Fundamentals of The

Bias Correction Problem

science applications inc.

PALO ALTO

I-088-71-820-37

Fundamentals of The

Bias Correction Problem

Technical Proposal

Solicitation Number RS-RES-81-223

to

U.S. Nuclear Regulatory Commission

Division of Contracts

Washington, D.C. 20555

December 14, 1981

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1.0 INTRODUCTION AND SUMMARY

The Experimental Engineering Department of Science Applications, Inc. is pleased to submit this proposal for the analysis of bias corrections required by 10 CFR 70.57. This is in response to the Nuclear Regulatory Commission RFP RS-RES-81-223.

The major objective of this work is to provide the NRC with a detailed report and expert consultation on the major accountability measurement systems. This analysis will highlight those areas pertinent to bias and bias corrections such as: error analysis, error propogation, standards, stability, measurement and calibration procedures. Methods to determine the bias and its variance will be defined. A control procedure for each measurement will be recommended.

The major types of accountability measurements ranked in order of their use in the industry are:

- analytical measurements - density, mass spectroscopy
- bulk measurements - weight, volume, density
- non-destructive assay - active, passive

The most important techniques from each category will be chosen for in depth analysis.

To complete this study requires broad expertise in each of these nuclear accountability measurement systems. The Experimental Engineering Department has assembled a team of experts experienced in analysis of regulatory systems, chemical methods of assay, bulk measurements, nuclear and other instrumental assay techniques, current fuel production practices and statistics. Members of the team authored the following highly relevant publications:

Volume 3 of NUREG - 0290 - A Study of Analytical Techniques

Mound Lab Handbook of Nuclear Safeguards Measurement
Systems- Chapter 5, Bulk Measurement

Mound Lab Hankbook of Nuclear Safeguards Measurement
Systems - Chapter 6, Active Assay

NUREG/CR - 0602 - Textbook: "Active Non-Destructive Assay of Nuclear
Materials - Principles and Appliations"

Study of the Parameters That Affect Non-destructive Assay
(in preparation for the NRC)

These publications serve as the starting point for this study, and allow us to perform the proposed work in a very efficient manner.

2.0 BIAS IN NUCLEAR ACCOUNTABILITY SYSTEMS

2.1 Sources of Bias

Measurement bias is one of the most difficult but important issues to face in the operation of a materials accountability system. Bias measurement is essential in the resolution of shipper- receiver differences, detection of diversion, and the understanding of inventory differences.

As measurement techniques have evolved with better instrumentation and a deeper understanding of the measurement process, bias has become smaller and more difficult to measure. Many accountability measurements now have precisions of better than one percent. Doing a measurement at this level requires considerable skill and good equipment. Bias can be an order of magnitude smaller. Consequently, its accurate determination taxes measurement systems and statistical analysis.

NDA and ANDA have found increasing use. Many of these measurements still have large biases especially when applied to difficult to assay bulk samples or wastes. There are four major sources of bias:

- Uncontrolled instrumental parameters
- Differences between standards and unknowns
- Sampling Error
- Analysis of the standards

A perfectly stable instrument will report biased results if the standard values are biased or if a significant difference exists between the standards and the unknowns. Likewise, perfect standards do not ensure a good assay if the instrument has drifted. In the analysis of measurement systems these sources of bias can be considered independently. These bias sources are discussed in more detail below.

Instrumental Parameters

In general, the response of a measurement system is a function of the mass of SNM plus a number of instrumental parameters such as temperature, line voltage, container size, particle size, composition, etc. As users and equipment have become more sophisticated these auxilliary parameters have become well controlled or are explicitly measured and compensated. In this area, all of the easy things have been done. The remaining sources of bias are more subtle. An important function of Task I of this report is to make available to all users the hard earn progress made in some facilities to reduce bias. The report should summarize sources of instrumental bias and their magnitude, if known.

Instrumental biases can be monitored by replicate analysis of a verification standard. The frequency of such measurement or full calibration is a function of the measurement variation with respect to the instrumental parameters and the parameters variability. The Task 1 report will define these issues for each measurement system.

Parametric studies wherein for example density is varied over a large range can be useful to identify uncontrolled parameters and develop a model for their correction. It is anticipated that some short studies of this type will be proposed and completed at a licensee facility.

The second major source of bias is differences between standards and unknowns. Standards are expensive to build and consequently may not be adequate to cover the range of properties found in the unknowns. Density effects, small non-uniformity in SNM loading, and non-uniformity in matrix are differences that can bias standard response away from that of the unknowns in non-destructive assay. Similar effects are found in analytical techniques where sample size, density, hardness, and presence of interferring compounds can cause bias. Thus a control issue is the types and number of standards required to ensure proper calibration.

Sampling error is an important special case of the last bias source. In analysis of large quantities of bulk materials only a small fraction of the material can actually be measured. Reliance is made on homogeneity or on a sampling procedure to ensure that the sample is representative. Bias of this type requires extensive sampling tests to properly evaluate. These tests are costly and can be time consuming. NDA of the bulk material is sometimes the best way to avoid sampling error.

The assay value of the standards is an obvious but difficult issue. If NBL or NBS standard material can be directly used, the problems are minimized. This often is not possible due to differences between the unknown and the reference material. Thus at best an indirect measurement trail is established back to national standards. Every step on this path is a source of bias and must be carefully analyzed. Deterioration of the standards from use or natural time dependent processes is also a concern.

