs will provide potential benefits to the Revised Reactor Oversight Process as follows:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state-of-the art models, data and methods for these areas;

- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

A graded threshold approach consistent with the Reactor Oversight Process will be used for the RBPIs. This approach will incorporate sufficient margins of safety to provide the NRC staff with the opportunity to take appropriate action to correct performance degradations before they become unacceptable. The greater coverage of risk-significant performance afforded by the RBPIs will allow for concomitant changes to inspections in those areas covered by the RBPIs and the explicit identification of risk-significant areas that the inspection program must cover.

The process for assessing licensee performance in the Revised Reactor Oversight Process is illustrated in Figure ES-1. The parts of the diagram in bold indicate how RBPIs will fit into the existing process. Some of the current Reactor Oversight Process performance indicators will be replaced with improved RBPIs. In addition to providing plant-specific information, the RBPI program results will provide industry-wide trends, including risk-significant trends on performance elements that are difficult, if not impossible, to trend on a plant-specific basis. This includes Accident Sequence Precursor (ASP) events, less-frequent initiators (e.g., loss of offsite power, steam generator tube rupture, and small loss-of-coolant accidents), and common-cause failure (CCF) events. When combined with the plant-specific RBPI trends, these additional trends and associated insights on key contributors provide information to assist in selecting areas for risk-informed inspection activities and to assess, in part, the effectiveness of the Revised Reactor Oversight Process.

RBPIs are developed by:

- Determining the risk-significant key attributes of each cornerstone
- Determining the elements of each of the risk-significant key attributes
- Obtaining performance data for each of these elements
- Identifying indicators from the data that are capable of detecting performance changes in a timely manner
- Identifying performance thresholds from the data consistent with a graded approach to performance evaluation outlined in the performance thresholds conceptual framework of SECY 99-007.

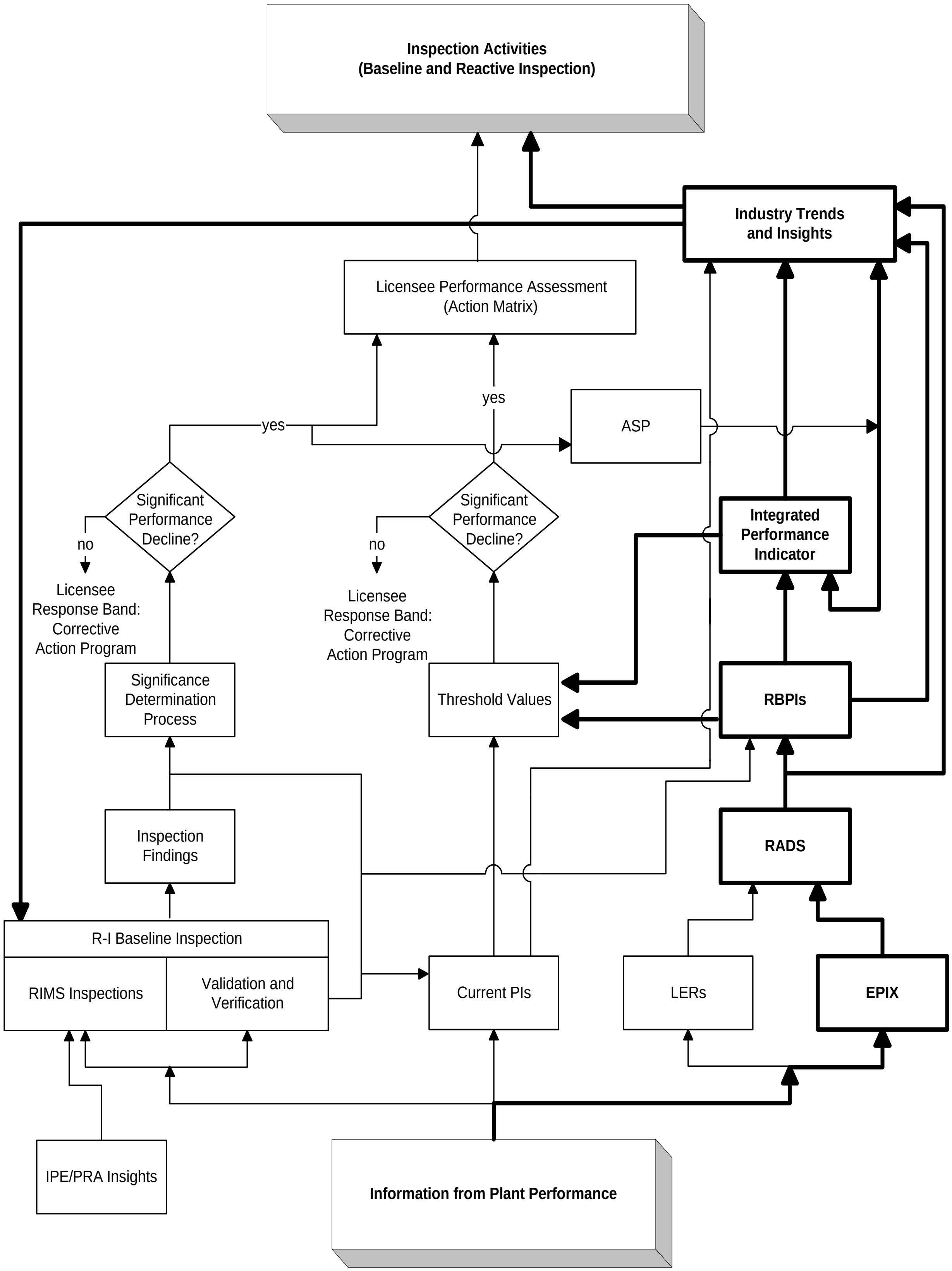


Figure ES-1. Assessment of Licensee Performance Under the Revised Reactor Oversight Process

Development of RBPIs will be accomplished in phases and will follow the following steps:

- Issue an RBPI program overview white paper for stakeholder comment;
- Brief the ACRS and Commission on the RBPI development plan outlined in the program overview white paper;
- Issue a Phase-1 RBPI development progress report, including example RBPIs, for stakeholder comment;
- Brief of the ACRS and Commission on the Phase-1 RBPI development progress;
- Issue a Phase-2 RBPI development progress report, including example of RBPIs, for stakeholder comment;
- Brief of the ACRS and Commission on the Phase-2 development progress.

