A Research Proposal

FUNDAMENTALS OF THE BIAS CORRECTION PROBLEM

2311105165

In Response to RFP RS-RES-81-223

to

U. S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

Battelle
Pacific Northwest Laboratories

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SCOPE: RECOMMEND CALIBRATION STANDARDS, CALIBRATION FREQUENCIES, AND METHODS FOR MONITORING AND CORRECTING BIAS FOR EACH OF THE MAJOR MEASUREMENT METHODS USED BY SPECIAL NUCLEAR MATERIAL LICENSEES

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST DIVISION
P. O. Box 999
Richland, Washington 99352

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BATTELLE-NORTHWEST
RICHLAND, WASHINGTON

December 10, 1981

INTRODUCTION

Pacific Northwest Division of Battelle Memorial Institute (Battelle-Northwest) proposes to evaluate and analyze the current practices utilized for calibrating and/or determining biases for the principal nuclear material measurement systems in use by licensees. The evaluation and analysis will provide U. S. Nuclear Regulatory Commission with guidance on applying bias corrections to measurement results or inventory differences as required by 10 CFR 70.57 and will enable U. S. Nuclear Regulatory Commission to determine (or estimate) the costs associated with each of the bias correction procedures.

Certain special nuclear material licensees are required to monitor and control measurement biases as part of their measurement control programs. This includes the generation of current data for determining bias corrections, their uncertainties (variances), and the application of bias corrections using appropriate statistical procedures.

The current resultions specify levels that the limit of error of inventory differences (LEID) should not exceed (10 CFR 70.51). Also, it is required that shipper/receiver differences that are statistically significant at the 95 percent confidence level be reconciled. In brief, the effects of bias in all special nuclear material (SNM) accounting measurements must be known and taken into account when calculating limits of error of inventory differences and shipper/receiver differences.

Determination of the amount of SNM in a batch, lot, or container often involves several mesurement systems and has several major sources of bias. For example, the measured amount of ^{235}U in a can of U_3O_8 will include a weight, uranium assay, and an isotopic assay. In addition, a sampling process is involved. Each of these is subject to one or more biases whose magnitude can be determined by a calibration procedure from which bias correction factors are obtained. The purpose of the calibration is to eliminate the bias and control the residual uncertainty resulting from bias corrections to some acceptable level.

The efficacy of the various bias correction alternatives depends on several considerations, including the nature and number of physical standards and the frequency of calibration. Of great importance is the decision as to which data bias corrections are to be applied. Several recent publications address these issues, and include:

Brouns, R. J., J. A. Merrill, and F. P. Roberts. 1980. Methods of Determining and Controlling Bias in Nuclear Material Accounting, NUREG/CR-1284, PNL-3264.

Brouns, R. J., J. A. Merrill, and K. B. Stewart. 1978. A Study of Alternatives for Applying Bias Corrections to Nuclear Materials Accounting Data, PNL-2675 (Draft).

Lowe, V. W. 1981. A Statistical Analysis of the Bias Correction Problem: Final Report on the Use of Mean-Squared Error, UCID-18968 (Draft).

Eisenhart, C. 1969. "Realistic Evaluations of Precision and Accuracy of Instrument Calibrations," In: Precision Measurement and Calibration, NBS SP-300, 1:27-47, H. H. Ku (Editor).

PROPOSED TECHNICAL APPROACH

The objective of the work described in this proposal is to evaluate and analyze procedures currently in use by special nuclear material licensees for calibrating measurement systems in order to provide bases for assessing various bias correction alternatives and to enable U. S. Nuclear Regulatory Commission to compare their relative costs. The work wil consist of accumulating data and procedural details on the major measurement systems and from this to determine the preferred procedures for calibration, bias control monitoring, and bias estimation and correction. The effects of the alternative bias correction procedures on the variances of shipper/receiver differences and inventory differences will be evaluated. The quantitative effects of de minimus values as specified in 10 CFR 70 on these variances will also be evaluated. The results of the work will be presented in a formal technical report and in an interim report. Additional details on the tasks and the technical approach are given below.

TASK 1. EVALUATION AND ANALYSIS OF CURRENT PRACTICES

The measurement systems selected by U. S. Nuclear Regulatory Commission will be investigated to develop a detailed description of each procedure, including the instrumentation and apparatus, with emphasis on:

- identifying potential sources of bias,
- ranking sources of bias by likelihood of occurrence and expected magnitude, and
- determining the measures used for protecting against bias.

The measurement systems to be investigated can include bulk weighing, volume, nondestructive and laboratory assay methods for uranium and plutonium, and isotopic analysis.

The calibration procedures and bias monitoring methods in common use for each measurement system will be described and analyzed to assess their effectiveness in eliminating bias and minimizing the variance associated with bias corrections (or with bias if corrections are not made).

Information and data needed to complete Task 1 will be obtained from the literature, from measurement laboratories, including U. S. Department of Energy laboratories, and from licensees, where possible.

A formal report describing the results and conclusions of Task 1 will be prepared.

TASK 2. SELECTION OF BIAS CONTROL ALTERNATIVES

Using the data and information obtained in Task 1 and the literature on the bias correction problem, requirements will be derived for acceptable treatment of bias for each of the measurement systems. This will result in recommended procedures, including the technical bases, for determining bias, controlling bias, and applying bias corrections to nuclear material accounting data. The factors involved in determining bias are:

- kinds and number of physical standards,
- traceability of physical standards,
- control of measurement methods used for calibrations, and data analysis.

The factors involved in monitoring bias include:

- frequencies of measurements and physical standards and/or calibrations;
- control of the physical standards used for monitoring bias, including required restandardization or replacement schedules; and
- establishing control limits.

Alternative procedures for applying bias corrections will be evaluated for each of the measurement systems. An example using a high enriched uranium fuel plant as a reference facility will be developed to show how the variance of inventory difference for a typical material balance is influenced by the alternative procedures.

Close interactions with U. S. Nuclear Regulatory Commission will be maintained by meetings with the sponsoring office as well as the regional offices.

The results of this task will be presented at meetings with the sponsoring office and regional offices and will be reported in an interim report.

TASK 3. COST ESTIMATES FOR BIAS CORRECTION ALTERNATIVES

Each of the alternatives, which are to be selected by U. S. Nuclear Regulatory Commission, will be analyzed to determine the incremental costs over some base case. The cost elements will include:

- additional reference standards,
- reference standards development,
- increased calibrations frequencies, and
- calculations and data analysis.

The cost data will be derived from contacts with other laboratories performing measurements on nuclear materials and from our own experience and knowledge. The results will enable U. S. Nuclear Regulatory Commission to make direct cost comparisons between any of the alternatives.

The results and conclusions of Task 3 will be presented in an interim report.

PLANNED REPORTING

Battelle-Northwest plans to prepare the reports requested in the Request for Proposal RS-RES-81-223 (RFP).

The technical reports listed below would be documented, produced, and disseminated in accordance with U. S. Nuclear Regulatory Commission's Manual, Chapter 3202, which will be incorporated into the resultant contract by reference.

1. Monthly letter progress report, one (1) copy to the Contracting Officer's Project Officer (PO), and one copy to the Contracting Officer, to be due by the 10th day of each month and include as a minimum:

   a. A technical report of progress describing findings to date, problems incurred and solutions proposed, and plans for the ensuring month.

   b. A report of costs incurred each month and cumulative costs at the end of each month as follows:

      - Direct Labor Costs
      - Rate of Overhead
      - Overhead Labor Costs
      - Rate of General and Administrative Expense and Amount
      - Fee
      - Travel
      - Other Direct Costs
      - Reproduction Costs
      - Percent that Costs Expended Bear to Authorized Costs.

2. Battelle-Northwest will furnish up to six (6) copies of a draft Task 1 report within three (3) months after the start of the contract. U. S. Nuclear Regulatory Commission will review the draft and furnish comments. Battelle-Northwest will incorporate the comments into the Final Report which will be resubmitted with thirty (30) days after receiving the comments.

3. Battelle-Northwest will prepare an interim technical report concerning Task 2 and Task 3 prior to the end of the project.