As important as the bias itself, a valid measurement of bias must include a measure of its standard error. Even in systems with no bias, the standard error in the bias enters the MSE (ID).

2.2 Bias Correction Problems in Analytical Techniques

Analytical methods are of great importance in accountability due to their inherent precision and the low bias achieved; they often are the basis for qualification of other methods. Thus, some discussion of bias in analytical techniques is merited.

A number of analytical methods are used in the Nuclear Material Accountability, each of them have some bias, namely an average deviation of the analytical result from the true value of the measured geometry. Bias of each analysis may be a sum of terms. For example, the analysis of uranium content in the input stream of a nuclear fuel plant can have three biases: bias of bulk measurement of input stream (bias of weighing or biases of volume and temperature measurements), bias of the sampling method (number of samples, local position of samples, method of sampling and adequate averaging of the samples from the stream), and, finally, the bias of the employed analytical method. If the analytical method is composed of several separate methods or operations in a sequence, the bias of each such individual method or operation should be evaluated. The three such biases - the bias of bulk measurement, bias of sampling and bias of analytical method are combined together yielding a final bias of the specified measurement. Next the standard error of the bias must be derived or explicitly measured. The study of the bias for each important analysis as mentioned above, should be performed by repeated calibration of all components of such analysis, using the proper standards with known amount of the measured material. The preparation and storing of the standards is a special problem that must be precisely defined for each analytical technique. Several reports at the most recent ANS meeting in San Francisco focused on problems of standard storage.

The knowledge of bias for all important analytical procedures could lead to a new combination of analytical methods which will have minimal final bias for the process stream measurement.

Taking into acccount, that the study of the bias for each analytical measurement is not an easy task, we assume that such studies should be concentrated only on the most important methods, which significantly contribute to the overall material accounting error in the inventory difference (ID).

2.3 Important Analytical Procedures in Uranium Determination

The most precise and most important method of uranium determination is the NBL method with Fe^{2+} reduction of hexavelant uranium to trivalent in H_3PO_4 solution, decomposing of Fe^{2+} excess by HNO_3 and back filtration of U^{4+} to UO_2^{2+} with $K_2Cr_2O_7$. High precision of this method is based on potentiometric indication of the end point and use of weighed burettes. This method has very low bias, of less then 0.06% and can be used as a sta: lard method for test of other methods (if the bulk measurement bias and sampling bias are known).

Similarly the gravimetric determination of uranium as U_3O_8 (by burning of uranium salt and weigning of U_3O_8), coulometry or filtration of U^{4+} reduced by Jones reductor with $K_2Cr_2O_7$ are low bias methods - if the uranium in the sample is free from interferring elements. This is the case if samples were prepared from UF_6 or uranyl nitrate solution.

In the case of Pu presence with the uranium the uranium can be quantitatively electrolyzed by coulometry only after removal of Pu, for example, by ion exchange separation of uranium from Pu. This method is important for uranium-Pu mixture analysis and its combined bias should be studied. The bias in only the coulometric part of this method is estimated to be 0.2%.

The other important method of uranium determination is a mass spectrometric method using isotopic dilution, which has larger bias but it can be used for uranium present in the mixture with Pu in highly radioactive solutions. The determination of bias for each operation of this method is very important. The isotopic composition of uranium from UF_6 gas (by gas source mass spectrometry) can be determined precisely, with low bias; similar mass spectrometric isotopic analysis with a thermal emission source in the mass spectrometric is important.

3.0 TECHNICAL APPROACH

3.1 Selection of Measurement Systems

The starting point of this study is to choose about fifteen measurement systems to be analyzed in detail. From the following lists of assay techniques, many marked with an asterisk should be included due to their extensive use in the industry and consequent impact on LEID and bias.

List of Accountability Measurement Systems

Analytical Measurements

Bulk Measurements

Density:

Passive Non-Destructive Assay

Delayed Gamma Ray Systems:

Delayed Neutron Systems Based On:

Prompt Neutron Systems:

Fast Concidence Systems (R.D., ISAF, ISAS)

3.2 TASK 1: Report on Selected Measurements

The format of the Task 1 report will be tailored to the requirements in Chapter 3202 of the NRC manual. The content of the report will be discussed at the start of the contract. The following major topics should be included.

- Statistical Analysis of Measurements
- Example Accountability Measurement Systems
- Measurement Control and Bias Correction
- Recommendations

Statistical Analysis of Measurements

The "Statistical Analysis of Measurements" will define terms and develop a general statistical formalism with which to deal with the selected measurement systems. Rigorous definitions will be given of bias sources and their errors and a classification scheme will be developed so that biases can be identified as:

long term

short term

reducible

ippeducible

calibration bias

standards bias

parameter dependent

sampling bias

erro[illegible] the bias determination

Formalism will be developed to show how the bias from any source and its standard deviation can be determined. This chapter will be developed in broad general terms so that the formalism is applicable to any of the selected measurement systems. For example, suppose a measured mass "m" is dependent on not only true mass "M" but also a series of instrument parameters P_i

$$m = f(M, P_i)$$

where f is a representation of the measurement process. If the parameters P_i are uncontrolled (random variables) and P_R (density, for example) is different between the standards and the unknown; then a bias is caused whose magnitude is,

$$\overline{M - m} = \frac{df}{dP_R} \Delta P_R$$

The variability in Pi causes an increase in random error. The uncertainty in the bias can also be derived and would involve the standard deviation of P_R, the expected value of P_R and its variability.