The RBPI development will be closely coordinated with the Office of Nuclear Reactor Regulation (NRR). Throughout the RBPI development process, there will be numerous interactions with internal and external stakeholders to ensure that their feedback is appropriately incorporated.

Phase-1 of the RBPI development will concentrate on indicators that are related to the initiating event cornerstone, the mitigating system cornerstone, and the containment portion of the barrier integrity cornerstone. Specifically, these will include:

- Reliability indicators for the mitigating system cornerstone;
- Containment;
- Fire;
- Shutdown;
- Industry trends.

The fire and shutdown indicators will be developed consistent with the current state of the art models, methods and data for these areas.

Additional phases will address:

- An integrated indicator;
- Improvements to the indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data;
- Additional unavailability indicators with plant-specific thresholds;
- Other external events (e.g., seismic and wind);
- Follow-on work to improve existing indicators in response to NRC and/or industry lessons learned from the Revised Reactor Oversight Process implementation.

The data sources and models needed for RBPI development already exist or are being developed under separate and multi-purpose programs (e.g., studies of system and component reliabilities and initiating event frequencies). Development and implementation of the RBPIs require the implementation of the industry Equipment Performance Information Exchange (EPIX) database and the associated NRC data extraction and analysis software called Reliability and Availability

Data System (RADS). Further research work on risk models and insights for external events and shutdown will be needed to better satisfy the RBPI development objectives in those areas.

ABBREVIATIONS AND ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
AFW	auxiliary feedwater
ASP	Accident Sequence Precursor
BWR	boiling water reactor
CCF	common cause failure
CCW	component cooling water
CDF	core damage frequency
EPIX	Equipment Performance and Information Exchange System
FSAR	Final Safety Analysis Report
INEEL	Idaho National Engineering and Environmental Laboratory
IPE	individual plant examination
IPEEE	individual plant examination of external events
LB	licensing basis
LER	Licensee Event Report
LOCA	loss-of-coolant accident
MOR	monthly operating report
NEI	Nuclear Energy Institute
NPRDS	Nuclear Plant Reliability Data System
PORV	pilot-operated relief valve
POS	plant operating state
PRA	probabilistic risk assessment
PWR	pressurized water reactor
RADS	Reliability and Availability Database System
RBPI	risk-based performance indicator
RCS	reactor coolant system
RG	Regulatory Guide
RHR	residual heat removal
RPS	reactor protection system
SALP	Systematic Assessment of Licensee Performance
SDP	Significance Determination Process

SCSS	Sequence Coding and Search System
SGTR	Steam Generator Tube Rupture
SPAR	Simplified Plant Analysis Risk
SSC	systems, structures, and components
SW	Service Water
TMI	Three Mile Island

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Purpose

The purpose of this document is to provide an overview of the current effort to develop risk-based performance indicators (RBPIs). The development of RBPIs is being undertaken as a possible enhancement to the Revised Reactor Oversight Process discussed in SECY 99-007 (Ref. 1) and SECY-99-007A (Ref. 2). However, at the present time, no decision has been made in that regard pending further development and evaluation. This work will be coordinated with the concurrent efforts to risk-inform 10 CFR Part 50.

This document addresses three major areas:

- the definition of RBPIs,
- the benefits of RBPIs in the Revised Reactor Oversight Process, and
- the process of developing RBPIs.

The Revised Reactor Oversight Process uses performance indicators and findings from risk-informed inspections to assess plant performance relative to the "cornerstones of safety." The RBPIs will improve the Revised Reactor Oversight Process as follows:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state of the art models, data and methods for these areas;
- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

2. What Are RBPIs?

2.1 Concept of Performance and Definition of RBPIs

With regard to the Reactor Oversight Process, "performance" refers to those activities in design, procurement, construction, maintenance and operation that support achievement of the objectives of the cornerstones of safety in the Reactor Oversight Process.

The Reactor Oversight Process samples plant behavior in order to verify that licensee performance is meeting the cornerstone of safety objectives. Two kinds of information are obtained in this sampling process: information obtained through inspections, and information obtained through monitoring of performance indicators. The term "sample" is used to emphasize that the Reactor Oversight Process does not inspect or monitor every possible aspect of plant behavior. Rather, it is designed to gather sufficient information in enough different areas to be able to support the conclusion that the licensee’s performance is effective.

Risk-significant performance changes generally affect system characteristics such as frequency of events and reliability, availability, or capability of systems, structures, and components (SSCs). Here, "capability" refers to the physical capacity of the system to accomplish a given function, such as "deliver required flow at a given pressure," or "successfully bear a given load." Availability refers to the fraction of time that the SSC is capable of performing its function. Reliability refers to the probability that a given SSC will function on demand and during the required mission time, given that it was available.

SECY 99-007, "Recommendations for Reactor Oversight Process Improvements," Attachment 2, "Technical Framework for Licensee Performance Assessment," lists the key attributes of performance within each cornerstone. RBPIs provide performance measures that are related as explicitly as practical to the risk-significant elements of these key attributes.

Collectively, the RBPIs will have the following characteristics:

- The RBPIs should be compatible with, and complementary to, the risk-informed inspection activities of the oversight process.
- The RBPIs should cover all modes of plant operation.
- Within each mode, the RBPIs should cover risk-important SSCs to the extent practical.
- The RBPIs should be capable of implementation without excessive burdens to licensees or NRC in the areas of data collection and quantification.
- To the extent practical, the RBPIs should identify declining performance before performance becomes unacceptable, without incorrectly identifying normal variations as degradations (i.e., avoid false-positive indications and false-negative indications).
- The RBPIs should be amenable to establishment of plant-specific thresholds consistent with the Revised Reactor Oversight Process.

2.2 Kinds of Performance That RBPIs Can Measure

The development of RBPIs will assess performance in the first three cornerstones of safety: initiating events, mitigating systems, and containment barrier integrity. To the extent possible, the RBPIs will correspond directly to quantities that appear explicitly in models of CDF or LERF. The cornerstones of safety for emergency preparedness, radiation safety, and safeguards are not part of the present development.

Figure 1 shows the risk-based hierarchy and associated levels of indication that will form the bases for the risk based PIs. The cornerstones of safety of the Revised Reactor Oversight Process have a direct relationship to key parts of the risk logic. In particular, Figure 1 shows the levels of RBPIs that devolve from industry and sequence level indications under the mitigating systems cornerstone. These further devolve to system, train, and basic event indicators which are constituent parts of plant risk. In this sense, the lower level indicators are "leading" indicators of overall risk. A similar scheme applies to indicators for other cornerstones.

