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Multi-aspect System for Measurement of Attributes of Fissile Materials and Explosives

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

- Multi-aspect System for Measurement of Attributes of Fissile Materials and Explosives (MAMS) is a product of the cooperation between Sandia National Laboratories (SNL) and the Russian Federal Nuclear Center All-Russian Research Institute of Theoretical Physics (RFNC-VNIITF) under the auspices of the U.S.-Russia Warhead Safety and Security Exchange (WSSX) Agreement.
- MAMS is intended for determining the major attributes of fissile materials (FM), such as uranium and plutonium, and high explosives (HE) in a package while assuring security of sensitive data.
- This project belongs to the area of development of technologies to enhance the safety and security of nuclear warheads (NW) and the materials composing them.
- A number of state-of-the-art radiation measurement techniques were incorporated into the MAMS design.

SNL Requirements for Measured Attributes

Measured Attributes:

- the presence of plutonium
- the quality of the plutonium, which is based on the $^{240}Pu/^{239}Pu$ isotope ratio
- the mass of plutonium (exceeding the threshold value)
- the presence of highly enriched uranium (HEU)
- the enrichment of uranium
- the mass of uranium (exceeding the threshold value)
- the presence of HE
- the mass of HE (exceeding the threshold value)

Measurement Techniques and Hardware of the First MAMS Prototype

#	Measured Attributes	Measurement Technique	Measurement Equipment
1.	Presence of Plutonium	High-resolution gamma spectrometry in the 630-670 keV energy region. Recording in the Pu radiation spectrum.	Gamma spectrometer with HPGe detector
2.	Quality of Plutonium	High-resolution gamma spectrometry in the 630-670 keV energy region. Comparison between 240Pu and 239Pu line intensities.	Gamma spectrometer with HPGe detector
3.	Mass of Plutonium	Detection of neutron flux and comparison of measured count rate versus threshold.	Sensitive neutron detector

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Measurement Techniques (continued)

#	Measured Attributes	Measurement Technique	Measurement Equipment
4.	Presence of Uranium	High-resolution gamma spectrometry. Finding 185.7-keV and 1001-keV peaks in the gamma spectrum.	Gamma spectrometer
5.	Enrichment of Uranium	Gamma spectrometry. Finding a 2614-keV peak above background in the gamma spectrum.	Gamma spectrometer with HPGe detector
6.	Mass of Uranium	Measurement of neutron multiplication using external neutron source. Requires pre-calibration using inert (without FM) mockup.	Neutron source with a yield of 10^6-10^7 n/sec. Neutron detector.

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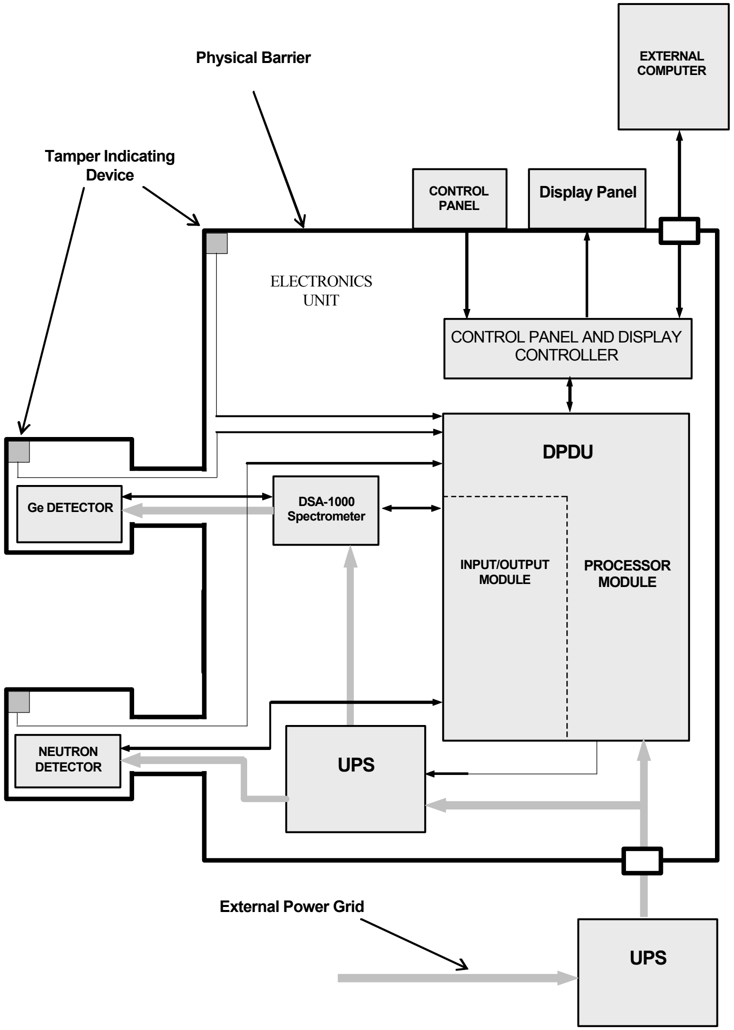
Measurement Techniques (continued)

