Technical Report on the Prioritization of Inspection Resources for Inspections, Tests, Analyses and Acceptance Criteria (ITAAC)

Corwin Atwood
Lauren Fleishman
Jon Johnson
Clifford Marks
Scott Newberry
Robert Youngblood

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Prepared by
Information Systems Laboratories, Inc.
11140 Rockville Pike
Rockville, MD 20852
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EXECUTIVE SUMMARY

This report provides a methodology for prioritizing NRC inspection resources for the Construction Inspection Program's inspections, tests, analyses and acceptance criteria (ITAAC) detailed in the Inspection Manual Chapter 2503 "ITAAC" (IMC-2503). The overall objective of this prioritization is to optimize NRC resources, while providing reasonable assurance that a significant flaw by the licensee does not go undetected (i.e., all ITAAC have been satisfied). The proposed prioritization provides a structured method for deciding which ITAAC to inspect, as well as a flexible aspect allowing for NRC judgement. Implementation of the prioritization will require an expert panel and periodic updates of information to incorporate inspection history.

A prioritization methodology was chosen for resource optimization as opposed to acceptance sampling. Simple statistical sampling would call for inspection at random, whereas the proposed methodology provides an educated and dynamic inspection. Further, the procedure-based nature of ITAAC activities call for periodic inspections over the course of the entire inspection program that correspond with the current state of knowledge of licensee performance. A prioritization methodology will be able to account for the inspection history more so than acceptance sampling.

The methodology presented in this report first provides guidance for classifying and grouping ITAAC. Once grouped, the ITAAC may then be prioritized within the group. It is proposed that ITAAC are classified based on the activity required to satisfy the ITAAC and then grouped by this "same activity." Judgement may be necessary to decide exactly what "same activity" should involve. The classification and grouping may loosely fit into the choices given for the intersections of the NRC's ITAAC Matrix. The overall idea is that observing licensee performance of the activity with one component (or ITAAC) gives an idea of what is done for the other components.

With all ITAAC classified and assigned to Inspection Groups, the proposed approach may then occur in two steps. The first step involves the rank-ordering of ITAAC based on defined attributes that make one ITAAC more or less important to inspect than others. These attributes are ITAAC characteristics of: Safety Significance, Propensity of Making Errors, Construction and Testing/Training Experience, Licensee Oversight Attention, and Opportunity to Verify by Other Means. They are weighted according to their impact on the overall objective using the Analytic Hierarchy Process (AHP). Further, each ITAAC is then rated for each attribute. The outcome of rating the ITAAC will provide an idea of the value of inspecting that ITAAC. The process described in the report does not recommend whether the attribute of safety significance would be addressed within or outside of the AHP process. A justifiable argument exists that safety significance should not be weighted and treated as part of a rating process. It may be treated separately, as a multiplicative factor. This is addressed in Appendix A.

This prioritization process is managed such that the calculated rank of an ITAAC will correlate to the amount of assurance one can obtain from inspecting that ITAAC. In this way, it is not the ITAAC that are prioritized, but rather the value of inspecting that ITAAC to the overall objective of optimizing resources to ensure that no significant construction flaw is undetected. The second step used in the methodology includes a portfolio perspective or "coverage check" for

all ITAAC. It requires that at least one ITAAC from every group be inspected. Further, the approach assures that a diverse set of ITAAC have been inspected such that it represents the entire ITAAC Universe.

On a higher level, the prioritization outlined previously also acts as a dynamic structure with a feedback loop of information that is necessary for an ITAAC inspection effort that is ongoing over the course of the inspection program. The methodology splits the process into two stages, an initial inspection and all subsequent inspections. The assumption is made that the NRC will make an initial inspection and this will focus on the high priority items. More focused inspections will follow at specific points in the overall inspection program based on a structured prioritization process that considers inspection experience to date. Initial and subsequent inspection periods are treated separately in the methodology, each with a separate rank-ordering and "coverage check" of ITAAC. An alternative method to rank-ordering ITAAC in subsequent inspection periods is also explained in this report. This method treats inspection experience at the ITAAC group level, which provides an extra amount of efficiency.

The report also offers an alternative approach for the rank-ordering of ITAAC, in which the rank of a component is defined as the estimated risk due to the component, and rank of an inspection group is the sum of those risks. An expert panel is still required, but rather than weighting the importance of various attributes, they must judge the effect of the attributes on the ITAAC process. The importance then falls automatically out of the risk calculation.

Both approaches act to guide the NRC in their inspection program as to optimize resources and ensure that no flaw is undetected. That is, the prioritization presented in this report assists in making the ITAAC inspection both efficient and effective.

While the proposed approaches have a rational basis and appear to be practicable for implementation, neither has been applied by an expert panel. This is seen as a significant limitation to date. Once exercised, issues may arise concerning the approaches and the methodology may need to be modified for purposes of feasibility. A trial exercise was performed on 40 ITAAC of the AP1000. Many of the insights gained from this first implementation have been incorporated into the existing methodology and report. Inputs and results from this exercise are summarized in Appendix D.

1 INTRODUCTION

1.1 Background

The NRC will identify a set of ITAAC when certifying a plant and begin inspecting these ITAAC when applicants begin procurement of long lead time components. ITAAC will need to be completed by the licensee and verified by the NRC over the course of the entire inspection program. Therefore, the staff will need to implement a phased ITAAC verification that is both effective, such that there is reasonable assurance that no flaw is undetected, and efficient, such that verification is completed to optimize NRC resources.

1.2 Objective

The objective of this report is to provide a methodology for the allocation of NRC resources to inspect the Construction Inspection Program's Inspections, Test, Analysis and Acceptance Criteria (ITAAC) to be used in accordance with the Inspection Manual Chapter 2503 "ITAAC." The methodology will support the objective that no flaw goes undetected by the licensee and in turn, all ITAAC are met.

An educated and adaptive prioritization process is proposed, as opposed to acceptance criteria sampling. This approach is organized with two primary objectives. First, prioritize the ITAAC such that the more important ITAAC are ranked higher and are therefore, inspected before ITAAC of lesser importance. Second, the approach includes a portfolio perspective or "coverage" for all ITAAC. ITAAC are ranked using identified attributes or characteristics. Five attributes are proposed in this methodology. An alternative prioritization approach is also outlined in the report. As a precursor to the prioritization, the report also provides guidance on the classification and grouping of ITAAC. ITAAC including similar activities are grouped together and then prioritized within this group

The overall theme of the methodology represented in this report is that of comparing the value of inspecting one ITAAC versus another. Inspection of some ITAAC will give more value in assuring that the licensee has detected any construction flaws. The methodology is set up to select those ITAAC which contribute more to obtaining this assurance.

1.3 Organization of the Report

Section 2 of this report reviews the ITAAC inspection process and provides reasoning for not recommending acceptance sampling for optimization of NRC resources. Section 3 provides two classification approaches for ITAAC and recommends how to group ITAAC by similar activity. Section 4 describes the methodology for prioritizing ITAAC. Section 4.1 identifies and manages attributes which assist in the ranking of ITAAC, Section 4.2 outlines the step-by-step calculation of ITAAC ranking and prioritization of these ITAAC and Section 4.3 provides some initial guidance on how to implement this prioritization using an expert panel. A summary of the above sections, including insights and limitations is described in Section 5.

2 SUMMARY OF THE ITAAC INSPECTION PROCESS

For clarity, the ITAAC process is summarized here, and compared to traditional statistical acceptance sampling.

2.1 The ITAAC Process Itself

There are hundreds of ITAAC, many of which involve many components. Each component is constructed and installed by one or more vendors and/or contractors, who have their own quality control procedures. In addition, the licensee performs 100% of the tests required by all the ITAAC. When flaws are discovered, the licensee has them corrected. At the end of the process, the licensee asserts that all of the ITAAC are satisfied.

The NRC verifies the above process and conclusions through their inspection program. It does this by observing some of the fabrication, installation and operations, by looking at the licensee's reports and paperwork, and by being physically present during some of the licensee's tests. At the end of this inspection, the NRC asserts that it has reasonable assurance that all the ITAAC are satisfied.

The NRC inspection is an inspection of plant construction programs and processes, checking whether the contractors and licensee are all following the correct fabrication, construction and testing procedures. Also, the prioritization of inspection is adaptive, dependent on findings that have been found earlier. As stated in the Executive Summary of NUREG-1789, "reduction in inspection effort may occur when reviews have identified effective program implementation that provides high confidence in the licensee's quality control process.... If the process controls are found acceptable, the [inspection] resources are reduced and that activity is inspected less frequently."

Because of the adaptive nature of the inspection, the approach used to prioritize inspection activities must be flexible enough to accommodate modifications in scheduling by the contractors and licensees. For example, if the NRC was planning to inspect two activities and the contractor unexpectedly schedules them at the same time in different places, the NRC's prioritization tools must be flexible enough to show which one has higher priority for inspection.

2.2 Use of Acceptance Sampling

In acceptance sampling, a "lot" of items has been produced. A "sample" of these items is inspected, and if few or no flawed items are found in the sample, the entire lot is accepted. (Any bad items found in the sample are repaired or replaced). Proper adjustment of the sample size permits a claim such as "95% confidence that at least 95% of the items in the lot are good." Acceptance sampling was used for the weld evaluation project at Watts Bar, and acceptance sampling is the basis for Draft Regulatory Guide DG-1070, "Sampling Plans Used for Dedicating Simple Metallic Commercial Grade Items for Use in Nuclear Power Plants."

The ITAAC process, including the NRC inspections, differs from traditional statistical acceptance sampling. First, the licensee is not performing sampling at all; instead it tests all of the components. But what about the NRC, who will observe some of the fabrication work and some of the ITAAC tests that the licensee performs? Can the NRC's process be treated as acceptance sampling? The "items" in the lot would be all of the fabrication activities for multiple components, or all the licensee's tests for an ITAAC, and the sample would consist of those particular fabrication activities or tests that the NRC observes or reviews. The activities are not appropriate for acceptance sampling, for the following reason.

In acceptance sampling, a lot of items may have some bad items, and a random sample is drawn and inspected. The probability that any sampled item is bad is the same. In the ITAAC process, a structure is useful to model bad fabrication or bad test performance. Most notably, we postulate that fabricating a component or performing an ITAAC test consists of following a procedure, and either a team of fabricators or testers knows how to follow the procedure and does so conscientiously or it does not. If the team is observed to be following the procedure correctly, then it is not necessary to watch the team again soon afterwards to see if they become less knowledgeable or less conscientious. Therefore, a dynamic and educated structure that directs inspection where it is most valuable is appropriate for ITAAC inspection. Further, the NRC is primarily inspecting overall processes, not individual activities. Thus, the appropriate NRC inspection approach resembles periodic testing more than it resembles random sampling. Periodic inspection of ITAAC by the NRC over the course of the entire licensee inspection, as well as periodically re-prioritizing NRC inspection resources to correspond with the current state of knowledge about the licensee's construction activities, may be the only method for inspecting ITAAC to gain reasonable assurance that all are satisfied. The methodology presented in this report assumes that certain situations are expected to arise over the course of licensee and NRC inspection which would justify the re-prioritization of NRC inspection resources over each new NRC inspection period. This is further discussed in Section 4.2.2 of this report.

3 CLASSIFYING ITAAC AND GROUPING ITAAC

This section describes two methods to combine ITAAC and pieces of ITAAC into groups, so that a single group can be inspected at once. Combining similar ITAAC into groups is an important part of the resource prioritization process, as the groups are first prioritized and only later, the ITAAC within a group. If groups are identified and populated with ITAAC that are relatively similar, knowledgeable selection of a part of the group population can ensure that the entire group is carried out with reasonable assurance.

Groups should contain similar ITAAC. There is no one way to group ITAAC, but a few considerations are outlined below. A few rules that should be followed include (1) assign each ITAAC to some group (i.e., the union of all the groups is the ITAAC Universe) and (2) the groups should be mutually exclusive (two groups do not contain the same ITAAC). To allow for more homogenous groups, the second method proposed in this paper advises that some ITAAC be parsed into ITAAC pieces. This will be discussed further in Section 3.2 of this report. Any such group of ITAAC or of ITAAC pieces will be referred to generically as an **inspection group**.

The proposed key is to combine ITAAC or portions of the ITAAC that use a single common procedure. For this methodology, a *procedure* is defined as one process such as fabrication, testing or qualification. A procedure loosely fits into the choices given for the columns of the NRC's ITAAC Matrix. The following section defines the different (procedure-based) classifications of ITAAC and some methods by which these can be grouped. The important similarity within a group is that the **same activity** is performed for all the components corresponding to a single inspection group. Judgement may be necessary to decide what "same activity" means. It may denote following the same checklist. The overall idea is that the same activity is performed for all the components such that observing performance of the activity with one component gives an idea of what is done for the other components.

The rationale for these proposals is based in part on our review of ITAAC provided by the NRC along with their "ITAAC Matrix." This review indicated that each of the Matrix headers was relevant to some individual ITAAC. In other words, individual ITAAC are made up of several distinctly different programs or activities. From the ITAAC Matrix, these are: the as-built inspection, welding, construction testing, operational testing, qualification programs, and design and fabrication processes. We reviewed 40 ITAAC for the Fuel Handling and Refueling System, the Component Cooling Water System, the Standby Diesel and Auxiliary Boiler Fuel Oil System, the In-Core Instrumentation System and the Onsite Standby Power System. We did not identify the need for additional classifications nor did we identify any classifications that were unnecessary. Based on our review to date, we believe that the classification approach formulated by the NRC staff provides a rational way to help identify component and ITAAC groups that can be used to prioritize NRC inspections of ITAAC activities. This insight is fundamental to our proposed approach for prioritizing inspection activities.

3.1 Classification and Grouping of ITAAC by Family or Subfamily

A manageable method for classifying and grouping ITAAC is to assign each to a family of the ITAAC matrix. A **family** is defined as the intersection of a row and a column of the ITAAC matrix. The column categories represent the interdisciplinary NRC inspection activities such as welding, operational testing, etc. The row categories represent the construction processes and resulting products (e.g., systems, structures and components) that relate to a unique discipline. Therefore, the intersection of these two ITAAC categorizations can qualify as a “same activity”.

The assignment of an ITAAC to its family is essentially the classification of that ITAAC. With 6 columns (procedures) and 19 rows (systems, structures or components), there are 114 different ITAAC classifications. These families may also represent the ITAAC inspection groups, defined previously. After populating the families, though, further judgement is necessary to assess whether some of these families of ITAAC should be divided into subfamilies. The importance of subfamily divisions will become clear when re-assessing the allocation of NRC inspection resources in subsequent inspection periods. This is explained further in Section 4.2.3 of this report. Essentially, one would attempt to divide ITAAC into subfamilies such that all ITAAC in a subfamily could be characterized similarly when evaluating them for licensee performance. A proposed group and its ITAAC population are shown in the next section as Example 3.1. The ITAAC are chosen from the AP1000 and all could be classified and grouped by the ITAAC Matrix Family 8D (Operational Testing of Valves). A “Stroke Test” subfamily division may also be a possibility for the ITAAC in this example.

3.2 Inspection Groups of ITAAC Systems and Components

Another method for classifying and grouping ITAAC is described in the following section. This method assumes that some ITAAC contain more than one “same activity” and therefore, may need to be divided into sub-parts. The use of this classification approach, then, may only be necessary if the inspection procedures for the ITAAC tend to be diverse such that they contain multiple procedures and licensee teams that need to be evaluated separately. The initial trial exercise of the prioritization outlined in this report did not find this detailed approach to be necessary. Therefore, the majority of the methodology focuses on a classification approach such as the one outlined in section 3.1.

3.2.1 ITAAC Involving One Procedure

Some groups of ITAAC are virtually identical, each involving the same one procedure for a group of components. It is proposed that they be combined into a “super-ITAAC,” and the ITAAC testing process for the components covered in these ITAAC be inspected as one group. We will use the term **inspection group of one-procedure ITAAC** for a group of ITAAC that all use the same one procedure. The NRC will inspect an appropriate portion of the licensee’s tests for the ITAAC in the inspection group, and then approve the entire group. The following four examples illustrate this concept. Note that the number of components is frequently summed in these examples, denoting the one-to-many relationship between ITAAC and components and the decomposition of an ITAAC at the component level.

Example 3.1. Stroke Test of Remotely-Operated Valves

Based on a review of the AP-1000 DCD, 11 ITAAC have the following design commitment, inspection/test/analysis, and acceptance criterion:

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
Controls exist in the MCR to cause the remotely operated valves identified in Table xxx to perform active functions.	Stroke testing will be performed on the other [i.e., non-squib] remotely operated valves listed in Table xxx using controls in the MCR.	Controls in the MCR operate to cause the remotely operated valves (other than squib valves) to perform active functions.

The wording varies slightly among the ITAAC: table numbers vary, some tables do not mention squib valves and sometimes the "active function" is called an "active safety function." Other than that, the ITAAC are worded virtually identically. The ITAAC are listed in Table 3.1.

Table 3.1 Example of Inspection Group of ITAAC for Remotely-Operated Valves

System	Isolation Valves	Control Valves	Other Valves	ITAAC Table and Line
Reactor Coolant	6		10[a]	2.1.1-4, 11a.ii
Containment	17			2.2.1-3, 10a
Passive Containment Cooling	3		3[b]	2.2.2-3, 6b
Passive Core Cooling	10	2		2.2.3-4, 11a.ii
Steam Generator	14	6	4[c]	2.2.4-4, 11a
MCR Emergency Habitability	4			2.2.5-5, 9a
Chem. Vol. Control	10			2.3.2-4, 10a
Residual Heat Removal	11			2.3.6-4, 11a
Liquid Rad Waste	1			2.3.10-4, 8
Primary Sampling System	6			2.3.13-3, 10a
Nucl. Isl. Nonradioact. Ventilation	6			2.7.1-4, 6a
TOTAL	88	8	17	

a. 6 other MOVs, 4 vent valves.
b. 3 isolation block MOVs.
c. 2 relief valve block MOVs, 2 PORVs.

If the same procedure is used to perform the stroke test for all these remotely operated valves, it seems acceptable to consider the 11 ITAAC as forming a single inspection group, referring to a total of 113 valves. Note the association of this single procedure to the NRC's ITAAC matrix; it is appropriate to assign this inspection group to cell 8D, Valves/Operational Testing.

An inspection group of ITAAC which is classified by the fabrication procedure of these components may not coincide with the components in Table 3.1. For example, the isolation valves and control valves may be manufactured with different processes, that have different requirements, justifying different inspection groups.

Example 3.2. ASME Code Section III Pressure Boundary Welds

Numerous ITAAC come in pairs, referring to welds on components and pipes, respectively. They all have the following design commitment, inspection/test/analysis, and acceptance criterion:

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
Pressure boundary welds in [components or piping] identified in Table xxx as ASME Code Section III meet ASME Code Section III requirements.	Inspection of the as-built pressure boundary welds will be performed in accordance with the ASME Code Section III.	A report exists and concludes that the ASME Code Section III requirements are met for non-destructive examination of pressure boundary welds.

The AP-1000 Design Control Document (Westinghouse 2004) does not state the number of such welds in each system, so no table totaling the counts is given here. However, it appears that many welds in components and welds in piping may all be tested by the same one procedure. This allows all the ITAAC to be placed in a single inspection group of ITAAC. However, different welding approaches for certain components may need to be put into different groups if observing one welding approach will not give an idea of what is done for the other components.

Example 3.3. ITAAC That Are Similar but Not Identical

Judgment must be used if different ITAAC are similar but not identical. For example, suppose that two ITAAC each say that a report exists giving a flow calculation. The licensee is supposed to have verified that both calculations are correct. One must decide whether the verification methods are similar enough that they may be regarded as a single procedure for verifying this type of flow calculation. If so, the two ITAAC satisfy the definition of an inspection group of ITAAC. Then the NRC must inspect whether the licensee carried out the verification process correctly.

The above examples illustrate a general scheme[1].

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[1]**Table 3.2 Components Tested by ITAAC That Involve the Same Single Procedure, and by the Inspection Group of ITAAC**

	Components Examined by Procedure
ITAAC 1 for System 1	n_1
ITAAC 2 for System 2	n_2
ITAAC 3 for System 3	n_3
…	
ITAAC k for System k	n_k
Inspection Group of one-procedure ITAAC	$\Sigma_i n_i$

where $i = 1,2,...,k$ and the $\Sigma_i n_i$ represents the number of components in this inspection group.