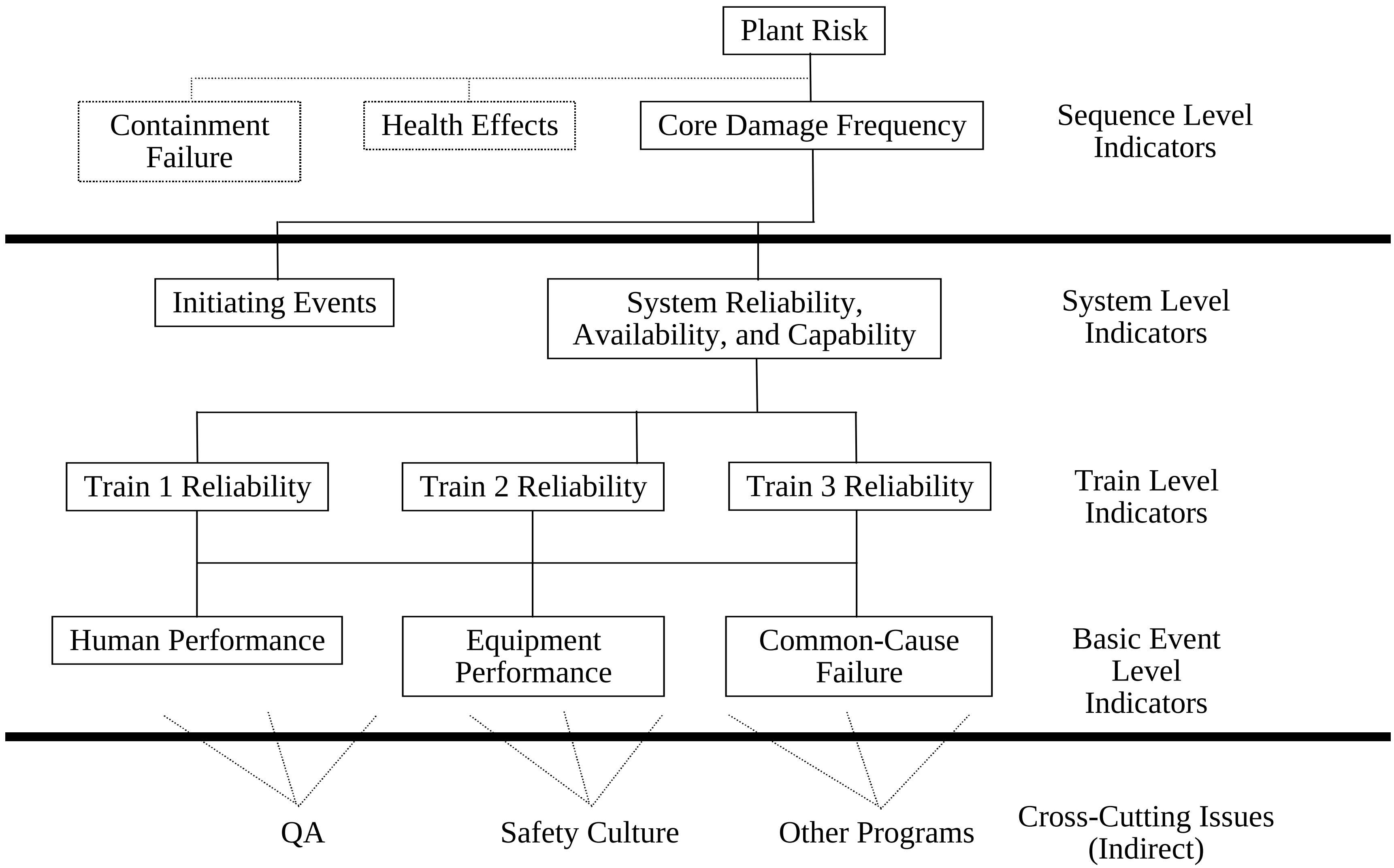
As shown in Figure 1, CDF explicitly depends on quantities such as the reliability and availability of certain systems, trains, and components, as well as human performance. RBPIs defined in terms of these quantities are direct indicators. Other performance influences on CDF, such as QA or safety culture, are not explicitly part of the calculation of CDF. Instead, their impact is related through the reliability, availability, and capability of systems, trains, and components that do affect CDF directly.

The conditions that contribute to the probability of failing to mitigate the consequences of an initiating event include:

- equipment unavailability due to maintenance;
- equipment unavailability due to test;
- the probability that an undetected equipment failure has occurred in standby and not been picked up in a test, or was picked up in a test and the item is now under repair;
- the probability of failure of equipment to function "on demand"; and
- the probability of failure of equipment to function during the required mission time ("fail to run/operate").

The RBPI development will address direct indicators: quantitative measures of performance in areas whose influence on CDF and on containment performance is explicit. RBPIs will reflect significant changes in these performance parameters for a broad set of systems and operational aspects associated with licensee performance under the cornerstones of safety.

Figure 1.
Elements of Risk



2.3 Graded Approach to Performance Evaluation

To the extent practical, the graded performance approach and the risk concepts used in the current Reactor Oversight Process will be used in the development of RBPI performance threshold values. Thresholds for each indicator will be based, to the extent practical, on the plant-specific impact on CDF (or LERF) of changes in the indicator value. The existing SECY 99-007 concepts of performance areas will be preserved, but the thresholds will be more plant specific. However, for any particular RBPI that applies to the industry or a group of plants, thresholds will differ only to the extent that the risk sensitivity to that performance varies substantially from one plant to another. This would occur if substantial design features and plant-specific operating history varied significantly among plants. For example, there may be different thresholds from emergency diesel generator (EDG) reliability among plants with two, three, or four EDGs. Within a group of plants with two EDGs, the threshold would likely be common unless the differences in risk sensitivity to EDG reliability were significant enough to warrant further refinement.

3. Benefits of RBPIs

3.1 Existing Oversight Processes

The Revised Reactor Oversight Process monitors performance on the basis of objective indicators and risk-informed inspection relating to the cornerstones of safety objectives. The risk-informed baseline inspections will cover those risk-significant aspects of licensee performance not adequately covered by performance indicators. NRC interaction with licensees will be based on the risk significance of that performance. The Revised Reactor Oversight Process has defined a set of performance indicators for measuring performance associated with each cornerstone of safety.