Analysis of Selected Accountability Measurement Systems

This section comprises the bulk of the report and the effort of Task 1. A subsection will be devoted to each measurement system. Each subsection will cover the following topics:

- Principle
- Applicability
- Importance
- Step-by-Step Procedure
- Calibration Procedure
- Calibration Standards
- Interferences
- Error Analysis
  - instrumental parameters
  - random error
  - long term bias
  - short term bias
  - calibration error
  - error in standards
- Control Procedure
- Bias Measurement
- Cost

Some of the topics are amplified below:

Importance

The overall impact on MSE(ID) in various types of plants is the likely choice for the importance factor. In addition, competing alternatives to this measurement, especially with better performance, will be mentioned.

Calibration Standards

It is very important to define the types of standards used, whether direct or indirect, synthesized as process material, and the range and number of standards. Possible differences between standards and product will be discussed and their input quantified by theory or data where available.

Error Analysis

The error analysis should give quantitative values of errors found in good plant practice. All significant sources of error and bias should be considered.

Control Procedure

A reliable measurement system requires a control procedure. Those in use will be described. Use of control charts and frequency of calibration will be documented. The control procedures will be assessed as to their adequacy and a recommended control procedure will be defined.

Bias Measurement

For some systems, such as volume tanks, a bias measurement may be difficult and done infrequently. Other systems such as fuel rod scanners are monitored for bias at least every shift. The bias measurement process will be outlined and expected standard error of the bias will be given. Frequency of bias determination will be discussed. Bias measurement procedures will be evaluated as to their completeness.

Cost

The cost of materials and labor hours per measurement will be estimated. Capital investment and useful life will also be tabulated. This provides a basis for the Task III effort.

Measurement Control and Bias Correction

The bias problem reduces for a licensee to how to measure a bias and then what to do with that measurement. NRC sponsored studies (NUREG/CR-2205) have shown that the commonly used rules of thumb for bias correction do not always result in a safeguards system that best fulfills its primary mission of diversion detection. Choices of best bias correction procedures and measurement system should be directed by the objective of reducing the MSE (ID). A formal decision rule based on this criteria should be applied to the measurement systems chosen to clarify questions of:

- number of standards

- types of standards

- calibration frequency

- measurement control

- measurement improvement

Using the data developed in the previous section several measurement systems will be discussed from this perspective.

Recommendations

Some recommendations such as control procedure and standards to use will be included in the discussions of individual measurement systems. This section will define areas that need further work in optimizing a bias control strategy.

3.3 TASK II: Technical Assistance at NRC and Licensee Facility

The key personnel involved in this project will be limited to four people. Three are physicists/chemists each with a broad understanding of accountability measurements, as discussed in section 5. Any of these three could provide the expert consultation required at NRC or licensee facilities. Thus, no scheduling problems should arise. SAI business frequently requires that T. Gozani or H. Bernatowicz be on the east coast. Thus with some coordination it is likely that some of the travel expenses can be reduced.

By providing a small, well focused staff with extensive experience, the NRC needs can best be met in a timely and inexpensive manner. The fourth member of the staff is a statistician experienced in the analysis of measurement systems. He would also be available for travel if required.

3.4 TASK III: Technical Assistance in Estimating Costs of Bias Correction Procedures

The key personnel have experience in the licensee application of all measurement systems for nuclear materials. Based on this experience and on their ongoing professional contacts with measurement experts at licensees and national laboratories, they can supply good estimates of the costs for bias correction options.

4.0 CORPORATE CAPABILITY AND RELEVANT EXPERIENCE

4.1 Corporate Background

Science Applications, Inc. (SAI) was established in 1969 to address the high-technology needs of government agencies and private enterprise. Since that time, SAI has grown to approximately 3,500 employees with a current sales rate of over $200 million per year. SAI provides technical and management consulting services to a variety of clients in the business areas of national security, energy, health, the environment, software, and information systems. SAI also is demonstrating success in systems engineering, management of demonstration projects, experimental research, laboratory services, and development of sophisticated instrumentation in all of these business areas.

The corporation was initially formed, and continues to thrive, on the principles of employee ownership and a decentralized form of management that has proven most responsive to the needs of our clients and the development of the staff. SAI has established a solid reputation for being capable of assembling a multidisciplinary team of professionals to deal with complex, high-technology problems.

The basic concept of the SAI organization is to provide specialized technical services in a manner tailored to the particular needs of its customers. This concept requires close cooperation with the customer at all stages of a contract to maintain a responsiveness suitable to the customer requirement.

Consequently, the growth of SAI is accredited to continued highly responsive services to its customers and continued high quality performance and products under existing contracts. SAI has established permanent operating divisions and offices near the sites of its major customers, staffed with competent, experienced professionals with the requisite skills to provide successful accomplishment of its contracts. Each of these operating divisions is highly visible within the corporate management structure. This decentralized operating policy with coporate management visibility to each site has provided the attendant responsiveness to SAI's customers, also a major factor in the company's dynamic growth.

SAI's staff commitment to performance excellence stems to a measurable extent from the fact that the company is primarily owned by its employees; they actively particpate in management and subscribe to the policy of professionals maintaining client-working relationships.

4.2 Experience in Instrumentation and Assay

The proposed program has a strong emphasis on the analysis of equipment and experimental procedures for SNM assay. For this reason it is improtant that the work be carried out by an organization with experience in instrumentation design and application. One of the strenghts of SAI is that some of its personnel have successfully designed and tested a number of instruments for specialized applications. Table 4.1 lists some of the SAI projects in ther ares of instrumentation development. Most of these projects are relevant to the proposed work, since they involve methods and techniques used also in fuel assay. A description of the projects is given below. In addition to these SAI projects, the proposed staff have participated in chemical assay, NDA design and testing prior to joining SAI. This experince is covered in Section 5.

