Joint US-China Integrated Nuclear Materials Management Technology Demonstration Workshop

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US Participants:

DOE/NNSA: NA-243 and NA-25
Los Alamos National Laboratory
Livermore National Laboratory
Sandia National Laboratories
Oak Ridge National Laboratory

U.S. Presentation Title:

Integrated Nondestructive Assay (NDA) Measurement Approach for a Facility

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Integrated Nondestructive Assay (NDA) Measurement Approach for a Facility

- **Purpose**
  - **To demonstrate how the integration and application of NDA measurement methods and systems enhance comprehensive safeguards for a facility**

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Applicability of NDA Methods to a Facility

- **NDA measurements provide support to nuclear material management efforts**
  - **Important element of the facility security plan**
  - **Essential sub-element of a nuclear materials control plan**
- **NDA methods are tailored to the regulatory and process requirements**
  - **Must meet regulatory detection limits for facility design and throughput**
  - **Integration of stationary measurement systems**
  - **Portable systems designed to take the analytical technique to the material**

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Design and Integration

- **Process, storage, and security issues must be understood to effectively integrate NDA methods and instrumentation into a comprehensive safeguards approach for the facility**
  - **Process flows and material types**
    - **Identification of key measurement points**
  - **System status: Dynamic vs. Static Storage**
  - **Diversion paths need to be evaluated**
    - **Personnel ingress/egress routes**
    - **Equipment ingress/egress routes**
    - **Waste stream evaluation**

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NDA Methods Application

- **Designed to meet the needs of the facility security plan**
  - **May require installation of stationary radiation monitors**
    - **Gamma and neutron**
  - **May require the use of hand-held instrumentation**
    - **Detailed surveys of items before removal from the facility**
    - **Capability to identify isotopes for items that exceed a threshold value**
  - **Requires that personnel are trained and knowledgeable**
    - **NDA equipment limitations and detection capabilities**
    - **Potential for shielding and removing nuclear material**
    - **Understand procedures for responding to anomalous situations**

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NDA Methods Application

- **Designed to meet the needs of the nuclear material control plan**
  - **Personnel are trained on the use and limitations of NDA instrumentation**
  - **Procedures are in place that provide instruction on use of the NDA systems**
  - **Selected NDA instrumentation is designed to meet detection limit criteria**
  - **Effective quality assurance and quality control measures are in place**

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NDA Methods Application

- **Process variables impact the NDA method selected for a facility**
  - **Process material being evaluated**
    - **Physical form – metals, powders, solutions**
    - **Chemical form – elemental, oxides, fluorides**
    - **Radionuclide distribution within a matrix**
    - **Isotopic homogeneity**
    - **Secular equilibrium**
    - **Geometry**
    - **Containerized versus in situ**

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NDA Methods Application

- **Selected NDA techniques and instrumentation are dependent upon level of characterization**
  - **Initial characterization is more detailed and must be traceable**
    - **Equipment calibrated using primary traceable standards**
    - **Can involve longer assay times**
    - **Designed to achieve the lowest level of measurement uncertainty**
  - **Confirmation or Verification**
    - **Measurement repeated on a previously characterized sample**
    - **Must verify that the container/item contents have not been disturbed**

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Other Factors that Impact the Selection of NDA Equipment for a Facility

- **Selected NDA equipment should function in a cost effective and efficient manner**
  - **Ambient affects**
    - **Temperature, dust, humidity, vibration, electromagnetic interference**
  - **Extraneous radiation**
    - **Radiation from surrounding areas of the process**
    - **Instrumentation should be properly shielded**
    - **Can effect detection limits**
  - **Budget**
    - **More accurate measurements typically involve purchasing more expensive equipment**
    - **Availability – Off-the-shelf versus in-house design**

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Selecting the Proper NDA System

- **Qualitative Techniques**
  - **Gross Gamma and Neutron Surveys**
    - **Portal monitoring**
    - **Process monitoring**
- **Relative Techniques**
  - **Gamma Analysis**
    - **Uranium enrichment**
    - **Medium resolution (CdTe, CdZnTe) systems**
      - **U and Pu isotopics**
    - **High resolution (Ge) gamma spectrometry**
      - **U and Pu isotopics**
      - **Multi group analysis algorithms**

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Selecting the Proper NDA System