PLANNED MEETINGS

It is planned that Battelle-Northwest will participate in meetings to be scheduled with U. S. Nuclear Regulatory Commission's Project Officer and other U. S. Nuclear Regulatory Commission personnel to review the progress and results of the project. The following meetings affecting personnel time and travel are planned.

1. Three project review meetings with U. S. Nuclear Regulatory Commission staff at U. S. Nuclear Regulatory Commission offices at Nicholson Lane, Rockville, Maryland. This will be a three-day meeting.

2. Three project review meetings with U. S. Nuclear Regulatory Commission staff at Battelle-Northwest.

3. Two meetings at U. S. Nuclear Regulatory Commission's regional offices, one at Atlanta and one at King Of Prussia, Pennsylvania, to discuss the alternatives with U. S. Nuclear Regulatory Commission staff. These will be three-day meetings.

4. One five-day meeting at a licensee site to discuss the alternative with U. S. Nuclear Regulatory Commission and licensee staffs.

SUPPORT PERSONNEL AND FACILITIES

All computer programming efforts required under this proposed project shall conform to "FORTRAN 78", the American National Standards Institute (ANSI) Standard X3.9-1978. Contract deliverables shall include documentation of all programming according to Field Inspection Procedures (FIPS) 38, February 12, 1978, and ANSI Standard N-413. Waiver to these requirements can be obtained through the Contracting Officer with the concurrence of the Division of Automatic Data Processing Standards (ADPS), U. S. Nuclear Regulatory Commission.

Any statistical packages required in the analyses will be reviewed with U. S. Nuclear Regulatory Commission's Project Manager prior to being used.

At U. S. Nuclear Regulatory Commission's option, any computing required shall be done on designated Government-owned computers.

PROPOSED SCHEDULE

It is planned that the proposed work would be performed in Fiscal Year 1982 within a time interval of eight months after authorization to perform the work has been received.

The draft Task 1 report will be submitted to U. S. Nuclear Regulatory Commission before the end of the third month and the final version will be completed 30 days after receiving U. S. Nuclear Regulatory Commission's comments. A draft interim report for Task 2 and Task 3 will be issued before the end of the 12th month and the final version before the end of the 13th month.

The estimated time expenditures are:

	Man-Weeks
Task 1	18
Task 2	17
Task 3	5
Total	40

RELATED PAST EXPERIENCE AND CAPABILITIES

Battelle-Northwest has extensive and broadly-based experience in nuclear materials safeguards research and development. Staff members who will be assigned to this project will bring together the expertise necessary to fulfill the commitments. Mr. F. P. Roberts and Dr. R. J. Brouns have been responsible for similar projects related to nuclear material control and accountability and are widely recognized for their contributions in the area. Dr. R. R. Kinnison is an expert in the field of applied and theoretical statistics with more than 20 years experience, much of it related to nuclear material safeguards. He is an expert on in-plant tank calibrations. Currently, he is contributing to a U. S. Nuclear Regulatory Commission project associated with a reform amendment development and is a major contributor to the revision of the book Statistical Methods in Nuclear Material Control. Messrs. K. R. Byers and J. E. Fager, and Ms. J. L. Pindak are chemists with more than 25 years combined experience in the nuclear field. Mr. Byers worked 10 years in the chemical processing operation with contributions in plutonium reference standards development. Mr. Fager has more than 12 years experience in nuclear measurement instrumentation and is an expert in applications of nondestructive assay (NDA) to nuclear materials inventory verification. Ms. Pindak is involved in safeguard-related tasks in process and measurements for high enriched fuel fabrication and scrap recovery operations.

The personnel resumes in Appendix A and the list of titles and abstracts of recent safeguard reports and publications in Appendix B show the background and experience of the key personnel and supporting staff for this project. In addition, recent related and current studies for U. S. Nuclear Regulatory Commission are as follows.

- Title: Example System Development for the MC&A Upgrade Rule

  FIN No. B2134, Office Standards of Development/John Montgomery and John Telford

  To help assure that the proposed MC&A Upgrade Rule is effectively implemented, Battelle-Northwest will develop two example MC&A systems. The example systems will demonstrate difference ways to implement the MC&A Upgrade Rule. The examples will be specified in enough technical detail so as to be an aid to the licensee during rule implementation. The example systems will cover different generic process operations of the existing licensees and will treat different major MC&A systems; e.g., computerized and manual accounting record systems.

- Title: Value Impact Analyses of Safeguards Regulatory Improvements

  FIN No. B2209, Nuclear Materials Management and Safeguards System/H. Smith

  It is the objective of this effort to provide U. S. Nuclear Regulatory Commission with an assessment of the "values and impacts" of proposed regulatory improvements with respect to safeguards. The assessments will provide the basis for formulating a value-impact assessment and making recommendations for regulatory changes. The comprehensive assessments resulting from this effort will also structure comparative information on the alternatives available to U. S. Nuclear Regulatory Commission so that informed and justified regulatory decisions can be achieved.

- Title: Inspection for Material Accounting

  TD0705/I&E/ W. D. Altman and E. W. Brach

  The purpose of this project is to provide U. S. Nuclear Regulatory Commission with an objective and technically uniform basis for applying material control and accounting inspection activities. This was accomplished by:

  - development of inspection strategies,
  - preparation of restructured inspection program,
  - preparation of detailed inspection modules,
  - pilot program for testing selected modules, and
  - evaluation of effectiveness of restructured inspection modules.

- Title: Resolution of Shipper/Receiver Differences

  U. S. Nuclear Regulatory Commission Contract No. Standards/J. Branscome01-81-012-02, RES/Division of Radiation

  The purpose of this project is to develop and evaluate statistical analysis methods for the resolution of shipper/receiver differences (SRD). The methods will provide more specific guidance to U. S. Nuclear Regulatory Commission and licensees than now provided in the Code of Federal Regulations and existing regulatory guides on effective ways to evaluate SRDs and determine their causes. Such guidance is expected to contribute substantially to U. S. Nuclear Regulatory Commission's program of developing methods for improving nuclear material control and accounting.

- Title: Technical Assistance in Development of Acceptance Criteria

  FIN No. B-2472, Nuclear Materials Management and Safeguards System/B. Mendelsohn

  This work is being conducted to develop and test a site-specific set of material loss alarm resolution procedures for a segment of an existing nuclear material processing plant. The primary aim of the alarm resolution will be to provide evidence as conclusive as possible regarding the validity and cause of a detection alarm. The primary aim of this demonstration is to provide material guidance that will benefit the licensee in developing a response system.

- Title: Statistical Methods for Nuclear Material Accountability

  TD1487, FIN No. B2420, RES/DFO/SB/J. Branscome

  The standard reference for the application of mathematical statistics methods to nuclear material control and accounting data analysis is document TID-26298, Statistical Methods in Nuclear Material Control, by J. L. Jaech. This reference will be updated, revised, and expanded to include some additional statistical topics. In addition, a training manual is needed to aid in the instruction of personnel for statistical analysis and interpretation of material control and accounting (MC&A) data at licensed facilities. This project will produce a collection of statistical methods acceptable for use in nuclear MC&A in a single consistent, understandable format. The methods will provide the guidance necessary for meeting the current regulatory requirments of 10 CFR 70.51 and 70.57.

- Title: Development of Guidance for Material Control and Accounting System Design

TD1413, FIN No. B2222, Nuclear Materials Management and Safeguards System/M. Miller

The objective of the project is to provide U. S. Nuclear Regulatory Commission with guidance and assistance in the following areas pertaining to Material Control and Accounting Reform Amendments:

- item control test procedure,
- detailed response to alarms,
- detection time guidance,
- analytical methods of plantwide false alarm control,
- user assessment methodology to assess licensees,
- method of false alarm control,
- assessment method to predict rate of unresolved false alarms.

- Title: Development of Material Control and Accounting Methodology

B20140, OSD/L. C. Solem

The purpose of this project was to develop concepts, procedures, and criteria that will form the basis for new regulations, regulatory guides, and licensing or enforcement practices that will strengthen nuclear material control and accounting in the nuclear industry. Specific studies or tasks are planned and carried out, as requested by the Safeguards Standards Branch, and the results of the studie are presented in Topical (NUREG) reports and, as appropriate, draft regulatory guides or amendments to the regulations.

