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INL SITE ARG-US IMPLEMENTATION

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ABSTRACT

The Packaging Certification and Life Cycle Management program at Argonne National Laboratory (ANL) developed a suite of monitoring systems known as ARG-US. ARG-US provides data for nuclear facility and system operation and maintenance, and has been demonstrated in hot cells, radioactive material (RAM) storage areas, RAM storage containers, RAM shipment trucks, and RAM shipping containers. ARG-US offers unique advantages over other monitoring systems by using wired and wireless data connections, conventional and battery power supplies, and customizable monitoring methods.

Idaho National Laboratory (INL) is investigating applications for ARG-US at its Site facilities. INL researchers have identified high-level goals for testing ARG-US: function in unique testing environments, implement new monitoring methods for ARG-US, and acquire monitoring data for the user facilities. After an initial assessment, INL suggests three potential areas for further investigation: the CPP-603 Fuel Handling Cave at Idaho Nuclear Technology and Engineering Center (INTEC), the legacy radioactive and chemical hazardous waste storage systems known as the Tank Farm, also at INTEC, and routine and emergency environmental monitoring that is widespread across the INL Site.

These test areas promise to challenge and expand ARG-US capabilities. Installations will be subjected to harsh environmental conditions, including high ionizing radiation, sudden changes across large temperature ranges, high humidity, and direct exposure to liquids and dust. ARG-US data transmission will be tested in several demanding scenarios, including electromagnetic radiation background conditions, geographically remote locations, and from radiation-shielded conditions. New ARG-US capabilities will include remote power generation, system parameter monitoring, and environmental data collection. Developing these capabilities and testing ARG-US in the new areas is a joint effort between ANL and INL personnel.

This paper describes activities undertaken so far in this investigation, provides details on the areas for ARG-US testing, and relates test implementation results to broader relevance for nuclear packaging and facility operations.

INTRODUCTION

Argonne National Laboratory (ANL) approached Idaho National Laboratory (INL) to investigate operational areas at the INL Site that may benefit from the ARG-US monitoring suite. The United States (US) Department of Energy (DOE) Office of Environmental Management Packaging and

Certification Program provided funding to assess the viability of ARG-US implementation at INL Site facilities.

The ARG-US system was previously demonstrated at other nuclear facilities (Ref. 1-4). Since these demonstrations, ARG-US has undergone technology and operational upgrades that merit new demonstrations. Additionally, INL facilities offer unique and demanding conditions for researchers to evaluate the capabilities of ARG-US and determine the monitoring suite's suitability for broader implementation at the INL Site.

ARG-US MONITORING SUITE DESCRIPTION

The ARG-US monitoring suite consists of two main systems: radio frequency identification (RFID) surveillance sensor tags and remote area modular monitoring (RAMM) units, which collect and transmit monitoring data to a web-based human-machine interface (HMI) and database. Together these systems provide flexible and robust condition monitoring for diverse facility and package configurations.

Radio Frequency Identification Surveillance Sensor Tag and Reader

The RFID surveillance sensor tag is a durable sensor and communications device for radioactive material package monitoring based on single board computers, solid-state sensors, an integral RFID antenna, and long-life batteries (Ref. 2). The RFID tag's low profile and compact form factor allows installation in many configurations, such as directly attached to radioactive material shipping containers. It consists of a metal backer plate, internal printed circuit boards constituting the control and communication computer, both integral and modular solid-state detectors, a battery cell bank, and a solid plastic cover.

Figure 1. RFID surveillance sensors tag (image courtesy of ANL).

RFID tag sensors include temperature, humidity, shock, gamma radiation, neutron radiation, tactile seal, and electronic loop seal for tamper indication. All the sensors are low-voltage, solid-state instruments with adjustable setpoints for alarms. Sensor data from each RFID tag is sent to a centralized data server by a commercially available RFID reader. The reader-tag communication is two-way, with periodic polling of the tag sensors by the fixed reader and an instantaneous alarm issued by the tag when any sensor alarm threshold is exceeded. The battery bank powering the RFID surveillance tag is expected to last up to 10 years on a 6-hour polling interval.

Remote Area Modular Monitoring (RAMM)

RAMM is a distributed sensing and monitoring system that could be deployed at various facilities such as fuel enrichment facilities, fuel manufacturing facilities, nuclear power plants, spent fuel dry storage systems, hot cells, and other radiological facilities (Ref. 4). RAMM is based on individual monitoring units consisting of single board computers, integral and modular solid-state sensors, and power over Ethernet (PoE).