3.2.2 ITAAC That Each Involve Many Procedures or Sub-Procedures

The ITAAC in the previous section each involved a single test procedure. A few ITAAC are not of this type, but instead are more complicated. The primary example is checking the as-built condition of a system. This may involve numerous procedures or sub-procedures, and require several technical disciplines. Probably different people will be responsible for checking the different portions of the ITAAC. For convenience, we will divide the ITAAC into pieces, one piece for each specified procedure or sub-procedure. For terms of discussion, let us call the pieces slices. A **slice** is formally defined for this methodology as a portion of an ITAAC that involves one process or procedure (e.g., testing, qualification, fabrication, etc.) and one type of component. The ITAAC is divided into a number of slices, with each slice checked by the same procedure. A slice may be, for example, a written procedure for the qualification of valves. Thus, any ITAAC which includes a qualification of valves of any type may be sliced to separate out this procedure for grouping with other similar slices. Example 3.5 further supports the definition of a slice. The ITAAC is satisfied when each of the components or systems in the slice has been checked and is satisfied. Again, the division into slices need not be unique, as any division that gives convenient slices is satisfactory. More important when slicing is that the observance of performing the process with one component gives an idea of what is done for other similar components[2].

Now consider *all* the ITAAC that use the same set of procedures or sub-procedures. As an example, consider all the ITAAC that check the as-built condition of any system. These are generally labeled as ITAAC 1 in the table for a particular system. Divide each of these ITAAC into slices in the same way.

Finally, combine all the slices that use a single procedure or sub-procedure into a single **inspection group of slices**. For example, it may be that all the pipe welding slices are checked by a single procedure. If so, combine the pipe welding slices into an inspection group. The methodology treats this group almost the same as an inspection group of one-procedure

[2]Table 3.3 illustrates this process, slicing by the procedure. Note, the same component may possibly be tested by several procedures, so that it contributes to the component count in several slices.

Table 3.3 Components Tested by the Slices of an ITAAC That Uses Multiple Procedures

	Slice 1: Components Examined by Procedure or Sub-procedure 1	Slice 2: Components Examined by Procedure or Sub-procedure 2	…	Slice *m*: Components Examined by Procedure or Sub-procedure *m*
ITAAC for System	n_1	n_2	…	n_m

ITAAC as defined in Section 3.2.1 of this report. Theoretically, the only difference is that now an inspection group contains slices instead of containing entire ITAAC[3].

Treat each inspection group of slices in Table 3.4 in the same way that the inspection group of one-procedure ITAAC in Table 3.2 is treated. That is, within each inspection group, the NRC will inspect a portion of the slices, and then document the result of that inspection. When all the inspection groups of slices are eventually approved, the corresponding ITAAC are all approved.

3.2.2.1 Special Consideration for Particular Processes Such As Fabrication

When grouping ITAAC slices that deal with particular processes, such as fabrication, special consideration is sometimes necessary. We propose to slice ITAAC by identical processes and component types. An example will illustrate the reasoning behind this special consideration.

Example 3.4. An Inspection Group of Fabrication Slices

One ITAAC may each include two types of valves that are tested using one procedure. The type of valve may be an isolation valve for one slice, while the valve associated with the other slice is a relief valve. An inspection group of slices can be created that refers to both isolation valves and relief valves if these two types of valves are tested using the same procedure. But, the two kinds of valves may not be able to be classified in the same inspection group of slices with respect to the fabrication procedure. (Note that this could also be applicable to other procedures or activities such as seismic qualification or ASME Code requirements that apply to

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[3]Table 3.4 shows *k* ITAAC, each divided into *m* slices, resulting in *m* inspection groups. For example, if Slice 1 in Table 5 corresponds to the procedure for checking pipe welding, the super-slice for pipe welding would look at $\Sigma_i n_{i1}$ components. It is all right if the set of procedures is not quite the same for all the ITAAC. That possibility can be handled by allowing some of the n_{ij} values to be zero.

Table 3.4 ITAAC that Involve Multiple Slices, and the Corresponding Inspection Groups of Slices

	Slice 1: Components Examined by Procedure or Sub-procedure 1	Slice 2: Components Examined by Procedure or Sub-procedure 2	…	Slice *m*: Components Examined by Procedure or Sub-procedure *m*
ITAAC 1 for System 1	n_{11}	n_{12}	…	n_{1m}
ITAAC 2 for System 2	n_{21}	n_{22}	…	n_{2m}
ITAAC 3 for System 3	n_{31}	n_{32}	…	n_{3m}
…	…	…	…	…
ITAAC *k* for System *k*	n_{k1}	n_{k2}	…	n_{km}
Inspection groups of slices	$\Sigma_i n_{i1}$	$\Sigma_i n_{i2}$	…	$\Sigma_i n_{im}$

the design and construction of components). Therefore, separate slices for each type of valve can be acknowledged; an isolation valve fabrication slice and a relief valve fabrication slice. These two fabrication slices may not be combined if it is judged that the activities were sufficiently different. See Example 3.5 for further clarification. There may be other ITAAC, though, that also include an isolation valve fabrication slice. ITAAC slices with this similarity may be combined. It should be noted that in many cases the isolation valve fabrication slices for different ITAAC may call for the same NRC inspection activity and therefore, the slices would overlap. This is further acknowledged and managed in Section 4.2.2.1 (Defining Efficient Collections of ITAAC) of this report.

Note two points.

- The converse of Example 3.4 may also be true such that several distinct ITAAC may refer to a single type of component. For example, a motor-operated valve must operate on demand and it must not leak. Presumably, two different ITAAC are written to test these two requirements. When inspecting the fabrication of the valves, the NRC will probably wish to keep both requirements in mind.
- Nominally identical components may be constructed by different contractors or vendors. Unless it cannot be reasonably assured that the vendors are using the same process, the components may need to be divided into several inspection groups, one for each vendor.

3.2.3 Stand-Alone ITAAC or Stand-Alone Slices

Some ITAAC or slices of ITAAC are unique, sharing their procedure with no other ITAAC. These "**stand-alone**" ITAAC/slices cannot be grouped with others into a homogenous inspection group. To see why, suppose that the NRC observes that the licensee tester correctly follows the test procedure for the one ITAAC/slice. That fact may not give adequate confidence that the licensee testers will correctly follow the different procedures of other ITAAC.

A less complete grouping may be possible, however, it would be a grouping that reflects a weaker similarity among ITAAC/slices. If other ITAAC/slices are tested by the same licensee personnel as the stand-alone ITAAC/slice in question, and if the same technical discipline is required to carry out the test, then some might argue that successful performance of the one ITAAC/slice procedure bodes well for the others. However, the confidence is not as great as if all the ITAAC/slices used the same procedure.

To follow this line of thinking further, see Appendix B. In the terminology of Appendix B, successful performance on the one ITAAC might indicate a small probability of human error, and this small probability applies to the other ITAAC that the same licensee personnel test. Successful performance on the one ITAAC may say little about the adequacy of the procedure for the other ITAAC. Depending on whether the same equipment is used in the different tests, good performance on the one ITAAC test might or might not say something about the probability that the test equipment used for the other ITAAC has an unrecognized malfunction.

This report does not make any recommendation on how to group stand-alone ITAAC. As with Example 3.3 above, the inspectors will need to exercise judgment as to whether different ITAAC/slices are similar enough to be considered an inspection group of ITAAC. Any stand-alone ITAAC that are not grouped by a similarity, but rather “lumped” together as a “remainder” inspection group will need to be treated separately in the prioritization. This will be addressed in Section 4.2.1.2 of this report.

In the following example, classifications of a few of the ITAAC for the Steam Generator System are provided.

Example 3.5. Steam Generator System ITAAC

- Consider ITAAC 2.2.4.2a: The components identified in Table 2.2.4-1 as ASME Code Section III are designed and constructed in accordance with ASME Code Section III requirements.

The components that correspond to this ITAAC are also addressed in 2.2.4.9b(ii), 10, 11a and 11b(I). But, should the NRC inspection program focus on the fabrication of these components, it is recommended that this inspection be assigned to ITAAC 2.2.4.2a exclusively. Therefore, 2a could be sliced, if necessary, such that one slice is the fabrication of PORVs. NRC judgement may also lead to this ITAAC not being sliced at all.

- Also consider ITAAC 2.2.4.5a: The seismic Category I equipment identified in Table 2.2.4-1 can withstand seismic design basis loads without loss of safety function.

This ITAAC deals with the qualification of the same components in Table 2.2.4-1. Based on the classification strategy presented above, this ITAAC may not involve a fabrication slice. Qualification includes type tests and analyses. NRC judgement would be needed on whether to slice between type tests and analysis. If not sliced, this ITAAC could then be classified as a one-procedure ITAAC, which may eventually be placed in a super-ITAAC inspection group with other qualification ITAAC. Again, this is most likely the judgement of an expert panel and these examples are given for further clarification of ITAAC classification only.

4 PRIORITIZATION OF ITAAC: THE METHODOLOGY

The prioritization presented in the following sections acts as a dynamic structure with a feedback loop of information that is necessary for an ITAAC inspection effort that is ongoing over the course of the inspection program. It is arranged such that an initial inspection will be the most resource intensive and lesser, but focused, inspections will follow at specific points in the overall inspection program based on a structured prioritization process that considers inspection experience to date. The ITAAC will be prioritized based on the value of inspecting them relative to the overall objective of ensuring that no flaw is undetected.

The prioritization below is chosen as an alternative to acceptance sampling, which is not recommended for optimizing ITAAC inspection efforts (see Section 2.2 of this report). Prioritization as a formal decision method offers benefits in situations having one or more of the following characteristics (NUREG/CR 6833 2003):

- complexity of the situation;
- significant uncertainties;
- multiple objectives/tradeoffs;
- different perspectives (e.g., multiple inspection planners, expert panel).

Prioritization of ITAAC involves all of these elements. But, it is also these elements that make the rank-ordering of ITAAC difficult. One could subjectively decide that one ITAAC should get priority over another, but this lacks structure and does not work well for situations where multiple inspectors are attempting to come to an agreement on this decision. A structured method for formulating and ranking decision options is appropriate for prioritizing ITAAC because it enumerates the choices available to the decision maker(s) (e.g., inspectors), quantifies the relative desirability of inspection options, provides rules for ranking the options and allows a cost/benefit evaluation of the information at hand (Weil and Apostolakis 2001).

A utility theory approach is used here to prioritize ITAAC such that preferences of the decision-maker can be collapsed into a single number for ranking purposes. The approach was modeled after the framework of a prioritization of operating experience in nuclear power plants by Weil and Apostolakis (2001). **Utility** is a figure of merit for a decision option that quantitatively shows how much the decision-makers' values and preferences will be addressed by implementing that option (U.S. NRC 2003).

Two parameters are necessary to obtain the utility function used in this methodology. Both are based on the existence of what will be referred to as ITAAC attributes. **Attributes**, for this methodology, are defined as the characteristics of an ITAAC that make it more or less important (or desirable) to inspect, relative to other ITAAC based on the overall objective of optimizing resources to ensure that a significant flaw does not go undetected (i.e., all ITAAC have been satisfied). The attributes, such as the Error Propensity of an inspection procedure or the ITAAC Safety Significance, are used in the methodology as both weights and measures. ITAAC Attributes are discussed further in Section 4.1 of this report. Some attributes may be more important to the overall objective than others and therefore, can be weighted respectively. Additionally, ITAAC will be given different impact levels or a constructed scale for the same attribute (e.g., one ITAAC may be of higher safety significance than another). The weights and measures of attributes are considered in this methodology as a utility function[4].

To assign weights to the attributes, this methodology recommends a quantitative process, the Analytic Hierarchy Process (AHP), a hierarchal method of pairwise comparisons in which expert preferences among the attributes are converted into numerical weights (Weil and Apostolakis 2001). AHP should reduce the subjectivity that is present when arbitrarily assigning weights, assist in coming to agreement and provide structure. Many believe that AHP is a useful tool as part of a prioritization process. In *The Logic of Priorities*, Saaty and Vargas (1982) assert:

> "...the [AHP] process may be considered an extension of our information-processing capacity and our thought processes ... the AHP assists in extending our ability to analyze multiple variables simultaneously."

The objective of the AHP process in this methodology is to calculate weights for attributes. ITAAC that are associated with the heavily-weighted attributes will in turn be allocated more inspection resources. The actual AHP process will be outlined in Section 4.1.2 of this report.

4.1 ITAAC Attributes

Choosing and processing the attributes is essential to the prioritization methodology. Section 4.1.1 of this report, recommends attributes to characterize ITAAC, Section 4.1.2 describes the AHP process to calculate attribute weights and Section 4.1.3 describes a method for deciding on the constructed scale, or utilities, that are assigned to each impact level option for ITAAC attributes.

4.1.1 Attribute Definitions and Classification

The attributes proposed and explained below are applicable at the ITAAC-level and in some cases, the ITAAC group-level. This applicability is further illustrated in Section 4.2.1 of this report. The methodology recommends 5 attributes to support the ITAAC Inspection Prioritization process. The following list itemizes these attributes with definitions. Also included are specific definitions for the constructed scale (i.e., the baseline ratings for High, Medium and Low), which will be further explained in Sections 4.1.3 and 4.2.1 of this report. These attributes

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$$Rank_j = \sum_i w_i u_{i,j} \qquad (1)$$

where w_i is the weight given to attribute A_i (where $\sum w_i = 1$), $u_{i,j}$ is the utility (a value representing the attribute's impact level, further discussed in Section 4.1.3) given to ITAAC *j* for attribute A_i and $Rank_j$ is the overall ranking for ITAAC *j*. For Equation 1, the value of w_i (between 0 and 1) exemplifies the relative importance of attribute A_i to other attributes, whereas the value of $u_{i,j}$ (also between 0 and 1) conveys how strongly ITAAC *j* displays the characteristics of attribute A_i.

all relate to one of two general themes in the methodology. If all ITAAC have been satisfied, this is similar to the NRC having reasonable assurance that any flaw that may exist in a system or component will be detected by the licensee and fixed. This statement assumes that if (1) the probability of flaws related to an ITAAC is relatively low and (2) the licensee's detection of these flaws is relatively high, the NRC will be able to declare that the ITAAC has been satisfied. Each attribute proposed below supports at least one of these two premises to ensure that there is a small chance that an undetected flaw will occur.

Attribute Definitions:

- Safety Significance - The safety significance assigned to the system, component, or structure included in the ITAAC. The definition of this attribute is dependent on the ITAAC. For example, ITAAC concerning components and their particular failure modes may be modeled in the PRA. In these cases, the Birnbaum measure provides an indication of the conditional significance of degraded item performance. For items not explicitly modeled in the PRA, a measure of element significance can be derived in terms of safety significance of the PRA success paths that the item supports. It is important to use documented PRA resources when available for this attribute to reduce expert panel subjectivity.

  Specific guidance is not provided in this report for the expert panel regarding assigning weights for this attribute. In fact, an argument can be made that the attribute of safety significance should be addressed outside of the AHP process. Should component level importance be desired, this information is derived during the NRC safety review of the plant design. It is available in the NRC staff SER and Tier 2 Chapter 19 of the DCD. Explicit information is also provided for individual PRA insights in these documents which can be useful in assisting the expert panel in identifying significant PRA success paths. While the use of importance information at the component level is an appropriate measure, it introduces a complexity to this process that has not yet been fully evaluated to date. More precise guidance, or even alternative means to consider safety significance, may become apparent after exercising this process. For further discussion on this, see Appendix C.

  Note that this attribute may be inter-related to the Opportunity to Verify by Other Means attribute. Many systems in today's advanced plants have simplified passive designs that include items in which the failures are not self-revealing. Success of these features is critical, but certain flaws or problems in these systems are probably difficult to address or identify beyond a certain point in construction. These advanced passive plants, which rely extensively on the high reliability of features that are relatively independent of support systems and plant programmatic activities, deliberately link high reliability, high safety significance and need to be assured during construction. This is explained and examples are given in Appendix C.

- Propensity of Making Errors - The degree of propensity to, or ease of, making errors in the process of fabrication, installation, or testing. This may depend on the complexity or inherent difficulty of the activity. As an example, a bimetallic weld on the reactor vessel safe end might be more difficult than welding structural steel for a seismic pipe support. The degree of training or certification required of the "doer" such as a Level III NDE technician is an indicator of the complexity. This typically is also related to the concept of a "special" process which has requirements associated with it per 10CFR50, Appendix B. This attribute may contribute to procedural, equipment, human, and inherent aspects of the probability of a flaw.

  Definition of Baseline Impact Level Options for Constructed Scales:

High =	A high probability of error in the process or activity due to inherent difficulties
Medium =	Some complexity or difficulty of activity that could directly lead to errors
Low =	A small probability of error in process or activity as a result of its simplicity or the routine-nature of the activity.

- Construction and Testing Experience - To the extent known, whether (1) the testing or construction activity is a "first of a kind" (FOAK) or (2) conducted by a company or testing team with little experience in the subject activity or nuclear field or (3) little experience in a field with quality assurance requirements or strict adherence to procedural controls. Additionally this includes whether there is a history of quality or other performance deficiencies associated with the activity. Included under this attribute is consideration for whether there is new technology or new techniques involved or whether the activity is an industry standard or known problem area. This attribute could contribute to human and inherent aspects of the probability of a flaw.

  Definition of Baseline Impact Level Options for Constructed Scales:

High =	Limited or no experience with the activity or known problem area for the industry
Medium =	Some experience with the activity or possible problem area for the industry
Low =	A great deal of experience with the activity or not considered to be a problem area for the industry.

- Opportunity to Verify by Other Means - The degree that the activity can be verified by observing other functional, pre-operational tests, or performance tests. This would also include the degree to which the sequence is, or is not a factor; for example, the lack of access associated with buried piping or cables, coatings inside tanks, or physical interferences. This would result in a preference to inspect now while the opportunity exists, or to defer the inspection until later when it may be just as useful to witness the pre-operational test instead. This attribute could contribute to the procedural and inherent aspects of the probability of flaw, as well as the ability of the licensee to detect the flaw, when associated with the sequencing of the construction program. For example, an ITAAC that concerns the rebar in prefabricated, reinforced concrete would be given a High impact level for this attribute. Conversely, when two ITAAC tests are available for inspection purposes, such as in the testing of pumps and valves, this attribute would be given a Low impact level.

Definition of Baseline Impact Level Options for Constructed Scales:

High =	No or very limited opportunity to verify by other means
Medium =	Possible to verify several aspects of the activity by other means
Low =	Can be verified almost completely by another test or inspection

Note that for a fabrication ITAAC, a High impact level could mean that there is no ITAAC test that can check the correctness of the fabrication, a Medium impact level may mean that an ITAAC test is only moderately effective at checking the fabrication and a Low impact level would be given to an ITAAC in which the probability of the licensee detecting the flaw itself is relatively good. For a testing ITAAC, this attribute takes on a somewhat different meaning. A High impact level may be given if an ITAAC analysis under consideration is the only analysis that could be performed to identify a potential flaw, and that the flaw may never be discovered during normal operation until there is a true demand. A seismic calculation is an example. A Low impact level for this attribute for a testing ITAAC may mean that the flaw would be easily discovered during normal operation.

- <u>Licensee (or applicant) Oversight Attention</u> - The effectiveness and extensiveness of the applicant or licensee's oversight attention and quality assurance efforts, including those of its contractors and suppliers. This also includes those self-assessment reviews or independent audits in addition to the specific QA effort. Note this may not be known early in the sequence of construction activities or until NRC has experience inspecting the licensee's QA efforts and other self-assessment activities and generated an opinion of their performance. If this attribute is referring to licensee oversight during fabrication, it would contribute to the probability of a flaw. If, instead, the oversight is during ITAAC testing, the attribute contributes to the probability of the licensee detecting the flaw. It is assigned periodically based on inspection results.

Definition of Baseline Impact Level Options for Constructed Scales:

High =	No or very limited licensee oversight such that construction flaws can easily go undetected by the licensee
Medium =	Some licensee oversight
Low =	A great deal of licensee oversight such that construction flaws rarely are undetected by the licensee

One consideration for rating ITAAC was Bundling. Bundling can be defined as the efficiency gained in "bundling" or scheduling an inspection or group of inspections because there are multiple opportunities to witness several ITAAC at the same time or during the same trip, especially if the activity is being conducted in a distant location. Each individual review might not have high importance otherwise, but because of the knowledge that there may be a chance to review several items at one time, it would make the choice very efficient in use of NRC resources. Again, this might not be known until after the construction sequence is in motion. While this could be viewed as an attribute, the proposed methodology considers bundling when optimizing inspection resources. The concept of bundling influences the inspection prioritization methodology by combining activity resources. It should be especially useful with expensive travel costs and lengthy travel time.

Each of these attributes were chosen because they will have a specific influence on the NRC inspection effort. These influences are listed below. The intent of this section is to provide more considerations that the NRC could use when rating and weighting attributes.

- Safety Significance: Provides a focus on the most important activities or components from the standpoint of public safety, which may be of particular importance for passive designs.

- Propensity of Making Errors: Provides a focus on the most error-prone areas which could be more likely to have quality deficiencies and therefore provide a greater likelihood to find the problems and have them fixed. Higher complexity or inherent difficulty could lead to a greater probability of a flaw, regardless if the ITAAC has been inspected previously.

- Construction and Testing Experience: This influences the inspection due to the lack of demonstrated track record, or the lack of a high quality construction or performance history by the industry as a whole. By definition, this attribute would most likely be rated High during an initial inspection and only in subsequent inspection would this rating drop to Medium and Low.