- Title: Evaluation of the Process Monitoring Technique

TD1187, FIN No. B2213, NMSS/B. T. Mendelsohn

The study was conducted for U. S. Nuclear Regulatory Commission to estimate the effectiveness of using process monitoring data to enhance special nuclear material accounting in nuclear facilities. Two licensed fuel fabrication facilities with internal scrap recovery processes were examined. The loss detection sensitivity, timeliness, and localization capabilities of the process monitoring technique were evaluated for single and multiple (trickle) losses. The impact of records manipulation, mass, and isotopic substitution, and collusion between two insiders as methods for concealing diversion werw also studied.

TECHNICAL STAFF UTILIZATION

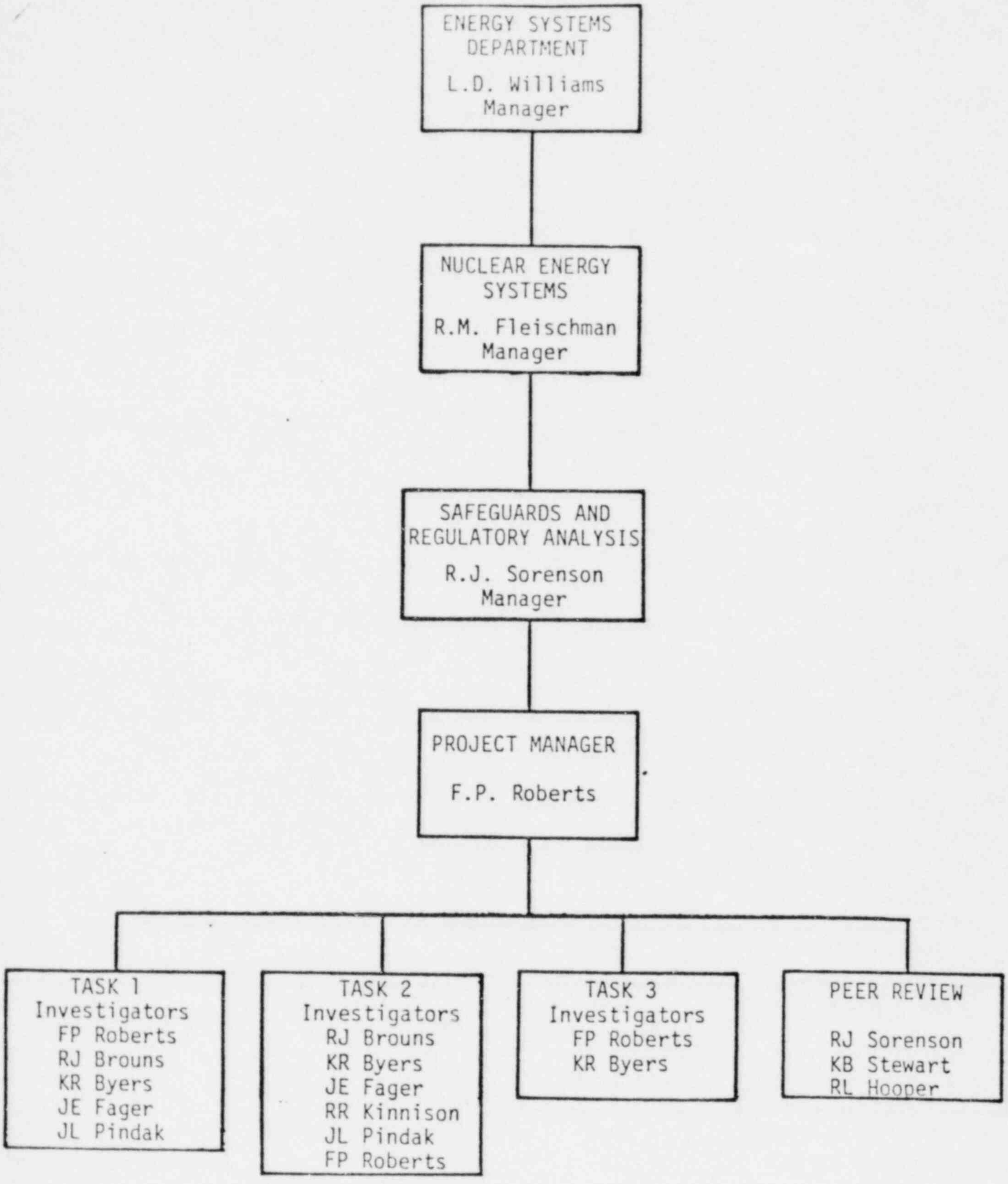
[redacted]

The full organizational structure and organization positions of the key personnel for this project are shown in the Figure. The key personnel to be assigned to this project have adequate time available to carry out the work during the period of performance of the contract. Their proposed commitments to the project are:

Hours of Work

Task 1 Task 2 Task 3

[redacted]



PROJECT MANAGEMENT

Battelle
Pacific Northwest Laboratories

Director
Douglas E. Olesen*

- **Research** — A. Judd Haverfield,* Director
  - Chemical Technology — Richard E. Nightingale, Mgr.; Jack L. McElroy, Associate Mgr.
  - Energy Systems — L. Donald Williams, Mgr.; Duane E. Deonigi, Associate Mgr.
  - Engineering Physics — Anthony M. Sutey, Mgr.
  - Materials — Court R. Hann, Mgr.
- **Research** — William R. Wiley,* Director
  - Atmospheric Sciences — Charles E. Elderkin, Mgr.; Jeremy M. Hales, Associate Mgr.
  - Biology — Harvey Drucker, Mgr.; Murlin F. Gillis, James F. Park, Associate Mgrs.
  - Ecological Sciences — Burton E. Vaughan, Mgr.; William L. Templeton, Associate Mgr.
  - Physical Sciences — Julian M. Nielsen, Mgr.; Richard W. Perkins, Associate Mgr.
  - Radiological Sciences — William A. Glass, Mgr.
  - Water & Land Resources — Dennis B. Cearlock, Mgr.; Gaynor W. Dawson, David W. Dragnich, Associate Mgrs.
- **Programs** — Robert P. Marshall,* Director
  - Environment, Health & Safety Research — William J. Bair, Mgr.; Sidney Marks, Associate Mgr.
  - Nuclear Waste Technology — Thomas D. Chikalla, Mgr.
  - National Security Technology — James M. Davidson, Mgr.
  - Strategy and Planning
    - Energy Technology — Ronald C. Liikala, Mgr.
    - Nuclear Technology — Allison M. Platt, Mgr.
    - Office of Planning — Loren C. Schmid, Mgr.
  - Thermochemical Conversion of Biomass — Gary F. Schiefelbein, Mgr.
- **Projects** — William D. Richmond,* Director
  - Major Project Development — James E. Minor, Mgr.
  - Project Management — John B. Schuette, Mgr.
  - Management Information & Support — George H. Stone, Mgr.
  - Facilities Planning & Engineering — Jack L. Boyd, Mgr.
  - Craft & Operation Services — Dan L. Weaver, Mgr.
- **Laboratory Support** — James J. Fuquay,* Director
  - Finance — Allan F. Johnston,* Controller & Director
  - Human Resources — Charles L. Simpson,* Director
  - Legal & Contracts — Sam J. Farmer,* General Counsel & Director

*Directors' Council
December 1981

BATTELLE-NORTHWEST PROJECT MANAGEMENT SYSTEM

Project management assignments are made by the Unit Manager with the concurrence of the Section Manager. The Project Manager is given the authority to direct and monitor the technical work within the terms and financial guidelines of the contract. This authorizes the Project Manager to delegate work to the persons assigned to the project and to issue interdepartmental work authorizations (work orders) for assistance from selected personnel in other departments. The Project Manager monitors the work of others through monthly progress and financial reports and personal conferences. Where additional assistance requiring greater management authority is needed, the Project Manager is supported by the Unit and Section Managers. Prior to review and approval by the Section and Department Managers of the Project Plan, as discussed below, insures assistance and cooperation at management levels sufficient to obtain necessary resources and resolve priority conflicts.

When a project is initiated, the Project Manager prepares a Project Plan for review and approval by the Section and Department Managers. The plan specifies a work breakdown structure, task and personnel schedules, and task and cost control plan. For study projects, the main quality control measures are usually: 1) peer reviews of the methodology, data, and reports; 2) management reviews of all reports and other products for the sponsor; and 3) professional editing and publication services and control.