3.2 How RBPIs Improve the Revised Reactor Oversight Process

RBPIs are intended to increase the breadth and depth of the risk coverage of the current indicators, which will allow for concomitant changes to the risk-informed baseline inspections. The RBPIs will provide benefits to the Revised Reactor Oversight Process as summarized below:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state of the art models, data and methods for these areas;
- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

The process for assessing licensee performance in the Revised Reactor Oversight Process is illustrated in Figure 2. The parts of the diagram in bold indicate how RBPIs will fit into the existing process. Plant performance information is derived from licensee performed tests and inspections as well as NRC initiated inspection activities. This ensemble of performance information is evaluated through either the SDP for inspection findings or the risk-based framework of the PIs. Therefore, licensee performance assessment involves the combination of performance data derived from both NRC inspections and performance indicator data. Risk-based PIs are expected to provide the bulk of PI data. The NRC inspection activities cover areas not amenable to PI development and provide continuing validation and verification for the PIs through a sample of licensee activities related to performance (see Section 4.3 on PI validation and verification).

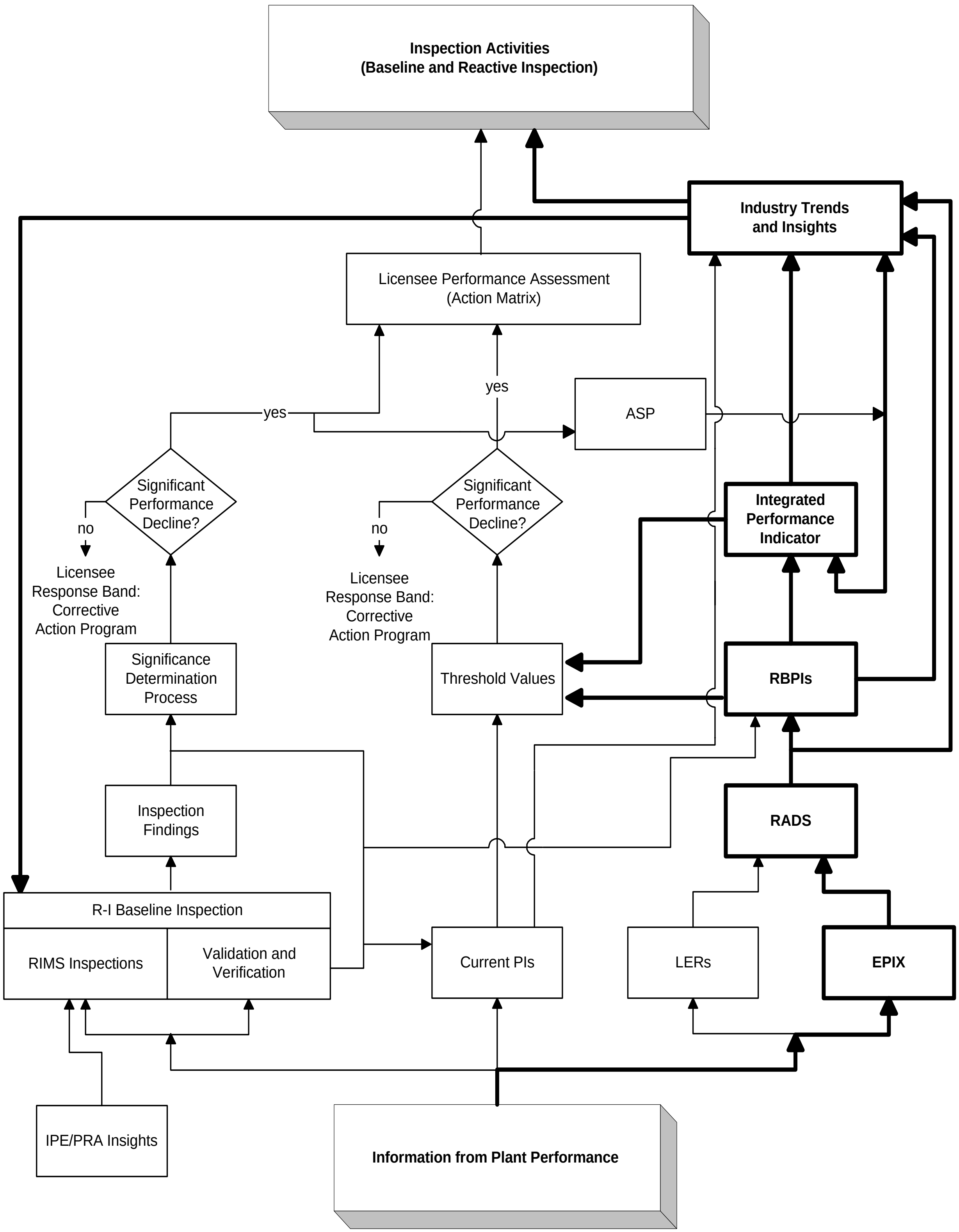


Figure 2. Assessment of Licensee Performance Under the Revised Reactor Oversight Process

In addition to providing plant-specific information, the RBPI program results will provide industry-wide trends (Ref. 3), including risk-significant trends on performance elements that are difficult, if not impossible, to trend on a plant-specific basis. This includes Accident Sequence Precursor (ASP) events (Ref. 4), less-frequent initiators (e.g., loss of offsite power, steam generator tube rupture, and small loss-of-coolant accidents), and common-cause failure (CCF) events. Because more data are available at the industry level, trends emerging at the industry level may be apparent before they are noticed at any given plant. When combined with the plant-specific RBPI trends, these additional trends and associated insights on key contributors provide information to assist in selecting areas for risk-informed inspection activities and to assess, in part, the effectiveness of the Revised Reactor Oversight Process.

The integrated indicator will reflect the combined risk significance of changes occurring in all monitored performance areas. Thresholds established for an individual RBPI reflect the risk significance of changes in that individual RBPI, with all other aspects of performance assumed to be nominal (i.e., green band). If only one area of performance is changing, assessment of its RBPI with respect to its threshold provides a satisfactory understanding of the risk significance of the change. However, if multiple areas of performance are changing, the overall risk significance of the changes should be assessed through an integrated indicator. By showing the degree to which the changes cause synergistic effects on risk, the integrated indicator furnishes additional input to the overall plant assessment. The thresholds for evaluating the significance of changes in the integrated indicator will use the concepts in RG 1.174 for evaluating the performance changes.