1. TITLE: Review of Non-Destructive Active Assay (NDAA) Systems

   SPONSOR: Mound Laboratory (NRC)

   Project Description: A comprehensive collection of technical and performance data is being conducted on NDAA systems. Detailed information on NDAA instrumentation and their performance is being gathered from the manufacturers and developers. The

Table 4-1. Projects Related to Instrumentation Development

TITLE	SPONSOR	SPONSOR CONTACT	CONTRACT NUMBER
Handbook of Nuclear Safeguards Measurement Systems - Active NDA and Bulk Measurements	Mound Laboratory (NRC)	D. Rogers	25271
Study of the Parameters that Affect NDA Response and the Development of Design Specifications to Minimize their Effect	Nuclear Regulatory Commission	J. Rivers	OSD-80-001
X-Ray Fluorescence for Explosive Detection	Federal Aviation Agency	N. Bell	FAA-DOT-FA77 WA-3963
Coal Slurry Sensor	Bureau of Mines	R. Wang	H0166047
Neutron Activation Analysis	Bureau of Land Management	A. Guida	BLM 8A550-CT6-40
XRD Borehole Probe	Bureau of Mines	G. Schneider	H0282019

description of the instrumentation, devices and techniques will be prepared in the form of a catalogue. The generic techniques and the specific systems will be evaluated from the point of view of applicability to different areas in the fuel cycles, their performance, accuracy, requirements of standards and future development. It is hoped that such a compilation and evaluation of NDAA systems will allow better and more extensive utilization of these vital components of the nuclear materials safeguards system.

2. TITLE: Handbook of Nuclear Safeguards Measurement Methods-
Active NDA Methods

SPONSOR: Mound Laboratory (NRC)

Project Description: The scope of this study covers all applicable active NDA methods for all types of SNM (Plutonium and uranium) bearing materials commonly encountered in the nuclear fuel industry for use in a handbook which will cover all applicable chemical assay, active NDA, passive NDA and bulk measurement methods, primarily intended to meet the needs of NRC and licensee safeguards management. It will provide the information necessary for a safeguards designer, manager, and/or regulator to select or evaluate the SUM measurement methods in order to meet material control requirements. It will not contain detailed experimental procedures but will cite key literature references to specific studies and procedures for implementation of the methods selected.

3. TITLE: Study of the Parameters that Affect NDA Response and the Development of Design Specifications to Minimize Their Effect

SPONSOR: NRC

Project Description: The literature, licensees, and national laboratories were investigated in depth to arrive at an analysis of NDA instruments. Environmental and sample related parameters affecting response were identified. The second phase of the program has begun. In it various experiments are being conducted to better understand the effects. Particular emphasis is on non-uniformity which is being analyzed experimentally, by Monte Carlo computer programs, and by statistical theory.

4. TITLE: X-Ray Fluorescence for Explosives Detection

SPONSOR: Federal Aviation Agency

Project Description: An X-ray fluorescence study is presently being conducted for the Federal Aviation Agency to assess the feasibility of utilizing X-ray fluorescence to detect explosives in luggage. This effort was awarded to SAI as a sole source procurement on the basis of SAI's preeminence in the field of X-ray fluorescence. The work involves experimental measurements with a high resolution germanium solid state detector to define parametrically the backscattered source function and the level of characteristic fluorescent radiation emitted by suitable taggants. A computer study will then be performed to assess the detection probability and false alarm rate for tagged explosive detection that can be obtained from an optimized system using previously measured luggage transmission data and the experimentally determined parametric functions for fluorescence detection levels.

5. TITLE: Coal Slurry Sensor

SPONSOR: Bureau of Mines

Project Description: SAI is presently developing a concentration sensor for coal slurries under contract to the Bureau of Mines. The sensor will provide real time weight concentrations of coal, refuse (rock) and water in haulage pipes that carry the material from deep coal veins to the surface of the mine. The two-phase, three-component flow gauging program involves the development of a coal-slurry concentration gauge that measures the density ratios of coal/rock/water to about a 2% accuracy in a 10 second sampling time. Since the densities of the coal and the surrounding rock vary, this three-component sensor requires a total of three independent probes. For a 6-inch steel haulage pipe, the combination of a gamma-ray probe, a neutron probe, and a conductivity gauge (coal and rock have essentially zero conductivity compared to the coal-slurry water) was found to be the most useful. The combination was successfully tested in the feasibility study phase of the program and has been incorporated into the engineering prototype which is presently in the final testing phase.

6. TITLE: Nuclear Instrumentation for Coal Assay

SPONSOR:

Project Description:

The potential upgrades being investigated include better yield calculations, more and better process measurements of parameters such as flowrates, and more uranium enrichment measurements. Diversion analyses of the potential systems and cost estimates will be prepared so that SAI can select the most cost/beneficial system for detailed design and eventual demonstration.