APPENDIX A

PROPOSED PROJECT PARTICIPANTS

resumes deleted

APPENDIX B

TITLES AND ABSTRACTS OF RECENT SAFEGUARDS RESEARCH AND DEVELOPMENT PUBLICATIONS AND REPORTS

TITLES AND ABSTRACTS OF RECENT SAFEGUARDS R&D PUBLICATIONS AND REPORTS

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON 99352

C.L. Timmerman, Isotopic Safeguards Techniques, International Safeguards Project Office, ISPO-25, PNL-SA-6761, June 1978. A generalized discussion of the application, demonstration and implementation of isotopic safeguards techniques to plutonium input measurements for chemical reprocessing facilities.

C.L. Timmerman and K.B. Stewart, Isotopic Safeguards Statistics, International Safeguards Project Office, ISPO-26, PNL-SA-6595, June 1978. The methods and results of statistical analysis of isotopic data using isotopic safeguards techniques are illustrated using example data from the Yankee Rowe reactor. The illustration provides greater insight into how statistics can be used to analyze and extract meaningful results from isotopic data. The statistical methods used are the paired comparison and regression analyses. A paired comparison results when a sample from a batch is analyzed by two different laboratories. Paired comparison techniques can be used with regression analysis to detect and identify outlier batches. The second analysis tool, linear regression, involves comparing various regression approaches. These approaches use two basic types of models: the intercept model ($y = \alpha + \beta x$) and the initial point model [$y - y_0 = \beta(x - x_0)$]. The intercept model fits strictly the exposure or burnup values of isotopic functions while the initial point model utilizes the exposure values plus the initial or fabricator's data values in the regression analysis. Two fitting methods are applied to each of these models: (1) the usual least-squares fitting approach where x is measured without error, and (2) Deming's approach which uses the variance estimates obtained from the paired comparison results and considers x and y are both measured with error. Some statistical results using the Yankee Rowe data are presented. Review of these results indicates the attractiveness of Deming's regression model over the usual approach by simple comparison of the given regression variances with the random variance from the paired comparison results.

B.A. Napier and C.L. Timmerman, Developing Isotopic Functions, International Safeguards Project Office, ISPO-27, PNL-SA-6594, June 1978. The operation of nuclear reactors results in burning of uranium isotopes and production of plutonium isotopes. The burnup and transmutation of the uranium is a process yielding simple relationships between the amount of uranium remaining and the amount of plutonium produced. Certain simple relationships among isotopic concentrations have been observed to be remarkably consistent over various reactor types or burnup conditions. These simplified relationships are known as isotopic functions and generally consist of ratios of two isotopic variables. An isotopic variable can consist of sums or products of one or more isotopic concentration(s) or total elemental weight(s). The use of isotopic functions is a developed empirical method of regaining the simplicity of the transmutation relationships. Isotopic functions can be used in the verification of plutonium and uranium concentration measurements of spent fuel at the head end of the reprocessing plant for safeguards and/or nonproliferation purposes. They can also be used to verify or improve theoretical models. Knowledge of the existence and importance of isotopic functions has led to the development of a systematic method of forming and evaluating them. The method used at Battelle to form and evaluate isotopic functions is described in this paper, including definition of those properties considered to be important.

C.L. Timmerman, G.P. Selby and B.A. Napier, Selected Isotopic Functions: A Description and Demonstration of Their Uses, International Safeguards Project Office, ISPO-37, PNL-2761, October 1978. The report includes a description of eleven selected isotopic functions useful in the safeguards verification of input accountability measurements at a reprocessing facility. It provides a summary of how various factors affect the selected isotopic functions for pressurized water reactors. A similar summary table is provided for boiling water reactors. The two tables summarize the descriptive portion of the report. The eleven isotopic functions use pairings of various combination variables of uranium and plutonium isotopics and totals. A description and explanation of these variables and functions are provided in the report. Also included in a demonstration of the verification process utilizing isotopic safeguards techniques. The example used is the verification (or nonverification) of various Pu/U measurements. The technique demonstrates both the internal consistency check and the external data source verification which uses a similar reference data source.

K.B. Stewart, Statistical Programs for Analyzing PAFEX Interlaboratory Test Data, International Safeguards Project Office, ISPO-10, PNL-2571, December 1977. In November 1973 the IAEA initiated an experiment called PAFEX I (Process Analysis Field Experiment). The purpose of the experiment was twofold: (1) to study the administrative and logistical problems that occur when an international network of analytical laboratories is used to perform chemical analyses of samples taken during IAEA inspections, and (2) to obtain estimates of measurement error components of variance. The variance components determined on the basis of the experiment were expected to be typical of those that would arise in the course of IAEA inspections. PAFEX I was a cooperative effort involving analytic laboratories in nine countries. The IAEA arranged for preparation of the samples and coordinated the shipments to each laboratory. Three kinds of samples were analyzed in PAFEX I: plutonium nitrate solution, plutonium dioxide powder, and mixed oxide pellets. A second experiment, PAFEX II, was undertaken in December 1974. The objectives were similar to those of PAFEX I except that PAFEX II involved samples of dissolver solution from a reprocessing plant. This report describes several computer programs developed to analyze data generated by the PAFEX experiments. The programs apply the methods of analysis of variance to produce estimates of variance components and to perform statistical significance tests. The actual data analysis has been reported elsewhere. This report presents only the statistical tools and computer programs. Four computer programs were developed for analyzing the data generated during the PAFEX experiments. The computer program PAFEX is used to obtain variance component estimates. The computer programs NONORT I and II and NONINT do a nonorthogonal analysis of variance to test for the statistical significance of effects, both main and first order interactions. Computation of nonorthogonal analyses of variance becomes very formidable on a desk calculator. Detailed descriptions of the program use are given in the report.

R.J. Sorenson, T.I. McSweeney, M.G. Hartman, R.J. Brouns, K.B. Stewart and D.P. Granquist, Independent Verification of a Material Balance at a LEU Fuel Fabrication Plant, International Safeguards Project Office, ISPO-7, PNL-2418, November 1977. This report describes the application of methodology for planning an inspection according to IAEA procedures, and an example evaluation of data representative of low-enriched uranium fuel fabrication facilities. Included are the inspection plan test criteria, inspection sampling plans, sample data collected during the inspection, acceptance testing of physical inventories with test equipment, material unaccounted for (MUF) evaluation, and quantitative statements of the results and conclusions that could be derived from the inspection. The analysis in this report demonstrates the application of inspection strategies that produce quantitative results. A facility model was used that is representative of large low-enriched uranium fuel fabrication plants with material flows, inventory sizes, and compositions of material representative of operating commercial facilities. The principal objective was to determine and illustrate the degree of assurance against a diversion of special nuclear materials (SNM) that can be achieved by an inspection and the verification of material flows and inventories. This work was performed as part of the U.S. program for technical assistance to the IAEA.

F.P. Brauer, W.A. Mitzlaff and J.E. Fager, Uranium and Plutonium Analysis with Well-Type GE(Li) Detectors, PNL-SA-6600, March 1978. Analysis of microgram and submicrogram quantities of ^{235}U and ^{239}Pu are required by the nuclear industry for process control, nuclear safeguards and effluent measurements. These analyses are of increasing importance in efforts to reduce inventory discrepancies and uncertainties. Current analytical laboratory methods used for measurement of small quantities of uranium and plutonium include X-ray fluorescence methods, spectrophotometric methods, fluorometric methods, radiometric methods and mass spectrometric methods. Many of these analytical laboratory methods measure only total plutonium and uranium while newer nondestructive analysis (NDA) methods, which have been developed primarily for in-plant use, can measure specific isotopes of uranium or plutonium. Adaptation of some of the NDA techniques to the analytical laboratory would result in more rapid and more specific analyses. This paper discusses an NDA method for rapid laboratory analysis of ^{239}Pu and ^{235}U. Gamma-ray spectrometric methods can be used in the analytical laboratory for both direct measurement of sample aliquots (NDA) and for performing measurements on samples following laboratory processing. Samples can often be prepared for gamma-ray spectrometric measurements with considerably less effort than is required for measurement by other methods. Gamma-ray spectrometric methods can measure specific radionuclides, an important consideration in facilities processing enriched uranium. Gamma-ray spectrometric methods also differentiate between ^{241}Am and plutonium and can be used for plutonium isotopic analyses. A well-type Ge(Li) detector was used for measurements on standard uranium ore, uranium and plutonium samples. This paper discusses the results of these measurements and the application of X-ray and gamma-ray spectrometric measurements to laboratory uranium and plutonium determination.