- **Quantitative Techniques**
  - **Gamma Analysis continued**
    - **Activity/Mass determination using portable systems**
      - **Efficiency modeling (ISOCS, IsoCart)**
      - **Must account for attenuation effects**
        - » **Use of external transmission source**
        - » **Iterative solution using multiple energy lines**
    - **Activity/Mass determination using stationary systems**
      - **Transmission corrected systems (SGS, TGS)**
      - **Less susceptible to heterogeneities**
      - **Linear mass calibrations**
      - **Efficiency modeling being evaluated**

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Selecting the Proper NDA System

- **Quantitative Techniques**
  - **Passive Neutron Analysis (HLNCC, HLNCC II, Slab detector)**
    - **Single, coincident, and total neutrons**
    - **Dependent upon chemical form**
      - **U and Pu compounds with F and O**
    - **Dependent upon isotopic content, decay mechanisms**
  - **Active Neutron Analysis (^{252}Cf Shuffler, AWCC, Neutron Coincidence Collar, Spent Fuel Monitor, Rod Scanner)**
    - **Uses an external source**
    - **Matrix and moderator dependent**
    - **Calibrations standards can be an issue**

Neutron Slab Detector

^{252}Cf Shuffler

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Selecting the Proper NDA System

- **Calorimetry**
  - **Analysis of entire container which removes sampling errors**
  - **Independent of geometry**
  - **Matrix independent**
  - **Not susceptible to inhomogeneous distributions of the radionuclide**
  - **Can assay a wide range of material forms**
  - **Useful for containerized samples**
  - **Calibration is traceable**
  - **Accuracies are comparable to destructive analysis but do not include sampling errors**
  - **Analysis is dependent upon isotopic distribution**
  - **Mass spectrometry or gamma spectrometry is needed to quantify mass**

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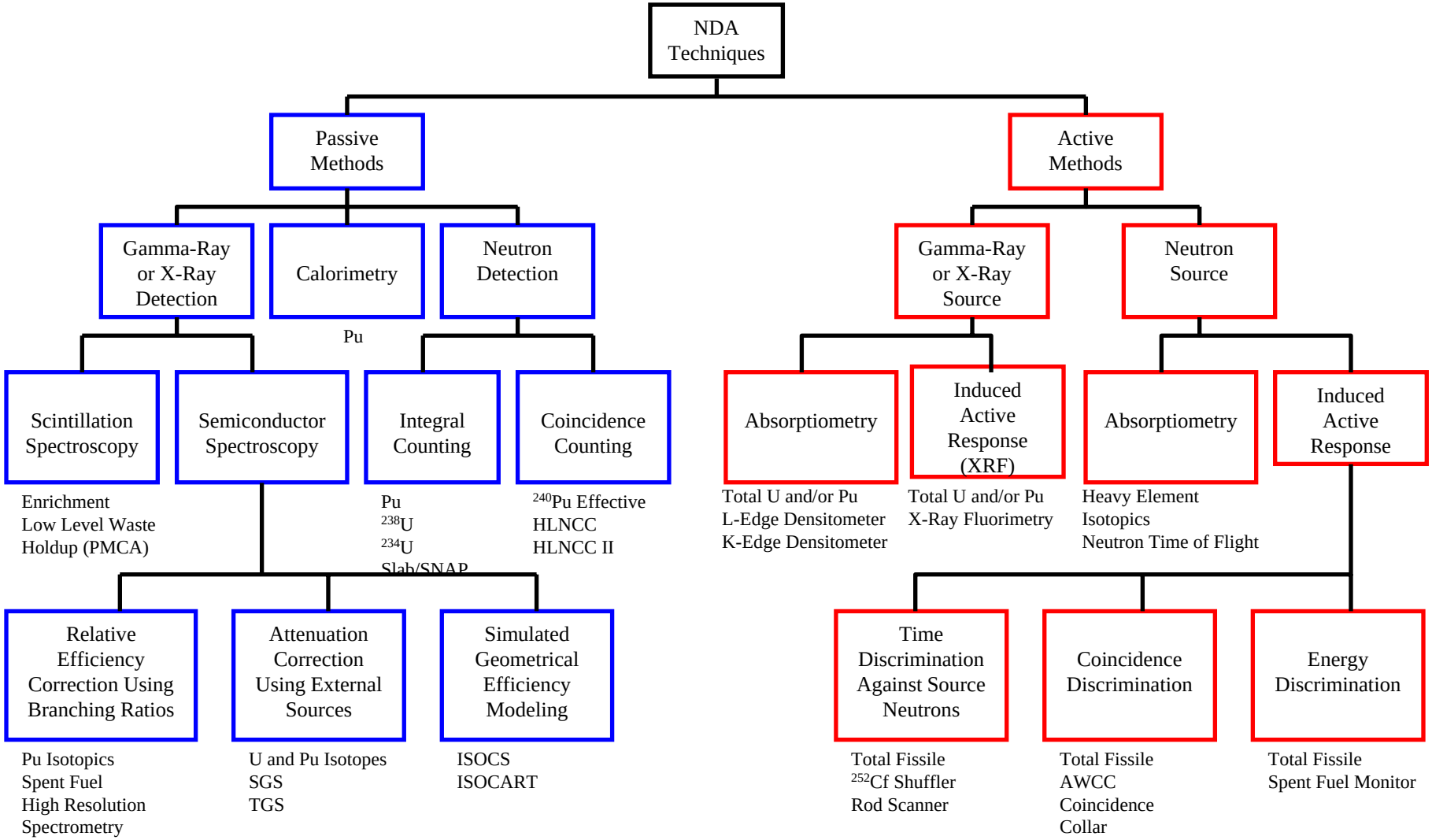
NDA Methods Chart