- Opportunity to Verify by Other Means: This influences the inspection plan by giving an input into whether there is another time or place that the ITAAC can be verified. In other words this might be the "only chance" to witness something important or it can be just as completely verified by observing or reviewing another activity at a later date.

- Licensee (or applicant) Oversight Attention: To maximize inspection effectiveness the NRC may choose to look at some activity in more detail if it knows that the licensee is not paying appropriate attention to it by lack of independent oversight. In general, the impact level for this attribute may be assigned a High value for the initial inspection period as a conservative estimate. The oversight impact level will only increase with NRC inspection of particular ITAAC groups or activities, which may in turn lead to greater licensee oversight.

4.1.2 Calculating Attribute Weights Using the Analytical Hierarchy Process

Once the attributes have been defined, a weighting system can be established for these attributes. The problem at hand is how to properly assess the importance of these attributes relative to one another and to the overall objective of allocating resources appropriately to ensure that all ITAAC have been satisfied. The Analytical Hierarchy Process (AHP) is a structured method of calculating weights for these attributes such that more resources will be allocated to ITAAC that exhibit the characteristics of the more heavily-weighted attributes. Note that this weighting could be completed in an arbitrary manner, such that the expert panel chooses a weighting system that adds to 1, but this is not recommended[5]. The following paragraphs explain the AHP and how to calculate attribute weights.

To apply the AHP process, we have used the MATLAB software package. MATLAB is a high-level language and computational environment that combines much of the capability of MS Excel or Access with other programming language such as C++. The software computes using matrices, which allows it to be the perfect tool for the linear algebra operations required when using AHP. There is a built-in function in Matlab for the necessary eigenvector calculation.

An expert panel could be assembled to provide the inputs for AHP. These inputs are in the form of pairwise comparisons between different attributes. An expert panel would be provided with a Relative Importance Assessment. An example Relative Importance Assessment follows in Example 4.1.

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[5]Choose a weight, w_i, for attribute A_i where $i = 1, \ldots, n$ and $\sum_{i=1}^{n} w_i = 1$

Example 4.1. Relative Importance Assessment for ITAAC Attributes

Compare the following attributes with respect to the overall objective of efficiently allocating resources to appropriate ITAAC.

Use: 1 - equally
3 - weakly
5 - strongly
7 - very strongly
9 - absolutely

Use even numbers to express compromise.

1. Attribute A_1 vs. Attribute A_2 ________
2. Attribute A_2 vs. Attribute A_3 ________
3. Attribute A_3 vs. Attribute A_1 ________

Note that (for the first comparison) if Attribute A_1 is more important than Attribute A_2, a whole number (e.g., 3, 5, etc.) is used, while if Attribute A_2 is more important than Attribute A_1, the reciprocal is used (e.g., 1/3, 1/5, etc.).

Ideally, the expert panel would agree upon the values chosen for the Relative Importance Assessment (RIA). If this is not the case, a method of compromise may be chosen, such as averaging (geometric or arithmetic) the values. Given that a compromise is eventually reached on the RIA values, the RIA should be assembled into matrix form[6]. An example matrix using a

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[6]The matrix is set up to represent the comparison of if Attribute A_i to Attribute A_j with a value x_{ij}:

Table 4.1 Matrix Format for Relative Importance Assessment

	Attribute A_1	Attribute A_2	....	Attribute A_j	....	Attribute A_m
Attribute A_1	$x_{11} = 1$	$1/x_{21}$		$1/x_{i1}$		$1/x_{n1}$
Attribute A_2	x_{21}	$x_{22} = 1$		$1/x_{i2}$		$1/x_{n2}$
....			...		...	
Attribute A_i	x_{i1}	x_{i2}		$x_{ij} = 1$		$1/x_{nj}$
....						
Attribute A_n	x_{n1}	x_{n2}	...	x_{nj}	...	$x_{nm} = 1$

few of the attributes defined in Section 4.1.1 is shown below. For a more complete example, see Appendix D.

Example 4.2. Matrix Example for Attribute Weighting

	Error Propensity	Verify by Other	Oversight
Error Propensity	1	1/7	1/3
Verify by Other Means	7	1	1/7
Oversight	3	7	1

The matrix represented in Table 4.1 should be inserted into a linear algebra solver to obtain the matrix's eigenvector[7].

The weights that are calculated should reflect the relative importance of the attributes to the expert panel. Weil and Apostolakis (2001) assert that the decision maker is under no obligation to use the results, and thus, the AHP process should act as guidance, not an absolute.

4.1.3 Assigning Utilities/Constructed Scales To Attributes

After the weights for the attributes have been calculated, agreement on the measure of the relative impact of each impact level option (e.g., high, medium, low) on a specific attribute is also necessary. In other words, a constructed scale can be defined for each attribute. This scale is referred to as the assigned **utilities** of the attribute. While only three impact level

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[7]An example code is shown below that computes the matrix's eigenvector using the Mathematical Software Package MATLAB.

Example 4.3. MATLAB Code to Calculate Eigenvectors

Given that a matrix has been input into MATLAB as matrix A:

First calculate the eigenvector, V, using the MATLAB function eig(), then normalize the eigenvector, V. This is completed in two steps in MATLAB:

1. [V, D] = eig(A) — **Note that two matrices must be assigned for the output to obtain the eigenvector. If no output is explicitly assigned, the answer will be the eigenvalue and not the eigenvector*
2. W = V(:,1) / (sum(V(:,1)))

where W will equal a vector of the appropriate weights: $\mathbf{W} = [w_1, w_2, \ldots, w_i, \ldots, w_n]$ and w_i is the associated weight for Attribute A_i.

options are proposed in this report, a greater number of options, such as the inclusion of "Very Low" or "Very High," may be necessary for a more accurate comparison between ITAAC.

Constructed scales (Clemen 1996) provide quantitative meaning to the attribute impact levels of High, Medium and Low defined in Section 4.1.1 of this report. In this methodology, the higher the ITAAC ranking, the more important the inspection. Therefore, one would assign the largest utility value to ITAAC characterized as High for any attribute listed in 4.1.1 (the higher the impact level, the more important it is to inspect). For a 3-tiered constructed scale, such as the one proposed in this methodology, an impact level of High would be assigned a value of 1 and Low, a value of 0. The Medium value would be chosen somewhere between 0 and 1.

As this scale assigns more points to the "worse" ITAAC (e.g. ones with higher error propensity or safety significance), the utility values for intermediate levels (e.g., Medium) should reflect the decision maker's thoughts on the impact of a Medium attribute versus a High or Low assignment. Utility assignments will need to be chosen separately for each attribute, differentiating the attributes by their utility values, as well as their weights.

Particular consideration is necessary when choosing a Medium utility value. In the following sections, an approach for calculating the value of inspection based on these utility values will be explained. This value of inspection is determined by the difference between two utility values for the same attribute, such as the difference between High and Medium for Safety Significance. When choosing a Medium utility value, the decision maker should decide the relative impact of an ITAAC attribute rating that changes from High to Medium versus Medium to Low. Is the impact exactly the same? If so, the Medium utility value should be 0.5. If the decision maker feels that there is a greater impact of an attribute impact level changing from High to Medium, this would be reflected by choosing a Medium utility value less than 0.5. The general strategy is to choose a larger difference between impact level options wherever the impact is believed to be larger.

An example of this differentiation in impacts is given here for the attribute Opportunity to Verify By Other Means. To illustrate this, assume the hypothetical situation in which a decision maker thinks there is only one chance to inspect an ITAAC (a High rating), but later they find that there is the ability to inspect some aspects more than once as a result of a new technology that was introduced (a Medium rating). This change in impact level from High to Medium may have a very large affect on the confidence of the NRC that this ITAAC will be met. Will the affect be as large for this attribute if the hypothetical situation was posed from a Medium to a Low rating? If not, a Medium utility may be chosen below 0.5 and the lower it is chosen, the more impact the High to Medium change will hold.

4.2 The Prioritization: ITAAC Ranking and the Portfolio Approach

In the following sections, a proposed approach to prioritizing ITAAC is explained. This specific prioritization provides a ranking between ITAAC and allocates resources by ITAAC groupings. It is assumed that the rating, ranking and prioritization processes presented below will be performed by knowledgeable expert panels.

This approach is organized with two primary objectives. First, prioritize the ITAAC such that the more important ITAAC are ranked higher and, therefore inspected before ITAAC of lesser importance. Second, the approach includes a portfolio perspective or “coverage” for all ITAAC. Namely, there is assurance that one ITAAC from each grouping is checked. Therefore, for any given ITAAC (say for example, in Inspection Group X) that has not been inspected, the NRC can be assured that at least one other ITAAC in Group X has been checked. By utilizing a portfolio approach, this methodology assures that a diverse set of ITAAC have been inspected such that it represents the entire ITAAC universe.

The methodology presented below acts as a dynamic structure with a feedback loop of information that is necessary for an ITAAC inspection effort that is ongoing over the course of the inspection program. Figure 4.1 displays a flow chart of this process. The methodology splits the process into two stages, an initial inspection and the all subsequent inspections. The assumption is made that the NRC will make an initial inspection and this will be the most resource-intensive. Lesser, but focused inspections will follow at specific points in the overall inspection program based on a structured prioritization process that considers inspection experience to date. Initial and subsequent inspection periods are treated separately in the methodology.

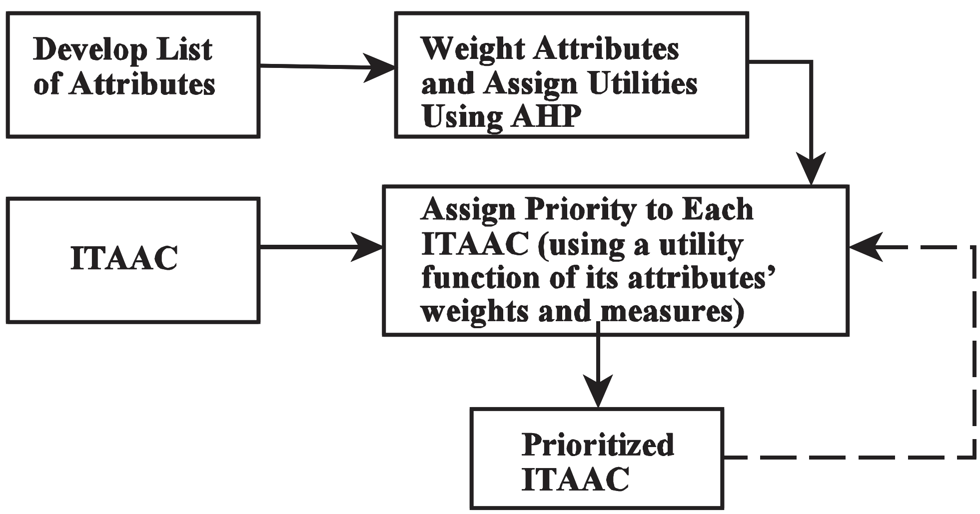

Figure 4.1 The Dynamic Prioritization Process Using AHP

4.2.1 Stage 1: The Initial ITAAC Inspection

4.2.1.1 Ranking the ITAAC

The first step in ranking the ITAAC is to rate each ITAAC by assigning it an impact level for each attribute defined in Section 4.1.1 of this report. If, for example, the impact level options for an attribute are low, medium and high for a specific ITAAC and high is the chosen attribute impact level, then the utility associated with the high impact level option (calculated in Section 4.1.3) would be designated as that ITAAC's utility, u. This type of association will be performed twice for every ITAAC such that two u parameters will be assigned to one ITAAC. These u parameters should be determined by and are defined as follows:

$u_{baseline}$: The attribute impact level and this associated utility is chosen *given the present conditions and state of knowledge.*

$u_{no\ flag}$: The attribute impact level and this associated utility is chosen *as if prior knowledge (inspection experience) already exists that the ITAAC was inspected by the NRC and nothing was found to be wrong (e.g., there were no "flags" raised for this ITAAC)*.

A major consideration when choosing the $u_{baseline}$ and the $u_{no\ flag}$ values is how these parameters may change given prior knowledge of a "no flag" situation. A "no flag" situation is considered for this methodology to be one in which the NRC finds no flaws in the system or component in question and verifies that the licensee's procedure and performance is not flawed. It is the change (or delta) between these two u values that will ultimately drive the rank of an ITAAC. Essentially, an ITAAC can be in one of three states at any time in the NRC's inspection period span:

1. The ITAAC was not inspected by the NRC and no prior NRC inspection knowledge can be deduced at the present time.
2. The ITAAC was inspected by the NRC and no flaws (procedural or in systems/components) were found by the NRC.
3. The ITAAC was inspected by the NRC and something was found to be wrong by the NRC. This was then corrected by the licensee such that the ITAAC was eventually considered to be satisfied.

An important point that is elicited from this list is that the entire prioritization methodology assumes that if the NRC finds a flaw of any kind, the licensee fixes the flaw and the corresponding ITAAC is considered to be satisfied. There are only two situations that should be considered for rating attributes during this initial inspection, 1 (the real conditions) and 2 (the hypothetical situation, in which nothing was found to be wrong).

The rating of attributes for the hypothetical "no flag" situation is not exactly the same as for the baseline rating because the no flag impact level should be chosen relative to the first baseline rating. The attribute definitions, defined in Section 4.1.1, are explicitly relevant for the baseline case. The decision maker should choose High, for instance for the Safety Significance attribute, if they think the ITAAC is of High safety significance. When choosing the no flag rating, a decision maker may think that this specific ITAAC will always be highly safety significant no matter how many times it has been inspected. But, the question should be posed whether inspecting that ITAAC and finding no flags would be valuable or would raise the confidence level of the NRC that no construction flaws are going undetected by the NRC. Again, it is this value of inspection that the proposed methodology actually prioritizes.

Therefore, this methodology suggests that an automatic reduction from the baseline rating to the no flag rating should be considered the standard method. Only in special cases should the baseline and no flag ratings remain the same, as this will not provide any increase in rank to the ITAAC being rated. If an ITAAC is rated Low, though, it cannot reduce any further and will therefore remain at Low. Choosing a baseline of High and a no flag of Low allows for the largest delta and will increase the ITAAC's rank the most of all.

Another method for considering this change from a baseline rating to the no flag rating is to reverse the question of value. Instead of the decision maker considering the value or assurance gained from the inspection of an ITAAC with no flags found, they could consider how much would be lost if that ITAAC was never inspected. In other words, what amount of assurance would have been attained (relative to a specific attribute) if that ITAAC was inspected? Choices would be "None," "Some" or "A Great Deal." If a baseline rating was High, and this question was answered as "A great deal," the no flag rating would become Low. If the answer was "Some," the rating would only change from High to Medium and "None" would leave the no flag rating equal to the baseline.

After an ITAAC has been assigned utility values, $u_{baseline,\, i}$ and $u_{no\ flag,\, i}$ for each attribute A_I, the change in u_I can be calculated by $\Delta u_I = u_{baseline,\, I} - u_{no\ flag,\, I}$. The parameter Δu_I provides an estimate, for a particular attribute A_I, of the value of inspecting the ITAAC. This process of assigning utilities/impact level to each ITAAC for each attribute should be completed for all ITAAC. In previous sections, a method to combine attribute weights and ITAAC utility values was introduced. The expert panel will now use the utility function (defined in Section 4) to compute a $\Delta Rank$ variable for each ITAAC. $\Delta Rank$ is a sum-product function of the attribute weights, w_I, and the change in utility value for attribute A_I, abbreviated as Δu[8]. At this point in the prioritization, a $\Delta Rank$ value should be calculated for every ITAAC.

The $\Delta Rank$ calculation is fundamental to the prioritization process presented in this report. The ITAAC's $\Delta Rank$ value is the metric that NRC will use to decide which ITAAC take priority over others. $\Delta Rank$ is a relative measure such that the value calculated for one ITAAC is only informative when compared to that of others. The greater the $\Delta Rank$ value, the more important

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[8] $\Delta Rank$ should be calculated for each ITAAC, *j*, using the following formula:

$$\Delta Rank_j = \sum_i w_i \Delta u_{i,j} \tag{2}$$

where w_i is the weight given to attribute A_I and $\Delta u_{i,j}$ is the change in utility given to ITAAC *j* for attribute A_I .

it is to inspect that ITAAC. In other words, the more assurance one can obtain from inspecting that ITAAC.

Obtaining a *ΔRank* value for every ITAAC is one milestone in this prioritization process. The next part of the methodology explains how to manage these values. It is cautioned here that the *ΔRank* values for all ITAAC can not truly be considered equal at this point, as the cost of actually inspecting this ITAAC has not yet been factored into the *ΔRank* value. A method could be formulated at this point in the prioritization process to factor the cost of inspection into the *ΔRank* value by dividing the *ΔRank* by the cost[9]. It is strongly recommended to continue on with the portfolio approach section of the methodology. The second part not only ensures a certain "coverage" of all ITAAC, but assists in the management of efficiently inspecting collections of ITAAC.

4.2.1.2 Prioritization of ITAAC Based on ΔRank Values and Cost of Inspection

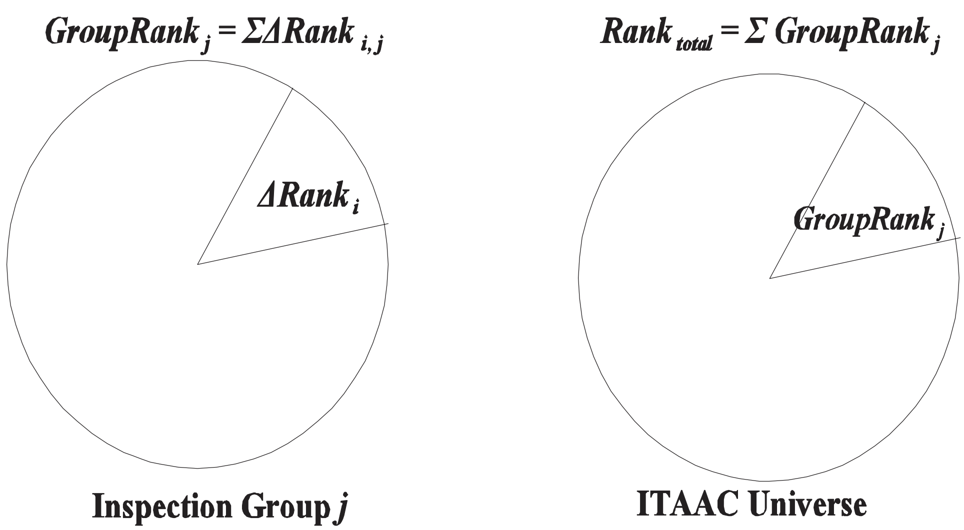

Figure 4.2 Allocating Resources to an Inspection Group

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[9]**Proposed Method To Factor in Cost of Inspection as an Alternative to the Portfolio Approach**

1. The cost (or resources) associated with inspecting an ITAAC *I* will be denoted as c_I. Then, the value, V_I, of inspecting that ITAAC can be calculated as:

$$V_i = \Delta Rank_i / c_i \tag{3}$$

2. Based on these values, V_I, for ITAAC *I*, all ITAAC in the Universe can be ordered such that the largest V_I value has the highest priority of inspection.

For this section of the methodology, it is assumed that every ITAAC has been populated into inspections groups similar to the types recommended in Section 3 of this report. Further, the union of these groups is the ITAAC Universe and each group is mutually exclusive such that every ITAAC contained within that group is unique. Given these conditions, an allocation of resources by group and by ITAAC can be performed using the following steps. This process is represented visually in Figure 4.2.

Allocating A Percentage of Resources to an Inspection Group

1. For each inspection group, sum the Δ*Rank* values of all ITAAC in that group[10].
2. Sum the Δ*Rank* values of all ITAAC in the Universe[11].
3. Calculate the percentage of Δ*Rank* that is contributed to the $Rank_{total}$ of the ITAAC universe[12].
4. Use the *%Rank* value to estimate the amount of resources that should be allocated to each group[13].

The Portfolio Approach: Given The Allocated Resources for a Group, Prioritize ITAAC Within The Group

5. It is now known that the NRC has x_j hours to complete the inspection for $i = 1,..,n$ ITAAC in Inspection Group *J*. It is assumed that the number of hours needed to complete an inspection of all *n* ITAAC in Group *J* will be greater than the maximum allowed amount, x_j. Given this assumption, the NRC can choose a subset of the total ITAAC that efficiently uses the x_j available hours and

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[10]Calculate $\sum_i \Delta Rank_{i,j} = GroupRank_j$ for each ITAAC *i* in Inspection Group *j*.

[11]Calculate $\sum_j \sum_i \Delta Rank_{i,j} = \sum_j GroupRank_j = Rank_{Total}$ (5)

[12] $\%Rank_j = (GroupRank_j) / (Rank_{Total})$ for Inspection Group *j*.