The RAMM system has a two-layered architecture: a wired Ethernet base layer and a wireless mesh network overlay. The wired network provides baseline data communication and powers the unit via PoE. A RAMM unit shown in Figure 2 carries a suite of sensors that can be customized, and multiple communication modules that are also functionally dependent; for example, cellular and satellite modems are installed only in those RAMM units that are “gateways” to the data server. ANL has previously incorporated a digital video camera, an electronic loop seal, and an array of type K thermocouples that are used as specialty sensors into several RAMM units. An embedded multimedia controller chipset with onboard flash and dynamic random-access memories is included in the single board computer that enables local data processing and storage in each RAMM unit as part of a distributed sensing system.

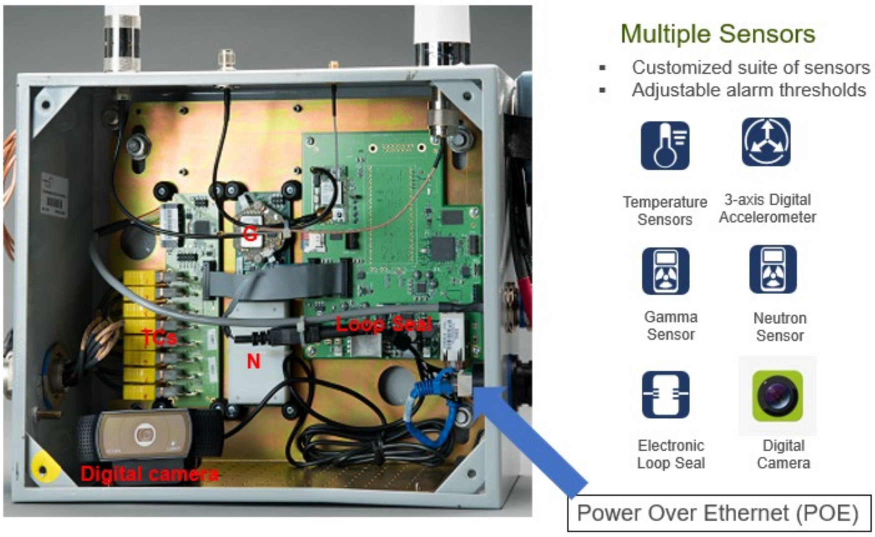

Figure 2. A RAMM unit with its multiple sensors and PoE for power and data communication (image courtesy of ANL).

RAMM Traveler is a mobile standalone RAMM that monitors and tracks a cargo conveyance shipment of risk-significant materials by truck, rail, or ship (Ref. 5). RAMM Traveler has the same sensor and alarm functions, redundant cellular-GPS-satellite communications, and a rechargeable Li-ion battery. Other options for power supplies include additional Li-ion batteries and a hard-wired vehicle electric power system.

Web Application HMI

The data collected by the various sensors are organized and displayed near real time by the HMI. When tracking a shipment, a visual representation of the monitored area and mapping functions is displayed and the sensor data are shown in tables and can be retrieved by time, location, and alarm notification. For operations with radioactive material shipment, the HMI includes geofencing and geographical information system information on hospitals, fire departments, emergency response stations, and law enforcement offices near the vehicle. Figure 4 shows the ARG-US web application

HMI in demonstrations and applications of RFID and RAMM remote monitoring of ANL Alpha Gamma Hot Cell Facility.