3.3 How the Revised Reactor Oversight Process Addresses Design (Capability) Issues

Problems with design (capability) issues can affect plant risk. As a result of design features, hardware performance may degrade prematurely in some areas, or undetected design errors could affect a system response to certain challenges. As stated earlier, there is a direct relationship between capability and availability. An SSC that is incapable of performing its safety function is also unavailable.

If a design deficiency affects the performance of a SSC, it will be detected through licensee problem identification programs, risk-informed baseline inspections, and/or through SSC performance data. If the design deficiency is detected through licensee or NRC inspections, its risk significance will be determined by the Significance Determination Process. Design deficiencies that are not amenable to detection by normal testing and routine surveillance activities will require properly focused design inspections by either NRC or licensees to detect their presence. Once found, the design deficiency represents performance data that can be evaluated through the SDP and/or PI framework as appropriate. When the design deficiency is reflected in the SSC performance data, the corresponding RBPIs will reflect the significance of the performance degradation, typically through degradations in reliability or availability of affected systems and components. Therefore, in both cases, the Revised Reactor Oversight Process will address design deficiencies and their risk significance.

3.4 How the Revised Reactor Oversight Process Addresses Cross-Cutting Issues

Some aspects of performance are "cross-cutting" in the sense that they affect multiple systems through similar if not identical causal factors. This could be manifested as a greater likelihood for common cause failure amongst redundant components or as a general decrease in reliability or availability of plant safety equipment. The oversight process will address cross-cutting issues in four ways:

- Indicators will cover a broad sample of performance to ensure that there are indicators capable of detecting risk-significant changes in programmatic performance areas.
- Indicators at the higher levels of Figure 1 (e.g., the integrated indicator) can show the impact of cross-cutting issues, even if individual lower-level indicators do not.
- Indicators that cover performance across system / train boundaries (e.g., component-level indicators) can show the impact of cross-cutting issues, even if individual system-level or train-level indicators do not. In addition, special inspections will be performed to address some cross-cutting issues.
- Potentially risk-significant cross-cutting issues not covered by indicators will be addressed through specific inspection areas (e.g., problem identification and corrective action program inspections).

4. The Process of Developing RBPIs

Development of RBPIs begins with the set of existing models, analyses, and databases that reflect risk performance of operating plants. These tools will be used in the selection of RBPIs. The process includes a validation and verification effort that covers initial and continuous use of RBPIs.

4.1 Existing Models, Analyses, and Databases

The initial development of RBPIs will rely on the adaptation of readily available models, analyses, and data. This section discusses the models, analyses, and databases that are required for the development of RBPIs. These include the SPAR models (Ref. 5); system reliability, component reliability, and event frequency analyses (Refs. 6, 7); and the EPIX (Ref. 8) and RADS (Ref. 9) databases.

The current set of models, analyses, and databases primarily cover risk performance relating to core damage frequency from internal events. Initial development in the areas of the containment barrier function, external events, and shutdown operation will use insights from currently available analyses such as IPEs, IPEEEs, and existing PRA studies of low-power/shutdown risk. Further improvements to risk models for external events, containment barrier, and shutdown operations may be needed to better satisfy the RBPI development objectives (see Section 4.2) in those areas. Based on the results of future research, enhancements to the initial set of RBPIs may be made.

Existing Standardized Plant Analysis Risk (SPAR) models, as well as system, component, and event frequency assessment models, will be used in RBPI development to:

- group similar plants so that a given set of RBPIs applies to the entire group
- select and formulate RBPIs for each plant group
- evaluate plant-specific baseline values for each RBPI
- evaluate plant-specific RBPI thresholds
- quantify integrated indicators.

The SPAR models are a set of CDF models developed by the NRC for all U.S. commercial nuclear reactors. These SPAR models are an outgrowth of the Accident Sequence Precursor program (Ref. 4). The ASP program identifies precursors to core damage events. Experience in the ASP program indicates that SPAR results and IPE results show a reasonable consistency. The more significant differences are usually due to credit for systems and procedures at plants that were not included in the original SPAR models (such as cross-tie capabilities or additional equipment).

Ongoing system and component reliability studies systematically evaluate operational data of risk-significant systems at nuclear power plants. These studies estimate system unreliability based on operational data and then to compare the results with data, models, and assumptions used in PRA/IPEs. They provide an engineering analysis of the risk-significant factors affecting system unreliability and determine trends or patterns in industry performance.

The system and component reliability studies will be used in the RBPI effort to:

- establish potential groupings of plants with respect to system configuration,
- identify system/train definitions and boundaries,
- establish baseline train and system performance levels (for plants, groups of plants, and the industry as a whole, as appropriate),
- identify important types of CCFs and human errors, and
- provide baseline performance data input to the integrated indicator models.

The report *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 – 1995* (Ref. 6) provides a summary of initiating event data (unplanned, manual, and automatic reactor trips) between 1987 and 1995 for power operation. The report identifies risk-significant initiators and their frequency of occurrence. The report *Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980 – 1996* (Ref. 7) focuses specifically on loss of offsite power initiators at power and during shutdown operations. The report analyzed and trended the underlying causes of loss of offsite power, and showed differences between types of events in both calendar-time trending and degree of plant-to-plant variation.

The EPIX database is an industry-sponsored effort to collect performance information for key components in or affecting risk-significant systems as identified in plant maintenance rule programs. EPIX is a replacement for the Nuclear Plant Reliability Data System (NPRDS) database (Ref. 10). (Data reporting to NPRDS stopped at the end of 1996.) All nuclear utilities have submitted reliability data for entry into EPIX. The RBPI development will use EPIX data to support the evaluation of mitigating system RBPIs. The Reliability and Availability Data System (RADS) (Ref. 9) will be used to analyze the EPIX and other relevant data to determine component, train, and system performance.

RADS provides reliability and availability data and parameter estimation capability for use in risk-informed applications and regulations. It imports data from EPIX as well as other established supplemental sources. The RADS program is under development, with a beta version that began testing in September 1999. The production version of RADS is scheduled for June 2000.

For external events, containment, and shutdown, there are fewer models, analyses, and databases available than for internal events, as noted above. Therefore, RBPI development will rely on insights from existing risk analyses in these areas. These include IPEs and a limited number of Level-3 PRAs for containment issues, IPEEEs for external events, and the limited number of PRAs for shutdown operations.