7. TITLE: Assessment of Nuclear Material Control and Accounting Systems

SPONSOR: Nuclear Regulatory Commission

Project Description: Nuclear fuel facilities, which are licensed by the NRC, are required to have nuclear material control and accounting (MC&A) systems. An initial compliance evaluation of each MC&A system is performed by NRC licensing staff,and continuing compliance evaluations are provided by NRC inspection and enforcement staff. The purpose of this project is to develop a general method for assessing the effectiveness of operating MC&A systems in meeting several different objectives. The method is to be sufficiently general to incorporate (1) the objectives of NRc's Comprehensive Evaluation Plant (May 1977); (2) the goals of NRC's Material Control and Material Accounting Task Force Report (NUREG-0450, April 1978); and (3) features of future NRC safeguards upgrade rules. The method is being developed by defining a hierarchical structure of safeguards functions and by designing an appropriate technique for synthesizing evaluations of lowest-level functions to achieve evaluations of the highest-level functions.

subject to licensing by the NRC. The purpose of this project is to provide to the NRC a data base which is applicable to the rulemaking process for safeguards at these repositories. The project considers the various possible forms of nuclear wastes and the corresponding types of geologic repositiories. For each waste form, reference sabotage scenarios are identified and the resulting health effects consequences are estimated. Safeguards requirements are then defined for each waste form, based on the level of protection required by current NRC rules for comparable health effects consequences. Using these safeguards requirements, safeguards system designs are developed for each HLW repository type. The costs and other impacts of the safeguards are examined.

6. TITLE: Bulk Material Control

SPONSOR: Nuclear Regulatory Commission (NRC)

Project Description: SAI is performing the first phase of a potentially three-phase project that would culminate with the demonstration of a material control system that uses process monitoring to assure the presence of bulk strategic special nuclear material in nuclear processes. General Atomic Company (GAC) is working with SAI as a subcontractor and the GAC high enriched uranium facility will be used for the demonstration. During this first phase, SAI is preparaing conceptual designs for process monitoring systems that extend existing capability so that better timeliness and diversion detection can be achieved.

4. TITLE: Assessment of the Implications of Technical Objective for IAEA Safeguards

SPONSOR: Battelle, Pacific Northwest Laboratories (NRC)

Project Description: SAI is assisting PNL with an assessment of the implication of technical objectives for IAEA safeguards that were prepared in a U.S. State Department Cable dated October 23, 1977. The objectives include quantitative amounts of nuclear material diversion to be detected, detection probabilities (90-95%), false alarm probabilities (1-5%), frequency of physical inventory (3-6 months for Pu) and timeliness for detecting diversion by surveillance (1 week). SAI is assisting in preparing the inspection plans to meet these objectives and is assessing the associated resources the IAEA will need to implement these plans. Also included is an assessment of facility design features that could improve the IAEA's capability to meet the criteria or could reduce the resources needed for implementation.

5. TITLE: Safeguards for HLW Repositories

SPONSOR: Nuclear Regulatory Commission

Project Description: One of the outstanding U.S. nuclear power problems to be resolved is the disposition of high-level radioactive wastes. It is anticipated that the Department of Energy will ultimately provide geologic repositories would be

3. TITLE: Evaluation of Real-Time Material Control and Accountability in a Model Mixed-Oxide Fuel Plant

SPONSOR: Lawrence Livermore Laboratory (NRC)

Project Description: This study evaluated the ability of a real-time accountability system operating in the proposed Westinghouse mixed-oxide fuel fabrication plant in Anderson, South Carolina. There were two important objectives: (1) to detect any covert attempt to steal special nuclear materials in a time frame that is adequate to contain subcritical quantities of special nuclear material within the boundaries of the material protection system; and (2) to maintain current knowledge of the quantity and location of all strategic special nuclear materials. The evaluation was accomplished in a quantitative and unambiguous manner by methodically tracing through the required actions of a diverter in a model fuel cycle facility equipped with a state-of-the-art real time system. This tested the ability of the system to satisfy the first Requirement Material balances and inventories and the uncertainties in these calculations were determined and thus the ability of the system to meet the second objective was evaluated.

material balance uncertainty. For each measurement the principle, applicability, importance, calibration, sensitivity, accurracy, vulnerability and references are given. Sources of bias are discussed.

2. TITLE: Material Control for Fuel Fabrication Facilities

SPONSOR: Lawrence Livermore Laboratory (NRC)

Project Description: This study was conducted to establish an information base on nuclear fuel fabrication processes and facilities. In order to assemble the information base, which is to be used in planning material controls studies of fuel fabrication facilities, the study consisted of three main tasks. One task is to compile descriptions of the physical characteristics of the fuel elements, the processes used in their fabrication and the facilities that house the processes. The second task is to describe the current mechanisms for material control, instrumentation and measurement techniques. The third task is to identify processes where modeling and simulation could aid in material control analyses and suggest techniques for developing appropriate process models.

Table 4-2. Projects Related to Analysis of Regulatory Systems.

TITLE	SPONSOR	SPONSOR CONTACT	CONTRACT NUMBER
A Study of Nuclear Material Accounting	Lawrence Berkeley Laboratory (NRC)	W.E. Siri	W-7405-ENG-48
Material Control for Fuel Fabricaction Facilities	Lawrence Livermore Laboratory (NRC)	A. Maimoni	P01236909
Evaluation of Real Time Material Control in MOX Fuel Plant	Lawrence Livermore Laboratory (NRC)	C. Pomernacki	P08698505
Assessment of Implications of Technical Objectives for IAEA Safeguards	Battelle Pacific Northwest Laboratories (NRC)	M. Mullen	B-25516-A-E
Safeguards for LHW Repositories	Nuclear Regulatory Commission	G. Gardes	NRC-02-79-035
Bulk Material Control	Nuclear Regulatory Commission	B. Mendehlsson	NRC-02-79-043-1
Assessment of Nuclear Material Control and Accounting Systems	Nuclear Regulatory Commission	R. Gramman	NRC-02-79-029

4.3 Experience in Analyzing Regulatory Systems

The success of the proposed program will depend to some extent on the understanding of the final usefulness of the information generated, that is, its incorporation into the regulatory process. It is therefore important that the program be conducted by an organization experienced in the analysis of regulatory as well as technical problems.

