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1

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TITLE: NDA ACCOUNTABILITY MEASUREMENT NEEDS TIN THE DOE PLUTONIUM COMMUNITY

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NDA ACCOUNTABILITY MEASUREMENT NEEDS
IN THE DOE PLUTONIUM COMMUNITY

August 31, 1988

Prepared by the DOE/MMEC
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EXECUTIVE SUMMARY

The Accountability Technology Exchange (ATEX) Working Group was established in October 1986 by the U.S. Department of Energy's (DOE) Materials Management Executive Committee (MMEC) to identify nuclear materials accountability measurement needs within the DOE plutonium community and to recommend potential improvements. ATEX membership comprises personnel within the DOE plutonium community representing nuclear materials management, production, nondestructive assay (NDA), analytical chemistry, and safeguards. Participating contractor sites include Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Rocky Flats Plant, Savannah River Laboratory and Plant, Westinghouse Hanford Company, and Westinghouse Idaho Nuclear Company.

The purpose of this first ATEX report is to identify the twenty most vital NDA accountability measurement needs in the DOE plutonium community to DOE and to contractor safeguards R&D managers in order to promote resolution of these needs. During 1987, ATEX identified sixty NDA accountability measurement problems, many of which were common to each of the DOE sites considered. These sixty problems were combined into twenty NDA accountability measurement needs that exist within five major areas:

- NDA "standards" representing various nuclear materials and matrix compositions;
- Impure nuclear materials compounds, residues, and wastes;
- Product-grade nuclear materials;
- Nuclear materials process holdup and in-process inventory; and
- Nuclear materials item control and verification.

The twenty NDA accountability measurement needs were then ranked using eight weighted criteria, and summary scores were tabulated. Out of the group of twenty, the "all-site" top five NDA accountability measurement needs are:

(1) NDA standards representing various nuclear materials and matrix compositions;

(2) Better NDA measurement technology for impure and often heterogeneous Pu oxides and fluorides;

(3) Better NDA measurement technology for process equipment holdup and in-process inventory;

(4) Better NDA measurement technology for heterogeneous plutonium/uranium mixed oxides; and

(5) Better NDA measurement techology for heterogeneous low-level and TRU solid wastes in container sizes ranging from 1-gallon "paint" cans to 55-gallon drums.

The top five site-specific NDA accountability measurement needs at each of the DOE sites considered are listed below in ranked order. Clearly, these highest ranking site-specific needs reflect the most important process or product concerns at each respective site. For comparison, numbers in parentheses represent the all-site mean rankings for these measurement needs.

Lawrence Livermore National Laboratory

(1) NDA standards representing various nuclear materials and matrix compositions
(4) Heterogeneous Pu/U mixed oxides
(16) Holdup and in-process inventory measurements involving isotopic variations
(19) Special isotope separation (SIS) process residues and solid wastes
(3) Holdup and in-process inventory measurements for process equipment

Los Alamos National Laboratory

(1) NDA standards representing various nuclear materials and matrix compositions
(10) Impure and heterogeneous pyrochemical salt residues
(2) Impure and often heterogeneous Pu oxides and fluorides
(3) Holdup and in-process inventory measurements for process equipment
(4) Heterogeneous Pu/U mixed oxides

Rocky Flats Plant

(1) NDA standards representing various nuclear materials and matrix compositions
(10) Impure and heterogeneous pyrochemical salt residues
(2) Impure and often heterogeneous Pu oxides and fluorides
(4) Heterogeneous Pu/U mixed oxides
(3) Holdup and in-process inventory measurements for process equipment

Savannah River Laboratory and Plant

(1) NDA standards representing various nuclear materials and matrix compositions
(2) Impure and often heterogeneous Pu oxides and fluorides
(4) Heterogeneous Pu/U mixed oxides
(3) Holdup and in-process inventory measurements for process equipment
(13) Impure and heterogeneous scrub alloy and salt strip buttons

Westinghouse Hanford Company

(1) NDA standards representing various nuclear materials and matrix compositions
(2) Impure and often heterogeneous Pu oxides and fluorides
(3) Holdup and in-process inventory measurements for process equipment
(11) Holdup and in-process inventory measurements for gloveboxes and canyon floors
(9) Neptunium (Np) analysis

Westinghouse Idaho Nuclear Company

Because their primary concern has been with uranium, their experience with plutonium accountability measurements is limited. Their future plutonium measurement concerns center around the SIS process, and hence are reflected by Livermore's needs.

The results of this ATEX study represent a consensus view among major sites within the DOE plutonium community with respect to NDA accountability measurement needs. We believe the needs identified and ranked within this report should receive the highest consideration in appropriations for safeguards R&D funding at the earliest possible time. Further, ATEX believes in the value and importance of the "user forum" approach we took to identify and rank NDA accountability measurement needs, and we believe that this approach may be useful in improving other areas of safeguards. Finally, the ATEX multi-site, multidisciplinary user forum developed a list of eight recommendations, which when implemented, can lead to considerable improvements in the NDA technology used to perform nuclear materials control and accountability measurements. Two of the more significant ATEX recommendations are:

- MMEC should immediately appoint a multi-site, multi-disciplinary task force to develop and recommend a program plan for providing the NDA working standards necessary to perform better accountability measurements within the DOE plutonium community.

- MMEC should pursue with appropriate DOE Offices the means to provide adequate funding of R&D efforts that address the highest priority NDA accountability measurement needs as identified in this report.

I. INTRODUCTION

The Accountability Technology Exchange (ATEX) Working Group was established in October 1986 by the U.S. Department of Energy's (DOE) Materials Management Executive Committee (MMEC). Its charter (Appendix A) is to identify nuclear materials accountability measurement needs within the DOE plutonium community and to recommend potential improvements.

ATEX Working Group membership (Appendix B) includes experts in nuclear materials management, production, nondestructive assay (NDA), analytical chemistry, and safeguards. These experts represent Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Rocky Flats Plant (RFP), Savannah River Laboratory/Plant (SRL/P), Westinghouse Hanford Company (WHC), Westinghouse Idaho Nuclear Company (WINCO), and DOE-Albuquerque. ATEX provides a multi-site, multidisciplinary forum for evaluating and recommending both existing and emerging nuclear materials accountability measurement technologies for implementation at DOE plutonium facilities.

During 1987, ATEX identified sixty NDA accountability measurement problems, many of which were common to each of the DOE sites considered. These sixty problems were combined into twenty NDA accountability measurement needs, which are discussed in Sec. III, and were categorized into five major areas and ranked (Appendix C). The five areas of NDA measurement needs are:

- NDA "standards" representing various nuclear materials and matrix compositions;
- Impure nuclear materials compounds, residues, and wastes;
- Product-grade nuclear materials;
- Nuclear materials process holdup and in-process inventory; and
- Nuclear materials item control and verification.