4.2 RBPI Selection

Figure 3 shows the process for selecting potential RBPIs for evaluation and development. This process includes the following:

- Determining the risk-significant key attributes of each cornerstone
- Determining the elements of each of the risk-significant key attributes

- Obtaining performance data for each of these elements
- Identifying indicators from the data that are capable of detecting performance changes in a timely manner
- Identifying performance thresholds from the data consistent with a graded approach to performance evaluation outlined in the performance thresholds conceptual framework of SECY 99-007.

The process shown in Figure 3 imposes two tests on candidate indicators. First, degraded performance in the indicated area must be risk-significant. Second, operational conditions (frequency of challenges, etc.) must be such that there is a significant statistical chance that degraded performance will be detected by the indicator within a reasonable time. The process in Figure 3 identifies areas for inspection that are risk-significant but not practical to monitor directly. This process also shows the relationship of individual RBPIs to the formulation of an integrated indicator. Finally, after a set of indicators and inspections has been identified, the process calls for an assessment of the risk coverage. The Revised Reactor Oversight Process is predicated on obtaining a sufficient sample of performance in risk-significant areas. It is desirable to understand the degree of coverage afforded by a complement of indicators and inspections.

External events are potentially risk-significant because they can causally link equipment failures whose coincidence is risk-significant and would be unlikely to occur as a result of independent causes. For example, a severe earthquake may damage multiple SSCs whose coincident failure without the earthquake would be extremely unlikely. The potential to link failure events is the reason that scenario types such as "fire" and "internal flood" are frequently discussed together with truly ex-plant external events such as seismic events and high winds.

Conditions that strongly affect the formulation of performance indicators for these events are the following:

- For external events such as earthquake and high wind, the hazard function is not under the control of the licensee. This sets external events apart from the kinds of initiating events that the licensee can affect (e.g., most internal-events transients).
- The initiating event frequency is low enough that data on equipment performance in "real" challenges are sparse.
- Certain mitigating features are not readily testable to produce typical performance indicator data.

Figure 3.
Developing Indicators for Internal Events/Full Power

<u>Sheet 1</u>

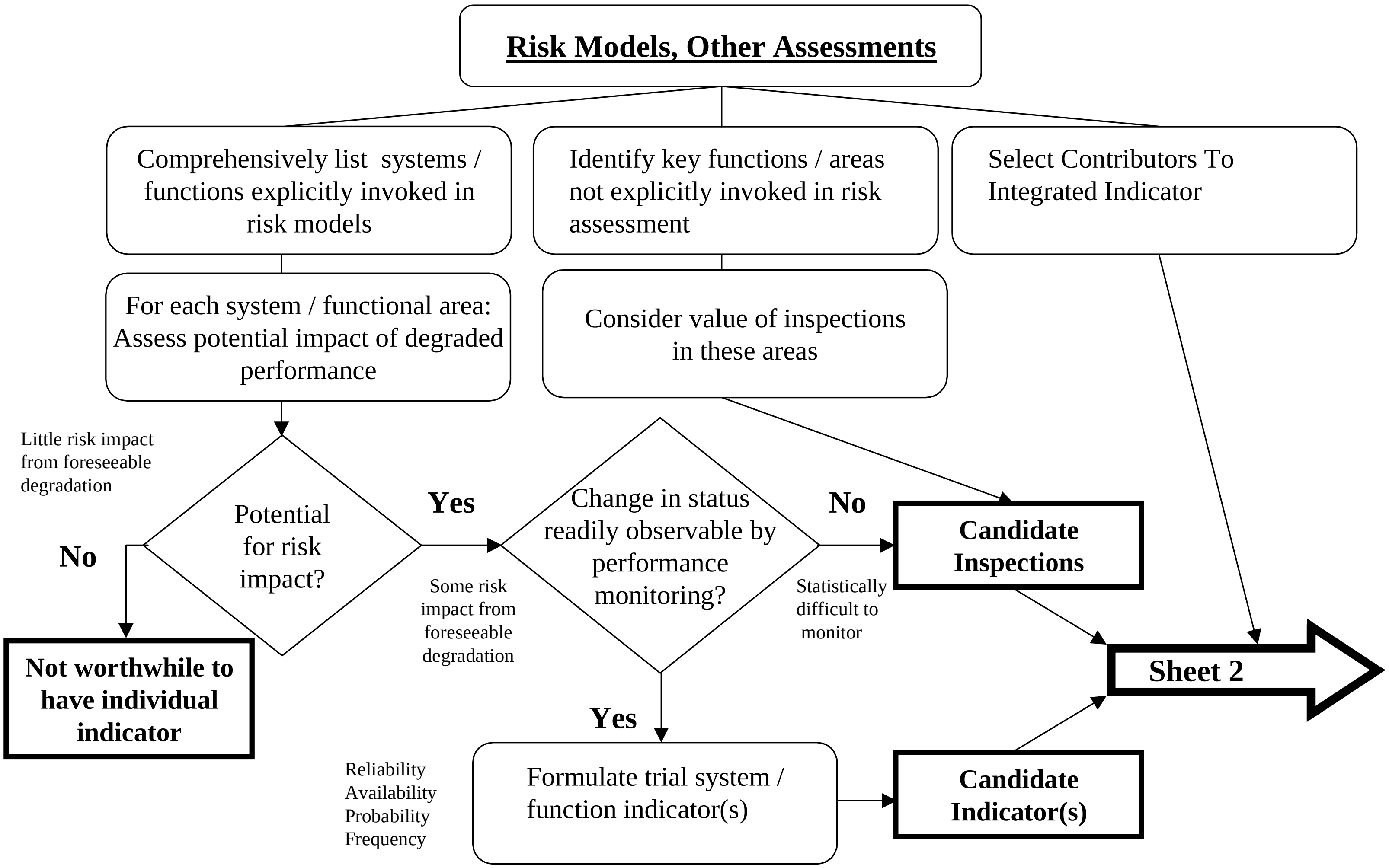
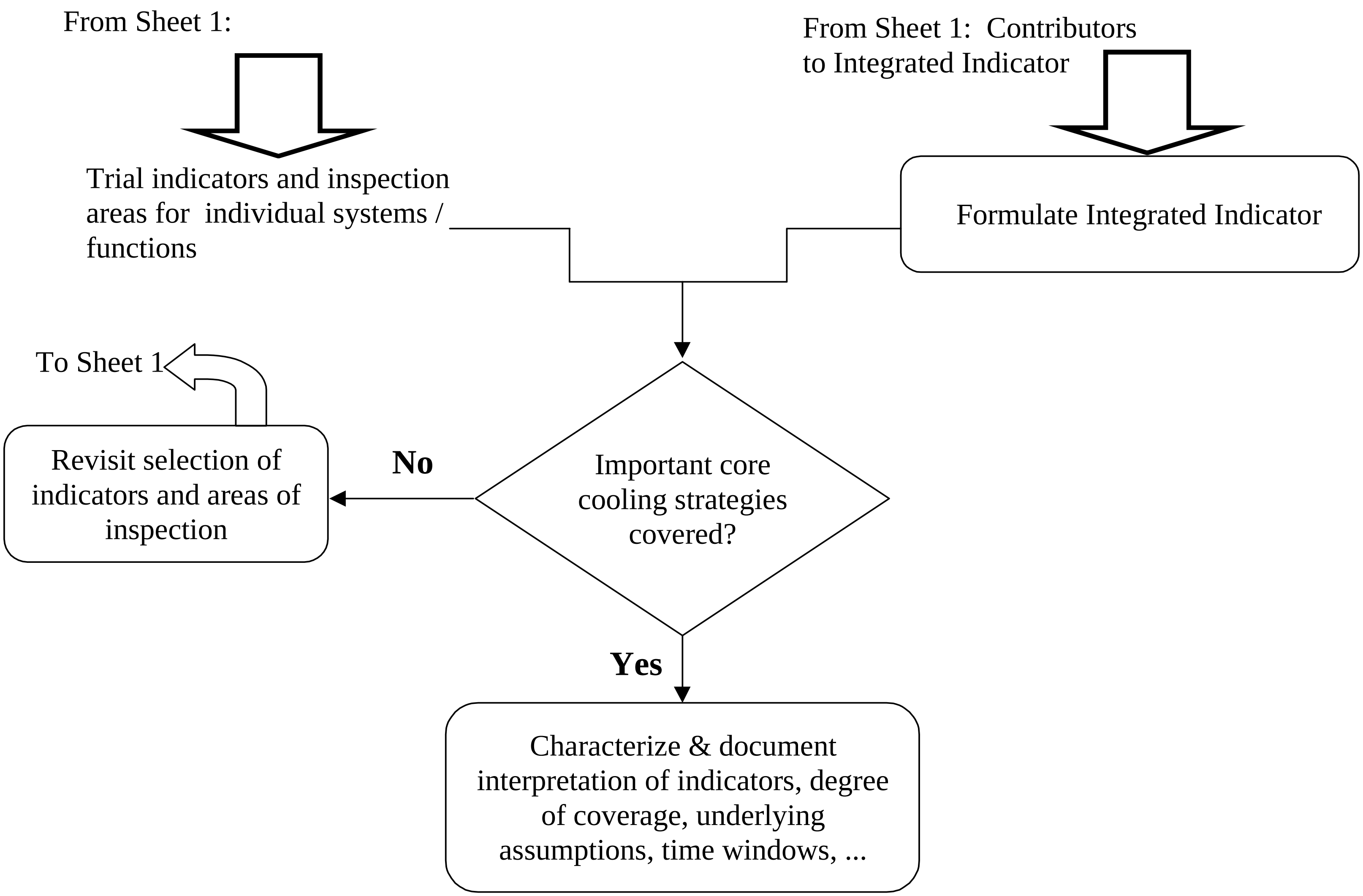