[13]For example, if the NRC has X hours to complete the entire ITAAC inspection during this initial inspection period, then $X \times \%Rank_j = x_j$ hours can be used to provide guidance for the resource allocation of Inspection Group *j*, where $\sum_j x_j = X$.

maximizes the sum of the *ΔRank* for this combination of ITAAC[14]. This process can be completed for each Inspection Group such that a set of *j* subsets have been chosen to be inspected.

Note that when defining an efficient collection of ITAAC, both bundling and cost should be considered. It is assumed that bundling and minimizing cost will overlap on some level (i.e., many times when two ITAAC are in a similar location, inspecting those two may about equal the cost of inspecting the one). This seems more applicable to costs related to travel to distant locations, but does not as accurately account for a situation where there is a full-time inspector at a local site. Therefore, caution must be exercised when choosing these efficient collections of ITAAC that one activity is not inspected over and over again because this minimizes cost. This idea leads to the purpose of the inclusion of step 6, which attempts to ensure that the identified ITAAC collections are diverse and representative of the ITAAC Universe.

6. Prior to actually implementing the inspection of these Inspection Group subsets, the NRC would also ensure that a certain amount of coverage exists. In other words, does the subset of ITAAC chosen for inspection properly represent the ITAAC Universe? If the subset is inspected and no flags are discovered, can the NRC have reasonable assurance that the ITAAC Universe is also "flag-free." It is recommended that the NRC be able to answer yes to the following questions:

   - Is at least one ITAAC in each Inspection Group being inspected?
   - If an ITAAC has been inspected and a "flag" has been found: Even if the flaw is fixed (through re-training or re-fabrication), has at least one other ITAAC in that Inspection Group also been inspected and no flaws found?

   If the answer is No to any of these questions, the NRC has 3 options:
   (1) Increase the number of hours, *X*, allotted to inspect the ITAAC Universe,
   (2) Adjust the percentage of hours allotted to each Inspection Group (Step 4), or
   (3) Adjust the efficient ITAAC combinations that were chosen for each group (Step 5).

The specific ITAAC that were inspected in this initial inspection period would be documented for easy retrieval to provide information when prioritizing inspection resources in the next period.

4.2.2 Stage 2: Subsequent ITAAC Inspections and the Feedback Loop

[14] That is, define an efficient collection of ITAAC (using judgement to find ITAAC that can be "bundled" such that the activities to inspect the ITAAC overlap, are in a similar location, etc.) such that the collection maximizes $\sum_{i_{sub}} \Delta Rank_{i_{sub}}$ for a subset, i_{sub}, of ITAAC $i = 1,..,k$ in Inspection Group *J*.

This methodology assumes that the NRC will periodically inspect ITAAC during the entire length of the inspection program. Given the flexibility of the prioritization process outlined in the next sections, there is no limit to the number of inspections that should be completed or to the frequency of these inspections. It is assumed that these periodic inspections will be a judgement of the NRC. For all subsequent inspections, the NRC would pay attention to what has been documented in past inspections. Note that the ITAAC classification and grouping that was initially completed during the first inspection may be reassessed, if necessary. The following sections assume that no classification or grouping reassessment has been carried out. If a grouping or classification is modified, the tie to the inspection history becomes obscured, but may still be applicable in some form if judgement is used.

4.2.2.1 Re-ranking the ITAAC

Similar to the initial inspection, each ITAAC will need to be rated again for each attribute. This time, though, the expert panel who rates the ITAAC will need to take inspection history into account when considering the attributes which could be influenced by updated knowledge. Most attributes are expected to be re-rated based on the inspection history and overall NRC judgement. These impact levels are expected to become less conservative (not as bad) for most, if not all, ITAAC.

As described in Section 4.2.1.1 of this report, ITAAC are essentially in one of 3 states: (1) Never been inspected, (2) Inspected with no flags, or (3) Inspected with a flag found that was eventually fixed. In these subsequent inspection periods, all ITAAC states are possible and the re-rating of the attributes will be dependent on the state of the ITAAC. Below are recommendations of how to re-rate an ITAAC of each type for a generic attribute, A_i. Note that the NRC may make a different judgement other than those illustrated below based on the history of the entire Inspection Group containing that ITAAC. The three cases below deal with an ITAAC that was rated in the initial inspection and received a conservative baseline impact level, $u_{baseline,\ period\ 1}$ = High for attribute A_i. It was also determined that if this ITAAC had been inspected previously and received no flags that the attribute impact level could decrease to, $u_{noflag,\ period\ 1}$ = Medium. The examples below are described for a generic attribute. Some attributes may not follow these rules exactly.

- (1)The ITAAC was not inspected in the initial inspection. Given that this ITAAC was never inspected in the initial (period 1) inspection, the impact levels chosen for period 1 could also be chosen for period 2, that is:

  $u_{baseline,\ period\ 1} = u_{baseline,\ period\ 2}$ = High and $u_{noflag,\ period\ 1} = u_{noflag,\ period\ 2}$ = Medium.

- (2) The ITAAC was inspected in the initial inspection and no flags were documented. Given that the ITAAC was inspected with no flags in period 1, the attribute impact level for the ITAAC in period 2 should decrease, that is:

  $u_{noflag,\ period\ 1} = u_{baseline,\ period\ 2}$ = Medium .
  $u_{noflag,\ period\ 2}$ may or may not decrease further to Low.

- (3) The ITAAC was inspected in the initial inspection and a flag was documented. Given that the ITAAC was inspected and a flag was found, but the problem was fixed, the expert panel may decide that the impact level for this ITAAC should remain the same. That is:

  $u_{baseline,\ period\ 1} = u_{baseline,\ period\ 2}$ = High and $u_{noflag,\ period\ 1} = u_{noflag,\ period\ 2}$ = Medium.

As in Section 4.2.1.1, the impact levels $u_{baseline}$ and $u_{no\ flag}$ are associated with utility values that are used to calculate $\Delta u_i = u_{baseline,\ i} - u_{no\ flag,\ i}$ for each attribute, A_i. The expert panel will again use the utility function (defined in Section 4) to compute a new Δ*Rank* parameter for each ITAAC, using Equation 2 from Section 4.2.1.1. Δ*Rank* should be recalculated for each ITAAC.

4.2.2.2 Re-Prioritization of ITAAC Based on ΔRank Values

Using the new *ΔRank* values for each ITAAC, resource allocation per Inspection Group can be carried out similarly to that outlined in Section 4.2.1.2, Steps 1-4. Note that the percent allocated for each group may change from that calculated during the initial inspection. Most likely, more resources will be allocated to groups that received less in the last inspection period. This is due to the fact that an Inspection Group which received a large $\sum \Delta Rank$ during the initial inspection was most likely inspected more thoroughly and therefore, there is greater assurance that ITAAC in this group have been met. This assurance leads to lower $u_{baseline}$ and *ΔRank* values in the subsequent inspection period, lowering the percentage of resources allocated to it in the subsequent period. Similarly, Inspection Groups which were not allocated much resources in the initial inspection will most likely have about the same $\sum \Delta Rank$ value in the subsequent inspection, but this will be large now relative to the other group's $\sum \Delta Rank$. In turn, this group will receive more resources compared to a group which was allocated a large amount of resources during the first inspection.

With resources allocated to the inspection groups, the NRC could again prioritize the ITAAC within each Inspection Group using the same method as described in Step 5 of Section 4.2.1.2. Once prioritized, the questions posed in Step 6 will need to be addressed again, though with a little more leniency than during the initial inspection:

- Is at least one ITAAC in each Inspection Group being inspected?
  - The answer to this question should still be yes in all subsequent inspections.

- If an ITAAC has been inspected and a "flag" has been found. Even if the flaw is fixed (through re-training or re-fabrication), has at least one other ITAAC in that Inspection Group also been inspected and no flaws found?
  - The answer to this question should still be yes in all subsequent inspections.

Subsequent inspections and periodic re-prioritization would be simple during the entire inspection program.

The process described in this section does not recommend whether the attribute of safety significance would be addressed within or outside of the AHP process. A justifiable argument exists that safety significance should not be weighted and treated as part of a rating process. It may be treated separately, as a multiplicative factor of *ΔRank*. This is addressed in Appendix A, where *ΔRisk* is calculated instead of *ΔRank*. The main idea supporting the *ΔRisk* calculation is analogous to that of *ΔRank*.

4.2.3 An Alternative to Stage 2: Subsequent ITAAC Inspection

Stage 2 of the prioritization process could be considered arduous and therefore, a more efficient, alternative approach is proposed in this section using the same concept of a feedback loop based on the NRC's assessment of licensee performance thus far during the inspection program. The new information, or evidence, can assist in the determination of which inspection groups need more focused NRC inspection based on licensee performance uncertainty.

The alternative approach, then, assumes that all ITAAC within an Inspection Group will be rated the same for the Licensee Oversight Attention attribute. This rating is based on the NRC's observations and their judgement of licensee performance for the set of activities (ITAAC) representing the group. Therefore, the groups' homogeneity should be ensured prior to implementing this more efficient approach. If ITAAC have been grouped at the family-level, it may be necessary to create new or different subfamilies to satisfy the necessary assumption. See Section 3.1 for further discussion on subfamilies.

The alternative approach allows for a re-ranking of ITAAC at the group level. More specifically, the percent of resources recommended for each Inspection Group of ITAAC will be recalculated, but the order of importance of ITAAC within the Inspection Group will not change. Therefore, in this approach, the Inspection Group is given a rating, not the individual ITAAC. Further, the only rating necessary is that of the Licensee Oversight Attention attribute. This simple methodology is possible given 4 assumptions:

1. Once an ITAAC has been inspected sufficiently and is considered to be fulfilled, it will be permanently taken off the list of ITAAC to inspect.
2. The impact levels (or Δu values) chosen for the first 4 ITAAC attributes (all attributes except for Licensee Oversight Attention) during the initial inspection period will remain constant for all subsequent inspection periods.
3. The impact level (or Δu value) chosen for the Licensee Oversight attribute will be equivalent for all ITAAC during the initial inspection period. The assumption here is that the NRC will have no prior knowledge of the licensee and will rate this attribute conservatively for all ITAAC. If all ITAAC have the same Δu values for this attribute, it is unnecessary to consider it during the initial inspection period, as it will not change the ranking outcome.
4. The impact level (or Δu value) chosen for the Licensee Oversight attribute will be based on the collective observations for all ITAAC within an Inspection Group.

Therefore, this attribute can be assessed at the group level during subsequent inspections.

Following the assumptions listed above, the Licensee Oversight attribute will not be considered during the initial inspection period for ITAAC rating purposes. It is still advisable to choose and/or calculate the attribute's weight and utilities at the same time as the others. The rank calculation for the initial inspection period will then be the sum-product of the first 4 weights and utilities, as opposed to all five of the values[15].

With the exception of this change in *ΔRank* calculation, the Stage 1 methodology remains the same. During subsequent inspection periods, only the 5th attribute, Licensee Oversight, would be considered and based on the observed performance of the licensee to date for the appropriate group. If ITAAC were evaluated at the group level for this attribute, then the Δu_5 value calculated for a particular group could filter down to all ITAAC within that group by factoring in the last $w_5\ \Delta u_5$ (the weight and utility values of the Licensee Oversight Attribute) value into each ITAAC's utility function equation for $\Delta Rank_{init}$, previously defined. Each ITAAC would therefore have a new *ΔRank* value for the subsequent inspection period[16].

Note that although the *ΔRank* values will become larger for each ITAAC, the absolute increase will be constant for all ITAAC within a group. Therefore, the rank-ordering of ITAAC within the group would remain the same. The sum of the *ΔRank* values for all ITAAC within the group would increase. This will directly affect the Percent of Resources By Group calculation as outlined in Section 4.2.1.2 of this report. It is this redistribution of resources which will act as the reassessment of ITAAC based on licensee inspection history. A new $w_5\ \Delta u_5$ will need to be calculated for each group for every subsequent inspection period, therefore producing new *ΔRank* values for every ITAAC.

4.3 Implementation of the Prioritization

Given that the prioritization outlined in Sections 4.1 and 4.2 is a decision-making process which may involve groups of individuals from a diverse set of backgrounds, this report also provides some guidance on its implementation. This guidance has come from insights collected during a trial prioritization of 40 ITAAC chosen from the AP1000. It is not meant as a comprehensive implementation plan, but rather a summary of implementation insights gained during a trial exercise. Additionally, the inputs and results from the trial exercise can be found in

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15 More specifically, if w_i and Δu_i is the weight and utility, respectively, chosen for Attribute A_i and there are five attributes A_1 through A_5, where A_5 is the Licensee Oversight attribute, then the initial calculation of *ΔRank* will only require a utility function:

$$\Delta Rank_{init} = \sum_{i=1}^{4} w_i \Delta u_i$$

16

$$\Delta Rank_{subsequent} = \Delta Rank_{init} + w_5 \Delta u_5 = \sum_{i=1}^{5} w_i \Delta u_i$$

Appendix D. A number of handouts were provided for this trial and are also included in the appendix.

First, the calculation of the attribute weights and utilities does not necessarily have to be related to a specific plant design, such as the AP1000. Therefore, these could be calculated once generically prior to implementing the rest of the methodology. Additionally, the process of weighting attributes and choosing a constructed scale for the utility values may also create an initial bias for the individuals involved in implementing this methodology. The knowledge of the exact numerical values chosen for these weights and utility values may bias the individuals who rate each ITAAC for the attributes. These biases undermine the structure and independence that the prioritization processes, such as AHP, assist in creating. Therefore, the methodology may need to be implemented by 2 to 3 separate teams. At the very least, the rating of ITAAC for each attribute may be best implemented within a group that was not involved in the weighting or choosing of utilities for attributes. The knowledge of these weights and utilities may skew how an individual rates an ITAAC. Further, separating the groups that determine the weights and utilities values may also be beneficial to the ideal of unbiasedness.

The actual process of completing the Relative Importance Assessment (RIA) for the attribute weights also could be considered on a scrupulous level. It is unlikely that all individuals within a group will rate one attribute against another with the same numerical value. Additionally, obtaining a consensus through open deliberation may prove difficult. One method of dealing with this difficulty is to allow the group members to arrive at these values separately and then a calculated average could be used as an input into the AHP process. Thus, the only deliberation step necessary may be to have the group arrive at a consensus of which attribute is more important. A constructed scale for each attribute could be determined similarly by a group. First, the group could decide whether the Medium impact level should receive a utility value above or below 0.5. Then, each individual would choose this value privately and the individual values could be averaged.

Some implementation considerations are also necessary when gathering a group of individuals to classify the ITAAC for each attribute. It may be necessary to inform the group that the family assignment given to an ITAAC will equate to which activity is inspected when reviewing that ITAAC. Further, some ITAAC may not need to be assigned to a family because their acceptance criteria is the successful completion of other ITAAC. The AP1000 ITAAC 2.1.1.3 is an example of this ITAAC type.

For the ITAAC that can be rated, open deliberations are thought to be useful. If a consensus is not reached by the group, enacting a rule of conservatism may be in order. That is, choosing the highest baseline rating in deliberation for an ITAAC and the lowest no flag rating in deliberation will produce the largest delta, raising the ITAAC's ranking. Additional considerations for implementation of the ITAAC rating process include the importance of using any available resources when determining the impact level to assign an ITAAC. For example, when evaluating the Safety Significance attribute for ITAAC, the DCD information that reflect safety considerations from the certification review may be very helpful. Resources such as this could be used to reduce subjectivity. Last, it may helpful to evaluate all ITAAC within a system for one attribute before moving on to the next attribute. This will allow for relative comparisons of ITAAC within a system and may improve the efficiency of the rating process.

5 SUMMARY

This report has provided a methodology for the prioritization of NRC resources to inspect ITAAC to provide reasonable assurance that no construction flaw is undetected by the licensee (i.e., all ITAAC are satisfied). Both the framework and recommendations for more specific information, such as attributes, ITAAC classifications and groupings and attribute utility scales, were also included. Further, an alternative approach was outlined with a risk calculation. The development of this methodology and a small trial exercise has led to some insightful conclusions and the need for a recognition of limitations. Many of the insights and limitations were managed and are implicit within the methodology, but a full exercise of the prioritization is needed to distinguish which are truly reconcilable.

5.1 Insights

Many insights, listed below, were realized during the development and trial exercise of the methodology presented in this report.

1. An educated and dynamic prioritization process is recommended rather than statistical acceptance sampling.

2. The ITAAC inspection process is dependent on inspection history and therefore, the prioritization should be dynamic and adaptive.

3. The prioritization of ITAAC actually ranks the value of the ITAAC inspection and/or the value of assuring that the licensee has detected any construction flaws.

4. The change from a baseline utility value to the no flag value drives the ITAAC ranking. This is based on the concept of “the value of inspection.” When choosing the constructed scales for each of the attributes, it is important that this relationship be fully understood by the expert panel.

5. ITAAC may be classified based on the activity required to satisfy that ITAAC. These unique activities may loosely follow the descriptions of the intersections of the NRC’s ITAAC Matrix. Combining ITAAC of similar activities into groups is key to the prioritization process and in turn, to the efficient use of NRC resources.

6. Grouping of ITAAC for purposes of prioritization may need to follow a set of rules including that the groups are mutually exclusive and the union of these groups is the ITAAC Universe.

7. One primary benefit of using a methodology involving AHP and utility theory is that of structure and objectivity. Arbitrarily choosing the importance of attributes or ranking the ITAAC may lead to a subjective and less accurate decision, as well as greater difficulty of arriving at an agreement.

8. Rather than defining some threshold value for *ΔRank* in which ITAAC above the threshold are inspected, the portfolio approach (or "coverage check") allows for NRC resource flexibility and a better estimate of the level of assurance that is possible from the ITAAC inspection.

9. It may be beneficial to create two or even three different NRC groups to (1) calculate attribute weights, (2) determine the constructed scales for attributes and (3) classify, group and rate ITAAC. This may eliminate a bias that could occur during the rating of ITAAC that had formed when performing the first two activities. Additionally, the first two activities could be determined generically for all plant designs, while the last activity cannot.

10. An alternative approach is described in the appendices of the report. This approach may allow for a more accurate use of risk. It was developed with the intention of using the technical basis provided in Appendix B, while conforming to the design of the methodology in the main report.

11. The Safety Significance attribute is inherently correlated to the Opportunity of Verifying by Other Means attribute. This insight is further described in Appendix C.

12. The methodology presented in this report can be implemented and/or interpreted in many different ways. Many interpretations would be acceptable given that there are consistent guidance and rules provided to the expert panel who is implementing the methodology for the entire set of ITAAC for a plant.

5.2 Limitations

Some limitations, listed below, were also realized during the development and trial exercise of the methodology presented in this report.

1. The prioritization was developed with the overall objective of optimizing NRC resources to give reasonable assurance that all construction flaws are detected by the licensee. This objective is specific and therefore, the prioritization is limited to this statement.

2. The argument can be made that the treatment of the safety significance attribute should be a multiplicative factor rather than as part of the AHP process.

3. A set of five attributes were chosen in this prioritization. More attributes are possible and identifying them may lead to better accuracy. The list was intentionally limited as to make implementation of the methodology more practical.

4. The methodology has only been exercised in a small trial and therefore, new issues may arise and will need to be addressed.

5. The use of a safety significance attribute in the methodology may involve obtaining information from the plant's PRA. Using values, such as the Birnbaum, to evaluate ITAAC requires that ITAAC be viewed at a component level. Therefore, the use of safety significance may burden the prioritization process, but will also allow for greater accuracy. It is important that PRA resources be used when rating ITAAC for this attribute to lessen subjectivity.

6 REFERENCES

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APPENDIX A

USE OF ESTIMATED RISK FOR RANK

APPENDIX A: USE OF ESTIMATED RISK FOR RANK

This section gives an alternative approach, in which the rank of a component is defined as the estimated risk due to the component, and rank of an inspection group is the sum of those risks. An expert panel is still required, but the experts need to answer somewhat different questions. Rather than weighting the importance of various factors, they must judge the effect of the factors on the ITAAC process. The importance then falls automatically out of the risk calculation.

This follows the terminology of Appendix A, in which the risk corresponding to a component is defined in terms of:

> p_{flaw} = probability that a flaw exists in the component after fabrication and before the ITAAC testing,
>
> $p_{nondetect}$ = probability that the ITAAC testing fails to detect the flaw,
>
> d = anticipated duration of an undetected flaw, as a fraction of total plant life
>
> R = risk importance of the flaw, e.g. change in core damage frequency or LERF as a result of the undetected flaw.

Then the probability that an undetected flaw will be present at the time of a true demand is

$$\text{Pr(undetected flaw at time of demand)} = d \times p_{flaw} \times p_{nondetect},$$

and the risk corresponding to the flaw is

$$R \times \text{Pr(undetected flaw at time of demand)} .$$

The estimated value of this term is the estimated risk, which will be used as the Rank and applied as in Section 4.2 of this report.

A.1 Relation of Attributes to Elements of Estimated Risk

An activity — either fabrication, qualification, or testing — is performed on a component. The NRC inspector is considering observing or checking this activity.