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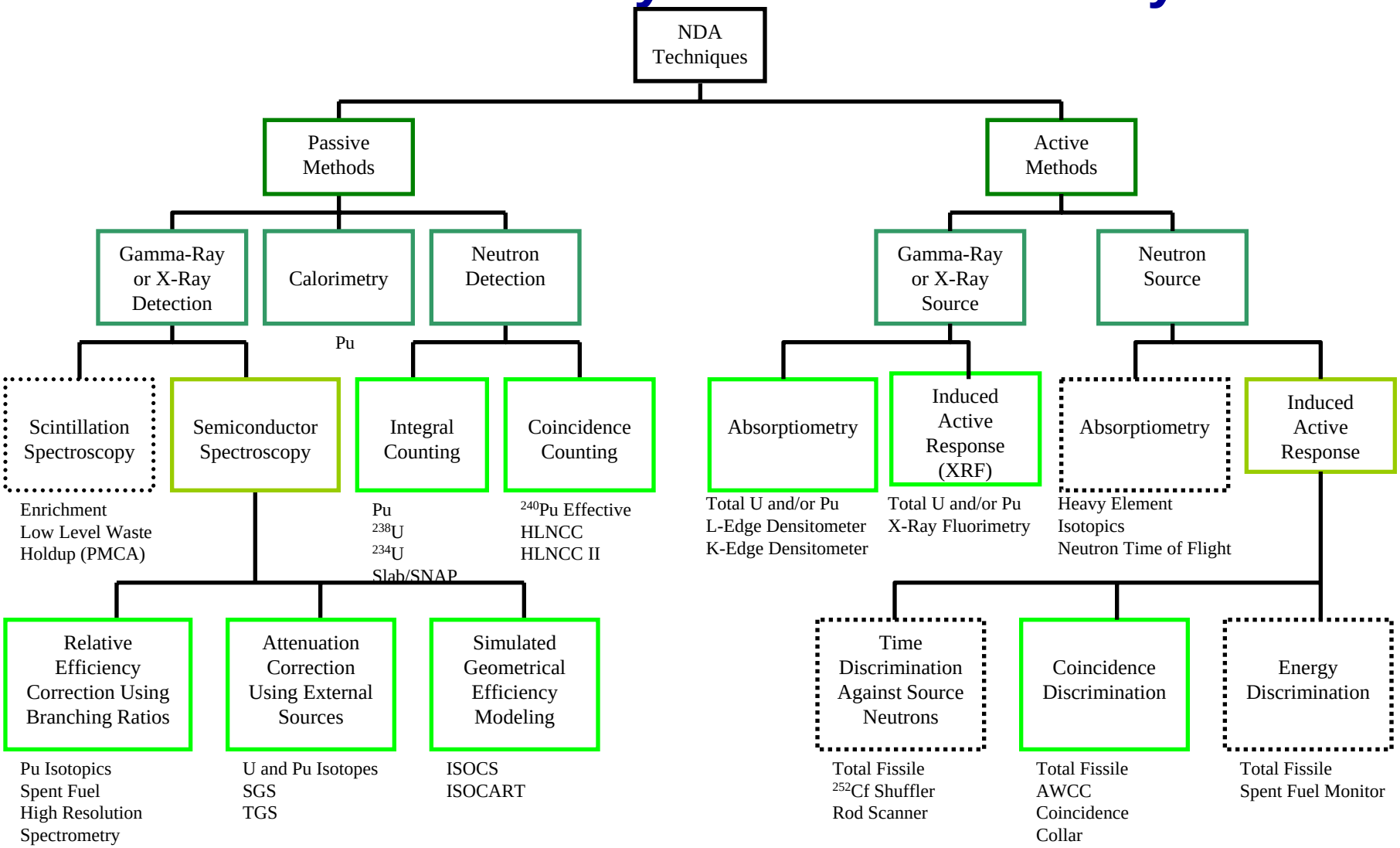
Methods Commonly Used for Pu Analysis