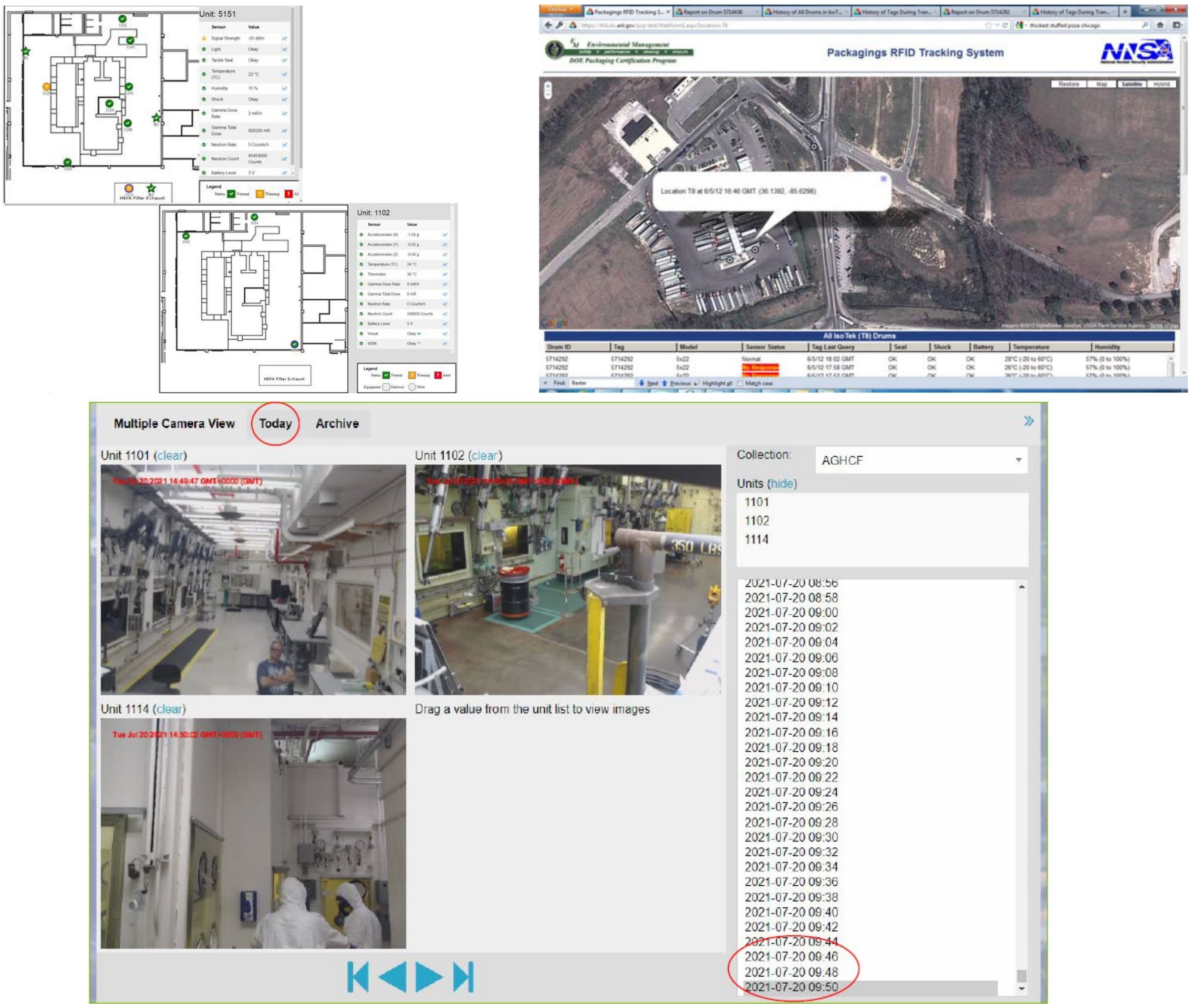

Figure 3. ARG-US web application HMI for RFID and RAMM (image courtesy of ANL).

INL SITE FACILITIES

The INL Site consists of a 2,305-square-kilometer area in southeastern Idaho, which is largely a sagebrush steppe with sparse road access. This area contains diverse nuclear and non-nuclear facilities, including operating reactors, related research facilities, fuel storage installations, and waste management facilities. In addition to the desert Site, there are laboratories and administrative buildings located 90 kilometers to the east in Idaho Falls. These facilities are operated by several DOE contractors, including Battelle Energy Alliance and Idaho Environmental Corporation (IEC) under DOE operating regulations. There is also a limited number of Nuclear Regulatory Commission licensed facilities, most notably the Three Mile Island Unit 2 independent spent fuel storage installation.

Preliminary investigations identified several facilities and operations that offer promising testing environments and would also potentially benefit from implementing the ARG-US monitoring suite.

CPP-603

The CPP-603 facility at the Idaho Nuclear Technology and Engineering Center (INTEC) consists of the Irradiated Fuel Storage Facility (IFSF), the decommissioned legacy basin facility, and common truck bays with overhead crane systems. The IFSF primary mission is to receive DOE-managed spent nuclear fuel (SNF), condition it for long-term storage, and provide a safe storage location (Ref. 6). Notable IFSF functional areas include the cask transfer pit, permanent containment structure (PCS), fuel handling cave (FHC), and fuel storage area.
Figure 5 has photos and plan views of the CPP-603 IFSF.