Figure 3.
Developing Indicators for Internal Events/Full Power

<u>Sheet 2</u>



The process for identifying indicators for external events will be similar to that in Figure 3 but will also take into account these factors.

It is widely agreed that shutdown risk is strongly dependent on plant operating state (POS). Correspondingly, the development of risk-based performance indicators will recognize that the risk profile at shutdown varies as RCS conditions change and mitigating systems are taken out of service.

Conditions that affect the formulation of RBPIs for shutdown include:

- Initiators will involve events leading directly to loss of decay heat removal, or loss of inventory leading to loss of decay heat removal, including human errors.
- Risk in the plant operating states (POSs) varies. POSs having high decay heat with reduced inventory tend to be more risk-significant.
- Operator recovery actions play a more prominent role affecting risk.
- There are significant differences in equipment availability between shutdown and at-power modes.

The process for identifying indicators during shutdown operation will be similar to that in Figure 3, but taking into account these key factors.

4.3 Validation and Verification

RBPIs will be validated and verified (V&V) in two phases. The first includes V&V activities undertaken as part of the development and testing of RBPIs. This involves steps similar to those described in SECY 99-007, Attachment 1, for the PIs used in the initial implementation of the Revised Reactor Oversight Process. This includes the following: (1) a systematic process to identify areas where PIs are needed and what kinds of PIs can potentially provide the level of monitoring desired; (2) assuring that the potential PIs satisfy the attributes that have been identified for successful PI development; (3) testing the PIs to assure credibility of results and practicality of implementation.

The second V&V phase involves activities that are an ongoing and integral part of the reactor oversight inspection process. This involves two V&V activities. The first relates to confirming through inspection, Maintenance Rule activities, and audit that the data and calculations that are the basis for the RBPIs are properly monitored, recorded, and calculated. The second aspect relates to inspection activities that verify that "true" performance characteristics are being captured by the RBPIs. The second aspect of validation and verification would involve inspections that determine whether the licensee's problem identification and corrective actions are performing adequately to detect (through testing, inspection or design reviews) faulted and defective conditions that would affect whether an SSC was capable of performing its risk-significant function. If the SSC were incapable of performing its risk-significant safety function and this were not detected by licensee activities (testing, inspection, design review), then the validity of the data used for the associated RBPI would be in question. This would indicate a weakness in licensee problem identification and corrective action programs.

4.4 Summary of Expected Accomplishments and RBPI Development Activities

This RBPI development will:

- Develop a rationale for choosing RBPIs and identifying thresholds for these indicators. This includes:
  - a rationale for grouping plants according to the applicability of indicators and thresholds;
  - formulation of indicators for each group;
  - quantification of thresholds and baseline values that are plant-specific if possible, and in any case group-specific.

- Apply this rationale to:
  - full power (to develop a more comprehensive set of indicators);
  - shutdown;
  - external events.