Green boxes with various shading indicates a commonly used technique

Dashed box indicates technique is not commonly used

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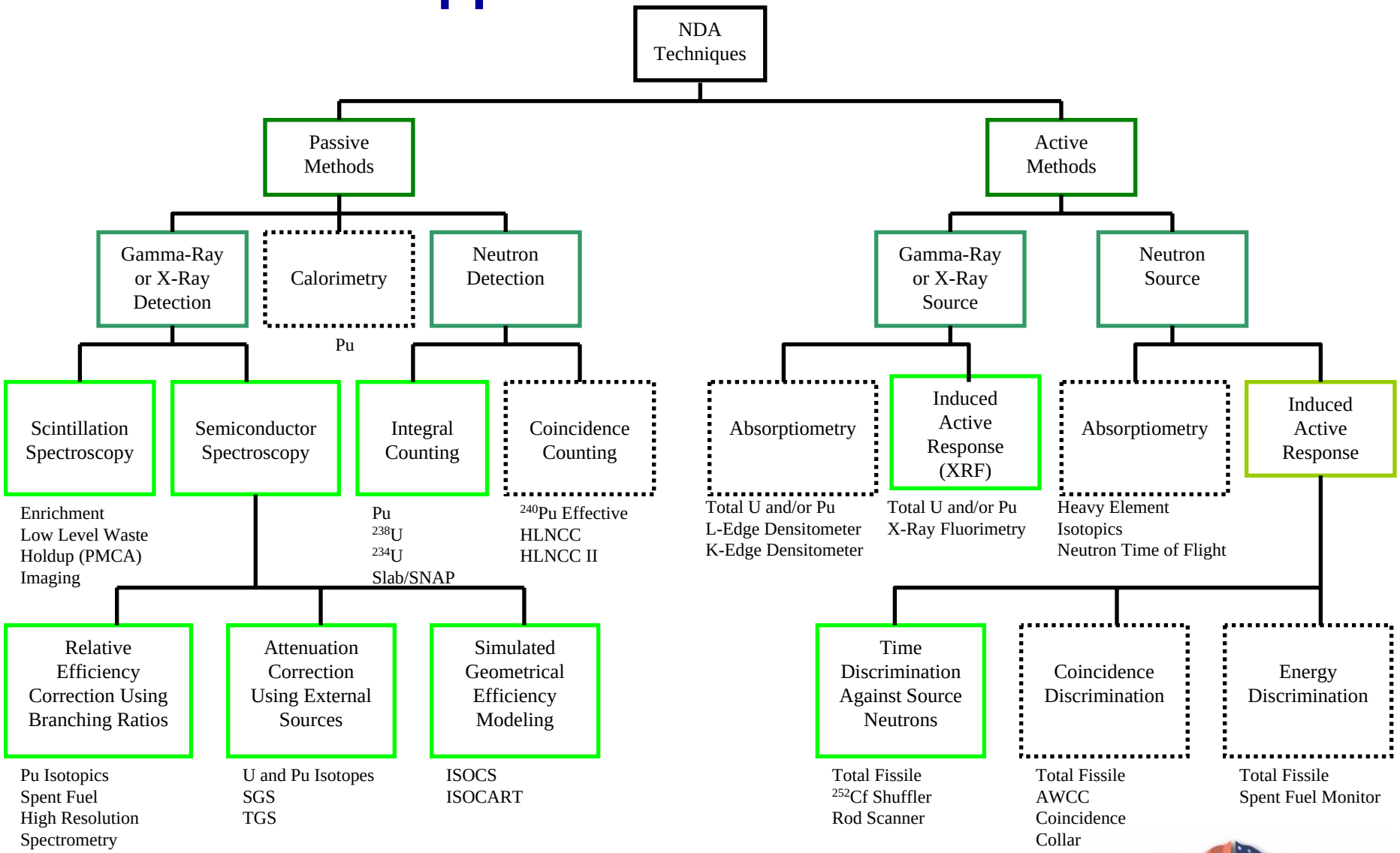
NDA Support for US Diffusion Plant