#	Measured Attributes	Measurement Technique	Measurement Equipment
7.	Presence of HE	Neutron radiation analysis. Recording in the spectrum of gamma energies ~10.8, 10.3, and 9.8 MeV while interrogating a package with neutrons	Gamma spectrometer. Neutron source with a yield of ~ 10^7 n/sec.
8.	Mass of HE	Neutron radiation analysis. Comparison of 10.8-, 10.3-, 9.8-MeV peak areas to values obtained in calibration measurements.	Gamma spectrometer. Neutron source with a yield of ~ 10^7 n/sec.

MAMS Schematic Diagram



MAMS Principal Components

- HPGe GMX50-P semiconductor gamma detector with a high efficiency of performance used in techniques that determine presence of plutonium, quality of plutonium, presence of uranium, enrichment of uranium, presence of HE, and mass of HE.
- SRPS-2 neutron detector unit with 3He neutron counters used in techniques that determine plutonium and uranium mass.
- DSA-1000 spectrometer used for collecting spectrometry data from the detector and sending it into the processor module for processing.
- Data Processing and Display Unit (DPDU).
- Control panel and Display panel

MAMS Modes of Operation

- The system is operated in two modes: open and closed.
- The open mode is intended for testing and authenticating the system. The open-mode operation requires an external computer to be connected to the Electronics Unit.
- In the closed mode, measurement results are shown on the Display Panel only as “Yes/No” statements to indicate whether the measured attributes correspond to the specified criteria.