F.P. Brauer, J.E. Fager, J.H. Kaye and R.J. Sorenson, A Mobile Computerized Gamma Ray Spectrometric Analysis and Data Processing System, PNL-SA-6571, March 1978. A mobile system was designed, assembled and evaluated. The system consists of a specially constructed vehicle, multichannel analyzer, and data processing equipment mounted in the vehicle, and GE detectors that can be moved to locations external to the vehicle for use. Applications of the system include nuclear material safeguards measurement, in-situ radionuclide analysis, activation analysis and research support.

F.P. Brauer, J.E. Fager, J.H. Kaye and R.J. Sorenson, A Mobile Nondestructive Assay Verification and Measurement System, INMM, Nuclear Materials Management, VI, No. III, Fall 1977, pp 680-694. A mobile, real-time, nondestructive assay system was developed for both nuclear material safeguards inventory verification and measurements on the Hanford project. The system includes electronic and computer support equipment mounted in a specially constructed vehicle, and passive and active neutron and gamma-ray measurement equipment transported in the vehicle but operated external to the vehicle. This system significantly increases safeguards verification and measurement capabilities.

T.I. McSweeney and R.J. Sorenson, The Role of Assurance in Material Safeguards, INMM, Nuclear Materials Management, VI, No. III, Fall 1977, pp 265-276. The role of assurance in materials safeguards has not been as clearly defined or emphasized as much as other safeguards measures. An effective assurance program provides a safeguards element not found in other safeguards measures, namely, that the physical protection and material control systems have been effective. This paper describes a quantitative assessment plan that can demonstrate such effectiveness. The major difficulties with evaluating safeguards measures are (1) defining a realistic goal for the assessment activities, and (2) obtaining the required data to quantify the results. It is much easier to assess for compliance with requirements than it is to evaluate systems' effectiveness and to express the results in a quantitative assurance statement. Statistical techniques are available to quantify many of the assessment activities. They require the concept of protecting against the diversion of a prescribed quantity of material, i.e., of goal quantity. Because of the difficulties associated with assessment, a number of strategies are employed depending on the specific situation. This results in a structured approach to assessment that emphasizes evaluating all of the strata from which diversion by an adversary is possible. Both the flow components as well as the more traditional inventory components are included because diversion from both strata classifications can occur. This paper summarizes the methodology and use of various strategies in a structural approach to assessment, which allows for quantifying the results. It also describes a computer code that enables rapid development of an assessment plan based on both the operation status at the time of the assessment and the material transfers since the previous evaluation. The application and limitations of the methodology are also presented.

C.L. Timmerman, D.E. Christensen and K.B. Stewart, Statistical Evaluation of Isotopic Safeguards Data, INMM, Nuclear Materials Management, VI, No. III, Fall 1977, pp 559-566. Statistical methods are being applied to the data base used in evaluating isotopic safeguards techniques. The statistics are used strictly as a means to achieve confirmation of the verification of the desired isotopic content. Utilizing two basic statistical approaches, paired comparisons

R.G. Clark, R.J. Brouns, A.D. Chockie and L.C. Davenport, Estimated Incremental Costs for NRC Licensees to Implement the US/IAEA Safeguards Agreement, PNL-2884, January 1979. At the request of the NRC, PNL conducted a brief study to identify the incremental cost for implementing the US/IAEA safeguards treaty agreement. The purpose of the study was to develop an estimate of the cost impact to eligible NRC licensees for complying with the proposed Part 75 of Title 10, Code of Federal Regulations (10 CFR 75), the rule that will implement the treaty. The study was conducted using cost estimates from several eligible licensees who will be affected by the agreement and from cost analyses by PNL staff. A survey instrument was developed and sent to 25 NRC licensees, some of whom had more than one licensed facility. Their responses were obtained primarily by telephone after they had reviewed the survey instrument and a list of assumptions. The primary information received from the licensees was the incremental cost to their particular facility in the form of manpower, dollars or both. In summary, the one-time cost to all eligible NRC licensees to implement 10 CFR 75 is estimated by PNL to range from $1.9 to $7.2 millions. The annual cost to the industry for the required accounting and reporting activities is estimated by PNL at $0.5 to $1.4 millions. Annual inspection costs to the industry for the limited IAEA inspection being assumed is $480K to $160K.

R.J. Sorenson, F.P. Roberts, R.G. Clark, R.J. Kofoed, R.J. Brouns, R.F. Eggers, J.C. Gibson, F.L. Adelman, J. Ballantine, J.F. Fagan, Jr., C.R. Schuller, D. Lowenfeld, R.A. Morris and A.M. Hankardt, Jr., Proliferation Resistance Design of a Plutonium Cycle, PNL-2832, January 1979. This report describes the proliferation resistance engineering concepts developed to counter the threat of proliferation of nuclear weapons in an International Fuel Service Center (IFSC). These concepts include (1) facility design and process considerations that provide passive resistance to proliferation, or enable the application of active use-denial technology, (2) technical aspects of a command, control and communication system (C^3) necessary to initiate active use-denial penalties, and (3) description of active use-denial technology that is either currently available or under development in other DOE programs. In addition, descriptions of the basic elements of an IFSC, including fuel reprocessing, fuel refabrication, product storage, transportation systems, the reactor facility, waste management process, and an advanced safeguards system are presented. Possible methods for resisting proliferation such as processing alternatives, close-coupling of facilities, process equipment layout, maintenance philosophy, process control, and process monitoring are discussed. The political and institutional issues in providing proliferation resistance for an IFSC are analyzed in terms of three major issues: (1) political acceptability of introducing passive and active use-denial technologies into an IFSC located in a host country, (2) the value of multinational presence in enhancing or reducing proliferation resistance, and (3) issues of organization, management and operation of a proliferation resistant IFSC. The conclusions drawn from a study of the major issues are: (1) use-denial can provide time for international response in the event of a host nation takeover. Passive use-denial is more acceptable than active use-denial, and acceptability of active denial concepts is highly dependent on sovereignty, energy dependence and economic considerations, (2) multinational presence can enhance proliferation resistance, and (3) use-denial must be nonprejudicial with balanced interests for governments and/or private corporations being served. The incremental costs imposed on the design, construction and operation of an IFSC by including the PRE concepts have been estimated. Comparisons between an IFSC as a national facility, an IFSC with minimum multinational effect, and an IFSC with maximum multinational effect show incremental design costs to be less than 2% of total cost of the baseline non-PRE concept facility. The total equipment acquisition cost increment is estimated to be less than 2% of total baseline facility costs. Personnel costs are estimated to increase by less than 10% due to maximum international presence. The work performed in the PRE program has shown that the concepts as viewed on an integrated basis have been developed to the stage where they could be considered as plausible. Further work must be performed to make a conceptual definition possible. The authors of this report represent the following contractors: Pacific Northwest Laboratory (PNL); Sandia Laboratories, Livermore (SLL); System Planning Corporation (SPC) and Battelle Human Affairs Research Center (HARC).

R.J. Brouns, F.P. Roberts and U.L. Upson, Considerations for Sampling Nuclear Materials for SNM Accounting Measurements, NUREG/CR-0087, PNL-2592, May 1978. This report presents principles and guidelines for sampling nuclear materials to measure chemical and isotopic content of the material. Development of sampling plans and procedures that maintain the random and systematic errors of sampling within acceptable limits for SNM accounting purposes are emphasized.

R.J. Brouns and F.P. Roberts, Procedures for Rounding Measurement Results in Nuclear Materials Control and Accounting, NUREG/CR-0033, PNL-2565, November 1977. This report defines procedures for rounding measurement results for nuclear material control and accounting. Considerations for the applications of these procedures are discussed.