SAI personnel has considerable experience in the analysis of nuclear regulatory systems. The experience is demonstrated by the number of projects of this nature in which SAI has participated. A partial list of these projects is given in Table 4.2. Most of the projects listed involve measurement aspects of regulatory systems and are therefore relevant to the proposed work.

A description of the projects follows:

1. TITLE: A Study of Nuclear Material Accounting

   SPONSOR: Lawrence Berkeley Laboratory (NRC)

   Project Description: This study resulted in NUREG-0290. Volume 3 contains a catalog of accountability measurement systems with an emphasis on analytical techniques. A measurement hierarchy is evolved which grades the measurements by their impact on plant feasibility of a logging tool designed to obtain in situ mineralogical information has been established. A 3-1/2 inch diameter probe is being designed based on a miniaturized X-ray generator (1-1/2 inch diameter) and X-ray imaging detector. A fiber optic-based data link will be used for the transmission to the surface of the digitized X-ray diffraction pattern data. After establishing practical feasibility of the XRD concept through extensive field testing of the 3-1/2 inch diameter sonde, consideration will be given to shrinking the sonde diameter to 2-1/4 inches.

7. TITLE: Neutron Activation Analysis

SPONSOR: Bureau of Land Management

Project Description: SAI is currently performing trace metal measurements using Neutron Activation Analysis (NAA) in a large number (over 2000) of water particulate, sediment and biota samples collected off the Southern California Coast in a Bureau of Land Management sponsored program designed to establish pollution baseline levels prior to off-shore oil exploration. The University of California at Irvine TRIGA nuclear reactor is being used to irradiate the samples and an automated Ge(Li) spectrometer system at SAI is used to count the samples. Sensitivities in the range of a ppm are routinely achieved for a number of elements, while ppb sensitivities can be achieved for a few element with high thermal neutron absorption cross sections. Vanadium and barium are of speical interest in the present program. Other elements which will be studied include copper, aluminum, titanium, silver, calcium, cadmium, chormium, iron, zinc, nickel, manganese and arsenic.

8. TITLE: XRD Borehole Probe

SPONSOR: U.S. Bureau of Mines

Project Description: SAI is currently engaged in the "Development of a Borehole Probe for In Situ X-ray Diffraction Analysis" for the Bureau of Mines (Denver). The technical

5.0 PERSONNEL QUALIFICATIONS AND FACILITIES

5.1 Project Organization

The Fxperimental Engineerinig has assembled a team including physicists, a chemist, and a statistician to conduct the proposed work. The major areas of experience that this group encompasses are:

- project management
- analysis of regulatory systems
- analytical chemical measurements
- NDA and ANDA instrumentation
- bulk measurement systems
- licensee nuclear material production processes
- safeguards practices and regulations

A project organization chart is shown in Figure 5.1. Its relation to the parent organization is hown in Figure 5.2.

is chief corporate scientist with an international reputation in safeguards instrumentation and analysis of safeguards systems. He will provide overall technical direction to the project. A partial list of his publications is included after his resume, with indication of those especially relevant to the proposed work.

Figure 5.1. Project Organization

Figure 5.2. Relationship of the NRC Bias Project to the SAI Organization.

5.2 Facilities

SAI possesses all facilities necessary for performance of this work. The Palo Alto office of the Experimental Engineering Division maintains a library including government reports dealing with safeguards. Word processor systems will speed report generation.

A fully equipped nuclear and chemical laboratory is available at the SAI-Sunnyvale Laboratory.

5.3 Resumes of Key Personnel

6.0 PROBLEM AREAS

This project demands a period of concentrated effort to complete Task 1 within three months, and also a longer term committment to provide technical assistance to the NRC in evaluation of bias correction methods.

SAI has identified the following possible problems areas and solutions.

1. Schedule - The Task 1 report is required 3 months after contract start. This is a relatively short period. However, the key personnel are >75% available during the first half of 1982 when task 1 would be likely to be performed. The key personnel are also sufficiently experienced in the field that no "start up" time will be needed. All required reference data is in our departmental library all familiar to the staff because of their ongoing work in safeguards measurements.

2. Travel Costs - Since key personnel are on the west coast, travel becomes a significant cost. If only one person is required per trip, this results in significant cost savings for the NRC. Personnel chosen are broadly experienced in nuclear assay measurements. Either of the three scientists alone could provide the experience and understanding required by the NRC. [ ] frequently travels to the east coast. He is the most experienced of the three and is because of his frequent travel is available to the NRC with a savings in travel expenses. In addition, other personnel at closer SAI offices could provide some technical support to the key personnel.

3. Level of Experience Required - The study covers all types of measurement systems ranging from wet chemistry to active NDA. The major requirements for successful completion of the proposed work is highly experienced personnel. The size of the study and the need for close coordination with the NRC also require a small staff. The Experimental Engineering Department is fortunate to have the personnel that have in depth experience in this field to allow a small staff to meet the NRC needs.