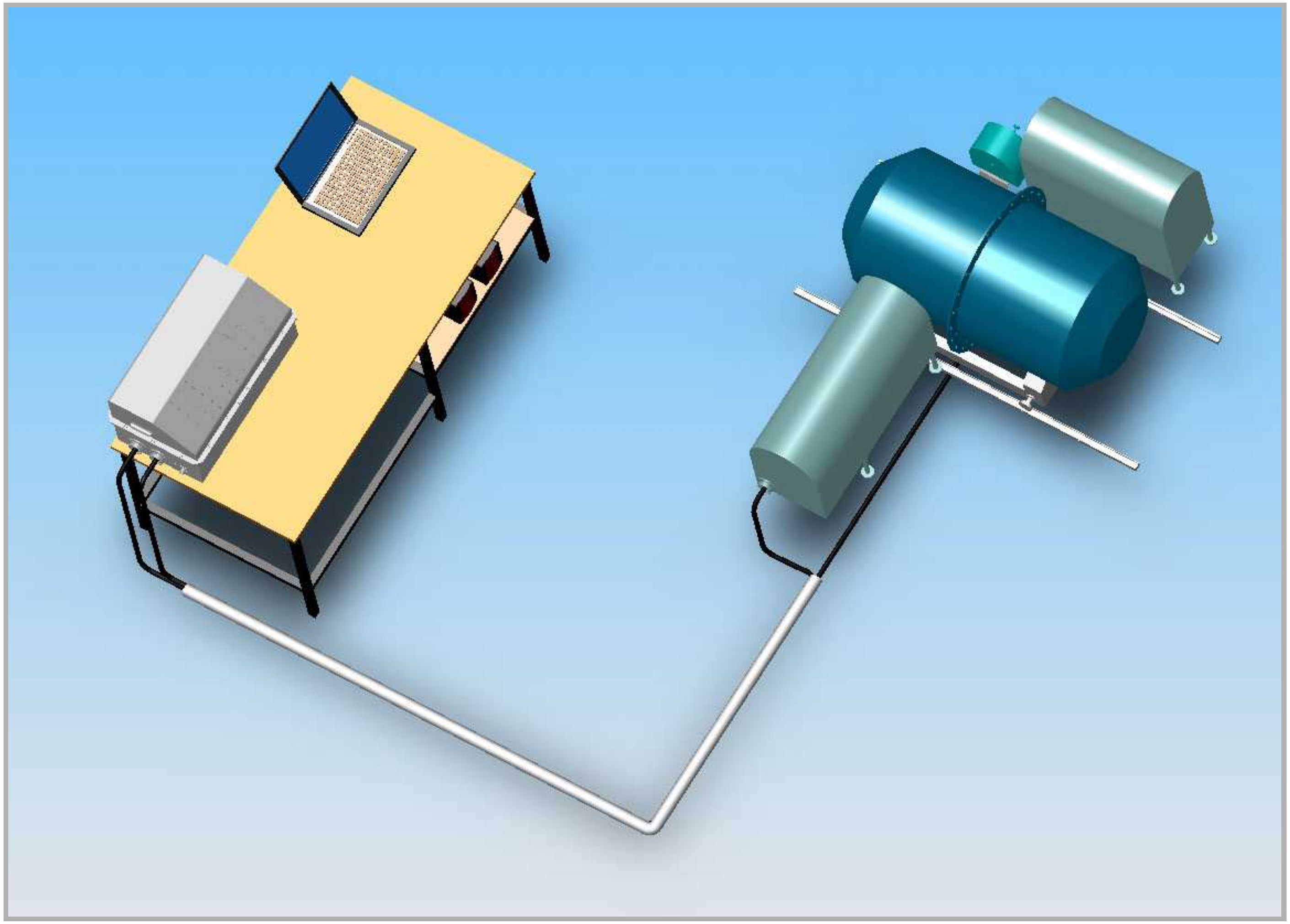
Security of Sensitive Data

- Sensitive data from the detectors is processed by the DPDU processor unit. The resulting data are displayed on the external Display Panel as “Yes/No” statements.
- The electronic and detector units are placed in protective enclosures (physical barrier) that provide mechanical and electromagnetic protection. Enclosures are also used to suppress intrinsic electromagnetic emissions of the electronic equipment.
- Electronic and detector units are equipped with tamper-indicating devices. When those devices are triggered, the detectors shut down and data residing in DSA-1000 and DPDU are erased.

Security of Sensitive Data

- The DSA-1000 analyzer and DPDU do not have non-volatile memory in which to store the data coming from the detectors. When power is off or if the electronics unit is tampered with, all accumulated data are erased.
- The system operation can be switched to the open mode only from the control panel. This should be done with all of the administrative and technical measures in place (such as sealing the cover that protects the mode switch button) to preclude unauthorized use of this mode.

First MAMS Prototype Design



The workstation and the measuring bench are connected via shielded cables.