Use the following notation:

> R = **r**isk importance for the component under consideration
> C = Error Propensity of the activity
> X = construction or testing e**x**perience, for the ones performing the activity
> V = opportunity of **v**erifying correctness of the activity by other means
> O = degree of **o**versight attention by the licensee.

A.2 Input from Expert Panel

The expert panel must consider the above attributes, and if possible define generic averages over all the fabrication activities and over all the qualification and testing activities.

In addition, the panel must express the value of an attribute for a particular activity as a multiple or fraction of the generic value. Suggested multiples and fractions are given in Section 4.1.1 of this report, but the panel and the NRC inspectors should feel free to deviate from those suggested values whenever it is appropriate.

If the above determinations can be made, with a generic value for all fabrication activities and a generic value for all qualification and testing activities, then the generic values do not need to be quantified. The generic portions will cancel out of all the prioritizations, and only the multiples or fractions will remain. Denote the generic, or **medium**, values of the above attributes by a subscript M: R_M, C_M, X_M, V_M, and O_M.

Finally, the panel must define a generic $p_{flaw,\ NOMINAL}$, the probability of a flaw in the fabrication of a component of medium Error Propensity, by a contractor or vendor with medium experience, and medium licensee oversight attention. Likewise, the panel must define a generic $p_{nondetect,\ NOMINAL}$, the probability that an ITAAC test fails to detect an existing flaw, if all the relevant attributes are medium.

Two other quantities must be determined for use in the risk equations: *n*, the number of components in the inspection group, and *t*, the likely number of distinct teams of personnel who will be performing the activity.

A.3 Connecting the Attributes to Risk

The following formulas will be used. First, from Section B.3.1, the risk for a flaw in a component is

$$R \times d \times p_{flaw} \times p_{nondetect} \qquad (6)$$

where R is defined above, and *d* is the estimated duration of an undetected flaw before it is discovered during normal operation and testing, expressed as a fraction of the total planned life of the plant.

We will use the formula

$$p_{flaw} = p_{flaw\ NOMINAL} \times (C/C_M) \times (X_M/X) \times (O_M/O), \qquad (7)$$

so that p_{flaw} increases if the activity has high Error Propensity, the contractor or vendor has low experience, and the licensee has low oversight attention.

Similarly, we will use the formula

$$p_{nondetect} = p_{nondetect\ NOMINAL} \times (C/C_M) \times (X_M/X) \times (O_M/O), \qquad (8)$$

where now C refers to the Error Propensity of the ITAAC testing procedure, X refers to the experience of the personnel performing the test, and O refers to the licensee oversight attention for the ITAAC testing.

The attribute V, opportunity of verifying the activity by other (later) means is discussed here. First, consider fabrication. A flaw in fabrication will normally be discovered by the ITAAC test. If not, it may be discovered after a time during normal operation of the plant. Thus, the difficulty of later verification corresponds to $p_{nondetect,\ anticipated}$ and to d, the expected duration of the flaw as a fraction of the total life of the plant. (The value of $p_{nondetect}$ cannot be known yet, because the component is still being fabricated, and it is not yet know to what extent the NRC will inspect the later ITAAC testing). For regulatory conservatism, the anticipated $p_{nondetect}$ might be set somewhat higher than $p_{nondetect\ NOMINAL}$. The value of d must be determined by the panel when V is considered for the component and flaw-type of interest. For active components, such as pumps and valves, $p_{nondetect}$ might be set to some small value, perhaps in the range 0.005 to 0.05, and d would be set to 1/60 if a previously undetected flaw is expected to be found during normal operations within the first year of a 60-year plant life. As an example at the other extreme, consider placement of rebar in concrete. There is no ITAAC test for this fabrication activity, so $p_{nondetect}$ is 1.0. It would not be discovered during normal plant operations, so d is also 1.0.

Now consider V in the setting of ITAAC testing. In most cases there is no second test, so V refers only to d, the portion of the plant's life when the flaw is expected to remain unrecognized. In a few cases a second test exists, for example when a weld is examined by NDE and then tested by a hydrostatic test. In this case, a second term, $p_{nondetect2}$ is introduced into the expression for the probability of an undetected flaw, as described at the end of Section B.3.3.

The value of n, the number of items in the inspection group, is used when the risks for the various components are summed over the entire group. The value of t is used to decide how much an inspection learns about the experience of the personnel, although the details here need development. If there are many distinct teams of personnel, then a single inspection reveals less about the overall performance than if there is just one team of personnel. This is illustrated in Example 4.5a below.

A.4 Examples

The ideas presented above are applied here to examples. Although the details need refinement, the general process is proposed as a means of prioritizing inspection.

Example A.4.1. Fabrication of Isolation Valves

Consider fabrication of the 88 isolation valves in Table 3.1. Consider this group as an inspection group. We cannot identify the valves that correspond to a particular ITAAC, because the valves are identical and could be installed in any system. Suppose an expert panel makes the following judgments.

There are 88 valves, destined for 11 systems. For example, 6 valves will be used in the Reactor Coolant System, and the panel decides that their risk importance is high, $R = 10 \times R_M$. Similarly the panel assigns risk values to the components in the other systems, resulting, say, in a total of

26 components with $R = 10 \times R_M$,
56 components with $R = R_M$
<u>6 components with $R = R_M/10$</u>
88 components with total $R = 316.6\ R_M$.

The factory has two lines for manufacturing the valves, each line staffed by a separate group of people. It is difficult to identify which people will be on any one line at any one time.

The panel also decides that for each isolation valve

Error Propensity is medium, $C = C_M$
Construction Experience is low, $X = X_M/2$
opportunity of Verifying is medium. That is, the ITAAC test is generally effective, but most ITAAC tests are effective and this one is no better than most. This means that we will use the nominal $p_{nondetect}$ in the equation for risk.

Licensee and Contractor Oversight attention is given a baseline value of Low, as a regulatory conservatism, $O_{baseline} = O_M/2$. If it looks satisfactory after one inspection, the no-flag value will be set to Medium: $O_{no\ flag} = O_M$. After a second inspection we will be willing to set O to $2O_M$.

Because the valves are tested periodically, it is decided that any initial flaws will probably be discovered within three years, out of a 60-year planned life. Therefore $d = 3/60 = 0.05$

Based on Equations (5) and (6) the baseline estimate of risk for a component is

$$
\begin{aligned}
Risk_{baseline} &= R \times d \times p_{flaw,baseline} \times p_{nondetect,anticipated} \\
&= R \times d \times p_{flaw,NOMINAL} \times (C/C_M) \times (X_M/X) \times (O_M/O) \times p_{nondetect,anticipated} \,. \qquad (9)
\end{aligned}
$$

We must substitute an anticipated value for $p_{nondetect}$. Based on the consideration of V, we use $p_{nondetect,\ NOMINAL}$. This gives

$$
\begin{aligned}
Risk_{baseline} &= R \times 0.05 \times p_{flaw,NOMINAL} \times 1 \times 2 \times 2 \times p_{nondetect\ NOMINAL} \\
&= 0.20 \times R \times p_{flaw,NOMINAL} \times p_{nondetect\ NOMINAL}
\end{aligned}
$$

If no problems are seen after one inspection at the factory, the value of O drops by a factor of 2 to O_M.

Since this inspection requires a visit to the factory, the inspector plans to look at both manufacturing lines while he is there. In this way, he will also manage to cover all the personnel in the manufacturing process. Because of the extra personnel observed, it is valid to count this as a second inspection, for almost no extra cost. The value of A drops by a second factor of 2 to $O_M/2$. This is an example of “bundling.”

Therefore, if no problems are seen at the plant inspection, the estimated risk will be

$$Risk_{2nd\ inspection} = 0.05 \times R \times p_{flaw,NOMINAL} \times p_{nondetect\ NOMINAL}$$

The difference for a single component will be

$$\Delta Risk = (0.20\,!\,0.05) \times R \times p_{flaw,NOMINAL} \times p_{nondetect\ NOMINAL},$$

where R is component specific.

The difference for the entire inspection group will be

$$\Delta Risk(\text{Inspection Group}) = 0.15 \times 316.6 \times R_M \times p_{flaw,NOMINAL} \times p_{nondetect\ NOMINAL},$$

and the per-cost ΔRisk for the group is

$$(47.5 \times R_M \times p_{flaw,NOMINAL} \times p_{nondetect\ NOMINAL})/(\text{cost of inspections})$$

This may be compared to the per-cost ΔRisk for other groups.

Example A.4.2. Stroke Test of Valves

This example is based on Example 3.1, but it has two variants. First consider the ITAAC slice that tests only isolation valves. Then consider the unsliced ITAAC that tests all the valves in the various systems of Table 3.1; the basis for not slicing is that the stroke test is performed in the same way for all the valves — it is the same activity.

Example A.4.3a. ITAAC slice for isolation valves.

There are 88 isolation valves, the same ones as in Example 1.

R is the risk importance for a component. It is not related to either fabrication or testing, so the values of R that were determined for fabrication in Example 4.4 continue to be used. The 88 valves have a total risk of $316.6 \times R_M$.

Suppose that the panel makes the following determinations:

> Error Propensity of the stroke test is Low, $C = C_M/2$
> Training and Experience of the testing staff has a Low baseline value $X = X_M/2$, for regulatory conservatism. This will be reset to a higher value after inspection.
> opportunity of Verifying by other means: as decided for Example 4.4, any difficulty in stroking will probably be discovered by periodic test within three years, so the duration of an undetected flaw is set to 3/60 = 0.05.

Licensee oversight attention is conservatively set High for the baseline, $O = O_M/2$. This can be reset after inspections.
$n = 88$
$t = 3$, the likely number of distinct teams of personnel performing the testing.

From Equation (8), the baseline value of $p_{nondetect}$ is

$$\begin{aligned} p_{nondetect,\ baseline} &= p_{nondetect\ NOMINAL} \times (C/C_M) \times (X_M/X) \times (O_M/O) \\ &= p_{nondetect\ NOMINAL} \times (½) \times (2) \times (2) \\ &= 2 \times p_{nondetect\ NOMINAL}. \end{aligned}$$

After satisfactory inspection, the value is set to

$$p_{nondetect,\ no\ flag} = p_{nondetect\ NOMINAL} \times (½) \times (1) \times (1) = ½ \times p_{nondetect\ NOMINAL}.$$

The reset value of X is determined as follows: The training and experience was conservatively set to $0.5 \times X_M$. After full inspection of the testing personnel, the value would be set to $2 \times X_M$. However, one inspection only observes one of three testing teams. We add $0.5 \times X_M$ for each team that is inspected:

After inspecting no teams, the value is $0.5 \times X_M$.
After inspecting one team, the value is $1.0 \times X_M$.
After inspecting two teams, the value is $1.5 \times X_M$.
After inspecting three teams, the value is $2.0 \times X_M$.

The difference between the baseline value and the no-flag value is $1.5 \times p_{nondetect\ NOMINAL}$.

Therefore, the Δ*Risk* for a single component is

$$\Delta Risk = (1.5) \times R \times d \times\ p_{flaw} \times p_{nondetect\ NOMINAL}\ ,$$

where p_{flaw} is whatever it was after any fabrication inspections. From Example 4.3, if no fabrication inspection was performed, p_{flaw} equals $4 \times p_{flaw,\ NOMINAL}$. If instead a satisfactory inspection at the fabrication site was performed, p_{flaw} equals $p_{flaw,\ NOMINAL}$.

The Δ*Risk* for the entire group of ITAAC slices is the sum over the components. This is

$$\Delta Risk(\text{Inspection Group}) = (316.6 \times 1.5 \times 0.05) \times R_M \times p_{flaw} \times p_{nondetect\ NOMINAL}$$

If a fabrication inspection was performed, this is

$$\Delta Risk(\text{Inspection Group}) = 23.75 \times R_M \times p_{flaw,\ NOMINAL} \times p_{nondetect\ NOMINAL}$$

If, instead, no fabrication inspection was performed, this is

$$\Delta Risk(\text{Inspection Group}) = 95.0 \times R_M \times p_{flaw,\ NOMINAL} \times p_{nondetect\ NOMINAL}.$$

(Of course second and third significant digits are ridiculous, considering the crudeness of the formulas and the estimates. They are shown here only to allow users to trace through the calculations.)

Example A.4.3b, ITAAC for stroke test of valves, whatever type.

The only differences between these calculations that those of the previous example are:

> the number of valves in the inspection group is larger, and
> the sum of risks for those valves is larger.

Example A.4.4, Rebar in concrete

There is no ITAAC for this except the as-built ITAAC. So we must inspect the fabrication. When calculating the risk, we must set $p_{nondetect,\ anticipated}$ = 1, i.e. if the rebar is placed incorrectly the flaw will not be detected. Suppose that the generic $p_{nondetect,\ NOMINAL}$ equals 0.01. Then the anticipated $p_{nondetect}$ in this particular case equals $100 \times p_{nondetect,\ NOMINAL}$. This factor of 100 enters into the $\Delta Risk$ calculations, making it likely that the rebar in concrete will be inspected during fabrication. In addition, the duration of the flaw is set to d = 1, because such an error would not be discovered during normal operations.

APPENDIX B

A PRIORITIZATION THAT MODELS THE PROBABILITY OF ERROR

APPENDIX B: A PRIORITIZATION THAT MODELS THE PROBABILITY OF ERROR

B.1   Modeling the Probability of Error

This Appendix considers the elements of an inspection group. One possible such group is a fabrication inspection group, consisting of components that all are made by the same process and that all have the same requirements. The other possible kind of inspection group is an inspection group of ITAAC or of ITAAC slices, all of which use the same one test procedure.

B.1.1   Examples

Several examples dealing with welds are given to motivate the mathematical modeling of this section. In the language below, the “contractor team” refers to the persons who make the welds, the term “team of testers” refers to those persons performing the ITAAC test on behalf of the licensee, one or more individuals, and the “NRC inspector” is the person who observes portions of the whole process.

Example B.1.1. Flaw Discovered During Fabrication

A contractor team makes some welds in a system of the plant. This involves locating the correct spot, getting the correct material, and making the weld. While the weld is being made there are contractor and licensee QA hold points. After the weld is complete, the contractor performs a radiographic examination. On one of the welds, the contractor identifies a flaw in the weld. Therefore the contractor removes part of the weld and re-welds it. In the end the contractor claims that all the welds have been made according to the requirements.

In this example, the flaw that the contractor discovered and fixed is not counted against anyone. The only flaws of concern are those that the contractor makes and does not fix.

Example B.1.2. Flaw Discovered During ITAAC Testing

The licensee team of testers performs an ITAAC test on the welds of the previous example, while the NRC inspector observes. Depending on the ITAAC, this testing could involve examining the radiograph, performing a hydrostatic pressure test, or some combination of these and other tests. The team finds a problem with one of the welds. The licensee then orders that the weld be repaired, and perhaps that a root-cause analysis be performed. The ITAAC 100% inspection continues, with special attention to any welds implicated by the root-cause analysis. Any welds found to be flawed are repaired or replaced.

In this example, unless the discovered flaws are numerous enough or serious enough to cause worry that some problems remain undetected, it seems reasonable to say that an equipment problem did exist but the testing process successfully discovered it and the subsequent repair/replacement process successfully removed the problem. Therefore, the ITAAC is satisfied.

Example B.1.3. Incorrect ITAAC Testing

As in the previous example, the team of testers is testing welds on behalf of the licensee while the NRC inspector observes. The team does not find a problem, but the NRC inspector notices that the test is not being performed correctly. Following appropriate channels, the NRC inspector brings this to the attention of the licensee management, which institutes additional training for this particular test procedure. The retrained team then tests all the welds, including the ones that had been inadequately tested before, with the NRC inspector observing at least some of the tests. No problems are found.

In this example, the ITAAC was not satisfied the first time, because the test was not performed correctly. After the team of testers is retrained and the tests are performed correctly, the ITAAC is satisfied.

In the above three examples, different kinds of problems existed. The first involved a flaw in the plant that was repaired before the ITAAC testing began, the second involved a flaw in the plant that was discovered by the ITAAC process, and the third involved a failure of the ITAAC process to detect a flaw. The first case did not involve a determination of whether the ITAAC was satisfied, because the ITAAC process had not yet begun. In the second and third cases the ITAAC was eventually satisfied, but only after the problem was fixed. These examples form a background for the mathematical treatment below.

B.1.2 The Two Basic Probabilities of Error, p_{flaw} and $p_{nondetect}$

Consider some component that is tested by some ITAAC. A flaw will be present at the end of the ITAAC process if

1. the flaw exists in the component as fabricated by the contractor, and
2. the licensee's ITAAC test fails to detect the flaw.

These two possible events have assumed probabilities. These probabilities and their combinations are introduced and discussed below, with a tabular summary given at the end.

Define p_{flaw} to be the probability that a flaw is present in a random component when the contractor has declared that the component is complete but *before* the ITAAC testing begins. If the components are made by different vendors or contractors, are not all of the same type, or are not all used in exactly the same way, p_{flaw} will vary somewhat among the components. Similarly, define $p_{nondetect}$ to be the probability that the licensee's testing process fails to detect the flaw. The value of $p_{nondetect}$ will vary with the experience and conscientiousness of the personnel performing the test, the particular test equipment used, the timing of the test (first test performed, test performed when people are getting tired, etc.), and perhaps other factors.

In Example B.1.1, the contractor's QC program successfully helped keep p_{flaw} small. In Example B.1.2, the licensee's inspection process helped keep $p_{nondetect}$ small. In Example B.1.3, the NRC's intervention made $p_{nondetect}$ smaller than it would have been. Similarly, one can imagine a variation of Example B.1.1 in which the NRC inspector sees an unrecognized problem in the fabrication process, and thus makes p_{flaw} smaller than it otherwise would have been.

The probability that a flaw is present at the end of the ITAAC process is the following product:

$$\Pr(\text{undetected flaw at end of ITAAC process}) = p_{flaw} \times p_{nondetect}. \qquad \text{(A-1)}$$

The NRC wants reasonable assurance that this product is very small.

Consider now the extent to which this product can be estimated from quantitative data. When a component is tested, the probability that a flaw will be discovered is

Pr(detected flaw) = Pr(flaw is present AND flaw is detected), which is the product

$$p_{flaw} \times (1 - p_{nondetect}).$$

This quantity can be estimated from the number of flaws detected during the licensee's 100% testing of the components. For example, if 1 flaw is discovered during a test of n components, a simple estimate of Pr(detected flaw) $\equiv p_{flaw} \times (1 - p_{nondetect})$ is $1/n$. This also gives an approximate estimate of p_{flaw} **— if** $p_{nondetect}$ is believed to be small, so that $1 - p_{nondetect}$ is nearly 1, then $1/n$ is also an approximate estimate of p_{flaw}. (The value $1/n$ is the maximum likelihood estimate. A Bayesian estimate could also be constructed, based on the data plus prior belief.)

However, none of the data from the test process gives an estimate of $p_{nondetect}$. That can only be inferred from past literature on the efficacy of the test procedure, together with the NRC inspector's judgment on whether the test was performed correctly.

As a result, the NRC's goal of "reasonable assurance that the ITAAC is satisfied" cannot be quantified exactly. The goal requires reasonable assurance that $p_{flaw} \times p_{nondetect}$ is very small for all the components. The first term of the product can be estimated (approximately) by quantitative statistical procedures, but the second term can only be assessed by subjective judgment.

The above discussion is summarized in Table B.1.

Table B.1. Parameters Involved in Modeling of Flaws and Detection

Row	Parameter or Expression	Interpretation	How to Estimate
1.	p_{flaw}	probability of flaw in a component just before ITAAC process begins	Use rows 2 and 4, or approximate this row by row 4.
2.	$p_{nondetect}$	probability of failing to detect a flaw that exists	Use literature on efficacy of test, plus NRC inspector's judgment of how well the test is performed.
3.	$p_{flaw} \times p_{nondetect}$	probability of undetected flaw in a component at end of ITAAC process. This is the probability of major concern for the regulator.	Use rows 1 and 2.
4	$p_{flaw} \times (1 ! p_{nondetect})$	Pr(detected flaw) = probability that a component will be found to be flawed during the ITAAC process.	Use number of flaws found and number of tests performed. Optionally, also use prior belief.

Fortunately, even if p_{flaw} and $p_{nondetect}$ are moderately large, the product is much smaller. For example, if the individual terms are each as large as 0.05, the product is only 0.0025. And even if some flaws are discovered and corrected during the licensee's testing, so that p_{flaw} appears to be moderately large, the ITAAC can be satisfied if $p_{nondetect}$ is believed to be small.

The NRC will start with initial, or baseline, estimates of p_{flaw} and $p_{nondetect}$. These initial estimates must be moderately large, if only for reasons of regulatory conservatism. The NRC can reduce its estimate of p_{flaw} in these ways:

- observation of the contractor's fabrication work, either that
  - the fabrication work is being performed correctly, or alternatively
  - the fabrication work is being performed poorly, so that the NRC or licensee recommends corrective action by the contractor, resulting ultimately in good fabrication work
- discovery of few or no flaws by the licensee's ITAAC tests.