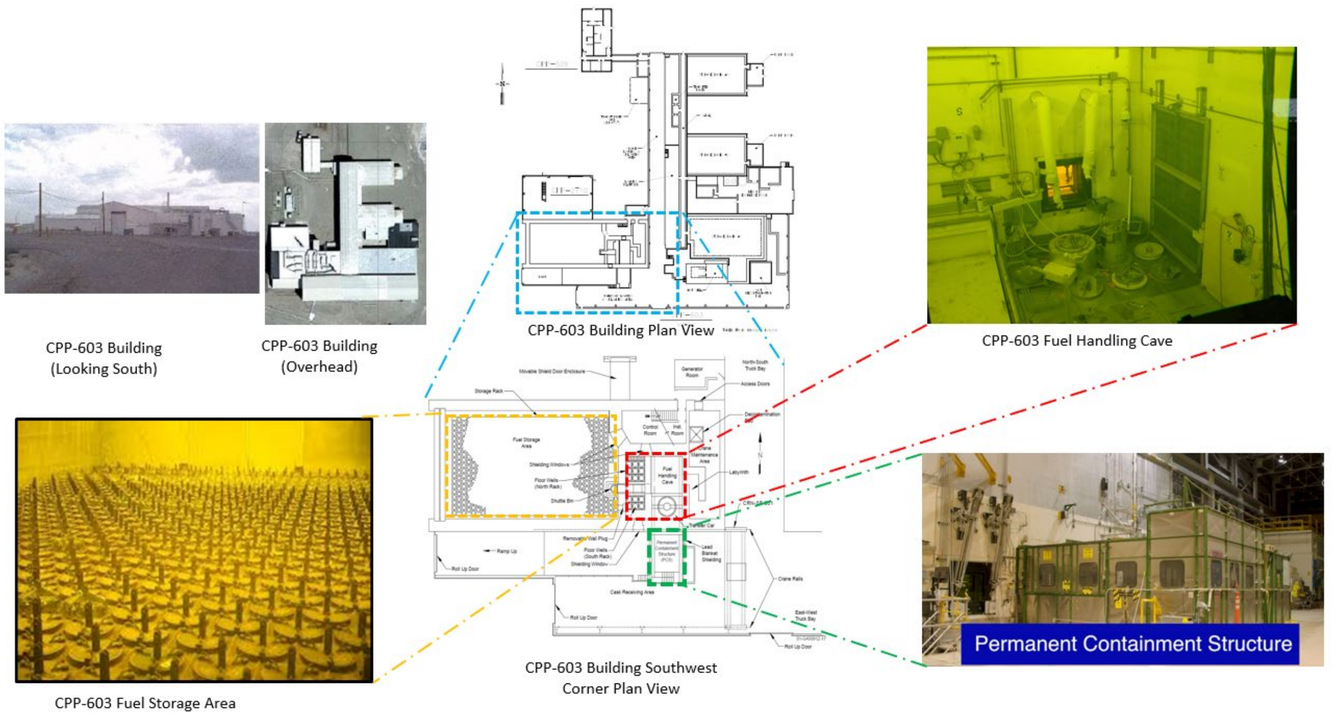

Figure 4. CPP-603 functional area photos and plan views (image courtesy of IEC).

The FHC is a 7.3-m-wide × 7.0-m-long shielded hot cell equipped with a set of wall-mounted telemanipulators, cranes, a PAR Systems™ telemanipulator arm on a crane, two shielding windows, video cameras, floor wells for temporarily storing fuel, and a shuttle bin for transferring fuel storage canisters between the FHC and the fuel storage area. A cask transfer car moves casks and other equipment between the FHC and the PCS. CPP-603 has minimal climate control systems and generally conforms to the temperature and humidity present outdoors, particularly in the FHC.
The PCS is a hard-walled structure that encloses the portion of the cask transfer pit in the truck bay with access doors to provide crane access and allow transfer of equipment. Walk-through doors on the east side of the PCS provide personnel access.
The cask transfer pit floor is 5.5 m below grade, measuring 3.0 m wide and 14.6 m long. The pit passes under the south wall of the FHC. Approximately one-half of the pit is under the PCS; the other half is in the FHC. The cask transfer is a specially designed car positioned on rails at the top of the cask transfer pit and is used to transfer packages or equipment between the PCS and the FHC.