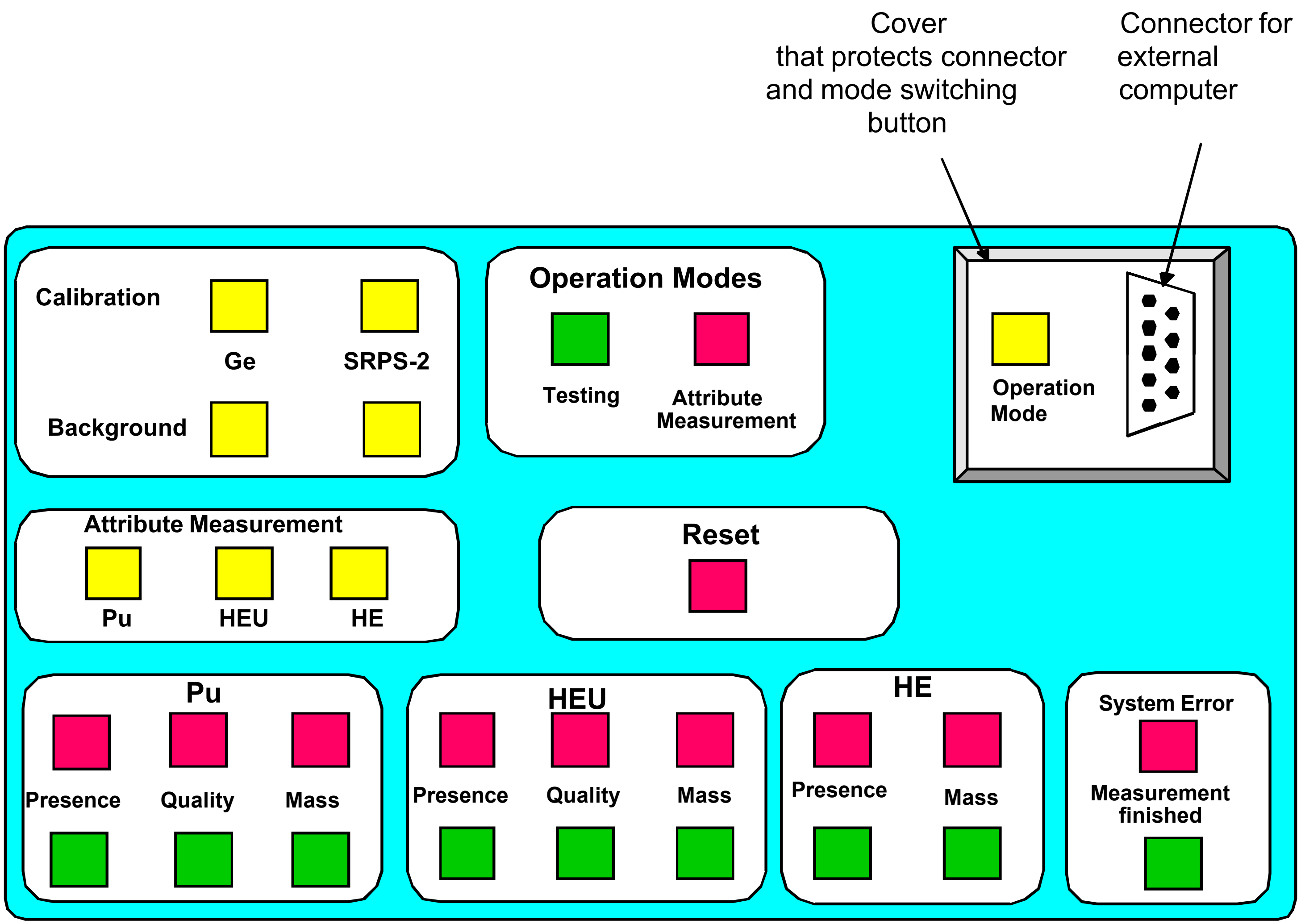
Measuring Bench

- Bed for placement of containers with FM and HE:
  - **Recording equipment in protective enclosures**
  - **Polyethylene block with a neutron source**

The Operator’s Workstation

The operator’s workstation is biologically shielded and located in a room with permanent personnel presence. The Electronics Unit, with the control and display panels and a computer, are placed on the worktable.