If the ITAAC testing finds few or no flaws, this helps confirm the positive impression gained from watching portions of the fabrication work, and also gives a quantitative estimate of p_{flaw}.

Similarly, the NRC can reduce its initial estimate of $p_{nondetect}$ by observing that the ITAAC tests appear to be sufficient in principle and performed well in practice.

The analysis below deals with contributors to the two error probabilities, and the corresponding NRC inspection.

B.1.3 Components of p_{flaw} and $p_{nondetect}$

Two activities have been considered, the fabrication of the components and the ITAAC testing of the components. In either case, errors can have several possible causes.

- The *procedure* or *process* might be incorrect or inadequate.
- The *equipment* used might have an unnoticed problem, such as a calibration error or an electrical problem.
- A *human* error might be made. Possible causes of human error could be the following.
  - The personnel do not have sufficient training, skills, or experience.
  - The personnel are unfit for duty (tired, distracted, not sober, etc.).
  - The personnel are not following the procedure or process correctly and conscientiously.
- Finally, the activity might have *inherent* difficulty, with a nonzero probability of error even if everything is done exactly correctly.

The probability of different kinds of human error can vary over time. For example, the very first fabricated component or first ITAAC test might carry an extra probability of human error because the personnel lack recent practice. Fitness for duty may vary over time, being somewhat low at the start of a shift, peaking after the first few activities and eventually degrading as the workers become bored or tired from repetition. Conscientious attitude could also degrade over time if the workers become overconfident and sloppy.

For the fabrication activity, denote the probability of each of the above-bulleted four kinds of error by

$p_{fab,\ proc}$ = Pr(procedure or process for fabrication is incorrect or inadequate)
$p_{fab,\ equip}$ = Pr(equipment problem in the fabrication)
$p_{fab,\ human}$ = Pr(human error in the fabrication)
$p_{fab,\ inherent}$ = Pr(error from inherent difficulty of fabrication).

Then the probability of a flaw at the end of the fabrication is

$$\begin{aligned} p_{flaw} &= 1 - (1 - p_{fab,\ proc})(1 - p_{fab,\ equip})(1 - p_{fab,\ human})(1 - p_{fab,\ inherent}) \\ &\approx p_{fab,\ proc} + p_{fab,\ equip} + p_{fab,\ human} + p_{fab,\ inherent} \end{aligned}$$

where the approximation is valid if the various probabilities are all small.

Similarly for the ITAAC test, denote the probability of each kind of error by

$p_{test,\ proc}$ = Pr(procedure for ITAAC test is incorrect or inadequate)
$p_{test,\ equip}$ = Pr(problem in the equipment used in the ITAAC test)

$p_{test,\ human}$ = Pr(human error in the ITAAC test)
$p_{test,\ inherent}$ = Pr(error from inherent difficulty of ITAAC test) .

Then the probability that the ITAAC test fails to detect an existing flaw is

$$p_{nondetect} = 1 - (1 - p_{test,\ proc})(1 - p_{test,\ equip})(1 - p_{test,\ human})(1 - p_{test,\ inherent})$$
$$\approx p_{test,\ proc} + p_{test,\ equip} + p_{test,\ human} + p_{test,\ inherent}$$

where the approximation is valid if the various probabilities are all small.

B.2 Relation of Inspection to p_{flaw} and $p_{nondetect}$

B.2.1 Goal of Inspection

When inspecting fabrication, the NRC inspector is trying to determine whether the fabrication activity is performed correctly, or in the language of Section B.1.2, to determine whether p_{flaw} is small. The desire is to verify that p_{flaw} is small. This could occur if the NRC inspector observes that the fabrication process seems under control, or it could occur if the NRC inspector discovers deficiencies in the fabrication or the quality control. When these deficiencies are corrected, the act of inspection actually reduces p_{flaw}.

No inspection at all may be necessary if the components are ordinary (such as bolts) and manufactured by a vendor with a good track record. In such a case, the NRC may already have sufficient grounds for thinking that p_{flaw} is small. For other cases, such as the manufacture of a newly-designed one-of-a-kind item, the NRC inspector may wish to observe the fabrication closely to gain some assurance that p_{flaw} is as small as feasible.

Similarly, the NRC inspector must try to verify that the licensee's testing activity will discover any flaws that may be present. In the language of Section 3.2, the NRC inspector wants to determine that $p_{nondetect}$ is small. As with fabrication, this could occur if the inspector observes that the test procedure seems adequate and the personnel and test equipment all perform well. Alternatively, if the NRC inspector discovers deficiencies in the performance of the testing and these deficiencies are corrected, the act of inspection actually reduces $p_{nondetect}$.

The treatment of p_{flaw} and $p_{nondetect}$ are similar in many ways, and are discussed together in the next section.

B.2.2 Effect of Inspection on Estimates of $\mathrm{p}_{\mathrm{flaw}}$ and $p_{nondetect}$

Now consider how the estimates of the parameter values may change. As mentioned at the end of Section B.1.2, the NRC initially estimates the values by conservative **baseline estimates**, but may reduce the estimates based on having performed an inspection.

- Consider first $p_{fab,\ proc}$, the probability of an error in fabrication because of an incorrect process or procedure. The NRC inspector can inspect the process or procedure with this in mind. If the fabrication process is inspected and judged to be correct in principle, the reduced value of $p_{fab,\ proc}$ applies to every component in the inspection group. Note the adaptive nature of the estimation. The estimate of $p_{fab,\ proc}$ changes based on the NRC inspector's experience of examining the procedure.

The reasoning is the same for $p_{test,\ proc}$. The NRC inspector should examine the ITAAC test procedure. If the procedure is judged to be adequate, the reduced value of $p_{test,\ proc}$ applies to every component tested by the inspection group of ITAAC.

- For $p_{fab,\ inherent}$, the contractor's QC program should discover most of the initially created flaws. If the QC program is successful, the resulting probability of a flaw should be small even if the fabrication is inherently difficult and involves repeated attempts, because flaws that are produced will be discovered and the work redone. Thus, an effective QC program will force $p_{fab,\ inherent}$ to be small. Therefore any NRC inspection of a difficult fabrication process should include inspection of the QC program, to judge how effective it is.

  For $p_{test,\ inherent}$, there is little that an NRC inspection can do. This probability is estimated based on any available information in the literature on the effectiveness of the test.

For the remaining terms we make the following important assumption:

ASSUMPTION
If equipment or personnel are seen to be working correctly, then they do not need to be inspected again for a time.

The basis for this assumption is the belief that equipment is generally consistent, until the equipment runs out of some needed material or is damaged or degraded somehow or otherwise rendered nonfunctioning. Likewise, people are believed to be consistent. If they are seen to be fit for duty, properly trained and experienced, and performing the required steps correctly on one occasion, they will generally continue to perform well until they become careless or tired or until they have stopped the task for some time. By the way, this belief in consistency is the reason that equipment is often tested periodically instead of at random times — if the equipment has been verified to work, it does not need to be retested for some time. The same belief in the present context calls for roughly periodic inspection of the fabrication and the ITAAC testing, not random inspection. With this in mind, consider the remaining error probabilities

- Consider $p_{fab,\ equip}$. If the fabrication equipment is inspected and judged to be working properly, the resulting reduced estimate of $p_{fab,\ equip}$ applies to all components made with that equipment for some time (with the length of time being a matter of judgment.)

The situation is similar for $p_{test,\ equip}$. If the equipment used in performance of an ITAAC test is seen to be working correctly, the resulting reduced value of $p_{test,\ equip}$ applies to all components tested with that equipment for some time.

- Finally, consider $p_{fab,\ human}$ or $p_{test,\ human}$. If the personnel involved in fabrication or ITAAC testing are seen to be properly trained, fit, and performing well, then the resulting reduced estimate of $p_{fab,\ human}$ or $p_{test,\ human}$ applies to all the work performed by that set of personnel for some time.

The summary conclusions of the above considerations for fabrication can be listed as follows.

- Every fabricated component is assigned a conservative baseline estimate of p_{flaw}. In principle, this value is built from baseline values of $p_{fab,\ proc}$, $p_{fab,\ equip}$, $p_{fab,\ human}$, and $p_{fab,\ inherent}$.
- After the NRC inspector examines the fabrication process, a new, smaller estimate of $p_{fab,\ proc}$ can be used for every component in the inspection group.
- After the NRC inspector observes the actual fabrication of a component, new smaller estimates of $p_{fab,\ equip}$ and $p_{fab,\ human}$ can be used. These apply at least to components fabricated with the same equipment by the same set of people, at least for some time.
- If no problems, or “flags,” are seen in the inspection, the overall estimate of p_{flaw} is reduced from the initial $p_{flaw,\ baseline}$ to a smaller value, denoted $p_{flaw,\ noflag}$.
- The value of an inspection of fabrication can therefore be quantified in terms of $\Delta p_{flaw} = p_{flaw,\ baseline}\ !\ p_{flaw,\ noflag}$.

The conclusions are similar for inspection of ITAAC tests:

- Every ITAAC test of a component is assigned a conservative baseline estimate of $p_{nondetect}$. In principle, this value is built from baseline values of $p_{test,\ proc}$, $p_{test,\ equip}$, $p_{test,\ human}$, and $p_{test,\ inherent}$.
- After the NRC inspector examines the test procedure, a new, smaller estimate of $p_{test,\ proc}$ can be used for every component test in the inspection group.
- After the NRC inspector observes the ITAAC test actually being performed on a component, new smaller estimates of $p_{test,\ equip}$ and $p_{test,\ human}$ can be used. These apply at least to components tested with the same equipment by the same set of people, at least for some time.
- If no problems, or “flags,” are seen in the inspection, the overall estimate of $p_{nondetect}$ is reduced from the initial $p_{nondetect,\ baseline}$ to a smaller value, denoted $p_{nondetect,\ noflag}$.
- The value of an inspection of ITAAC testing can therefore be quantified in terms of
$\Delta p_{nondetect} = p_{nondetect,\ baseline}\ !\ p_{nondetect,\ noflag}$.

B.3 Prioritization of Inspection Resources

B.3.1 The Quantity to Optimize

One could argue that an inspection should be performed that, for a given cost, gives the greatest value to Δp_{flaw} or $\Delta p_{nondetect}$. However, the NRC inspection is supposed to be risk-informed. Therefore, consider the risk of core damage or some other undesired consequence as a result of the flaw. To evaluate this, we must now consider the anticipated **duration** of an undetected flaw. Many flaws, such as a tendency of a valve to stick or the inability of a pump to reach rated capacity, are discovered during normal operations and periodic testing. Other flaws, such as incorrect placement of rebar in concrete or an incorrect seismic calculation, are difficult to discover until a true demand reveals them. Define d as the anticipated duration of the flaw, as a fraction of the planned plant life. For example, if the plant is planned to have a 60-year life and the flaw will probably be discovered in the first year of operation, define d = 1/60. The probability of an undetected flaw at the time of a demand is

Pr(undetected flaw at time of demand) = d × Pr(undetected flaw at end of ITAAC process).

Now consider risk of core damage, as an example of one kind of risk. The risk corresponding to an undetected flaw is

Pr(undetected flaw at time of demand) × ΔPr(core damage from such a flaw).

The second term in the above expression is the difference in core damage probability if the flaw is present or if the flaw is absent. If the flaw is assumed to automatically cause the component to fail, the ΔPr term equals the Risk Achievement Worth (RAW) of the component. If the Birnbaum importance is more convenient to obtain, it may be used as an approximation of RAW. If the flaw only causes component failure with some probability $q < 1$, the ΔPr term equals q times the RAW. We will use the symbol R for the ΔPr term, a generic notation indicating a risk weight. Therefore, the risk corresponding to an undetected flaw in a component can be rewritten as

R × Pr(undetected flaw at time of demand) = $R \times d \times p_{flaw} \times p_{nondetect}$

The prioritization proposed here is to perform inspections, within the allowed total cost, to maximize the reduction in the estimated total risk of all the inspection groups. The details are presented in the next two subsections.

B.3.2 Inspection of Fabrication

At the outset it must be acknowledged that a component may be tested by more than one ITAAC. This occurs because a component can have various kinds of flaws, and to a lesser extent because several tests may be used to try to detect one kind of flaw. For the moment, assume that each potential kind of flaw in the component is tested by exactly one ITAAC (or ITAAC slice, if the ITAAC has been sliced). The more complicated case, with several distinct tests to discover one kind of flaw, will be mentioned later. Then the risk corresponding to all the possible undetected flaws in the component is

$$\begin{aligned}\text{Risk(component)}&\\ &= \Sigma_i\,[R_i \times \Pr(\text{undetected flaw}_i \text{ at time of demand})]\\ &= \Sigma_i(R_i \times d_i \times p_{flaw,\,i} \times p_{nondetect,\,i}) \qquad \text{(A-2)}\end{aligned}$$

where i indexes the different types of flaw, and also the corresponding risks, durations, and ITAAC tests.

The total risk corresponding to all the components in a fabrication inspection group is the sum of expressions of form (A-2), summed over all the components in the fabrication inspection group,

$$\text{Risk(fabrication inspection group)} = \Sigma_j\,[\Sigma_i(R_{j,\,i} \times d_{j,\,i} \times p_{flaw,\,j,\,i} \times p_{nondetect,\,j,\,i})] \qquad \text{(A-3)}$$

where j indexes the components in the fabrication inspection group.

Now we ask, “If the fabrication of a component is inspected, what improvement can be achieved in the estimated risk for the fabrication inspection group?” First, the overall fabrication process would be inspected, and if the inspection is satisfactory, $p_{fab,\ proc}$ would drop from the baseline value to the “no-flag” value. This would apply to every component in the inspection group. Second, if the fabrication of a component is seen to be performed correctly, then $p_{fab,\ equip}$ and $p_{fab,\ human}$ each drop from the baseline value to the no-flag value. However this drop does not necessarily apply to every component in the inspection group. It applies to the components that will be fabricated by the same team of people with the same equipment, for a limited time. The details are not given here. (As a computational simplification, the number of components with the reduced values might be estimated from the average production process. For example, if a team of welders can accomplish n welds in a week, that might be the number of welds assumed to have the reduced values. The NRC inspector or other experts will need to decide on the appropriate time period, one week or one shift or indefinite or …)

The final prioritization is the following.

- Within the one fabrication group, a component should be inspected to maximize ΔRisk(fabrication inspection group). This assumes that each fabrication costs the same amount to inspect.
- Suppose several inspection groups are competing for the inspection resources. In each group, choose a component to maximize ΔRisk(fabrication inspection group). The group with the largest [max ΔRisk(fabrication inspection group)]/(cost of inspection) should have the highest priority. More exactly, within the budgeted total cost, those groups should be inspected which together have the highest total [max ΔRisk(fabrication inspection group)].

One difficulty has been ignored in the above explanation. At the time of fabrication, the ITAAC inspections have normally not begun, so what values of $p_{nondetect}$ should be used? Here the planners must anticipate. If it is expected that most ITAAC inspection groups will be inspected, at least for the components under consideration, then it would be appropriate to set $p_{nondetect}$ to the no-flag value. If instead it is anticipated that most of the relevant ITAAC inspection groups will not be inspected, then $p_{nondetect}$ should be set to the baseline value.

Finally, we consider the case when more than one ITAAC is used to try to detect the same kind of flaw. For example, some welds may be examined by NDE and again by a hydrostatic test. Then there are two tests for flaws. In this case, replace Equation (A-1) by

$$\text{Pr(undetected flaw at end of ITAAC process)} = p_{flaw} \times p_{nondetect1} \times p_{nondetect2},$$

where $p_{nondetect1}$ is the probability that the first ITAAC test does not detect an existing flaw and $p_{nondetect2}$ is the probability that the later test will also not detect the flaw. As before, inspectors or other experts must decide whether the baseline values or the no-flag values are more appropriate for $p_{nondetect1}$ and $p_{nondetect2}$. The remainder of calculation is analogous to that given above.

B.3.3 Inspection of ITAAC Testing

Now consider the tests in an inspection group of ITAAC. The risk corresponding to a particular test of one component is

$$R \times \text{Pr(undetected flaw)} = R \times d \times p_{flaw} \times p_{nondetect} \qquad \text{(A-4)}$$

just as before. The total risk corresponding to an entire inspection group is the sum of expressions of form (A-4), summed over all the ITAAC tests in the inspection group,

$$\text{Risk(inspection group of ITAAC)} = \Sigma_i(R_j \times d \times p_{flaw,\ i} \times p_{nondetect,\ i}). \qquad \text{(A-5)}$$

Here *i* indexes the ITAAC tests and also indexes the components, because each test is on one component.

In the present context, p_{flaw} has already been established based on any inspections of fabrication. The estimate of $p_{nondetect}$ will depend on the results of any NRC inspection. Initially it has the conservative baseline value. After a satisfactory inspection, the value of $p_{test,\ proc}$ drops to the no-flag value for all the components tested in the inspection group, and the values of $p_{test,\ equip}$ and $p_{test,\ human}$ drop to the no-flag value, at least for the components tested by the same people with the same equipment for some limited time in the future. Therefore, for each component, $p_{nondetect}$ drops to a no-flag value that may vary from component to component.

The final prioritization is the following.

- Within the one inspection group of ITAAC, a test should be inspected to maximize ΔRisk(inspection group of ITAAC). This assumes that each test costs the same amount to inspect.

- Suppose several inspection groups are competing for the inspection resources. In each group, choose a component to maximize ΔRisk(inspection group of ITAAC). The group with the largest [max ΔRisk(inspection group of ITAAC)] / (cost of inspection) should have the highest priority. More exactly, within the budgeted total cost, those groups should be inspected which together have the highest total [max ΔRisk(inspection group of ITAAC)].

As a short digression, consider now the case when more than one ITAAC is used to try to detect the same kind of flaw. For example, some welds may be examined by NDE and again by a hydrostatic test. Then there are two tests for flaws. In this case, replace Equation (A-1) by

$$\Pr(\text{undetected flaw}) = p_{flaw} \times p_{nondetect1} \times p_{nondetect2},$$

where $p_{nondetect1}$ is the probability that the current ITAAC test does not detect an existing flaw and $p_{nondetect2}$ is the probability that the later test will also not detect the flaw. As before, inspectors or other experts must decide whether the baseline values or the no-flag values are more appropriate for the anticipated value of $p_{nondetect2}$. The remainder of calculation is analogous to that given above.

B.3.4 Choosing Between Inspection of Fabrication and ITAAC Testing

If some components are being fabricated or installed at the plant while others are being tested, the inspector may need to choose between inspecting a fabrication or an ITAAC test. In principle, the above calculations can form the basis for the above choice among candidate inspections.

- Within each fabrication inspection group that is a candidate for inspection, a component should be inspected to maximize ΔRisk(fabrication inspection group).
- Within each candidate inspection group of ITAAC, a test should be inspected to maximize ΔRisk(inspection group of ITAAC).
- The highest priority inspection has the largest value of [max ΔRisk(inspection group)]/(cost of inspection of that group). More exactly, for the available hours or dollars, those groups should be inspected to maximize the total ΔRisk

The bookkeeping and scheduling details may be formidable, requiring early judgment of probabilities and a computer program that can give immediate updates. However, in principle the optimization of resources can be carried out by the process outlined here.

B.3.5 Examples

Here are some simple examples to give the flavor of the prioritization, with the hope of bringing it out of the realm of formulas and into the world of plant construction. The logistical and scheduling aspects of the prioritization are not considered here.

Example B.3.1. Inspect Fabrication or Testing?

Suppose, for simplicity, that all the components under consideration are constructed by one team of contractor personnel in one day, and that the ITAAC tests are all performed by one team of licensee personnel in one day. Suppose also that the inspection group of ITAAC coincides with the fabrication group of components.

Suppose now that the inspector cannot learn much from watching the fabrication. It is believed *a priori* that fabrication is probably pretty good, so watching the fabrication process can reduce the estimate of p_{flaw} by a factor of only 2. On the other hand, suppose that the ITAAC test has the potential for human error, so watching the ITAAC test being performed well can reduce the estimate of $p_{nondetect}$ by a factor of 10. It follows that the estimated value of Expression (1) is reduced much more by observing an ITAAC test than by observing a component fabrication. If either inspection costs about the same amount and only one can be performed, it would be better to inspect the licensee's ITAAC test.

Example B.3.2. Same Question, When Costs Differ

Continue with the same example, but suppose now that it costs more than five times as much to inspect an ITAAC test as to inspect a fabrication. Then for a given cost we gain more by inspecting the fabrication than by inspecting the ITAAC test.

Example B.3.3. Which Team of Testers to Inspect?