K.B. Stewart, Minimum Variance Linear Unbiased Estimators of Loss and Inventory, INMM, Nuclear Materials Management, VI, No. 4, Winter 1977-78, pp 47-54. The article illustrates a number of approaches for estimating the material balance inventory and a constant loss amount from the accountability data from a sequence of accountability periods. The approaches all lead to linear estimates that have minimum variance. Techniques are shown whereby ordinary least-squares, weighted least-squares and generalized least-squares computer programs can be used. Two approaches are recursive in nature and lend themselves to small specialized computer programs. Another approach is developed that is easy to program, could be used with a desk calculator, and can be used in a recursive way from accountability period to accountability period. Some previous results are also reviewed that are very similar in approach to the pesent ones and vary only in the way net throughput measurements are statistically modeled.

R.J. Cole, C.A. Bennett, H. Edelhertz, M.T. Wood, R.J. Brouns and F.P. Roberts, Structure and Drafting of Safeguards Regulatory Documents, NUREG/CR-0377, BNWL-2408, September 1977. The objective of this study was to develop hypotheses about the relationship between the structure and drafting of safeguards regulatory documents and the ability of the document users to understand and implement them in a way that reflects the intent and requirements of the NRC. Licensing offices, licensees, inspectors, and the general public must understand the NRC's requirements if the regulatory system is to function effectively and in compliance with legal requirements. Unless the NRC's processes for setting standards and imposing license conditions can communicate to licensees and others what they are expected to do, and unless inspectors understand what to

R.G. Clark, R.J. Brouns, A.D. Chockie and L.C. Davenport, Estimated Incremental Costs for NRC Licensees to Implement the US/IAEA Safeguards Agreement, PNL-2884, January 1979. At the request of the NRC, PNL conducted a brief study to identify the incremental cost for implementing the US/IAEA safeguards treaty agreement. The purpose of the study was to develop an estimate of the cost impact to eligible NRC licensees for complying with the proposed Part 75 of Title 10, Code of Federal Regulations (10 CFR 75), the rule that will implement the treaty. The study was conducted using cost estimates from several eligible licensees who will be affected by the agreement and from cost analyses by PNL staff. A survey instrument was developed and sent to 25 NRC licensees, some of whom had more than one licensed facility. Their responses were obtained primarily by telephone after they had reviewed the survey instrument and a list of assumptions. The primary information received from the licensees was the incremental cost to their particular facility in the form of manpower, dollars or both. In summary, the one-time cost to all eligible NRC licensees to implement 10 CFR 75 is estimated by PNL to range from $1.9 to $7.2 millions. The annual cost to the industry for the required accounting and reporting activities is estimated by PNL at $0.5 to $1.4 millions. Annual inspection costs to the industry for the limited IAEA inspection being assumed is $480K to $160K.

R.J. Sorenson, F.P. Roberts, R.G. Clark, R.J. Kofoed, R.J. Brouns, R.F. Eggers, J.C. Gibson, F.L. Adelman, J. Ballantine, J.F. Fagan, Jr., C.R. Schuller, D. Lowenfeld, R.A. Morris and A.M. Hankardt, Jr., Proliferation Resistance Design of a Plutonium Cycle, PNL-2832, January 1979. This report describes the proliferation resistance engineering concepts developed to counter the threat of proliferation of nuclear weapons in an International Fuel Service Center (IFSC). These concepts include (1) facility design and process considerations that provide passive resistance to proliferation, or enable the application of active use-denial technology, (2) technical aspects of a command, control and communication system (C^3) necessary to initiate active use-denial penalties, and (3) description of active use-denial technology that is either currently available or under development in other DOE programs. In addition, descriptions of the basic elements of an IFSC, including fuel reprocessing, fuel refabrication, product storage, transportation systems, the reactor facility, waste management process, and an advanced safeguards system are presented. Possible methods for resisting proliferation such as processing alternatives, close-coupling of facilities, process equipment layout, maintenance philosophy, process control, and process monitoring are discussed. The political and institutional issues in providing proliferation resistance for an IFSC are analyzed in terms of three major issues: (1) political acceptability of introducing passive and active use-denial technologies into an IFSC located in a host country, (2) the value of multinational presence in enhancing or reducing proliferation resistance, and (3) issues of organization, management and operation of a proliferation resistant IFSC. The conclusions drawn from a study of the major issues are: (1) use-denial can provide time for international response in the event of a host nation takeover. Passive use-denial is more acceptable than active use-denial, and acceptability of active denial concepts is highly dependent on sovereignty, energy dependence and economic considerations, (2) multinational presence can enhance proliferation resistance, and (3) use-denial must be nonprejudicial with balanced interests for governments and/or private corporations being served. The incremental costs imposed on the design, construction and operation of an IFSC by including the PRE concepts have been estimated. Comparisons inspect, the NRC cannot achieve the objectives of its safeguards program. Improving communication will require a sequence of decisions. Certainly the first and most important decision is: (1) should improvement of safeguards regulatory documents as communication instruments be an explicit NRC program? If an explicit program is advisable, the next decision is: (2) what specific methods of communication should be the focus of improvement efforts? The third decision, and the primary focus of this study, is: (3) what actions to improve communications are feasible and desirable? The final decision required is: (4) how should the NRC divide its available effort and resources among desirable actions in order to provide the most effective communication through regulatory documents? The NRC is already making decisions similar to these four, implicitly if not explicitly, each time it prepares and issues a safeguards regulatory document. This study was primarily concerned with how to bring about better communication (decision 3 above), not how badly improvements are needed or what should be communicated. As a consequence, the study reflects only partially and indirectly on the first two decisions in the sequence above. However, insights gained during our study lead us to make some comments and recommendations in all these decision areas. The summary is organized in terms of these four decisions. For each decision the factors involved are discussed, possible alternatives described, and recommendations for improvement given.

H. Edelhertz and M. Walsh, The White-Collar Challenge to Nuclear Safeguards, Lexington Books, D.C. Heath and Company, Lexington, MA, 1978. The book assesses the white-collar threat to the commercial nuclear energy field. The study examines the concept of white-collar crime in a descriptive fashion to pinpoint potential safeguards vulnerabilities.

M.A. Wincek, K.B. Stewart and G.F. Piepel, Statistical Methods for Evaluating Sequential Material Balance Data, NUREG/CF-0683, PNL-2920, February 1979. Present material balance accounting methods focus primarily on the 'material unaccounted for' (MUF) statistic, which utilizes the data from only one material balance period as an indicator of a possible loss of nuclear material. Typically a cumulative MUF (CUMUF) statistic, which utilizes all the available flow data, is also calculated but there is no statutory requirement that it be reported or evaluated. Previous work has shown that CUMUF has greater power than MUF to detect small constant losses. Techniques that emphasize the sequential nature of MUF (i.e., MUF as a sequence of values related over time) are also expected to be more sensitive for detecting losses. The recursive estimation algorithm known as the Kalman filter has been proposed as a possible solution that uses the above idea. The purpose of this study was to evaluate the application of the Kalman filter to the MUF problem, to propose other approaches to the problem, and to reexamine the traditional MUF and CUMUF statistics in more general settings. The report considers the material balance model where the only modeled variability is that due to the measurements of the net throughput (inputs minus outputs) and the inventories. The problem discussed is how to extract more information from all the available data. Section 2 considers material balance models that assume no loss, while Section 3 considers the constant loss and all-at-once loss situations. Emphasis was placed on explaining state variable models and Kalman filtering in relation to the general linear statistical model to which least-squares is applied, yielding a minimum variance unbiased estimator. All errors affecting material balances were assumed to be random.