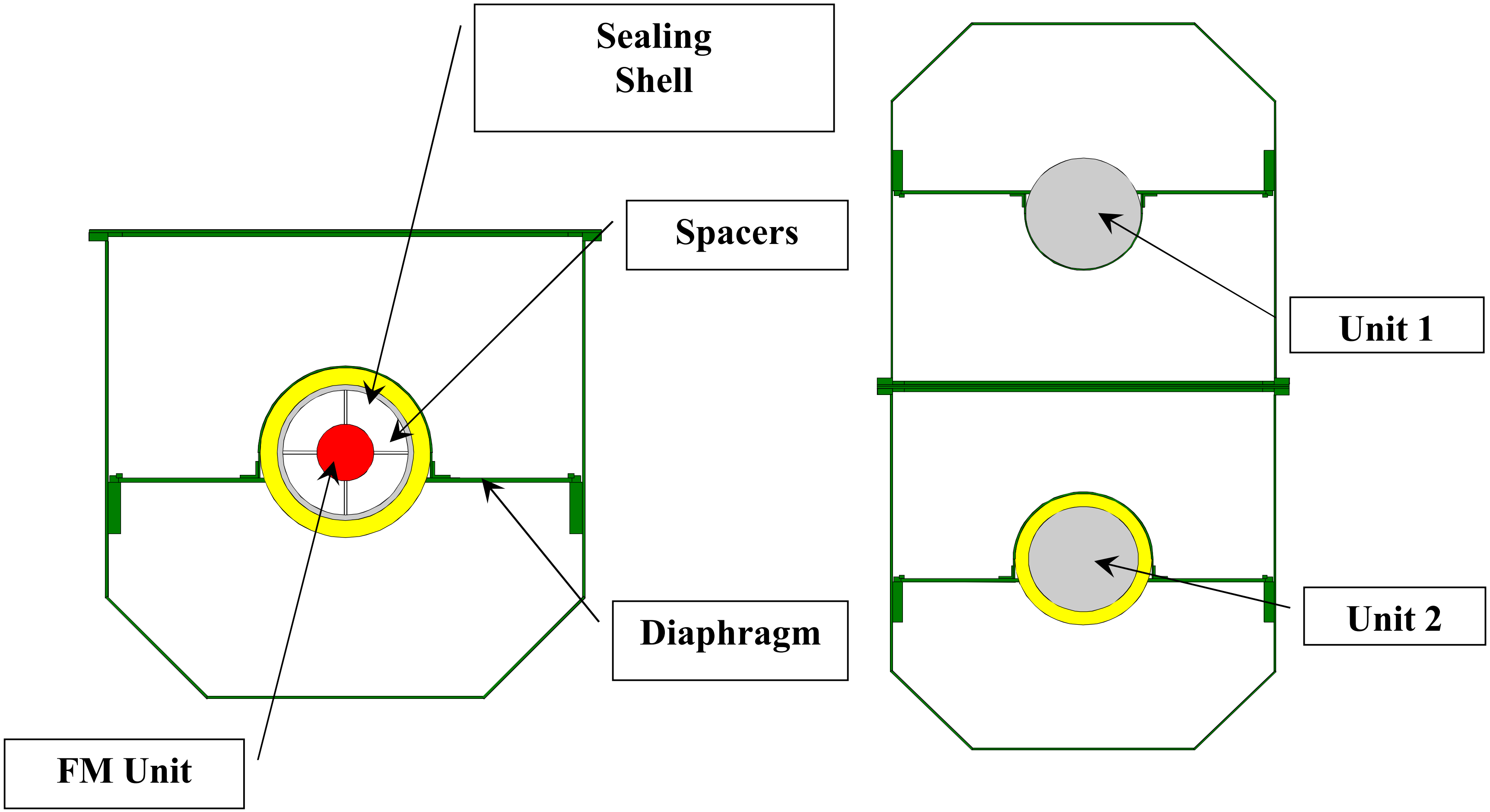
Control and Display Panels



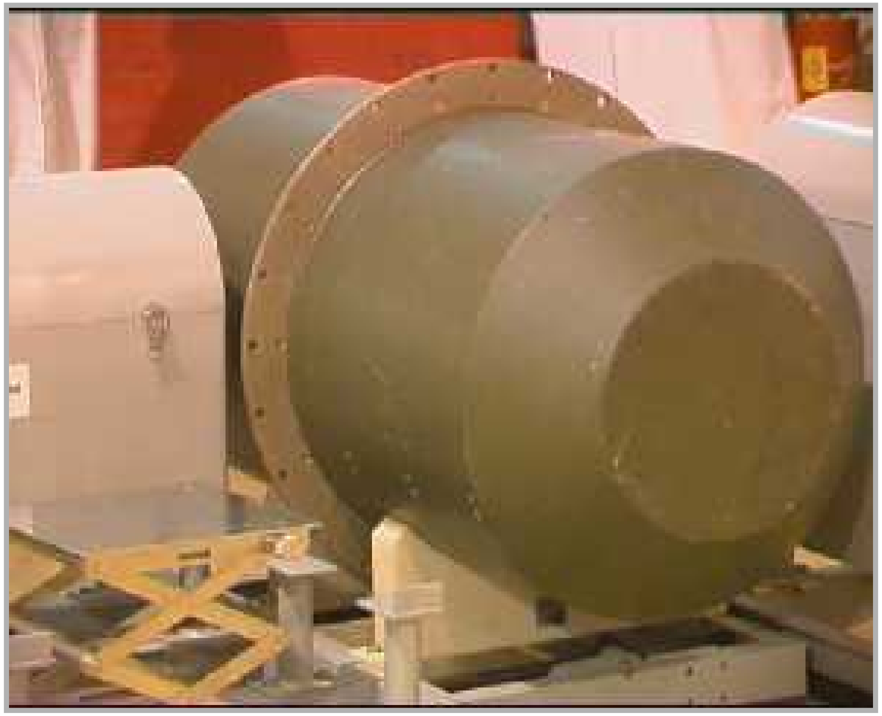
Model Assembly

- A Model Assembly (MA) was developed for experimental validation and testing of the system.
- The MA design allows several units made of uranium, plutonium, simulated HE, and combinations thereof to be mounted in the assembly at the same time.

Various MA Options



Physical Configuration of MA



System Testing

MAMS was tested with the MA that consisted of units of varying configurations containing HEU, plutonium, and simulated HE.

As demonstrated by the test results, it was quite easy to assess the presence and quality of plutonium in the units. Measurement of plutonium mass, which was based on the neutron detector count rate, provided satisfactory results when calibration was performed.

The presence of HEU in the MA can be clearly determined through the presence of 2614-MeV energy lines in the recorded spectrum.

System Testing

Measurement of the uranium mass by measuring the external multiplication factor requires a series of preliminary calibrations using mockups with a similar composition, in which the enriched uranium parts are replaced with similar parts made of non-enriched uranium.

Measurements with units containing simulated HE demonstrated that the neutron-radiation method determined the presence of more than 1 kg of HE in the units. However, this type of assessment required a considerable amount of time (for the 1-kg HE mass, the required measurement time was ~ 2 hours). HE mass can be measured only after calibration is performed. During the tests, calibration was carried out by placing simulated HE of varying mass into the MA and plotting the corresponding calibration curves.

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Potential System Enhancement