The needs identified within each of these areas were evaluated and ranked (Appendix D) using eight weighted criteria . These criteria and the associated evaluation methodology are discussed in Sec. II.

II. EVALUATION METHODOLOGY

The NDA accountability measurement needs described in this report were ranked using a weighted-criteria methodology. Application of this methodology involved the following sequence:

1. Defining evaluation criteria;
2. Assigning a weighting factor of one to ten to each criterion;
3. Scoring each measurement need from one to ten for the estimated impact that improved technology would have on each of these criteria;

4. Multiplying the measurement need scores by their respective criteria weights; and

5. Summing the weighted scores over all criteria to determine the ranking for each measurement need.

Each site individually scored the twenty NDA needs and their results are tabulated in Appendix D. The individual scores for all sites were then averaged to determine the overall, all-site ranking of the twenty NDA accountability measurement needs within the DOE plutonium community (Appendix C). The individual criteria and weights that were applied in this evaluation are defined in the paragraphs below.

CRITICALITY AND RADIATION SAFETY: Accountability measurements are frequently used as the basis for determining compliance with criticality safety limits. Improved technology for measuring fissile materials is essential for safety. Also, properly designed, fast and reliable accountability measurement equipment frequently results in reduced radiation exposure to measurement personnel. This criterion was assigned a weight of 10.

INVENTORY DIFFERENCE (ID) AND LIMIT OF ERROR FOR INVENTORY DIFFERENCE (LEID): Accountability measurements clearly impact both the actual ID and the uncertainty propagated about the ID, i.e., the LEID. An improved LEID provides greater sensitivity for diversion detection. This criterion was assigned a weight of 10.

SHIPPER/RECEIVER DIFFERENCE: DOE orders require nuclear materials measurements by both the shipper and receiver, and evaluation of the resulting measurement differences. Significant resources are expended by all sites in resolving shipper/receiver differences that occur for difficult to measure materials. Improvements in this area will assist in minimizing shipper/receiver differences and provide earlier detection of diversion. This criterion was assigned a weight of 10.

COMMONALITY: When evaluating measurement technology needs, commonality of existing problems among the DOE sites must be a key consideration in the decision-making process. This promotes efficient allocation of available resources for system improvements that will benefit the largest number of sites. This criterion was assigned a weight of 9.

TECHNICAL FEASIBILITY/COST EFFECTIVENESS: Practical solutions to accountability measurement problems require either that technology exists or that it has the potential to be developed in a timely and cost-effective manner. This criterion was assigned a weight of 8.

PROCESS BENEFIT: Process operations can frequently benefit from improvements in measurement technology. NDA measurements can preclude the need to sample, they can be used for product certification, and they can assist in evaluating and assuring process performance. This criterion was assigned a weight of 6.

POLITICAL SENSITIVITY: Nuclear material accountability measurement data are important in initiating activities that may be sensitive such as the investigation of significant IDs or the resolution of major shipper/receiver differences. This criterion was assigned a weight of [illegible].

PRESENT VS FUTURE NEED: This criterion was used to assign a higher priority to present measurement needs as opposed to anticipated needs for emerging process technologies. This criterion was assigned a weight of 3.

III. CURRENT NDA MEASUREMENT NEEDS

The ATEX Working Group's review of current nuclear materials accountability measurement problems and practices within the DOE plutonium community revealed twenty distinct NDA measurement needs. These needs were evaluated and ranked using the methodology discussed in Sec. II. The following paragraphs describe each of these NDA measurement needs in their ranked order.

RANK (1): <u>NDA standards representing various nuclear materials and matrix compositions</u>. Suitable NDA standards representing plutonium-bearing scrap and waste are generally lacking at the major DOE plutonium-handling facilities. This lack of suitable NDA standards is a serious problem that needs proper definition and resolution. Simply stated, a wide range of physical, elemental, and isotopic matrix compositions and sample geometries exist for plutonium scrap and waste that are routinely generated, packaged, and measured nondestructively. However, individual facilities have been unable to command the necessary resources required to generate the scrap and waste standards and standards validation (i.e., destructive analysis) programs needed to quantity and reduce bias in NDA to acceptable levels. Instead, to calibrate NDA instruments used to measure scrap and waste materials, facilities have often used non-representative homogeneous reference materials (e.g., plutonium dioxide), or generated "working standards" by assaying actual production samples with methods judged to be "relatively" bias free (typically calorimetry and gamma-ray isotopics). Biases incurred during measurement of scrap and waste using instrumentation calibrated by these methods can be small, but frequently are large relative to accountable units of nuclear material. As a result, biased scrap and waste measurements can generate inter- and intra-facility inventory differences and shipper/receiver problems. If these biases are not corrected, facilities may be placed in the position of not being able to assess their inventory uncertainty with confidence. The provision of site-suitable NDA standards should be addressed by a multi-site, multidisciplinary task force.

RANK (2): <u>Impure and often heterogeneous Pu oxides and fluorides</u>. Quantification of plutonium by NDA is difficult for incinerator ash and glovebox/cabinet sweepings, which can contain varying ratios of plutonium oxides and fluorides mixed with virtually every element in the periodic table. Also, slag and crucible residues from PuF_4 thermite reduction are difficult to assay. These have a CaF_2/Ca metal matrix (and up to a few wt% CaI_2) with MgO crucible shards, and generally have (1) a highly heterogeneous distribution of Pu (0-lkg) as shot, (2) small quantities of PuO_2 (from initial incomplete oxide-to-fluoride conversion), and (3) trace amounts of PuF_4. The matrix densities, moisture content, and plutonium isotopic ratios can vary from container to container.

RANK (3): <u>Holdup and in-process inventory measurements for process equipment</u>. Process equipment design often makes reliable measurement of nuclear materials holdup or in-process inventory difficult, if not impossible. Examples of such equipment include (1) rotary calciners and hydrofluorinators (current semiannual inventory "tear-downs" cause large production losses and excessive personnel radiation exposures), (2) fluidized-bed incinerator system components, tilt-pour electrorefining furnaces, and horizontal and vertical tanks (some with post-precipitation), (3) process lines, and (4) emerging complex equipment for plutonium special isotope separation programs. Often the measurement environment is complicated further by relatively high background radiation, inaccessibility, and high ambient temperatures.

RANK (4): Heterogeneous Pu/U mixed oxides. Quantification of plutonium and uranium in mixed-oxide powders depends on mechanical mixing efficiency and particle densities, sizes, size distributions, and size ratios. Verification of homogeneity is difficult. Also, these mixed oxides can contain virtually every element in the periodic table and can span a wide range of moisture content, bulk density, and Pu-to-U ratio.

RANK (5): Heterogeneous low-level and TRU solid wastes in volumes up through 55-gallon drums. Quantification of nuclear materials in various waste packages, e.g., 1- and 5-gallon paint cans and 30- and 55-gallon drums, is extremely difficult because they typically contain highly heterogeneous materials with diverse matrix and isotopic compositions and widely varying matrix densities.