C.A. Bennett, E.W. Christopherson, R.G. Clark, F. Martin and J. Hodges, DOE Assessment Guide for Safeguards and Security, HCP/W 1830-01, May 1978. This guide describes the philosophy and mechanisms through which safeguards and security assessments are conducted. The assessment program described in this guide is concerned with all contractor, field office and Headquarters activities that are designed to assure that safeguards and security objectives are reached by contractors at DOE facilities and operations. Some clarifications of the scope are: (1) SS has assessment responsibility only for DOE facilities, but has responsibility for basic research and development on safeguards and security systems for all applications (e.g., contractor, licensee and international), (2) certain activities of SS serve some DOE functions in areas other than safeguards such as nuclear materials management; other agencies are served in these areas as well, for example NRC and DOD, and (3) relative to classified information the primary responsibility applies to restricted data and it extends to (a) protection of other classified information received and stored by DOE facilities, and (b) assuring that DOE-restricted data are not transferred to outside facilities unless adequate storage and handling facilities exist. Headquarters' Assessment Branch responsibility includes provision of technical support concerning the determination of the adequacy of physical protection measures in other countries as a condition for nuclear export and certain aspects of bilateral safeguards. This guide takes into account the interlocking relationship between many of the elements of an effective safeguards and security program. Personnel clearance programs are a part of protecting classified information as well as nuclear materials. Barriers that prevent or limit access may contribute to preventing theft of government property as well as protecting against sabotage. Procedures for control and surveillance need to be integrated with both information systems and procedures for mass balance accounting. Wherever possible, assessment procedures have been designed to perform integrated inspection, evaluation, and followup for the safeguards and security program.

K.B. Stewart, The Loss Detection Powers of Four Loss Estimators, INMM, Nuclear Materials Management, Vol. VII, No. 3, Fall 1978, pp 74-80. The power-to-detect loss curves are developed for four loss estimators under different loss conditions. The loss estimators studies are MUF, CUMUF, $L_{(n)}$ and $M_{(n)}$ where $L_{(n)}$ and $M_{(n)}$, respectively, are designed to have maximum powers for the constant loss and the one-time loss situations.

M.A. Wincek and M.F. Mullen, INSPECT-A Package of Computer Programs for Planning Safeguards Inspections, International Safeguards Project Office, ISPO-58, PNL-2559, April 1979. The Pacific Northwest Laboratory has developed a package of computer programs for use in planning safeguards inspections of various types of nuclear facilities. The INSPECT software package is a set of five interactive FORTRAN programs which can be used to calculate: the variance components of the MUF (Material Unaccounted For) statistic; the variance components of the $\bar{D}$ (Difference) statistic; attribute and variables sampling plans; a measure of the effectiveness of the inspection; a measure of the cost of implementing the inspection plan. This report describes the programs and explains how to use them.

M.F. Mullen and M.A. Wincek, Estimation of Inspection Effect for Chosen Inspection Procedures, International Safeguards Project Office, ISPO.35, PNL-2558, June 1979. The Pacific Northwest Laboratory developed a method for estimating the manpower required to inspect various types of nuclear facilities. This report describes the method that was developed. Part I explains the method in general terms. An overview of IAEA inspection activities is presented and the problem of evaluating the effectiveness of an inspection is discussed. Two models are described: an effort model and an effectiveness model. The effort model breaks the IAEA's inspection effort into components; the amount of effort required for each component is estimated and the total effort is determined by summing the effort for each component. The effectiveness model quantifies the effectiveness of inspections in terms of probabilities of detection and quantities of nuclear material to be detected, if diverted over a specific period. In Part II the method is applied to a 200 MT per year low-enriched uranium fuel fabrication facility. A description of the model plant is presented, a safeguards approached is outlined, and sampling plans are calculated. The required inspection effort is estimated and the results are compared to estimates obtained by the IAEA. In Part III other applications of the method are discussed briefly. Examples are presented that demonstrate how the method might be useful in formulating guidelines for inspection planning and in establishing technical criteria for safeguards implementation.

C.L. Timmerman, Isotopic Safeguards Data Bank (ISTLIB) and Control Program (MISTY), International Safeguards Project Office, ISPO-34, PNL-2726, September 1978. The Pacific Northwest Laboratory has developed a computer code and data bank to aid in the safeguards verification of spent fuel content at the head end of a reprocessing facility. A description and user instructions that use isotopic safeguards techniques are presented for MISTY, a computer program for analyzing an isotopic data base (ISTLIB). The input, operating procedures, and output from MISTY are explained in detail. An output listing of an example computer run is provided to illustrate the program's operation. The contents of the data bank are summarized and show the isotopic data sets that are available.

R.J. Sorenson, J.E. Fager and F.P. Brauer, Recent Experience with a Mobile Safeguards Nondestructive Assay System, IAEA-SM-231/82, PNL-SA-6826, September 1978. A mobile, real-time, nondestructive assay system for nuclear material safeguards applications has been designed, assembled and evaluated. The system is designed to be used by either an independent agency for verification of prior measurements or by plant personnel for various sample measurements. The system consists of electronic and computer-support equipment mounted in a specially constructed vehicle. This vehicle also carries passive and active neutron and gamma-ray measurement equipment that is operated outside the vehicle. Currently the analysis capabilities include gross sample weight, neutron counting, spontaneous fission neutron counting, gamma-ray spectrometry, and fissile material detection by fissions induced with a neutron source. The minicomputer mounted in the vehicle is used for measurement control, data acquisition and data analysis. Recent field experience with the system includes handling and measuring plutonium metal, plutonium oxide and plutonium nitrate. A variety of fuel research materials have also been measured, including ^{233}U, ^{235}U, plutonium, and thorium in various matrices. The system also has been used to measure amounts of material received, stored, or shipped. Field measurements are now underway on a variety of fuel cycle waste materials such as low-enriched ^{235}U, high-enriched ^{235}U, and plutonium in heterogeneous matrices. During field use, a number of practical problems were encountered that are as important as the technical considerations in achieving results with the system. The question of calibration standards and our attempts to operate without such standards are also discussed.

R. J. Sorenson, K. B. Stewart, and R. A. Schneider, A Structured Approach to Inspection, BNWL-SA-5731, INMM, Nuclear Materials Management Vol. V, No. III, Fall 1976. The report describes a structured approach to inspection, the purpose of inspection and its specific objectives, with the aim of providing a basis for an inspector to structure his activities in order that the inspection results may be expressed quantitatively. The various objectives of inspection are discussed as they relate to the origin of threat (adversary), the degree of assurance required, and the inspection body. The basic aim of inspection is discussed as it relates to the role of assessment. The degree of the safeguards assurance is described in increasing levels of inspection activity; and the various roles (responsibilities) in the inspection process are discussed as they relate to the threat they are designed to counter.

F. P. Roberts and R. J. Brouns, Auditing Measurement Control Programs, NUREG/CR-0772, PNL-3019, October 1979. Requirements and a general procedure for auditing measurement control programs used in special nuclear material accounting are discussed. The areas of measurement control that need to be examined are discussed and a suggested checklist is included to assist in the preparation and performance of the audit.

M. F. Mullen and P. T. Reardon, Analysis of the Impact of Safeguards Criteria, ISPO-13, PNL-3711, January 1981.

As part of the U. S. Program of Technical Assistance to IAEA Safeguards, the Pacific Northwest Laboratory (PNL) was asked to assist in developing and demonstrating a model for assessing the impact of setting criteria for the application of IAEA safeguards. This report presents the results of PNL's work on the task.

The technical approach involves the following activities. The first requirement is to define a model that relates the impacts and the effectiveness of IAEA safeguards to the safeguards criteria that are to be considered. For this purpose, PNL used the model and computer programs developed as part of Task C.5 (Estimation of Inspection Effort) of the Program of Technical Assistance. In order to apply the C.5 model to perform an analysis of the impact of safeguards criteria, a three-step procedure is followed. First, the input varibles to the model are systematically varied using an experimental design. Second, the response of the system to changes in the input parameters is calculated and recorded. Third, a standard statistical software package is used to analyze the results.

Among the key results and conclusions of the analysis are the following:

The variables with the greatest impact on the probability of detection are the inspector's measurement capability, the goal quantity, and the throughput.

The variables with the greatest impact on inspection costs are the throughput, the goal quantity, and the goal probability of detection.

There are important interactions between variables. That is, the effect of a given variable often depends on the level or value of some other variable. With the methodology used in this study, these interactions can be quantitatively analyzed.

Reasonably good approximate prediction equations can be developed using the methodology described here.