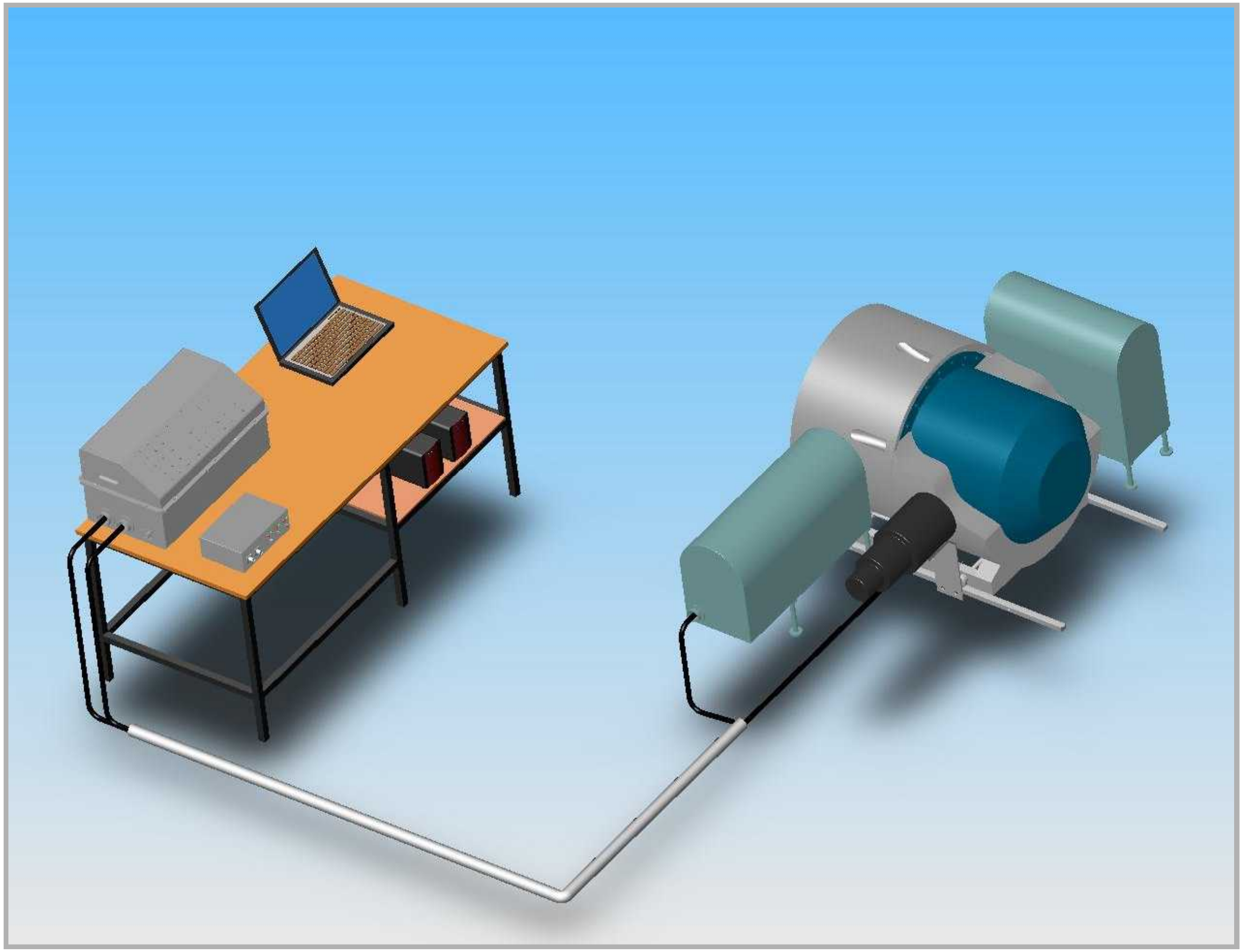
The test results demonstrated that the biggest challenge was to determine uranium mass and HE mass. In addition, it was technically inconvenient to use the isotope neutron source.

Therefore, a neutron generator (d, d) is now being considered for the second MAMS prototype. An ING-07D neutron generator was recently purchased that can be operated in a continuous mode and provide a neutron yield of ~107 n/sec.

A new component is a polyethylene chamber into which all of the measured objects will be placed. In our estimation, the use of such a chamber will significantly reduce the time of measurements.

It is proposed to measure uranium mass by recording delayed neutrons that are generated by uranium fission.

Proposed Schematic Layout of Second MAMS Prototype



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Conclusions

- The first MAMS prototype was developed.
- The MA was developed and used to support a large number of experiments on finding the specified FM and HE attributes.
- Challenges and problems with measuring certain FM attributes were identified.
- Proposals on further improvement of the MAMS prototype were formulated.