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NDA Support for a US Diffusion Plant

- NDA support utilizes gamma and neutron measurement techniques
- Two NDA labs on site
  - ^{252}Cf Shufflers, SGS, B-25 Box Analyzers
- Suite of portable instrumentation
  - Holdup measurement systems
    - Passive neutron slab detector
    - Portable quantitative gamma analysis systems
  - Isotopic analysis systems
  - Confirmatory carts
  - Mobile waste assay systems
    - Transmission corrected gamma and passive neutron
  - Gamma ray imaging capabilities

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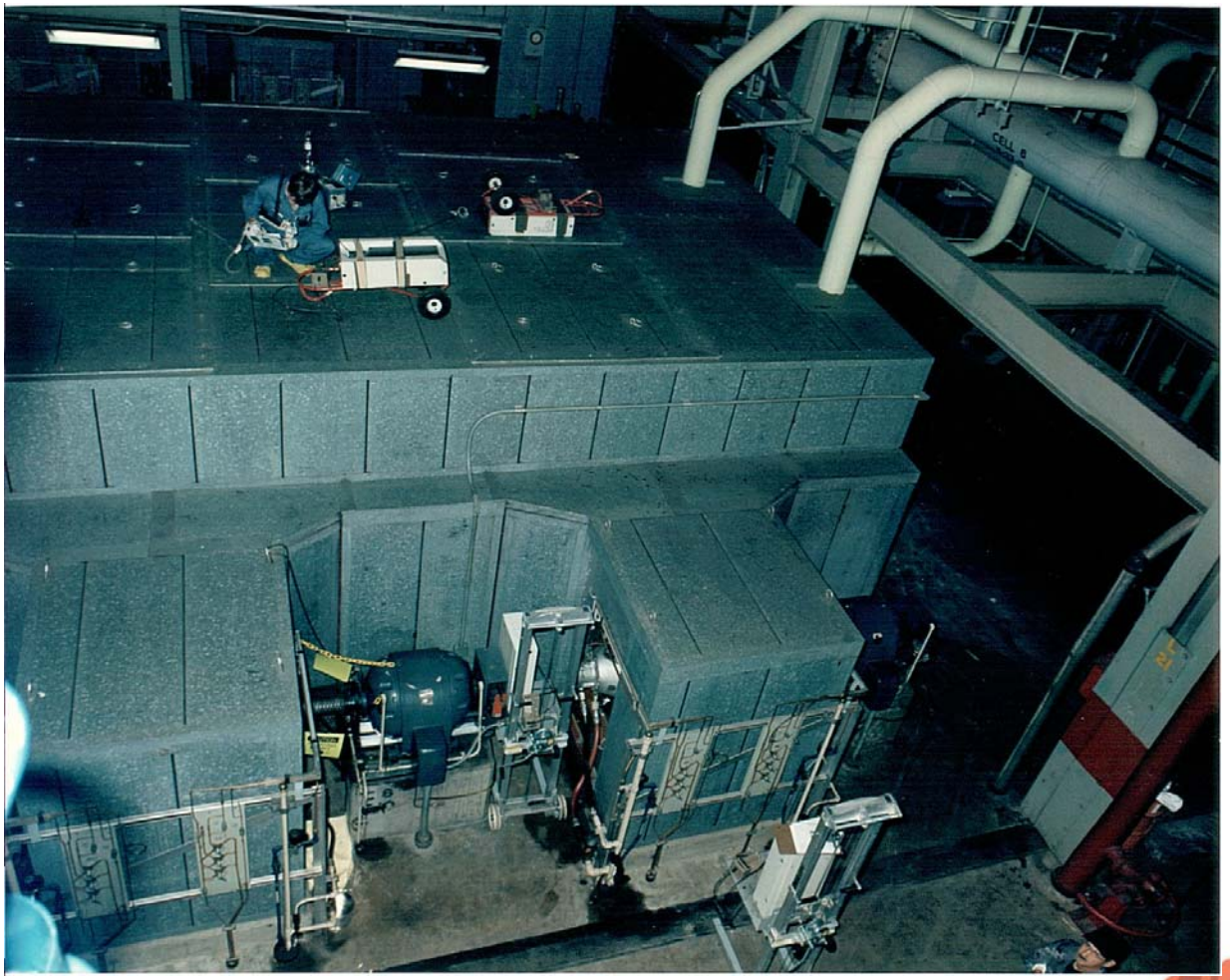
Passive Neutron Measurements of a Diffusion Cascade