<u>INTEC Tank Farm</u>

For many years, INTEC operated SNF reprocessing and storage facilities. This resulted in large volumes of high-level liquid mixed (radioactive and regulated hazardous) waste. Between 1950 and 1964 a system of large, underground tanks and related hardware including sumps, valve boxes, monitoring enclosures, and control stations was constructed to handle the waste, collectively known as the Tank Farm (Ref. 7).

The Tank Farm no longer receives new liquid waste and is actively under decommissioning and demolition activities. There are four remaining storage tanks in use at the Tank Farm that hold about 3.4M L of highly radioactive and corrosive sodium-bearing waste following volume reduction and other waste treatment. These are designated WM-187, WM-188, WM-189, and WM-190. The newly operational Integrated Waste Treatment Unit at INTEC will process this remaining liquid waste. The other tanks shown on Figure 7 (designated with “WM-XXX”) were drained and grouted in place.

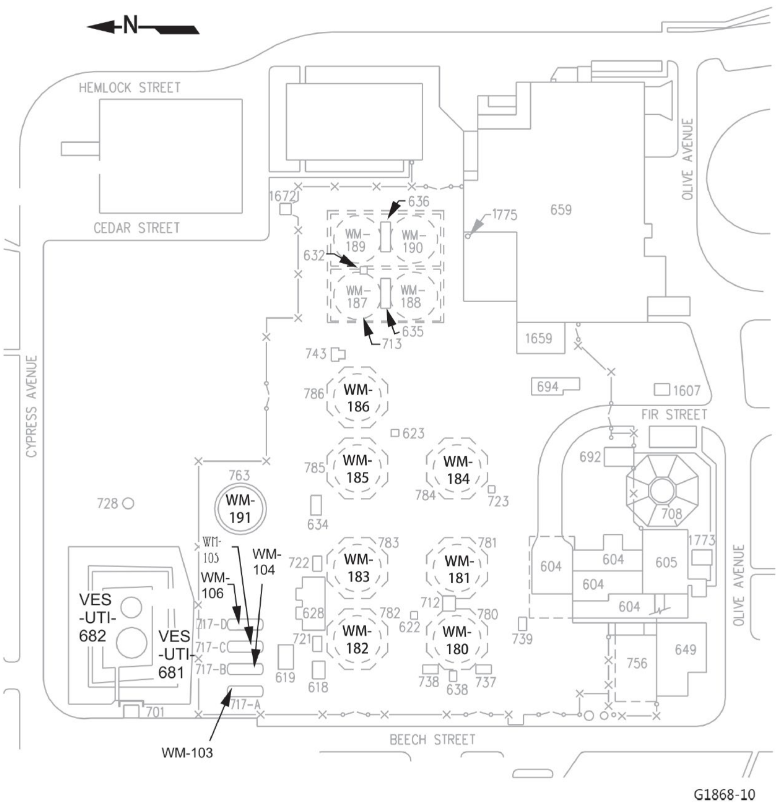

Figure 5. Tank Farm location at INTEC (image courtesy of IEC).

These tanks are housed in underground concrete vaults. The tanks themselves are nominal 1.1M L cylindrical stainless-steel tanks, approximately 15.2 m in diameter and 6.4 m to 7.0 m in height. Tank risers provide access for monitoring systems as well as operational systems for liquid transfer, pressure relief, etc.

Existing tank monitoring systems are a combination of vintage monitoring components originally installed on the tanks and newer components that were installed during repairs or upgrades. The monitoring systems are focused on operating conditions of the tank and include pneumatic liquid level, digiquartz liquid level, electronic liquid level and temperature, pneumatic liquid density, pneumatic tank pressure, and secondary liquid temperature. In addition to the tanks themselves and their condition monitoring systems, there are several other Tank Farm systems and related monitoring instruments that are relevant to ARG-US implementation including a vessel off-gas system, vacuum and pressure relief valves, vault sumps, other sumps, instrument buildings, and the Waste Operations Control Room.

<u>INL Environmental Monitoring</u>

INL performs environmental monitoring of several varieties: facility system monitoring, routine field monitoring, and emergency response monitoring (Ref. 8).