Suppose now that two licensee teams are performing ITAAC tests today, and we believe that we need to inspect any team only once in a day. For simplicity, assume that the testing procedure has already been inspected and found satisfactory, and every team's baseline value already reflects this fact. Team A will inspect n_{A} components today, and they have a total sum of p_{flaw} values equal to $p_{flaw,\,\mathrm{A}}$. Team B will inspect n_{B} components today, and they have a total sum of p_{flaw} values equal to $p_{flaw,\,\mathrm{B}}$. The portions of Expression (A-5) corresponding to the two teams simplify to

$$R \times d \times p_{flaw,\,\mathrm{A}} \times p_{nondetect} \quad \text{and} \quad R \times d \times p_{flaw,\,\mathrm{B}} \times p_{nondetect}.$$

Here, R and d are generic for a single component, assumed to be the same for all the components.

Assume that neither team of testers has been inspected before. Therefore, if either team is observed to perform well, the reduction in the estimate of $p_{nondetect}$ will be $\Delta p_{nondetect}$, the same for each team. The reduction in Expression (A-5) from inspecting one of the two teams is

$R \times d \times p_{flaw,\,\mathrm{A}} \times \Delta p_{nondetect}$ if Team A is inspected and
$R \times d \times p_{flaw,\,\mathrm{B}} \times \Delta p_{nondetect}$ if Team B is inspected.

If only one team can be inspected, it should be the team with the largest potential reduction in Expression (A-5), hence the largest sum of the p_{flaw} values. This assumes, of course, that the costs of inspecting the two teams are equal.

Example B.3.4. Same Question, with Different Histories

Continue with the previous example, but suppose now that Team A was also observed on the previous day. Therefore, it is already known that Team A has the proper training and experience. Therefore, Team A begins this new day with a somewhat smaller prior estimate of $p_{nondetect}$ than does the unknown Team B. Thus, the potential for reduction of $p_{nondetect}$ is smaller for Team A than Team B. Denote the potential reductions by $\Delta p_{nondetect,\mathrm{A}}$ and $\Delta p_{nondetect,\mathrm{B}}$. Then, assuming the same cost for inspecting each team, we compare the potential reductions

$R \times d \times p_{flaw,\mathrm{A}} \times \Delta p_{nondetect,\mathrm{A}}$ if Team A is inspected, and
$R \times d \times p_{flaw,\mathrm{B}} \times \Delta p_{nondetect,\mathrm{B}}$ if Team B is inspected.

If only one of the two teams can be inspected, it should be the team corresponding to the larger potential reduction.

APPENDIX C

SAFETY SIGNIFICANCE OF ITAAC

APPENDIX C: SAFETY SIGNIFICANCE OF ITAAC

The purpose of this appendix is to support characterization of ITAAC items in terms of their safety significance as part of ITAAC prioritization. The premise of this discussion is that an item's inspection priority ought to be determined in part by the increase in risk that would be caused by degraded performance of the item.

For purposes of this appendix, it is assumed that the safety analysis together with the PRA and associated documentation establish risk significance and safety significance as those concepts are understood in the PRA context. However, in order to support ITAAC prioritization, these concepts must be extended and must be placed in a certain programmatic context.

Risk Significance and Safety Significance

To begin with, it is useful to clarify a distinction made by some between "risk significance" and "safety significance." Items that are "risk significant" are generally understood to be involved in those scenarios that contribute a probabilistically significant fraction of a risk metric such as CDF or LERF. Some use the phrase "safety significant" as if it were equivalent to "risk significant," but there is an argument for distinguishing "safety significant" from "risk significant," and interpreting "safety significant" as meaning that an item is involved in functions that play a key role in achieving plant safety (low values of CDF and LERF). An item can be both; for example, its failure can be involved in dominant accident sequences, and its low failure probability can be a factor in the absolutely low likelihood of those sequences. It can be risk significant and not safety significant; for example, a marginal, non-safety success path can fail in many accident sequences, and be so unreliable that its failure does not change CDF or LERF very much. It can be safety significant but not risk significant; examples are components in a highly reliable success path that does not contribute significantly to risk (but might if it were not reliable) (the reactor protection system (RPS) is an example of this).

One key "risk" attribute, then, is the degree to which we would care about degraded performance in an item. This is not the same as "risk significance." Some would try to use RAW for this; other candidates include Prevention Worth and Birnbaum. This issue has recently been treated at great length in the Mitigating Systems Performance Index (MSPI) program, in which simplified indices are quantified that reflect change in risk due to change in performance of safety-significant items (e.g., unreliability of key pumps). The MSPI makes essential use of a quantity that is essentially the Birnbaum importance. Though Birnbaum is defined in different ways, it is useful to think of the Birnbaum *B* of a basic event as the change in top event frequency per unit change in basic event probability. Then, for example, one can write the change in CDF associated with a given pump's unreliability as

$$\Delta CDF = \Delta UR_{pump} * B_{pump}.$$

Definitions of RAW vary, but depending on how RAW is defined, the Birnbaum of an item may be obtainable simply by multiplying its RAW by the CDF, or a minor variation of this procedure. This should be confirmed before use by checking on the RAW definition supplied with RAW results.

Since not all ITAAC bear solely and directly on the probabilities of specific PRA basic events, it is necessary to push this concept a bit to apply it to such ITAAC. Conceptually, we can write

$$\Delta CDF = (\Delta issue)\left[\frac{\partial P_{failure\ mode}}{\partial issue}\right]B_{failure\ mode}$$

in order to link an "issue" such as improper layout to an actual change in CDF. In this hypothetical example, improper layout (D*issue*) causes an increase in $P_{failure\ mode}$, the probability of some failure mode, which then propagates to a change in CDF through the Birnbaum of that failure mode. Computing the indicated derivative is actually very difficult to do in practice. However, it is important to address the issue at some level, because layout can affect CDF by affecting such things as driving head of passive systems or inadvertent co-location of components that become available to common cause environmental influences as a result of co-location.

Some ITAAC address the above situation by functionally testing portions of systems in ways that address many of the concerns reflected in the above discussion. These ITAAC serve to confirm very significant aspects of system performance, aspects that tend to be taken for granted in PRAs.

Since the Birnbaum of an item depends on what else is credited in the risk model, use of Birnbaum measures in regulatory applications needs to be conditioned on regulatory confidence in the performance of items credited in the calculation of Birnbaum measures. For certified designs whose importance measures have been provided in the process of certification, checking this presumption is beyond the scope of this report, which will correspondingly rely on reported values of importance measures.

A panel approach could be considered for assessing the safety significance of some ITAAC objectives, based on an understanding of the key success paths credited in the PRA and in the certification.

Implicit and Explicit PRA Results

Measures of risk significance or safety significance are explicitly tabulated for some basic events, as when values for "Risk Reduction Worth" are cited in the design certification documentation. However, not all SSCs appear in PRA results, and measures for such items are only implicit. For example, many plant success sequences culminate in IRWST injection to the vessel, and it is clear that all elements of this are safety significant in some way, even though some elements may not be modeled in the PRA, and even though certain flow properties are only implicit in the PRA.

Programmatic Context of Item Performance

Moreover, some ways of deriving risk insights tell us useful things about the risk model, without necessarily sufficing for decision-making. For example, a high-"RAW" component has an important role to play, because utterly failing it increases risk (this is the meaning of high RAW). But utter failure may be unlikely, or may be so immediately detectable and repairable that the practical duration of the risk increase associated with its failure is short and the practical significance therefore much more limited than the RAW measure alone might suggest. Failure of a running pump during an otherwise normal scenario is an instance of this.

On the other hand, some items' failures are not self-revealing, and may in fact be difficult to discover. Some items, especially passive components, may be difficult to fix after the construction phase. Flow properties that depend on geometry, elevations, layouts, and valve internals may likewise be difficult to establish most of the time, and difficult to repair. This is arguably more of an issue in the simplified passive designs than it was in today's operating LWRs. Many systems in today's plants provide coolant makeup using pumped flow at driving heads that have plenty of margin relative to flow resistances. But some of the simplified passive designs make use of systems in which the forces driving the flows are much less dominant compared to some of the forces resisting those flows, and this is true in the most safety-significant success paths. Success of these features is critical to plant safety. But certain flaws or problems in these systems are probably difficult to address, or perhaps even identify, beyond a certain point in construction.

In short, the safety of the advanced passive plants relies extensively on features whose high reliability derives from features that are relatively independent of support systems and plant programmatic activities (compared to today's plants), but are dependent on layout and physics. Such features cannot easily be retrofitted into the plant, but rather need to be built into the plant initially. In a sense, the advanced passive plants deliberately link high reliability, high safety significance, and need to assure during construction (as opposed to "can achieve later").

ITAAC Associated with SSCs Having Nominal Safety Significance but Less Safety Case Risk

Some SSCs are "important" in the sense that failing them completely and permanently would increase risk, but there is no real prospect of such a scenario occurring, because their failure is too easily detected and remedied for this to be the sole basis for ITAAC priority. The subject SSCs are:

- Important
- Testable during operations
- Repairable/Replaceable

An example is the pumps in the chemical and volume control system (CVS, in Westinghouse notation). The pumps in the CVS will be challenged much more frequently than elements of the passive safety systems. ITAAC on flow rate of these pumps (Table 2.3.2-4, items 8ff) are therefore less decisive; lack of flow from the CVS is easy enough to detect. Moreover, because active components are involved, problems during operation are not unexpected anyhow. This is not to say that lack of flow from the CVS is unimportant, but only that there is more of a safety net for CVS in operation than there is for the passive systems.

ITAAC Associated with Items that are Safety Significant and Will Be Difficult to Fix Later

2.2.3-4, 8 c mandates actual measurement of achieved flow rates from core makeup tanks, accumulators, and IRWST. Criteria are given for flow resistance. This test is more integrated than a component-level check and directly verifies properties of the as-built plant that are very basic and very important (safety-significant). Some causes of excessive resistance or inadequate flow might be very difficult to remedy later, and might also be difficult to diagnose later. It is useful to derive a high degree of confidence that the desired properties obtain, and that the mandated tests are appropriately conducted.

Summary

The underlying principle is that the safety significance of an item (here understood to include not only an SSC but also a prescribed property such as layout) is determined by the magnitude of the change in risk associated with its failure, degradation, or deviation. The safety significance influences priority together with the probability of item failure, degradation, or deviation, which is treated separately. In relating performance issues directly to absolute changes in risk metric, this conceptualization is equivalent to the approach taken in the new NRC Reactor Oversight Process.

For particular failure modes associated with particular components that are modeled in the PRA, the Birnbaum measure provides an indication of the conditional significance of degraded item performance. (See above for how to obtain Birnbaum from other measures.) This attribute needs to be considered in the context of influences that affect the *probability* of degraded item performance; those influences are discussed elsewhere in this report.

Some ITAAC relate to functions that are modeled in the PRA, but whose importance measures are not presented explicitly. In such a case, the safety significance is determined by the safety significance of the paths containing those functions:

{risk metric if those paths fail} - {risk metric if those paths succeed}.

Some ITAAC relate to items for which there is no explicit PRA importance information available (e.g., because the PRA did not explicitly treat the items). In such a case, the relevant safety significance inference is made based on the safety significance of the success paths in which the item appears. If failure of those paths would cause a significant risk increase, then the paths are safety significant, and so are the elements of those paths. To repeat: this does NOT mean that high safety significant items automatically receive a large allocation of inspection resources; the allocation depends also on the probability of a performance issue. This probability is treated separately. An example of this is piping that does not show up in the PRA, but is obviously necessary for a system to perform its function. The piping is significant in the sense that if it were missing, there would be a problem. Seismic qualification is therefore of some interest, along with certain other properties, but the real potential for problems in those areas needs to be assessed along with the attribute of "significance."

Implicit in the above is that items not part of a success path's function may however influence a success path by failing in a way that adversely affects SSCs having direct safety significance. Items that are co-located with safety-significant items, and can physically impinge on, or flood, or burn safety-significant components are instances of this. Such items are considered to be covered by the general principle articulated above: consider the impact of the loss of success paths, and the probability of that loss being occasioned by performance of the subject SSCs.

Some ITAAC relate to properties that are not simply related to PRA importance measures. Layout is an example. It is possible for layout to be important, but it is not customary to parameterize "LAYOUT" in a way that lends itself to assessment of a PRA importance measure. (For example, in the passive plants, elevation is important, but there may not be a PRA basic event for "tank installed 3 feet low"). For ITAAC that address layout, it may be necessary to derive insights from a panel activity, which might beneficially consider not only the significance of a deviation from prescribed layout, but also the possible causes of such a deviation and their prior probabilities.

Many ITAAC, such as the ITAAC mentioned above relating to flow resistance in key safety systems, relate to conditions that are implicitly assumed in the PRA, and whose satisfaction is key to the PRA results. Moreover, in the passive designs, many of these features are in the "now or never" category. Very high confidence is needed for those features.

APPENDIX D

EXAMPLE TRIAL

APPENDIX D: EXAMPLE TRIAL

A trial prioritization of 40 ITAAC from the AP1000 was implemented to exercise the methodology presented in the main document of this technical report. First, the attribute weights and utilities were calculated. Next, the trial effort included the classification and grouping of the 40 ITAAC. Finally, the ITAAC were rated for each of the attributes for an initial inspection period. The subsequent inspection period methodology and portfolio aspect of the methodology were not exercised. The overall objective of the trial effort was to identify lessons learned from exercising the methodology. This included the practicality of the prioritization approach (including ITAAC classifications) with respect to time constraints, rigor and whether the results correctly reflect NRC judgement of which ITAAC should be prioritized. The objective was not to determine ITAAC priority.

Eight handouts were given to the group conducting the trial including:

1. Agenda/General Objective/General Definitions
2. A 7-page “Preparation Reading”
3. Attribute Definitions
4. Procedural Steps of the Prioritization Process
5. Relative Importance Assessment and Utility Value Worksheets
6. Example Attribute Weights and Utility Values
7. “Top 40” ITAAC
8. The ITAAC Matrix

All of these handouts were helpful to the group. One suggested handout for future groups was that of an ITAAC Rating Table so that each individual could record the impact levels chosen for each ITAAC and attribute during the deliberation process. The General Objective/Definitions and the Procedural Steps handout are shown in Attachments D-1 and D-2 of this Appendix.

The group was first asked to complete a Relative Importance Assessment (RIA) to assist in the calculation of the attribute weights. A sample RIA, including the groups' choices are shown in Example D-1.

Example D-1
Relative Importance Assessment for ITAAC Attributes

Compare the following attributes with respect to the overall objective of efficiently allocating resources to appropriate ITAAC.

Use: 1 - equally
3 - weakly
5 - strongly
7 - very strongly
9 - absolutely

Use even numbers to express compromise.

Note that if the first Attribute is more important than the second Attribute, a whole number (e.g., 3, 5, etc.) is used, while if the second Attribute is more important than the first Attribute, the reciprocal is used (e.g., 1/3, 1/5, etc.).

1. Safety Significance vs. Error Propensity **5**
2. Safety Significance vs. C & T Experience **7**
3. Safety Significance vs. Other Means **3**
4. Safety Significance vs. Licensee Oversight **1**
5. Error Propensity vs. C & T Experience **4**
6. Error Propensity vs. Other Means **1/4**
7. Error Propensity vs. Licensee Oversight **1/6**
8. C & T Experience vs. Other Means **1/6**
9. C & T Experience vs. Licensee Oversight **1/7**
10. Other Means vs. Licensee Oversight **1/4**

These values were formed into a matrix and input into MATLAB to calculate the normalized eigenvector (as described in Section 4.1.2 of this report). The resulting weights were calculated to be:

Attribute	Safety	Error Propensity	C & T Experience	Other Means	Licensee Oversight
Weight	0.34	0.07	0.03	0.16	0.39

Next, the group was given a Utility Determination Worksheet. A sample worksheet, including the group's choices are shown in Example D-2.

Example D-2
Determining Utilities for Attribute Impact Levels

Compare the following impact levels for each attribute with respect to the overall objective of efficiently allocating resources to appropriate ITAAC. The constructed scale used here will be a scale of 0 to 1, where 0 is given to the impact level that best exemplifies the overall objective (such as a Low level for Error Propensity) and 1 is given to the impact level that most poorly exemplifies the overall objective (such as a High level for Error Propensity). The expert panel chooses a value between 0 and 1 to represent the Medium level. This choice should consider if the impact from decreasing the level from High to Medium should be the same as the impact from Medium to Low. If the impact on the overall objective is greater from High to Medium, the Medium utility value should be less than 0.5 (closer to the Low value of 0).

For the Safety Significance Attribute

11. High 1
12. Medium **0.5**
13. Low 0

For the Error Propensity Attribute

14. High 1
15. Medium **0.7**
16. Low 0

For the C & T Experience Attribute

17. High 1
18. Medium **0.3**
19. Low 0

For the Other Means Attribute

20. High 1
21. Medium **0.2**
22. Low 0

For the Licensee Oversight Attribute

23. High 1
24. Medium **0.3**
25. Low 0

This exercise proved to be more difficult than calculating the Attribute Weights. It was pertinent that the group had a good understanding of the prioritization concept of "value of inspection" and how the choice of the Medium utility value would affect the ranking of ITAAC. As a result of this difficulty, sensitivity studies were performed on these utility values and are included in this appendix.

After attribute weights and utilities were found, the trial group attempted to classify and assign the 40 trial ITAAC to groups. It quickly became evident that the initial classification and grouping was highly correlated to the ITAAC Matrix. The group decided that a matrix family would encompass the ITAAC classifications and groups could be formed from those families. If significant differences appeared between ITAAC within a family, subfamilies could be formed for the prioritization process. Allowing a matrix family system for classification and grouping would also allow ease in the data management process. The ITAAC classification and groups are shown in the results section.

The final exercise for the trial prioritization was that of rating the ITAAC for the first four attributes (excluding the last attribute of Licensee Oversight Attention to follow with the alternative prioritization approach proposed in Section 4.2.3 of the main report). In general, the initial baseline rating for each ITAAC was easily determined. The “no flag” rating did not prove to be as simple of a task. The idea that the change in the baseline rating to no flag rating drives the ranking of the ITAAC was difficult at first for the group to grasp. Multiple methods of explaining the no flag rating were necessary. These other interpretations are reflected in the main report. Essentially, it was decided that the change in baseline to no flag rating should almost be automatic (that is, in most cases, inspecting an ITAAC will add some value or assurance to the overall objective that no significant flaw goes undetected) unless there is a good case to keep the rating the same. The inputs to the ITAAC rating process are shown in Table D-1. Note that only 21 of the 40 trial ITAAC were completed because extra time was spent explaining and discussing the methodology concept of the value of inspection.

Table D-1
Trial ITAAC Rating Input

		Safety		Error Propensity		C & T Experience		Verify by Other Means	
ITAAC	**Matrix Assignment**	**Baseline**	**No Flag**	**Baseline**	**No Flag**	**Baseline**	**No Flag**	**Baseline**	**No Flag**
2.1.1.1	14A	L	L	L	L	L	L	L	L
2.1.1.2	14A	L	L	L	L	L	L	L	L
2.1.1.4	14D	M	M	M	L	L	L	L	L
2.1.1.5	14D	M	M	M	L	L	L	L	L
2.1.1.6i	14A	L	L	L	L	L	L	L	L
2.1.1.6ii	14E	L	L	L	L	M	L	M	L
2.1.1.7i	14F	M	M	H	L	M	L	L	L
2.1.1.7ii	14A	L	L	L	L	L	L	L	L
2.1.1.7iii	14E	M	L	H	M	M	L	M	L
2.1.1.7iv	14F	M	L	H	M	M	L	M	L
2.3.1.1	15A	L	L	L	L	L	L	L	L
2.3.1.3i	7F	M	L	M	L	L	L	M	L
2.3.1.3ii	7D	M	L	M	L	L	L	M	L
2.3.1.4	11D	M	L	M	L	M	L	M	L
2.3.1.5	11A	L	L	L	L	L	L	L	L
2.6.4.1	9A	L	L	L	L	L	L	L	L
2.6.4.2a	9D	M	L	L	L	L	L	M	L
2.6.4.2b	9D	M	L	L	L	L	L	M	L
2.6.4.2c	9D	M	L	M	L	M	L	M	L
2.6.4.3	11A	L	L	L	L	L	L	L	L
2.6.4.4	11D	M	M	L	L	L	L	L	L

Results

The inputs from Examples D-1 and D-2 and Table D-1 were coordinated in a simple database to calculate the *ΔRank* values and the Percent of Resources per Group. The following reports display the results of the prioritization using the inputs shown above and 4 sensitivity studies on the utility values, the attribute weights and the Safety Significance attribute.