RANK (6): Pu solution sampling techniques. There is a lack of capability for reliable solution sampling. For gamma-ray-based NDA, the primary sources of variable systematic error (bias) are: the sampling procedures and sample characteristics (e.g., heterogeneity and non-representativeness), sample vial and fill-height variability, sample positioning variability with respect to the assay detector, wide plutonium concentration range (beyond calibration), isotopic non-equilibrium, and solution density and acid normality changes due to sample evaporation, etc.

RANK (7): Nuclear materials item control and verification. Item identification data recorded in a facility's accountability records may include item name, account, material type, seal number, nuclear materials content, and item weight. To meet today's stringent safeguards and safety requirements, it is important that this information, both in the accountability data base and on the item label, be "error free". Improvements needed to reduce the manual transcription-error frequency include automated reading and writing equipment.

Improvements are also needed in current confirmation methods that compare item accountability data-base information with the item label and weight information determined during physical inventory. In particular, periodic weight-confirmation measurements of vault items can cause accountability concerns when weight gains or losses are observed, even for those items for which it is known that significant moisture sorption and desorption are occurring.

To assure that personnel radiation exposures remain as low as reasonably achievable and to minimize personnel access to nuclear materials, techniques developed to provide "error-free" measurements, label generation, and accountability records may require increased remote and automated operation.

RANK (8): Pu bulk solution assay. Problems associated with properly sampling flow lines and tanks could be substantially reduced if total bulk solution assay were possible. In addition, nuclear materials transfers could be confirmed by difference (i.e., bulk solution assay before and after solution transfer at both the sending and receiving tanks).

RANK (9): Neptunium analysis. Improved methods for analysis of Np in solids and solutions are needed for both accountability and process control. Solution process streams can include (1) low Np concentrations (∿100 ppm) with irradiated uranium (∿3 g/l), fission products, and Pu-238 (∿3 g/l); (2) moderate Np concentrations (∿.03 g/l) with irradiated uranium (∿5 g/l), fission products, and low levels of Pu; or (3) high Np concentrations (∿1.5 to 50 g/l) with very low levels of U, Pu, and fission products. Current off-line assay methods include solvent extraction/alpha counting (10-15% precision) and ion exchange/DC argon plasma emission spectrophotometry (1-2% precision). Both methods are hard to control and labor intensive.

RANK (10): Impure and heterogeneous pyrochemical salt residues. This includes spent electrorefining (ER) salts and molten salt extraction (MSE) salts resulting from plutonium metal purification. ER salts have a NaCl/KCl matrix containing Pu shot, $PuCl_3$, and $AmCl_3$, with (1) the Pu and Am distributions mutually heterogeneous, (2) the Pu nominally divided 50/50 between the chloride and shot, and (3) the Am:Pu ratio ∿1200-12,000 ppm at ∿100-500g Pu. MSE salts are very similar to ER salts, except the Pu shot size is typically smaller, and nominally they may contain up to 30 wt% $MgCl_2$, ∿50-500g Pu, and ∿1200-100,000 ppm Am. There are several sources of bias in gamma-ray solids isotopics assay of pyrochemical salt and metal (e.g., spent ER anode) residues. These include: Am summing interferences, isotopic heterogeneity, non-Pu interferences (e.g., U, Np, Am, and Cm), and heterogeneous distributions of Pu and Am. The vast majority of pyrochemical residues have heterogeneous distributions of Pu, Am, and, sometimes, U, Np, and Cm, with Pu ranging from 0-1kg and Am ranging up to several percent.

RANK (11): Holdup and in-process inventory measurements for gloveboxes and canyon floors. Though typically at a low level, accumulation of nuclear materials on glovebox and canyon floors can significantly impact materials balance calculations. Dusting from solids-handling operations and leakage from pipe connections during routine processing and equipment changeout contribute to inventory differences. Methodology to measure or estimate nuclear materials quantities of varying isotopics distributed over large surface areas would represent a substantial benefit to inventory reconciliation/verification practices in plutonium processing facilities across the DOE complex.

RANK (12): Real-time assay of Pu solution waste streams. This includes solution waste streams associated with spent fuel reprocessing that nominally contain small amounts of plutonium. Nondestructive assay techniques potentially offer great benefits over current time-consuming sample handling and analytical chemistry procedures for assuring that plutonium losses are acceptably small. However, a fast, reliable, and accurate gamma-ray-based nondestructive solution assay technique is unavailable.

RANK (13): Impure and heterogeneous scrub alloy and salt strip buttons. Scrub alloy (Pu/Am/Mg/Al) and salt strip (Pu/Am) metal buttons result from Ca metal reduction of MSE salts. These buttons typically have a heterogeneous distribution of Pu and Am and high radiation levels prohibiting routine "hands-on" movement of these containers for assay.

RANK (14): Holdup and in-process inventory measurements in high radiation environments. In spent-fuel reprocessing plants nuclear materials holdup measurements are complicated by the presence of high levels of beta/gamma radiation. The presence of fission products rules out the use of NaI, the most commonly used detector type for holdup measurements. Also, some processes involve large quantities of fluoride and other elements that can yield alpha-induced neutrons which complicate passive neutron measurements.

RANK (15): Pu-238 solids isotopics assay. There is a need for NDA capability to verify the Pu-238 isotopic percent in scrap heat-source oxide shipments and receipts. Currently, the amount of Pu-238 packaged in the standard EP-61 containers is confirmed by high-wattage calorimetry. Shippers' values are used for the Pu isotopics until the material is dissolved. Typically, the Pu-238 is between 80-85%, with Pu-239 about 14% and the other Pu isotopes <1%. A gamma-ray spectrometric method is needed to allow total Pu accountability soon after receipt.

RANK (16): Holdup and in-process inventory measurements involving isotopic variations. Plutonium holdup determination generally employs a measured Pu-239 signal and a nominal isotopic distribution to deduce the total plutonium. This procedure may not be valid with the developing special isotope separation processes that achieve variable plutonium isotopic enrichment distributions.

RANK (17): Impure and heterogeneous electrorefining (ER) heels. Quantification of plutonium by NDA is difficult for spent metal anodes, which nominally contain 1-3kg Pu and essentially all of the elemental impurities introduced via the metal feed ingots to the electrorefining process cell. These spent anodes can have heterogeneous distributions of Th, U, Np, Pu, Am, and Cm, and a stratified layer, or upper "skin", of metallic impurities high in Am.

RANK (18): Heterogeneous low-level and TRU solid wastes in volumes greater than 55-gallon drums. Quantification of nuclear materials in various waste packages larger than 55-gallon drums, e.g., 4' x 4' x 7' plywood boxes, is extremely difficult because they typically contain highly heterogeneous materials with diverse matrix and isotopic compositions and widely varying matrix densities.