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Gamma Ray Image of Cascade Header

Gamma Ray Imaging System

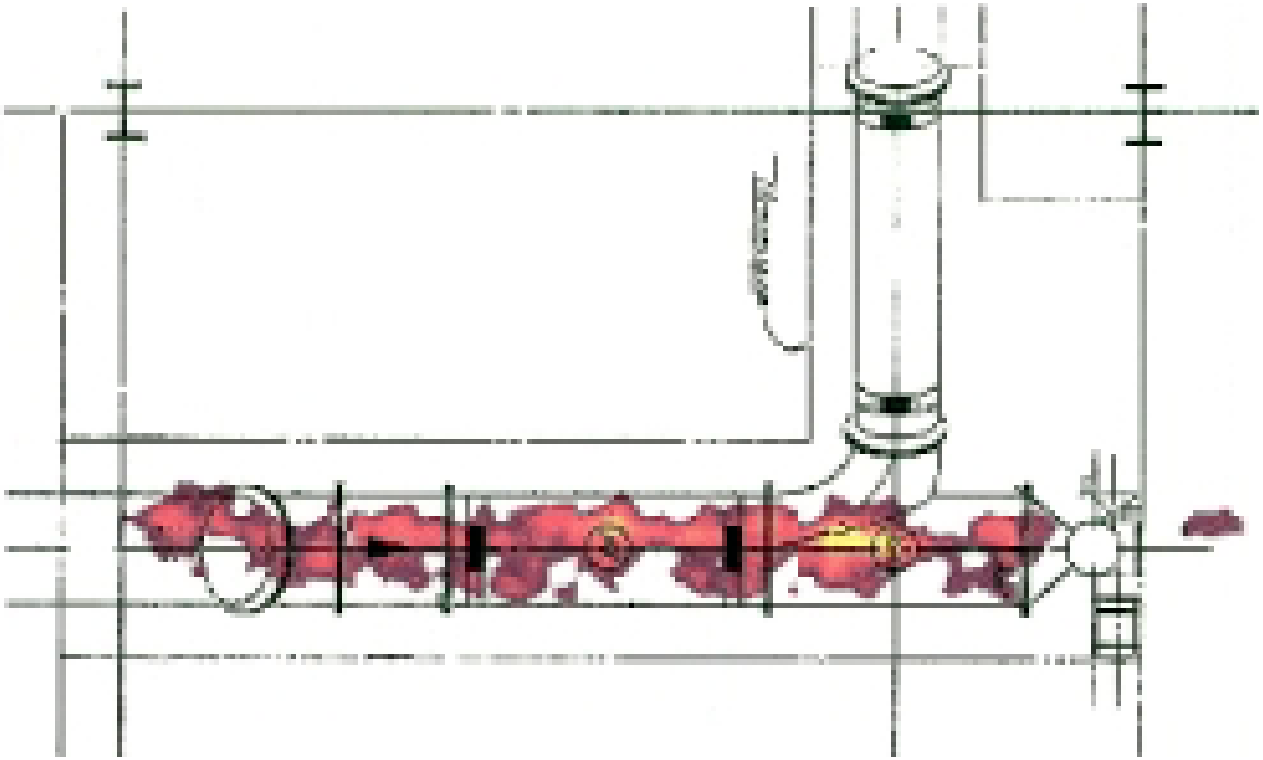

Image of deposit in Piping

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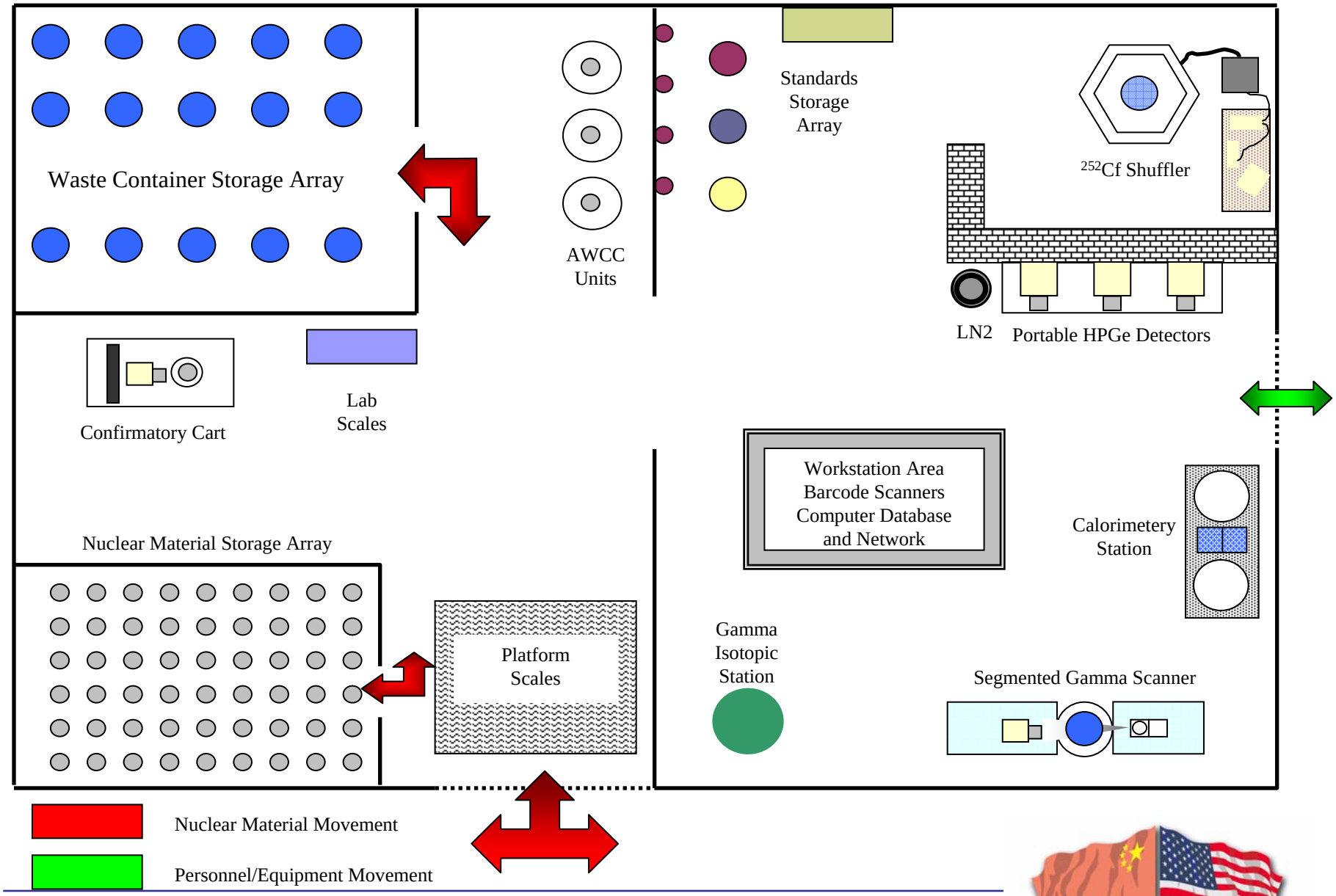
Conceptual Layout of a Nondestructive Assay Laboratory



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Conclusion

- **Integration and application of NDA systems into a facility nuclear material management program can significantly enhance comprehensive safeguards for the facility**
- **NDA systems enhance the application of Physical Protection capabilities**
- **NDA methods and applications are an essential component of the material control and accountability process for the facility**
- **Technological advancements for NDA systems are expanding applicability and improving measurement uncertainties**

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