4. Focus - It is possible for a smaller project such as this which is extended over a long period of time to lose management and personnel focus. Key personnel are committed less than 25% over the first six months of this project. proposed project leader, is not committed in that capacity to any other project during 1982. Thus his attention and that of the key personnel will remain focused on this work.

, as departmental manager, can ensure that management support for the program is available.

7.0 PROJECT PLAN

7.1 Work Breakdown Structure (WBS)

SAI's work breakdown structure (WBS) for the project is presented in Figure 7.1. The work will be divided into four task areas, three corresponding to tasks defined in the RFP, and one for management. Each task is further divided into work elements. This will be SAI's initial plan for doing the work, but revisions may be made as the project progresses.

SAI will use this work breakdown structure to assign budgets and work descriptions for each of the work elements. This will assure control of the project by the principal investigator, and will prevent unexpected budgetary problems. A discussion of each task is presented below.

Task 0 Management

SAI will: prepare monthly reports to NRC (010); prepare for briefings and meetings with NRC at SAI (020); manage the overall project (030); and administer the project within SAI (040). The management element involves maintaining the work plan, assigning budgets and work, and reviewing to assure proper completion of each work element.

Task 1 Report on Selected Measurement Systems

SAI will divide this task by measurement method. This allows application of resources and effort to fit NRC requirements for which types of measurements should receive emphasis. There will be five work elements: analytical techniques (110), bulk measurements (120), non-destructive assay (130), statistics (140), and editorial functions (150).

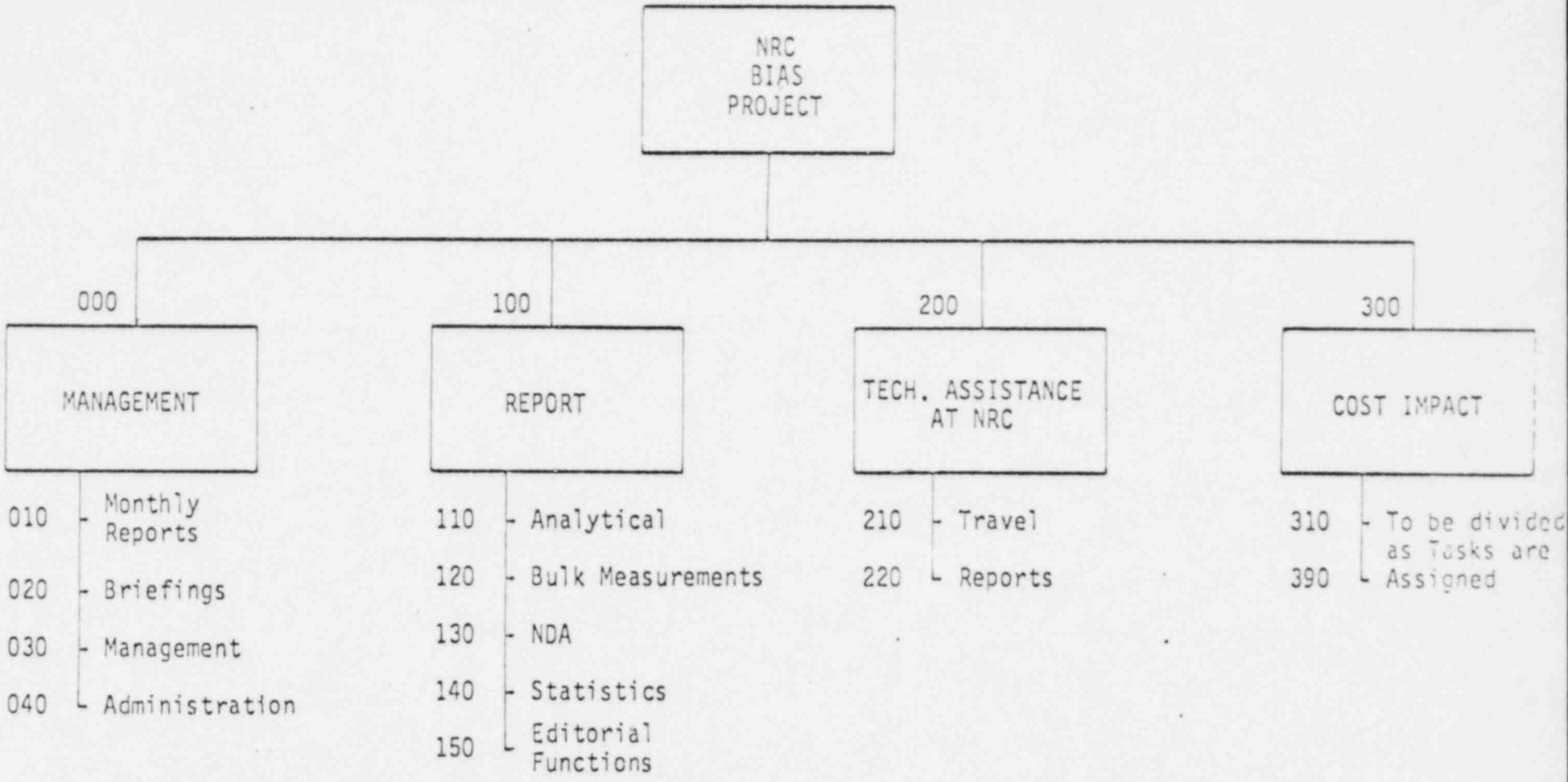

Figure 7.1. Work Breakdown Structure.