RANK (19): Special isotope separation process residues and solid wastes. Improved NDA techniques are essential for quantifying the plutonium in items having heterogeneous and diverse plutonium isotopics as anticipated for the emerging special isotope separation processes. Particularly challenging will be the development of accurate in-line gamma-ray analysis of highly heterogeneous solids isotopics.

RANK (20): Highly radioactive spent-fuel dissolver solutions. Spent-fuel dissolver solutions, which nominally have small quantities of undissolved solids, are highly radioactive, containing U, Pu, and virtually all of the fission products. Isotopic-dilution mass spectrometry is generally employed for accurate and precise Pu determinations, but this technique is highly labor intensive and requires strict sample handling. A fast, reliable, and accurate gamma-ray-based nondestructive solution assay technique is desirable, but unavailable. The primary sources of variable systematic error (bias) for solution NDA are the sampling procedures and sample characteristics.

IV. DISCUSSION OF RESULTS

Figure 1 summarizes the ATEX ranking of the twenty most vital NDA accountability measurement needs within the DOE plutonium community. The data plotted are taken directly from Appendix C. Vertical bars indicate the cumulative site-specific scores for each measurement need in descending order. For reference, the twenty NDA accountability measurement needs are listed below the bar chart.

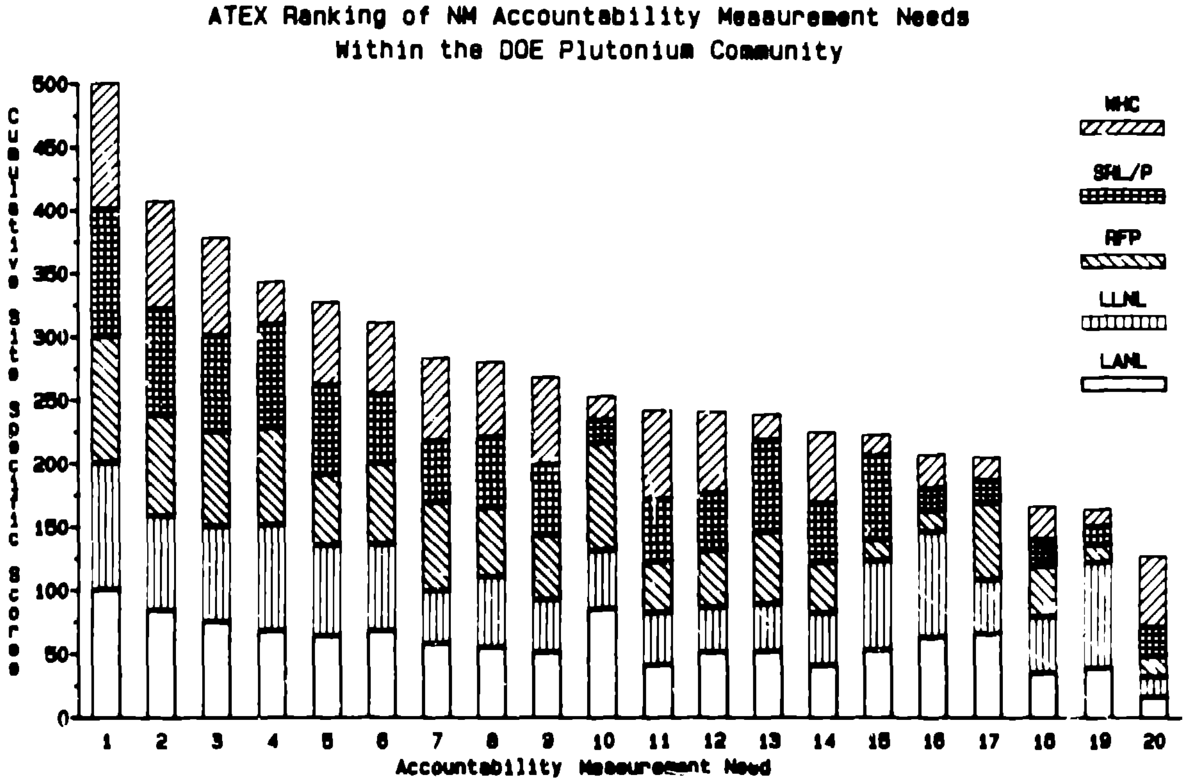
Figure 2 includes five plots, one for each of the DOE sites considered, to display the site-specific scores for the twenty ranked NDA accountability measurement needs relative to the all-site means. The similarity of the measurement-need distributions between the sites illustrates site-wide commonality of the needs and their relative importance. The few significant deviations between individual site-specific scores and all-site means reflect particular process or product concerns at those sites. These deviations are discussed below.

For LANL, three NDA needs (#10, 16, and 17) scored substantially higher than the respective all-site means. This results because of LANL's pyrochemical production support program and, until recently, its special isotope separation program. Some LANL needs scored below the all-site means because of the absence of spent-fuel reprocessing and the associated measurements of highly radioactive solutions and canyon-floor holdup.

For LLNL, three NDA needs (#15, 16, and 19) scored substantially higher than the respective all-site means. This reflects the measurement needs of LLNL's special isotope separation program. Some LLNL needs scored below the all-site means because of LLNL's minimal aqueous and pyrochemical production support activities and associated measurements of in-process inventory and holdup, residues and wastes, and highly radioactive solutions.

For RFP, two NDA needs (#10 and 17) scored substantially higher than the respective all-site means. Like LANL, this results because of RFP's major pyrochemical production program. Two of RFP's NDA needs (#15 and 16) scored substantially below the all-site means because of the absence of high concentrations of the Pu-238 isotope, and the relatively constant isotopic concentrations in weapons-grade plutonium streams.

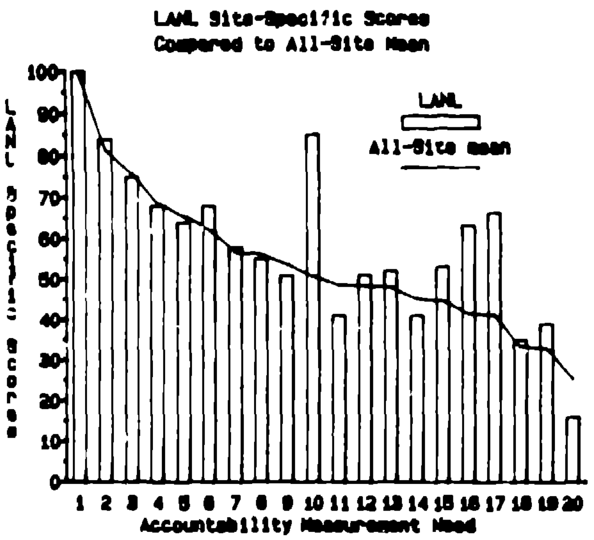
For SRL/P, two NDA needs (#13 and 15) scored substantially higher than the respective all-site means. This reflects SRP's need to (1) verify the plutonium content in scrub alloy shipments from RFP prior to their dissolution and conversion to plutonium metal; and (2) verify the Pu-238 isotopic percent in scrap heat-source oxide shipments and processing.