Facility system monitoring, which includes radionuclide releases, liquid effluent volumes, and liquid effluent content, is performed at numerous locations at the INL Site, including INTEC, the Advanced Test Reactor Complex, and at the Materials and Fuels Complex. Historically, the implementation of automated and manual monitoring systems has been specific to each facility, but the results have never been consolidated into a single all-encompassing report.

Routine field monitoring occurs at numerous locations on and off the large desert Site area and includes manual material sampling (i.e., well water, vegetation), placement of optically stimulated luminescent dosimeters, and airborne radionuclide sampling. This work is very labor intensive and requires many monthly personnel hours for sample collection and instrument maintenance. Even the more automated process, airborne radionuclide sampling, requires periodic hands-on access to change filters, calibrate instruments, and perform instrument maintenance.

INL implements emergency response monitoring through the emergency response plan. While facilities include many real-time monitors for external radiation and airborne radioactivity, broad environmental monitoring during an emergency response is primarily accomplished by high-volume air sampling with a filter-patch or chemical cartridge collection in downwind locations. Some pre-established monitors are located near facilities for this purpose, but surveying response teams with portable instruments perform most of the emergency response monitoring.

INL ARG-US TEST IMPLEMENTATION

INL has several interests for bringing the ARG-US suite to the INL Site for a test implementation.

1. Assess ARG-US function in unique testing environments.

   ANL has tested ARG-US at facilities located at ANL and Savannah River Site and in radiological shipments from the Nevada National Security Site (NNSS) to Savannah River National Laboratory, and from Oak Ridge National Laboratory to NNSS. These installations and transit operations occurred in climate-controlled buildings or during spring to early autumn months. In contrast, the southeast Idaho climate reliably offers extended operating conditions below freezing and periodic conditions below -18° Celsius during winter months.

   The INL Site also offers physically widespread locations with limited utilities. Subjecting ARG-US to long-term use in such locations, rather than just in temporary transit use, will provide unique requirements for implementation.

   The INL Site is home to numerous aged legacy and in-service facilities. These buildings were built with no regard to wireless communications and often do not have available facility power or network connections. Modifications to these facilities are often limited by the existing construction or by the industrial condition of the facility (radiological restrictions, operational impact, etc.).

   All these conditions contribute to unique testing environments for ARG-US, which will push product development and further demonstrate ARG-US capability.

2. Implement new monitoring methods for ARG-US.

   Some monitoring at INL Site facilities will be within established ARG-US capabilities, but INL relies on numerous other monitoring modes for regulatory, safety, and industrial control purposes. There is useful development work for ARG-US to implement new monitoring methods such as:

- Industrial operating conditions (e.g., valve position, container liquid level, etc.)
- Sump leak detection
- Airborne radioactivity
- Weather conditions
- Effluent flow and conditions.

3. Acquire monitoring data for the user facilities.
Implementing a new monitoring system will necessarily require effort on the part of the affected facility and may even cause interruptions in regular operations. The monitoring provided by ARG-US must provide benefit to the affected facility users commensurate with the effort required to implement it.

An initial period of testing will involve installation of stand-alone ARG-US units to familiarize personnel with the system and perform bench-scale investigation of new monitoring and power configurations. After initial testing, larger scale testing will begin with multiple units, INL Site network connections, and longer-term facility placement in the INL Site areas and operations described above.

<u>CPP-603</u>

ARG-US system testing in CPP-603 will be centered around monitoring within the FHC. This monitoring will serve several purposes:

- Provide early indication of radiological conditions prior to personnel entry
- Gather data of facility conditions during diverse operations and ambient environments
- Further demonstrate ARG-US operation in heavily shielded, high-radiation environments.

Standard RAMM units will be the primary ARG-US hardware operated in the facility while RFID surveillance tags may be used for some of the mobile hardware used in the facility.
The RAMM monitoring capabilities of primary interest are for gamma radiation dose rate, neutron radiation indication, temperature, and humidity. Other sensor capabilities such as loop seal, accelerometer, and digital camera are not expected to be used. The camera may be deactivated for security purposes.
A combination of PoE and standard US 110 VAC facility power are expected to power the RAMM units. Standard US 110 VAC outlets are available near all positions but may require extension cords. The data connection to the ARG-US HMI will be made through one or more RAMM units connected to the facility intranet by the PoE connection. Due to the age of the facility, the limited occupancy of the FHC, and the difficulty of making facility modifications, it is possible that only a single RAMM unit will have an Ethernet connection available. Those RAMM units without an Ethernet connection will communicate through the mesh wireless network built into the RAMM units.