Task 2 Technical Assistance at NRC and Licensee Facilities

This task divides into actual travel and time at NRC and licensee facilities (210) and preparation of interim reports requested by the NRC (220).

Task 3 Technical Assistance to Assess Cost Impact of Bias Correction

This task will be further broken down by assigned tasks during the course of the work.

7.2 Schedules and Milestones

SAI's detailed schedule for the work is shown in Figure 7.2. SAI estimates it can accomplish the work so that it meets the schedule requirements of the RFP.

The solid lines on the schedule indicate expected periods of a high level of activity, with the dashed lines indicating work on the task but at a moderate level or intermittently as required to meet other project objectives. Milestones are shown by solid triangles and briefings/meetings by the numbered circles. Scheduling for the individual tasks is discussed below. Exact scheduling of trips and meetings is at the discretion of the NRC.

Task 0 Management

Monthly project reports will be delivered starting with the first month after start of the contract. The two briefings/meetings with NRC at SAI have been tentatively scheduled to coincide with major milestones or reviews in most cases. Management and administration will extend over the course of the project.

Task 1 Report on Selected Measurement System

The first milestone is selection of systems to analyze. The second is

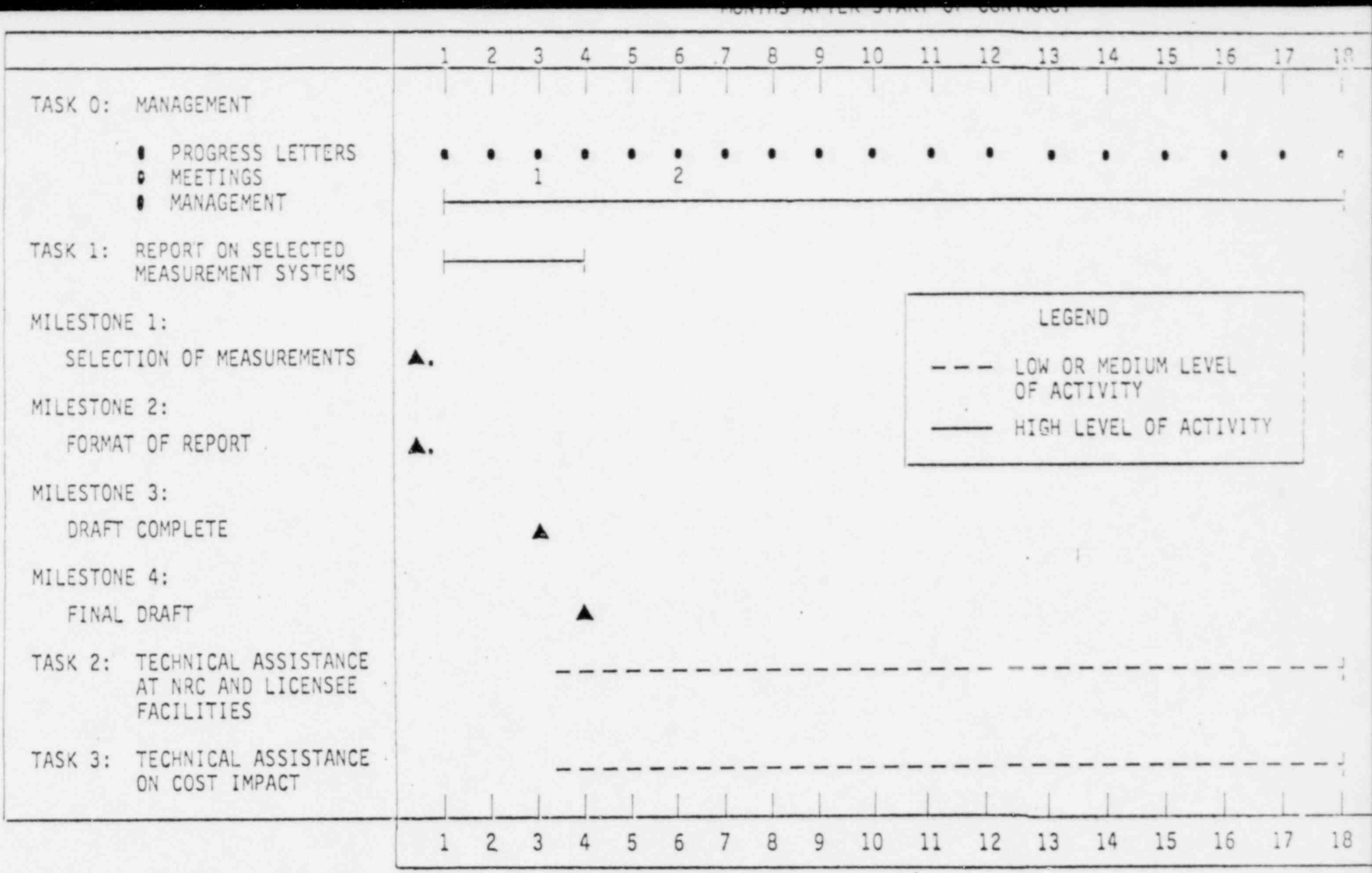

Figure 7.2. Schedule of Work.

report format. The third is report completion. The fourth milestone is final report following NRC review.

Task 2 Technical Assistance at NRC and Licensees

Schedule here is flexible to fit NRC requirements.

Task 3 Technical Assistance on Cost Impact

Schedule for this task is flexible to fit NRC requirements.

7.3 "Key" Personnel Commitments

7.4 Security Clearances and Nuclear Material Licenses