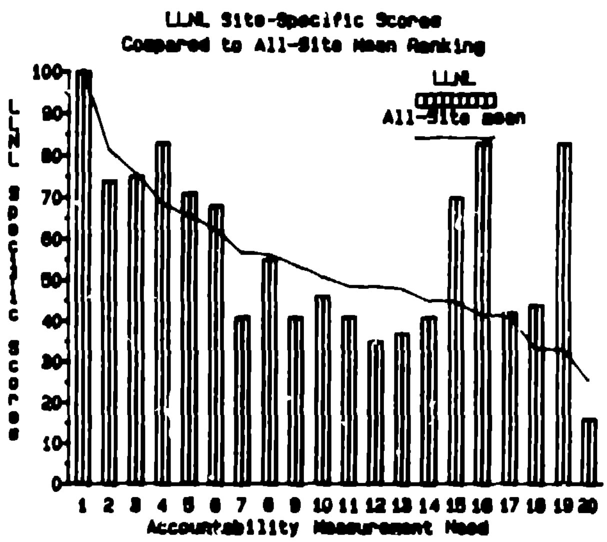


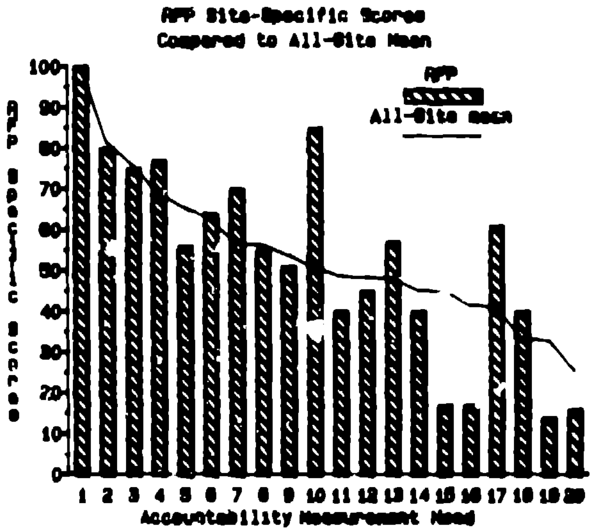
THE TWENTY DOE PU COMMUNITY NDA ACCOUNTABILITY MEASUREMENT NEEDS

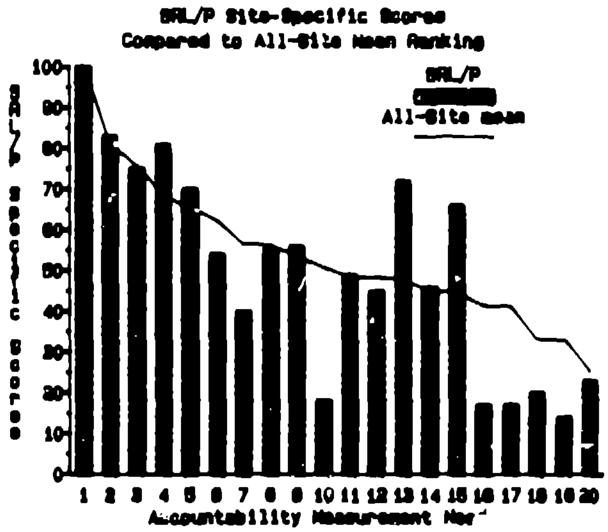
(1) NDA standards representing various nuclear materials and matrix compositions
(2) Impure and often heterogeneous Pu oxides and fluorides
(3) Holdup and in-process inventory measurements for process equipment
(4) Heterogeneous Pu/U mixed oxides
(5) Heterogeneous low-level and TRU solid wastes in volumes up through 55-gallon drums
(6) Pu solution sampling techniques
(7) Nuclear materials item control and verification
(8) Pu bulk solution assay
(9) Neptunium (Np) analysis
(10) Impure and heterogeneous pyrochemical salt residues
(11) Holdup and in-process inventory measurements for gloveboxes and canyon floors
(12) Real-time assay of Pu solution waste streams
(13) Impure and heterogeneous scrub alloy and salt strip buttons
(14) Holdup and in-process inventory measurements in high radiation environments
(15) Pu-238 solids isotopics assay
(16) Holdup and in-process inventory measurements involving isotopic variations
(17) Impure and heterogeneous electrorefining (ER) heels
(18) Heterogeneous low-level and TRU solid wastes in volumes greater than 55-gallon drums
(19) Special isotope separation (SIS) process residues and solid wastes
(20) Highly radioactive spent-fuel dissolver solutions

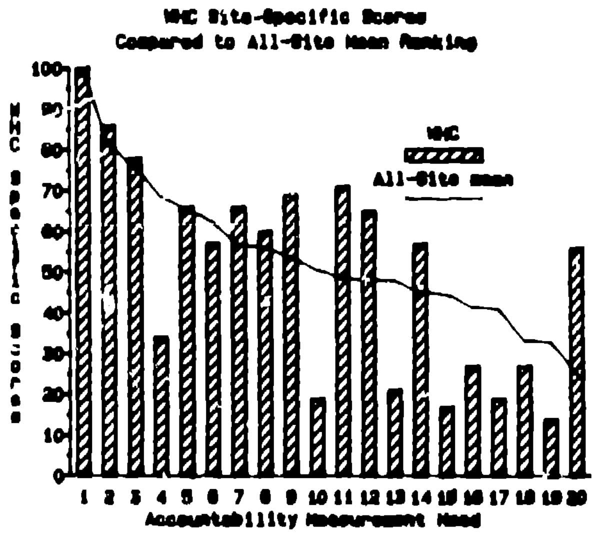
Fig. 1. ATEX ranking of the twenty NDA accountability measurement needs within the DOE Pu community.











THE TWENTY DOE PU COMMUNITY NDA ACCOUNTABILITY MEASUREMENT NEEDS

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(15) Pu-238 solids isotopic assay
(16) Holdup and in-process inventory measurements involving isotopic variations
(17) Impure and heterogeneous electrorefining (ER) heels
(18) Heterogeneous low-level and TRU solid wastes in volumes greater than 55-gallon drums
(19) Special isotope separation (SIS) process residues and solid wastes
(20) Highly radioactive spent-fuel dissolver solutions

Fig. 2. DOE site-specific scores for the twenty NDA accountability measurement needs relative to the all-site means.

Three of SRL/P's NDA needs (#10, 16, and 17) scored substantially below the all-site means because of the absence of pyrochemical production activity and, like RFP, the relatively constant isotopic concentrations in weapons-grade plutonium streams.