<u>Tank Farm</u>

ARG-US system testing in the Tank Farm will be more physically widespread and diverse than for CPP-603, using a variety of RFID and RAMM configurations. The system will serve several purposes:

- Supplement or improve current monitoring on Tank Farm systems
- Consolidate monitoring from several physical locations to a single web-based HMI
- Demonstrate ARG-US adaptability to new monitoring hardware and methods.

RFID tags will be used in physically confined locations where numerous monitoring points can be served by a single RFID reader, or where external power cannot be supplied. RAMM units will provide data nodes to connect to the network in cases where monitoring requirements exceed the low-voltage capability of the RFID tags.

ARG-US monitoring methods in the Tank Farm will vary for each unit. Gamma radiation, temperature, and humidity will be used at all locations. For some applications, such as sump and valve box monitoring, liquid detection will be added to current ARG-US capability. In other applications, valve position, flow rate, and other operational control parameters will be monitored. Additionally, ARG-US may provide data transmission for existing monitoring devices.

RFID tags will be powered by standard onboard batteries. Standalone RFID readers will require regular US 110 VAC facility power, which may limit their positioning. Where facility power is not available, a mobile test kit may be used to collect RFID surveillance tag data to supplement the permanently located RFID readers. RAMM units are expected to use a combination of PoE and US 110 VAC facility power depending on location. Data connections will be made through a combination of RFID readers, RAMM mesh network, and RAMM Ethernet connection to the facility intranet.

<u>Environmental Monitoring</u>

ARG-US system testing for INL Site environmental monitoring will fall under two basic categories: facility-based monitoring and routine area monitoring. Most ARG-US testing will be implemented in parallel with existing, required monitoring systems. Implementing ARG-US in these areas will serve to:

- Simplify or improve current facility monitoring
- Reduce direct access required for routine area monitoring
- Assess potential benefit for emergency monitoring
- Demonstrate ARG-US adaptability to new monitoring and power supply methods.

This test is expected to use RAMM and RAMM Traveler monitoring units. The difference in selection will depend on availability of Ethernet connection to INL intranet and monitoring capability.

ARG-US capability for environmental monitoring will depend on implementation of new hardware beyond the scope of simple integration to RAMM. Existing RAMM sensors for temperature, humidity, and digital cameras will be beneficial. The loop seal sensor may be used to provide hardware security in remote or publicly accessible locations. For units in remote locations, low-battery warnings will also be necessary. Current RAMM gamma and neutron radiation sensors are not sensitive enough for long-term environmental monitoring purposes. New hardware implemented for RAMM that is expected to interface directly to the single-board computer could an anemometer, a precipitation sensor, or an effluent/stack flow rate sensor. Implementing new monitoring hardware needed for ARG-US environmental monitoring is best achieved by using commercially available systems with RAMM or RAMM Traveler for data communication. Examples of this hardware include airborne radioactive gas or particulate monitoring.

In some locations, PoE or US 110 VAC facility power will be available for RAMM power, particularly for facility applications. In most environmental area monitoring applications, the monitoring location will be far removed from regular power distribution. For units designated for emergency response monitoring, it is possible that battery-powered RAMM Traveler units can be pre-positioned in a stand-by condition, then activated only as needed. Other RAMM Traveler units may be configured to use vehicle power and provide monitoring and data transmittal for dispatched emergency response teams. Routine area monitoring will need regular, remotely available power sources. These RAMM Traveler units will be supplied with a battery bank and fitted with a recharging system, such as solar photovoltaic or wind turbine.

Monitoring systems will transmit data by Ethernet connection where available, but most locations are too far from regular facilities for Ethernet access. For these locations, RAMM Traveler communication by cellular network or GPS satellite network will be necessary.

CONCLUSIONS

The planned ARG-US test implementation at the INL Site will contribute to significant improvements, expanded capability, and increased confidence in the monitoring suite. While building on previously demonstrated capabilities, CPP-603, the Tank Farm, and INL environmental monitoring offer unique and demanding circumstances to test the capabilities of ARG-US. The development of new sensors and new power sources will greatly expand use cases for ARG-US, while operating experience in new environments can identify previously unknown risks. These tests will provide insights for future ARG-US development and inform permanent use cases at INL and elsewhere.

ACKNOWLEDGMENTS

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