P. T. Reardon, M. F. Mullen, and N. L. Harms. Calculations of Parameters for Inspection Planning and Evaluation - Low-Enriched Uranium Conversion and Fuel Fabrication Facilities, ISPO-140, PNL-3712, February 1981. As part of Task C.35 (Calculation of Parameters for Inspection Planning and Evaluation) of the U. S. Program of Technical Assistance to IAEA Safeguards, Pacific Northwest Laboratory has performed some quantitative analyses of IAEA inspection activities at low-enriched uranium (LEU) conversion and fuel fabrication facilities. This report presents the results and conclusions of those analyses.

R. F. Eggers et al., Modern Methods of Material Accounting for Mixed Oxide Fuel Fabrication Facility, PNL-SA-9371, 1981. The generic requirements loss detection, and response to alarms of a contemporary material control and accounting (MC&A) philosophy have been applied to a mixed oxide fuel fabrication plant to produce a detailed preliminary MC&A system design that is generally applicable to facilities of this type. This paper summarizes and discusses detailed results of the mixed oxide fuel fabrication plant study. Topics covered in this paper include:

mixed oxide fuel fabrication process description,

process disaggregation into MC&A system control units,

quantitative results of analysis of control units for abrupt and recurring loss detection capability,

impact of short- and long-term holdup on loss detection capability,

response to alarms for abrupt loss, and

response to alarms for recurring loss.

J. L. Pindak et al., An Advanced Material Control and Accounting Program for a High Enriched Uranium Conversion and Particulate Fuel Fabrication Facility, PNL-SA-9374.5, 1981. Development of a conceptual material control and accounting (MC&A) program for a high enriched uranium conversion and fuel particle fabrication facility is described. The (disaggregation) of the process into control units is shown. The loss detection sensitivity, timeliness, and localization capabilities of the program are discussed for single (abrupt) and multiple (trickle) losses with the unique problems of localization of losses of SSNM in liquid form. In addition, material control during interim transfers, and examples of response to loss alarms are described.

L. C. Davenport et al., Advanced Material Control and Accounting Program for a Uranium Scrap Recovery Facility, PNL-SA-93695, 1981. Advanced MC&A methods are demonstrated which subdivide a uranium scrap recovery facility into control units which permit rapid detection of small SNM losses. This method utilizes frequent material balances plus data from process monitoring, accountability measurements, and quality control. The hypothetical facility, based on classical processes, was divided into ten and later eight control units. The latter selection optimized alarm capability to successfully meet the 5 kg U goal quantity detection requirement for this example facility.

R. F. Eggers, R. L. Wilson, and K. R. Byers, Material Control and Accounting Self-Test Program Design, PNL-SA-93735. A controversial but potentially beneficial MC&A strategy that has not been widely attempted in the past is Self-Test. In this strategy, a processor of Strategic Special Nuclear Material (SSNM) devises a program of internally-administered tests to determine if the MC&A system performs in a reliable, expedient manner in the face of a simulated loss or compromise. Self-Test procedures would include, for example, the actual removal of SSNM from process equipment in order to determine whether the MC&A system will detect the simulated theft.

Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509)

Telex 15-2874

March 8, 1982

U. S. Nuclear Regulatory Commission
Division of Contracts
Office of Administration
Washington, D.C. 20555

SUBJECT: RECOMMEND CALIBRATION STANDARDS, CALIBRATION FREQUENCIES AND METHODS FOR MONITORING AND CORRECTING BIAS FOR EACH OF THE MAJOR MEASUREMENT METHODS USED BY SPECIAL NUCLEAR MATERIAL LICENSEES
RFP No. RS-RES-81-223
2311105165, Revision 1

Ladies/Gentlemen:

BEST AND FINAL OFFER

Per your February 26, 1982, request, Battelle-Northwest is pleased to submit one original and four (4) copies of the subject Best and Final Offer.

Listed below are the technical questions and answers discussed during your telephone conference with Battelle-Northwest staff on February 23, 1982

QUESTIONS AND ANSWERS
RS-RES-81-223
FUNDAMENTALS OF THE BIAS CORRECTION PROBLEM

1. *What is the status of clearances for key personnel?*

   All key personnel have U.S. Department of Energy "Q" clearances.

2. *Can Battelle-Northwest identify any possible difficulties that might be encountered and how could they be resolved?*

   One potential difficulty is the gathering of the information needed early in the time period allocated for Task 1. This information will be obtained to a large extent from U.S. Department of Energy laboratories and from licensees. Timely

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responses to requests for information are needed to complete the task within the three-month period. Direct contact with the sources will be utilized. Assistance from the NRC will be needed to obtain timely responses from the licensees.

A second possible difficulty is that some measurement systems in current use may not be sufficiently developed or may not have been in use long enough to have a body of information to permit an assessment of the bias determination and bias correction approaches. If such cases arise, we intend to describe the calibration or bias correction method being used and identify their deficiencies.

3. *On page 4, the proposal gives factors for determining and monitoring bias; what factors cause bias?*

Listed below are examples of some common causes of biases that are to be considered.

- Changes in sample composition prior to analysis
- Presence of interfering substances in samples and not present in calibration standards
- Items measured by NDA having different chemical or physical characteristics than the calibration standards
- Incorrect sampling procedures, e.g., non-random sampling of stratified material
- Shifts in instrument response due to environmental changes or due to instrument instability
- Deterioration or contamination of chemical reagents
- Incorrect use of procedure or use of incorrect procedure

4. *What approach would you propose in Task 1 to identify the causes of bias?*

The approach in Task 1 for identifying causes of bias will be to devise investigative procedures. Typical steps will involve:

- Remeasurements to enable detection of outliers
- Recheck calibrations to detect possible calibration shifts
- Recheck physical standards for possible calibration change

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- Resample, if possible, by an alternative sampling procedure and remeasure

- Remeasure by an independent method

The best steps and sequence depend on factors such as the nature of the material and the sampling and measurement methods used.

5. *On Page 5, how will you include the costs of (1) monitoring a measurement system for departure from calibration, and (2) correcting for bias after-the-fact, e.g., at the end of the inventory period?*

We will include (1) the monitoring of measurement systems for departure from calibration and (2) correcting for bias after the fact as cost elements. The cost assessment will include the comparative costs for:

- Standards preparation and maintenance

- Routine standards measurements for monitoring bias

- Record keeping, calculations and analysis and maintaining control charts

- Making bias corrections

We intend to use an example enriched uranium fuel fabrication facility as a model in deriving comparative costs for various bias correction alternatives.

6. *On Page 14, could the results of Task 1 be improved by adding more time for R. J. Brouns? Does he have the time available?*

Upon review, we have concluded that the performance of Task 1 will be more efficient by greater use of R. J. Brouns. We propose the following estimated manpower schedule:

	Hours of Work		
Staff Member	Task 1	Task 2	Task 3

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7. *For key personnel, what percent of their time is committed to other projects?*

For key personnel, the percent of time committed to other projects is approximately as follows:

8. *What assumptions are made in the technical approach?*

We assumed that the scope of Tasks 2 and 3 would include an informal report describing:

- procedures for monitoring and controlling bias and for making bias corrections,
- evaluation of the effect of various bias correction alternatives, and
- the main cost elements in the acceptable alternative bias control and correction procedures on a comparative basis.

9. *Does the offeror understand that Tasks 2 and 3 are primarily for assisting the NRC technical monitor in the conduct of his study?*

It is our understanding that Tasks 2 and 3 are primarily to provide technical assistance to NRC in the conduct of the study.

10. *Why is more than one individual scheduled for each trip?*

We originally proposed to have two people (three to the Region Office in Atlanta) attend each of the project review and technical interchange meetings in order to use the meetings, in part, as working sessions, because we perceive a need for a close working relationship with the sponsor. With more than one person at the meetings, additional flexibility is allowed in serving the sponsor's needs.

Upon review, we have reduced the number of participants and propose the following travel schedule:

Battelle

Type of Meeting	Location	No. of PNL Staff
Program Review	Washington, D.C.	1
" "	"	2
" "	"	1
Technical Interchange	King of Prussia	1
" "	Atlanta, GA	2
" "	Erwin, TN	2

11. *Who would make each of the trips?*

We are planning that either F. P. Roberts or R. J. Brouns will make each trip. The second person, if needed, will be determined based on the specific purpose and agenda of the meeting.

TIME AND COST ESTIMATE

Very truly yours,

A. J. Haverfield

A. J. Haverfield
Director, Research

AJH:jp

Enclosures