For WHC, four NDA needs (#9, 11, 12, and 20) scored substantially higher than the respective all-site means. This reflects WHC's major spent-fuel reprocessing program, which includes highly radioactive dissolver solutions, actinide separation and purification via solvent extraction, and liquid waste streams. Also, measuring attendant plutonium releases on production canyon floors is difficult, disruptive, time consuming, and labor intensive. Finally, many WHC needs scored substantially below the all-site means because of the absence of pyrochemical and Pu-238 production activity, and the relatively constant isotopic concentrations in weapons-grade plutonium streams.

V. SUMMARY AND RECOMMENDATIONS

The ATEX Working Group was established in October 1986 by DOE's Materials Management Executive Committee to identify nuclear materials accountability measurement needs within the DOE plutonium community and to recommend potential improvements. During 1987, the multi-site, multi-disciplinary ATEX "user forum" discussed both site-specific and community-wide accountability measurement problems, available solutions, and technology needs. Following these discussions, each ATEX member sought and identified their individual site measurement needs. We examined this multiplicity of needs and found commonality among many of them. All of these were combined into a list of twenty NDA accountability measurement needs. We then developed a set of criteria and weights that each site used to "score" its own measurement needs. A summary of these weighted scores resulted in a consensus ranking that represents the most pressing NDA accountability measurement needs within the DOE plutonium community.

The NDA accountability measurement needs identified by ATEX span a wide range of problems. The top five needs listed in descending order of importance include:

(1) NDA standards representing various nuclear materials and matrix compositions;

(2) Better NDA measurement technology for impure and often heterogeneous Pu oxides and fluorides;

(3) Better NDA measurement techology for process equipment holdup and in-process inventory;

(4) Better NDA measurement technology for heterogeneous plutonium/uranium mixed oxides; and

(5) Better NDA measurement technology for heterogeneous low-level and TRU solid wastes in container sizes ranging from 1-gallon "paint" cans to 55-gallon drums.

The results of this ATEX study represent a consensus view among the major sites within the DOE plutonium community with respect to NDA accountability measurement needs. We believe that the needs identified and ranked within this report should receive the highest consideration in appropriations for safeguards R&D funding at the earliest possible time. Further, ATEX believes in the value and importance of the "user forum" approach taken to identify and rank NDA accountability measurement needs and believes that this approach may be useful in improving other areas of safeguards. Finally, the ATEX multi-site, multidisciplinary user forum developed the following list of recommendations, which when implemented, can lead to considerable improvements in the NDA technology used to perform nuclear materials control and accountability measurements.

- ATEX should present the results contained in this report to the DOE MMEC.
- ATEX should make similar presentations to the DOE Office of Safeguards and Security R&D Council and to other safeguards and production management personnel within the DOE plutonium community.
- ATEX should submit a paper representing the results of this study to the Journal of the Institute of Nuclear Materials Management.
- ATEX should continue to assess accountability measurement needs within the DOE plutonium community and communicate these as necessary.
- ATEX should pursue additional means to enhance exchange of measurement technology and experience between sites.
- MMEC should consider establishing working groups similar to ATEX to address measurement needs for nuclear materials other than plutonium.
- MMEC should immediately appoint a multi-site, multidisciplinary task force to develop and recommend a program plan for providing the NDA working standards necessary to perform better accountability measurements within the DOE plutonium community.
- MMEC should pursue with appropriate DOE Offices the means to provide adequate funding of R&D efforts that address the highest priority NDA accountability measurement needs as identified in this report.

APPENDIX A

DOE/MMEC ACCOUNTABILITY TECHNOLOGY EXCHANGE (ATEX) WORKING GROUP CHARTER

- Assess the state of nuclear materials accountability measurement practices at DOE/DP plutonium facilities, including their effect on process efficiencies, and recommend improvements that help assure compliance with DOE safeguards regulations;

- Interact with other DOE/DP MMEC technical working groups and recommend a methodology for integrating state-of-the-art nuclear materials accountability measurement practices into existing and emerging process designs;

- Open and maintain effective communications with DOE/OSS personnel; and

- Promote effective integration of safeguards research and development with operational activities.

APPENDIX B

DOE/MMEC ACCOUNTABILITY TECHNOLOGY EXCHANGE (ATEX)
WORKING GROUP MEMBERSHIP

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APPENDIX C

SUMMARY OF NDA ACCOUNTABILITY MEASUREMENT NEEDS WITHIN THE DOE PLUTONIUM COMMUNITY

Problem Rank	(Area)*	Site-Specific Normalized Scores (100 Max.) LANL	LLNL	RFP	SRL/P	WHC	Cumulative Scores SUM	Mean
1	(I)	100	100	100	100	100	500	100
2	(II)	84	74	80	83	86	407	81
3	(IV)	75	75	75	75	78	378	76
4	(II)	68	83	77	81	34	343	69
5	(II)	64	71	56	70	66	327	65
6	(III)	68	68	64	54	57	311	62
7	(V)	58	41	70	48	66	283	57
8	(III)	55	55	55	55	60	280	56
9	(II)	51	41	51	56	69	268	54
10	(II)	85	46	85	18	19	253	51
11	(IV)	41	41	40	49	71	242	48
12	(II)	51	35	45	45	65	241	48
13	(II)	52	37	57	72	21	239	48
14	(IV)	41	41	40	46	57	225	45
15	(III)	53	70	17	66	17	223	45
16	(IV)	63	83	17	17	27	207	41
17	(II)	66	42	61	17	19	205	41
18	(II)	35	44	40	20	27	166	33
19	(II)	39	83	14	14	14	164	33
20	(II)	16	16	16	23	56	127	25

*Problem Area Definitions:

I NDA "standards" representing various nuclear materials and matrix compositions

II Impure nuclear materials compounds, residues, and wastes

III Product-grade nuclear materials

IV Nuclear materials process holdup and in-process inventory

V Nuclear materials item control and verification

APPENDIX D

NUCLEAR MATERIALS NDA ACCOUNTABILITY MEASUREMENT NEEDS
WITHIN THE DOE PLUTONIUM COMMUNITY

Criterion: (Weight):		Crit./Rad. Safety (10)		ID & LEID (10)		S/R Diff. (10)		Common-ality (9)		Tech. Feas. & Cost Eff. (8)		Process Benefit (6)		Political Sensitivity (5)		Present vs. Future (3)		Site Totals	
Rank (Prob. Area): NDA Need	Site	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	Wt'd Score	Normal Score
1(I):NDA standards representing various nuclear materials and matrix compositions	LANL	(ALL SITES SCORED HIGHEST POSSIBLE)																610	100
	LLNL																	610	100
	RFP																	610	100
	SRL/P																	610	100
	WHC																	610	100
2(II):Impure and often heterogeneous Pu oxides and fluorides.	LANL	6	60	10	100	10	100	10	90	9	72	4	24	7	35	10	30	511	84
	LLNL	3	30	9	90	9	90	10	90	9	72	3	18	6	30	10	30	450	74
	RFP	6	60	10	100	9	90	10	90	9	72	3	18	6	30	10	30	490	80
	SRL/P	6	60	9	90	10	100	10	90	9	72	4	24	8	40	10	30	506	83
	WHC	8	80	9	90	9	90	10	90	9	72	5	30	9	45	10	30	527	86
3(IV):Holdup and in-process inventory measurements for process equipment.	LANL	9	90	9	90	1	10	10	90	5	40	10	60	10	50	10	30	460	75
	LLNL	9	90	9	90	1	10	10	90	5	40	10	60	10	50	10	30	460	75
	RFP	9	90	9	90	1	10	10	90	5	40	10	60	10	50	10	30	460	75
	SRL/P	9	90	9	90	1	10	10	90	5	40	10	60	10	50	10	30	460	75
	WHC	9	90	10	100	1	10	10	90	6	48	10	60	10	50	10	30	478	78
4(II):Heterogeneous Pu/U mixed oxides.	LANL	6	60	6	60	8	80	10	90	4	32	7	42	7	35	6	18	417	68
	LLNL	7	70	8	80	9	90	10	90	7	56	8	48	9	45	9	27	506	83
	RFP	7	70	6	60	9	90	10	90	6	48	8	48	7	35	10	30	471	77
	SRL/P	7	70	8	80	9	90	10	90	6	48	9	54	7	35	10	30	497	81
	WHC	4	40	3	30	1	10	10	90	1	8	1	6	1	5	6	18	207	34
5(II):Heterogeneous low-level and TRU solid wastes in volumes up through 55-gallon drums.	LANL	7	70	9	90	1	10	10	90	5	40	7	42	6	30	7	21	393	64
	LLNL	6	60	8	80	2	20	10	90	8	64	9	54	7	35	10	30	433	71
	RFP	6	60	7	70	1	10	10	90	5	40	7	42	3	15	5	15	342	56
	SRL/P	7	70	9	90	1	10	10	90	8	64	7	42	7	35	8	24	425	70
	WHC	6	60	8	80	2	20	10	90	7	56	6	36	7	35	8	24	401	66
6(III):Pu solution sampling techniques.	LANL	3	30	10	100	1	10	10	90	9	72	6	36	9	45	10	30	413	68
	LLNL	3	30	10	100	1	10	10	90	9	72	6	36	9	45	10	30	413	68
	RFP	3	30	8	80	1	10	10	90	9	72	6	36	9	45	10	30	393	64
	SRL/P	3	30	4	40	1	10	10	90	9	72	6	36	4	20	10	30	328	54
	WHC	3	30	5	50	1	10	10	90	9	72	6	36	6	30	10	30	348	57

NUCLEAR MATERIALS NDA ACCOUNTABILITY MEASUREMENT NEEDS
WITHIN THE DOE PLUTONIUM COMMUNITY

Criterion: (Weight):		Crit./Rad. Safety (10)		ID & LEID (10)		S/R Diff. (10)		Common-ality (9)		Tech. Feas. & Cost Eff. (8)		Process Benefit (6)		Political Sensitivity (5)		Present vs. Future (3)		Site Totals	
Rank (Prob. Area): NDA Need	Site	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	1-10 Score	Wt'd Score	Wt'd Score	Normal Score
7(V): Nuclear materials item control and verification.	LANL	6	60	1	10	1	10	10	90	7	56	10	60	7	35	10	30	351	58
	LLNL	2	20	2	20	1	10	10	90	3	24	2	12	9	45	10	30	251	41
	RFP	6	60	10	100	1	10	10	90	3	24	10	60	10	50	10	30	424	70
	SRL/P	5	50	1	10	1	10	10	90	3	24	7	42	7	35	10	30	291	48
	WHC	6	60	8	80	1	10	10	90	6	48	8	48	7	35	10	30	401	66
8(III): Pu bulk solution assay.	LANL	3	30	10	100	1	10	10	90	1	8	10	60	1	5	10	30	333	55
	LLNL	3	30	10	100	1	10	10	90	1	8	10	60	1	5	10	30	333	55
	RFP	3	30	10	100	1	10	10	90	1	8	10	60	1	5	10	30	333	55
	SRL/P	3	30	10	100	1	10	10	90	1	8	10	60	1	5	10	30	333	55
	WHC	5	50	10	100	1	10	10	90	2	16	10	60	2	10	10	30	366	60
9(II): Neptunium analysis.	LANL	1	10	5	50	5	50	10	90	9	72	2	12	2	10	6	18	312	51
	LLNL	1	10	3	30	3	30	10	90	7	56	2	12	2	10	5	15	253	41
	RFP	1	10	5	50	5	50	10	90	9	72	2	12	2	10	5	15	309	51
	SRL/P	1	10	10	100	5	50	10	90	5	40	2	12	3	15	9	27	344	56
	WHC	1	10	9	90	9	90	10	90	5	40	6	36	8	40	8	24	420	69
10(II): Impure and heterogeneous pyro-chemical salt residues.	LANL	8	80	10	100	10	100	6	54	7	56	9	54	9	45	10	30	519	85
	LLNL	3	30	3	30	3	30	6	54	6	48	7	42	3	15	10	30	279	46
	RFP	8	80	10	100	10	100	6	54	7	56	9	54	9	45	10	30	519	85
	SRL/P	1	10	1	10	1	10	6	54	1	8	1	6	1	5	3	9	112	18
	WHC	1	10	1	10	1	10	6	54	1	8	1	6	1	5	4	12	116	19
11(IV): Holdup and in-process inventory measurements for gloveboxes and canyon floors.	LANL	2	20	2	20	1	10	10	90	7	56	2	12	3	15	10	30	253	41
	LLNL	2	20	2	20	1	10	10	90	7	56	2	12	3	15	10	30	253	41
	RFP	2	20	2	20	1	10	10	90	5	40	3	18	3	15	10	30	243	40
	SRL/P	5	50	6	60	1	10	10	90	3	24	3	18	3	15	10	30	297	49
	WHC	8	80	9	90	1	10	10	90	4	32	9	54	9	45	10	30	431	71
12(II): Real-time assay of Pu solution waste streams.	LANL	7	70	1	10	1	10	10	90	5	40	9	54	2	10	10	30	314	51
	LLNL	3	30	1	10	1	10	10	90	3	24	2	12	2	10	10	30	216	35
	RFP	3	30	1	10	1	10	10	90	5	40	9	54	2	10	10	30	274	45
	SRL/P	3	30	1	10	1	10	10	90	5	40	9	54	2	10	10	30	274	45
	WHC	5	50	8	80	1	10	10	90	8	64	8	48	5	25	10	30	397	65