Report 1 - Trial Results:

Resource Allocation by Family

Family 9D — Percent of 31%

Operational Testing of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.2c	Load sequencers initiates a closure signal	0.26
2.6.4.2a	Diesel generator starts on loss of power	0.20
2.6.4.2b	Diesel generator to supply power to selected electrical components	0.20

Family 14F — Percent of 15%

Design/Fabrication Requirements of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iv	New and spent fuel storage racks can withsatnd design basis dropped fuel assembly loads	0.23
2.1.1.7i	Calculated effective neutron multiplication factor in new and spent fuel storage racks	0.08

Family 14E — Percent of 13%

Qualification Criteria of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iii	Seismic analysis of the new and spent fuel storage racks	0.23
2.1.1.6ii	RM and FHM can withstand seismic design basis dynamic loads	0.04

Family 11D — Percent of 12%

Operational Testing of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.4	Actuate CCS pumps using controls in MCR	0.26
2.6.4.4	Controls in MCR operate to start/stop each diesel generator	0.00

Family 7D — Percent of 12%

Operational Testing of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3ii	CCS can provide cooling water to the RNS HXs and SFS HXs	0.25

Family 7F — Percent of 12%

Design/Fabrication Requirements of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3i	Heat transfer capability of the CCS heat exchangers	0.25

Family 14D — Percent of 5%

Operational Testing of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.5	Lift height of RM and FHM masts is limited	0.05
2.1.1.4	RM and FHM gripper will not open with a dummy test assembly	0.05

Family 11A — Percent of 0%

As-Built Inspection of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.3	Retrievability of ZOs parameters in MCR	0.00
2.3.1.5	Retrievability of CCS parameters in MCR	0.00

Family 14A — Percent of 0%

As-Built Inspection of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7ii	New and spent fuel storage racks located on island	0.00
2.1.1.2	FHS has the RM, FHM and new and spent fule storage racks	0.00
2.1.1.6i	RM and FHM located on nuclear island	0.00
2.1.1.1	As-Built FHS conforms with functional arrangement	0.00

Family 15A — Percent of 0%

As-Built Inspection of Complex Systems with Multiple Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.1	Functional arrangement of CCS	0.00

Family 9A — Percent of 0%

As-Built Inspection of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.1	Functional arrangement if ZOS	0.00

Report 2 - Sensitivity Study (Uniform Attribute Weights - All set to 0.2)

Resource Allocation by Family

Family 9D Percent of 23%
Operational Testing of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.2c	Load sequencers initiates a closure signal	0.34
2.6.4.2a	Diesel generator starts on loss of power	0.14
2.6.4.2b	Diesel generator to supply power to selected electrical components	0.14

Family 14F Percent of 19%
Design/Fabrication Requirements of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iv	New and spent fuel storage racks can withsatnd design basis dropped fuel assembly loads	0.26
2.1.1.7i	Calculated effective neutron multiplication factor in new and spent fuel storage racks	0.26

Family 14E Percent of 13%
Qualification Criteria of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iii	Seismic analysis of the new and spent fuel storage racks	0.26
2.1.1.6ii	RM and FHM can withstand seismic design basis dynamic loads	0.10

Family 11D Percent of 13%
Operational Testing of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.4	Actuate CCS pumps using controls in MCR	0.34
2.6.4.4	Controls in MCR operate to start/stop each diesel generator	0.00

Family 7D Percent of 10%
Operational Testing of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3ii	CCS can provide cooling water to the RNS HXs and SFS HXs	0.28

Family 7F Percent of 10%
Design/Fabrication Requirements of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3i	Heat transfer capability of the CCS heat exchangers	0.28

Family 14D Percent of 10%
Operational Testing of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.5	Lift height of RM and FHM masts is limited	0.14
2.1.1.4	RM and FHM gripper will not open with a dummy test assembly	0.14

Family 11A Percent of 0%
As-Built Inspection of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.3	Retrievability of ZOs parameters in MCR	0.00
2.3.1.5	Retrievability of CCS parameters in MCR	0.00

Family 14A Percent of 0%
As-Built Inspection of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7ii	New and spent fuel storage racks located on island	0.00
2.1.1.2	FHS has the RM, FHM and new and spent fule storage racks	0.00
2.1.1.6i	RM and FHM located on nuclear island	0.00
2.1.1.1	As-Built FHS conforms with functional arrangement	0.00

Family 15A Percent of 0%
As-Built Inspection of Complex Systems with Multiple Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.1	Functional arrangement of CCS	0.00

Family 9A Percent of 0%
As-Built Inspection of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.1	Functional arrangement if ZOS	0.00

Report 3 - Sensitivity Study - Medium Utility Values all set to 0.5

Resource Allocation by Family

Family 9D Percent of 32%
Operational Testing of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.2c	Load sequencers initiates a closure signal	0.30
2.6.4.2b	Diesel generator to supply power to selected electrical components	0.25
2.6.4.2a	Diesel generator starts on loss of power	0.25

Family 14E Percent of 16%
Qualification Criteria of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iii	Seismic analysis of the new and spent fuel storage racks	0.30
2.1.1.6ii	RM and FHM can withstand seismic design basis dynamic loads	0.10

Family 14F Percent of 15%
Design/Fabrication Requirements of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iv	New and spent fuel storage racks can withsatnd design basis dropped fuel assembly loads	0.30
2.1.1.7i	Calculated effective neutron multiplication factor in new and spent fuel storage racks	0.09

Family 11D Percent of 12%
Operational Testing of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.4	Actuate CCS pumps using controls in MCR	0.30
2.6.4.4	Controls in MCR operate to start/stop each diesel generator	0.00

Family 7D Percent of 11%
Operational Testing of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3ii	CCS can provide cooling water to the RNS HXs and SFS HXs	0.29

Family 7F Percent of 11%
Design/Fabrication Requirements of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3i	Heat transfer capability of the CCS heat exchangers	0.29

Family 14D Percent of 3%
Operational Testing of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.5	Lift height of RM and FHM masts is limited	0.04
2.1.1.4	RM and FHM gripper will not open with a dummy test assembly	0.04

Family 11A Percent of 0%
As-Built Inspection of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.3	Retrievability of ZOs parameters in MCR	0.00
2.3.1.5	Retrievability of CCS parameters in MCR	0.00

Family 14A Percent of 0%
As-Built Inspection of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7ii	New and spent fuel storage racks located on island	0.00
2.1.1.2	FHS has the RM, FHM and new and spent fule storage racks	0.00
2.1.1.6i	RM and FHM located on nuclear island	0.00
2.1.1.1	As-Built FHS conforms with functional arrangement	0.00

Family 15A Percent of 0%
As-Built Inspection of Complex Systems with Multiple Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.1	Functional arrangement of CCS	0.00

Family 9A Percent of 0%
As-Built Inspection of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.1	Functional arrangement if ZOS	0.00

Report 4 - Sensitivity Study - Medium Utility Values all set to 0.4

Resource Allocation by Family

Family 9D Percent of 31%

Operational Testing of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.2c	Load sequencers initiates a closure signal	0.24
2.6.4.2a	Diesel generator starts on loss of power	0.20
2.6.4.2b	Diesel generator to supply power to selected electrical components	0.20

Family 14F Percent of 16%

Design/Fabrication Requirements of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iv	New and spent fuel storage racks can withsatnd design basis dropped fuel assembly loads	0.25
2.1.1.7i	Calculated effective neutron multiplication factor in new and spent fuel storage racks	0.08

Family 14E Percent of 16%

Qualification Criteria of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iii	Seismic analysis of the new and spent fuel storage racks	0.25
2.1.1.6ii	RM and FHM can withstand seismic design basis dynamic loads	0.08

Family 11D Percent of 12%

Operational Testing of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.4	Actuate CCS pumps using controls in MCR	0.24
2.6.4.4	Controls in MCR operate to start/stop each diesel generator	0.00

Family 7D Percent of 11%

Operational Testing of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3ii	CCS can provide cooling water to the RNS HXs and SFS HXs	0.23

Family 7F Percent of 11%

Design/Fabrication Requirements of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3i	Heat transfer capability of the CCS heat exchangers	0.23

Family 14D Percent of 3%

Operational Testing of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.5	Lift height of RM and FHM masts is limited	0.03
2.1.1.4	RM and FHM gripper will not open with a dummy test assembly	0.03

Family 11A Percent of 0%

As-Built Inspection of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.3	Retrievability of ZOs parameters in MCR	0.00
2.3.1.5	Retrievability of CCS parameters in MCR	0.00

Family 14A Percent of 0%

As-Built Inspection of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7ii	New and spent fuel storage racks located on island	0.00
2.1.1.2	FHS has the RM, FHM and new and spent fule storage racks	0.00
2.1.1.6i	RM and FHM located on nuclear island	0.00
2.1.1.1	As-Built FHS conforms with functional arrangement	0.00

Family 15A Percent of 0%

As-Built Inspection of Complex Systems with Multiple Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.1	Functional arrangement of CCS	0.00

Family 9A Percent of 0%

As-Built Inspection of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.1	Functional arrangement if ZOS	0.00

Report 5 - Sensitivity Study - Safety Significance Excluded

Resource Allocation by Family

Family 9D Percent of 21%

Operational Testing of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.2c	Load sequencers initiates a closure signal	0.09
2.6.4.2a	Diesel generator starts on loss of power	0.03
2.6.4.2b	Diesel generator to supply power to selected electrical components	0.03

Family 14F Percent of 19%

Design/Fabrication Requirements of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7i	Calculated effective neutron multiplication factor in new and spent fuel storage racks	0.08
2.1.1.7iv	New and spent fuel storage racks can withsatnd design basis dropped fuel assembly loads	0.06

Family 14E Percent of 14%

Qualification Criteria of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7iii	Seismic analysis of the new and spent fuel storage racks	0.06
2.1.1.6ii	RM and FHM can withstand seismic design basis dynamic loads	0.04

Family 14D Percent of 13%

Operational Testing of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.5	Lift height of RM and FHM masts is limited	0.05
2.1.1.4	RM and FHM gripper will not open with a dummy test assembly	0.05

Family 11D Percent of 12%

Operational Testing of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.4	Actuate CCS pumps using controls in MCR	0.09
2.6.4.4	Controls in MCR operate to start/stop each diesel generator	0.00

Family 7D Percent of 11%

Operational Testing of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3ii	CCS can provide cooling water to the RNS HXs and SFS HXs	0.08

Family 7F Percent of 11%

Design/Fabrication Requirements of Mechanical Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.3i	Heat transfer capability of the CCS heat exchangers	0.08

Family 11A Percent of 0%

As-Built Inspection of I&C Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.3.1.5	Retrievability of CCS parameters in MCR	0.00
2.6.4.3	Retrievability of ZOs parameters in MCR	0.00

Family 14A Percent of 0%

As-Built Inspection of Equipment Handling and Fuel Racks

ITAAC	ITAAC Description	Delta Rank
2.1.1.7ii	New and spent fuel storage racks located on island	0.00
2.1.1.1	As-Built FHS conforms with functional arrangement	0.00
2.1.1.2	FHS has the RM, FHM and new and spent fule storage racks	0.00
2.1.1.6i	RM and FHM located on nuclear island	0.00

Family 15A Percent of 0%

As-Built Inspection of Complex Systems with Multiple Components

ITAAC	ITAAC Description	Delta Rank
2.3.1.1	Functional arrangement of CCS	0.00

Family 9A Percent of 0%

As-Built Inspection of Electrical Components and Systems

ITAAC	ITAAC Description	Delta Rank
2.6.4.1	Functional arrangement if ZOS	0.00

Discussion of Results

Report 1, shown previously, is the base case and displays the Trial Results. This report has assigned nearly a third of the resources to Family 9D, with 5 families following above 10% and 1 family at 5%. The rest of the families were assigned no resources. The latter is a direct result of the ITAAC ratings chosen during the trial. Therefore, it may be necessary for a facilitator of the prioritization to make this situation known and reinforce the impact of having no delta between the baseline and no flag rating for any attribute. Inspection Groups receiving no resource allocation would be a concern if not for the Portfolio Approach/Coverage Check part of the methodology.

Even with these results, two steps remain in the initial prioritization. First, define the efficient collections of ITAAC. That is, can all 3 ITAAC in Family 9D be inspected with 31% of the resources? If not, a collection of these ITAAC could be chosen that would maximize the sum of the ΔRank values for the group, but also efficiently uses the resources. Second, the Portfolio Approach should be used prior to actually implementing the inspection of ITAAC. The first question is: Is at least one ITAAC from every group being inspected? In this case, 4 groups have 0% resources, so the answer is No. Then, following the approach, the NRC could choose to move some resources from another group to these families to satisfy the portfolio criteria. Most likely, when all ITAAC are prioritized, not many groups will have 0% resources allocated. Some, though, may have so few resources allocated that this will not be enough to fully inspect one ITAAC in that group. In this case, it will also be necessary to follow the guidelines of the Portfolio Approach and redirect some resources from another group.

The sensitivity analyses of the attribute utility values indicate the methodology to be moderately insensitive to a change in all Medium utility values to 0.5 or 0.4. The change to a 0.5 value increases the percent of resources allocated to Family 14E by a small percentage, but does not affect the rank-ordering of the ITAAC within any of the family groupings. The change to a 0.4 value also increases the percent of resources allocated for Family 14E, as well as a small increase to the percentage for Family14F.

A sensitivity analysis performed on the attribute weights, though, proves the prioritization approach to be more sensitive. While the rank-ordering of ITAAC within a family remains the same as the base case, the percent of resources for each family flattens such that there is less of a differential between families. This fact seems intuitive, as a flattening of the attribute weights (i.e., changing them all to 0.2) should also flatten the results.

Finally, the sensitivity studies performed by removing the safety significance attribute completely also tended to flatten the percent of resources calculations for all families. The most noticeable change in this sensitivity analysis is the increase in resources allocation to Family 14D. This large increase is an indirect result of the small decrease in many other families' resource allocation as a result of the loss of any boost those families had received from the safety rating. Again, no change in rank-ordering of ITAAC within a family is shown, though the differential between these ITAAC did decrease (most notably, the ITAAC in Family 14F).

Attachment D-1: Objective and Definitions Handout for Trial Prioritization

Objective:

The objective of this trial effort is to exercise the methodology presented in the technical report, using the “Top 40” ITAAC, for the prioritization/allocation of NRC resources to inspect ITAAC.

First, this trial effort will include the classification and grouping of the 40 ITAAC. Second, the ITAAC will be prioritized such that the more important ITAAC are ranked higher and are therefore, inspected before ITAAC of lesser importance. Finally, the approach includes a portfolio perspective or “coverage” for all ITAAC.

The overall theme of the methodology is that of comparing the value of inspecting one ITAAC versus another. Inspection of some ITAAC will give more value in assuring that the licensee has detected any construction flaws. The methodology is set up to select those ITAAC which contribute more to obtaining this assurance.

Finally, another objective of the trial effort is to identify lessons learned from exercising the methodology. This most likely includes the practicality of the prioritization approach (including ITAAC classifications) with respect to time constraints, rigor and whether the results correctly reflect NRC judgement of which ITAAC should be prioritized.

Handouts:

1. A 7-page “Weekend Preparation Reading” (Included -Should be read prior to meeting)
2. Attribute Definitions (Included)
3. Procedural Steps of the Prioritization Process (Included)
4. Relative Importance Assessment Worksheets
5. Example Attribute Weights and Utility Values
6. “Top 40” ITAAC
7. The ITAAC Matrix

Definitions:

ITAAC slice - a portion of an ITAAC that involves one process or procedure (e.g., testing, qualification, fabrication, etc.) and one type of component

Same Activity - an activity that when performance is observed for the activity with one component, this will give an idea of what is done for the other components.

One-Procedure vs. Many-Procedure vs. Stand Alone ITAAC - A one-procedure ITAAC will generally only have one “same activity,” such as a stroke test of valves. A Many-Procedure ITAAC may contain more than one “same activity,” such as an As-Built ITAAC. These ITAAC may need to be decomposed into “slices” so that the slices of different ITAAC can be grouped together accordingly.

Inspection Group - A group of ITAAC or ITAAC slices that are all similar (i.e., they have the "same activity").

Attribute - characteristics of an ITAAC/slice that make it more or less important (or desirable) to inspect, relative to other ITAAC/slices based on the overall objective of optimizing resources to ensure that a significant flaw does not go undetected (i.e., all ITAAC have been satisfied).

Attribute Impact Levels - A plain English rating (e.g., high, medium, low) that is assigned to an ITAAC for each attribute.

Attribute Utility - A numerical value representing an attribute's impact level. Different attributes will have different utilities to represent the impact levels of high, medium and low.

Baseline Rating - The impact levels and corresponding utility assigned to an ITAAC for a specific attribute *given the present conditions and state of knowledge*.

No Flag Rating -The impact levels and corresponding utility assigned to an ITAAC for a specific attribute *as if prior knowledge (inspection experience) already exists that the ITAAC was inspected by the NRC and nothing was found to be wrong (e.g., there were no "flags" raised for this ITAAC)*.

ΔRank - The metric that NRC will use to decide which ITAAC take priority over others. The greater the Δ*Rank* value, the more important it is to inspect that ITAAC.

Portfolio Approach - A coverage aspect to the prioritization approach that assures that a diverse set of ITAAC have been inspected such that it represents the entire ITAAC universe.

Attachment D-2: Procedural Steps Handout for Trial Prioritization

Step-by-Step Procedure for Initial ITAAC Prioritization Process

26. Calculate Attribute Weights - Use Relative Importance Assessments (RIA) and the Analytical Hierarchy Process (AHP) to calculate weights for the attributes. An alternative approach is acceptable given that the sum of all the weights chosen add to 1.

27. Calculate the Attribute Utilities - Identify the impact levels (e.g. high, medium, low) for each attribute (some attributes may need more than 3 levels). Determine the utility values that correspond to these impact levels for each attribute. The constructed scale used here will be a scale of 0 to 1, where 0 is given to the impact level that best exemplifies the overall objective (such as a Low level for Error Propensity) and 1 is given to the impact level that worst exemplifies the overall objective (such as a High level for Error Propensity). The expert panel chooses a value between 0 and 1 to represent the Medium level.

28. Classify and Group ITAAC - The classification and grouping of ITAAC may be an iterative process. Is the ITAAC a one-procedure, many-procedure or stand-alone ITAAC? Many-procedure ITAAC should be sliced. The one-procedure ITAAC and the slices of the many-procedure ITAAC should be grouped together by "same activity." If one of these cannot be placed in a group, it may need to be considered a stand-alone ITAAC/slice. Stand-alone ITAAC should be considered last and grouped, if possible, by similarity. The methodology recommends that all stand-alone ITAAC that cannot be placed in a group be inspected.

29. Rate ITAAC for Each Attribute *(with the exception of the Licensee Oversight Attention Attribute*)* - Assign an impact level for each ITAAC for each attribute. These assignments should be completed twice. The first assignment considers the ITAAC in a baseline situation or given the current conditions. The second assignment considers the ITAAC in a hypothetical "no flag" situation in which the ITAAC was assumed to be previously inspected and no flags were raised at that time.

30. Computation of *ΔRank* - Most of this step could occur using a database or other data management tool. Find the utility values that correspond to the impact levels assigned to each ITAAC for each attribute (calculated in step 2). Calculate a Δu, the difference between the baseline utility value and the no flag utility value, for each attribute for each ITAAC. A *ΔRank* value can be calculated by taking the sum-product of these Δu values and the attribute weights (calculated in step 1) for each ITAAC.

31. Calculation of Percent of Resources for Each Inspection Group - Most of this step could occur using a database or other data management tool. By summing the *ΔRank* values for all ITAAC in a group and comparing this value to the sum of the *ΔRank* values for all ITAAC in the universe, a percent of resources that could be assigned to that group can be estimated.

32. Using Percent of Resources Estimate, Define Efficient ITAAC Collections - Given the resources available to inspect a particular group, a collection of ITAAC should be chosen within that group that are most efficient to inspect and maximize the sum of the *ΔRank* values for those ITAAC.

33. Coverage Check/Portfolio Approach - After defining efficient collections for each group of ITAAC, ensure that the entire portfolio of ITAAC to be inspected is both diverse and represents the ITAAC Universe. Questions that could be posed:
    a. Is at least one ITAAC in each Inspection Group being inspected?
    b. If an ITAAC has been inspected and a “flag” has been found: Even if the flaw is fixed (through re-training or re-fabrication), has at least one other ITAAC in that Inspection Group also been inspected and no flaws found?
    c. For all ITAAC that have been sliced, do the subsets (of each Inspection Group) to be inspected at least include one slice of each ITAAC in the Universe? That is, are all of these “slice-able” ITAAC being checked at least in part?

34. Iterate Process if the ITAAC Portfolio is Not Sufficient - If the answer is No to any of these questions, the NRC has 3 options:
    (1) Increase the number of hours allotted to inspect the ITAAC Universe,
    (2) Adjust the percentage of hours allotted to each Inspection Group (Step 6), or
    (3) Adjust the efficient ITAAC combinations that were chosen for each group (Step 7).

** Note that the methodology assumes that the impact levels chosen for the Licensee Oversight Attribute during this initial inspection will be the same for all ITAAC. The utility values and calculated Δu value for this attribute will therefore be the same for every ITAAC. This acts as a constant in the ΔRank calculation and will have no effect on the outcome of the initial prioritization process. Therefore, the methodology recommends that this attribute not be considered in the ΔRank* calculation until subsequent inspection periods.