- Characterize the degree of coverage of the proposed indicator set for each plant group, including identification of important areas not covered by indicators.

- Develop a protocol as well as an automated process for quantifying the indicators:
  - data needed;
  - calculations;
  - quantification of trends.

- Develop an indicator that highlights the integrated impact of current performance levels on CDF. This indicator will provide additional information to the action matrix by supplementing the information provided by RBPIs that are defined for specific systems and component groups.

Development of RBPIs will be accomplished in phases and will follow the following steps:

- Issue an RBPI program overview white paper for stakeholder comment;
- Brief the ACRS and Commission on the RBPI development plan outlined in the program overview white paper;
- Issue a Phase-1 RBPI development progress report, including example RBPIs, for stakeholder comment;
- Brief the ACRS and Commission on the Phase-1 RBPI development progress;
- Issue a Phase-2 RBPI development progress report, including example of RBPIs, for stakeholder comment;
- Brief the ACRS and Commission on the Phase-2 development progress.

The RBPI development will be coordinated with the Office of Nuclear Reactor Regulation (NRR). Throughout the RBPI development process, there will be numerous interactions with internal and external stakeholders to ensure that their feedback is appropriately incorporated.

Table 1 presents a summary of the present status of both the current oversight process indicators and a set of potential RBPIs. In the table, phases 1 and 2 refer to current and future work on the development of RBPIs. Also shown in the cornerstone column in Table 1 is the integration of initiating events and mitigating systems into reactor safety performance (currently represented by core damage frequency). Both full power and shutdown/refueling plant operating modes are identified in Table 1.

The current regulatory oversight process indicators are presented in column four in Table 1. The development of these indicators is discussed in detail in SECY 99-007 and SECY 99-007A (Refs. 1 and 2).

Phase 1 of the RBPI development will concentrate on indicators that are related to the initiating event cornerstone, the mitigating system cornerstone, and the containment portion of the barrier integrity cornerstone. Specifically, these will include:

- Component/train/system reliabilities;
- Containment;
- Fire;
- Shutdown;
- Industry trends.

The fire and shutdown indicators will be developed consistent with the current state of the art models, methods and data for these areas.

Additional phases will address:

- An integrated indicator;
- Improvements to the indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data;
- Additional unavailability indicators with plant-specific thresholds;
- Follow-on work to improve existing indicators in response to NRC and/or industry lessons learned from the Revised Reactor Oversight Process implementation.

Table 1. Current and Potential Performance Indicators

Phase	Cornerstone	Operating Mode	Revised Reactor Oversight Process Indicators	Potential Risk-Based Performance Indicators
1	Initiating Events	Power	Unplanned reactor scrams Reactor scrams with loss of normal heat removal Unplanned reactor power changes	Loss of feedwater frequency Loss of ultimate heat sink frequency Loss of offsite power frequency
		Shutdown/ Refueling	Shutdown margin (future)	Loss of offsite power frequency Loss of residual heat removal system frequency Loss of inventory frequency
	Mitigating Systems	Power	Safety system unavailability Safety system functional failures Safety system unreliability (future)	Basic event level reliability - Pumps (motor and turbine) [key risk systems] - Valves [key risk systems] - Common-cause failure - Operator performance in response to transients Train level reliability - Emergency diesel generators - Auxiliary feedwater pump trains - Auxiliary feedwater injection paths - PWR high pressure injection pump trains - Component cooling water and service water pump trains System level reliability - On-site emergency ac power - Auxiliary feedwater - PWR high pressure injection - BWR high pressure coolant systems - Component cooling water and service water
		Shutdown/ Refueling	Mitigation system availability (future)	Train level reliability and availability - Emergency diesel generators - Reactor vessel inventory control (e.g., high and low pressure injection) - Residual heat removal - Component cooling water and service water
	Barriers	Power	Reactor coolant system specific activity Reactor coolant system identified leak rate	Train level reliability and availability - Containment spray system trains - Containment cooling system trains - Containment isolation system trains
2	Mitigating Systems	Power	None	Plant-specific availability
	Barriers	Shutdown/ Refueling	Reactor coolant system specific activity Reactor coolant system identified leak rate	Reliability and availability - Containment spray system trains - Containment isolation components (e.g., equipment hatches)
	Integrated	Power	None	Core damage frequency + barrier integrity
		Shutdown	None	Core damage frequency + barrier integrity
	Improvements to Phase 1 indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data			

5. References

1. SECY-99-007, "Recommendations for Reactor Oversight Process Improvements," U.S. Nuclear Regulatory Commission, January 8, 1999.

2. SECY-99-007A, "Recommendations for Reactor Oversight Process Improvements (Follow-Up to SECY-99-007)," U.S. Nuclear Regulatory Commission, March 22, 1999.

3. Baranowsky, P. W., "Indications of U. S. Nuclear Industry Trends from the Risk-Based Analysis of Reactor Operating Experience," Proceedings of the 4th International Conference on Probabilistic Safety Assessment and Management, 13-18 September 1998, New York City, USA (PSAM-4), Vol. 2, p. 1367 (Springer-Verlag London Limited, 1998).

4. *Precursors to Potential Severe Core Damage Accidents*, NUREG/CR-4674 (new volumes published annually with different authorship).

5. Long, S. M., P. D. Reilly, E.G. Rodrick, and M. B. Sattison, "Current Status of the SAPHIRE Models for ASP Evaluations," Proceedings of the 4th International Conference on Probabilistic Safety Assessment and Management (PSAM 4), pp. 1195-1199, September 13-18, 1998.

6. Poloski, J. P., et al., *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 – 1995*, NUREG/CR-5750, Idaho National Engineering and Environmental Laboratory, February 1999.

7. Atwood, C. L., et al., *Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980 - 1996*, NUREG/CR-5496, INEEL/EXT-97-00887 (USNRC, 1998).

8. *Equipment Performance and Information Exchange System (EPIX), Volume 1 – Instructions for Data Entry, Maintenance Rule and Reliability Information Module*, INPO 98-001, Institute of Nuclear Power Operations, February 1998.

9. Reliability and Availability Data base System (RADS), Version 1.0, Critical Design Review Document, February 1999.

10. *NPRDS Reportable System and Component Scope Manual*, Westinghouse Pressurized Reactors, INPO 83-020W, Rev. 5, Institute of Nuclear Power Operations, November 1994.