NUCLEAR MATERIALS NDA ACCOUNTABILITY MEASUREMENT NEEDS
WITHIN THE DOE PLUTONIUM COMMUNITY

Criterion: (Weight): Rank (Prob. Area): NDA Need	Site	Crit./Rad. Safety (10) 1-10 Score	Crit./Rad. Safety (10) Wt'd Score	ID & LEID (10) 1-10 Score	ID & LEID (10) Wt'd Score	S/R Diff. (10) 1-10 Score	S/R Diff. (10) Wt'd Score	Commonality (9) 1-10 Score	Commonality (9) Wt'd Score	Tech. Feas. & Cost Eff. (8) 1-10 Score	Tech. Feas. & Cost Eff. (8) Wt'd Score	Process Benefit (6) 1-10 Score	Process Benefit (6) Wt'd Score	Political Sensitivity (5) 1-10 Score	Political Sensitivity (5) Wt'd Score	Present vs. Future (3) 1-10 Score	Present vs. Future (3) Wt'd Score	Site Totals Wt'd Score	Site Totals Normal Score
13(II): Impure and heterogeneous scrub alloy and salt strip buttons.	LANL	3	30	10	100	1	10	8	72	5	40	3	18	3	15	10	30	315	52
	LLNL	3	30	1	10	1	10	8	72	5	40	3	18	3	15	10	30	225	37
	RFP	3	30	1	10	10	100	8	72	5	40	3	18	10	50	10	30	350	57
	SRL/P	3	30	10	100	10	100	8	72	5	40	3	18	10	50	10	30	440	72
	WHC	1	10	1	10	1	10	8	72	1	8	1	6	1	5	3	9	130	21
14(IV): Holdup and in-process inventory measurements in high radiation environments.	LANL	2	20	3	30	1	10	10	90	4	32	4	24	3	15	10	30	251	41
	LLNL	2	20	3	30	1	10	10	90	4	32	4	24	3	15	10	30	251	41
	RFP	2	20	2	20	1	10	10	90	4	32	4	24	3	15	10	30	241	40
	SRL/P	5	50	4	40	1	10	10	90	3	24	4	24	3	15	10	30	283	46
	WHC	5	50	6	60	1	10	10	90	6	48	6	36	5	25	10	30	349	57
15(III): Pu-238 solids isotopics assay.	LANL	1	10	3	30	10	100	6	54	9	72	1	6	6	30	8	24	326	53
	LLNL	3	30	8	80	8	80	6	54	8	64	8	48	8	40	10	30	426	70
	RFP	1	10	1	10	1	10	6	54	1	8	1	6	1	5	1	3	106	17
	SRL/P	1	10	9	90	10	100	6	54	9	72	3	18	6	30	9	27	401	66
	WHC	1	10	1	10	1	10	6	54	1	8	1	6	1	5	1	3	106	17
16(IV): Holdup and in-process inventory measurements involving isotopic variations.	LANL	9	90	10	100	1	10	6	54	2	16	10	60	7	35	7	21	386	63
	LLNL	9	90	10	100	8	80	6	54	7	56	9	54	9	45	10	30	509	83
	RFP	1	10	1	10	1	10	6	54	1	8	1	6	1	5	1	3	106	17
	SRL/P	1	10	1	10	1	10	6	54	1	8	1	6	1	5	1	3	106	17
	WHC	1	10	3	30	1	10	6	54	2	16	2	12	2	10	8	24	166	27
17(II): Impure and heterogeneous electrorefining heels.	LANL	3	30	8	80	10	100	6	54	7	56	3	18	7	35	10	30	403	66
	LLNL	2	20	3	30	3	30	6	54	6	48	2	12	6	30	10	30	254	42
	RFP	3	30	5	50	10	100	6	54	7	56	3	18	7	35	10	30	373	61
	SRL/P	1	10	1	10	1	10	6	54	1	8	1	6	1	5	1	3	106	17
	WHC	1	10	1	10	1	10	6	54	1	8	1	6	1	5	4	12	115	19
18(II): Heterogeneous low-level and TRU solid wastes in volumes greater than 55-gallon drums.	LANL	3	30	2	20	1	10	8	72	4	32	1	6	5	25	7	21	216	35
	LLNL	3	30	5	50	2	20	8	72	4	32	2	12	5	25	10	30	271	44
	RFP	3	30	4	40	1	10	8	72	4	32	1	6	5	25	10	30	245	40
	SRL/P	1	10	1	10	1	10	8	72	1	8	1	6	1	5	1	3	124	20
	WHC	3	30	2	20	1	10	8	72	1	8	1	6	2	10	2	6	162	27

NUCLEAR MATERIALS NDA ACCOUNTABILITY MEASUREMENT NEEDS
WITHIN THE DOE PLUTONIUM COMMUNITY

Rank (Prob. Area): NDA Need	Site	Crit./Rad. Safety (10) 1-10 Score	Crit./Rad. Safety (10) Wt'd Score	ID & LEID (10) 1-10 Score	ID & LEID (10) Wt'd Score	S/R Diff. (10) 1-10 Score	S/R Diff. (10) Wt'd Score	Commonality (9) 1-10 Score	Commonality (9) Wt'd Score	Tech. Feas. & Cost Eff. (8) 1-10 Score	Tech. Feas. & Cost Eff. (8) Wt'd Score	Process Benefit (6) 1-10 Score	Process Benefit (6) Wt'd Score	Political Sensitivity (5) 1-10 Score	Political Sensitivity (5) Wt'd Score	Present vs. Future (3) 1-10 Score	Present vs. Future (3) Wt'd Score	Site Totals Wt'd Score	Site Totals Normal Score
19(II):Special isotope separation process residues and solid wastes.	LANL	5	50	3	30	1	10	4	36	3	24	10	60	2	10	5	15	235	39
	LLNL	8	80	9	90	9	90	4	36	9	72	10	60	10	50	10	30	508	83
	RFP	1	10	1	10	1	10	4	36	1	8	1	6	1	5	1	3	88	14
	SRL/P	1	10	1	10	1	10	4	36	1	8	1	6	1	5	1	3	88	14
	WHC	1	10	1	10	1	10	4	36	1	8	1	6	1	5	1	3	88	14
20(II):Highly radioactive spent-fuel dissolver solutions.	LANL	1	10	1	10	1	10	5	45	1	8	1	6	1	5	1	3	97	16
	LLNL	1	10	1	10	1	10	5	45	1	8	1	6	1	5	1	3	97	16
	RFP	1	10	1	10	1	10	5	45	1	8	1	6	1	5	1	3	97	16
	SRL/P	2	20	1	10	1	10	5	45	3	24	4	24	1	5	1	3	141	23
	WHC	5	50	9	90	1	10	5	45	8	64	8	48	2	10	9	27	344	56