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REAL TIME INSTRUMENTATION MEASUREMENT PROGRAM

EXCAVATION MONITORING SYSTEM II (EMSII) ACCEPTANCE TESTING PLAN

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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REVISION SUMMARY

Revision	Date	Description of Revision
Rev. 1	6-25-01	Initial controlled issuance.
PCN 1	1-7-02	Added Attachment B to include the Acceptance Test Requirements for EMSII completed 12-12-2001which addresses all issues from Attachment A completed in June 2001.
TC	2-12-02	Data completed from field testing.

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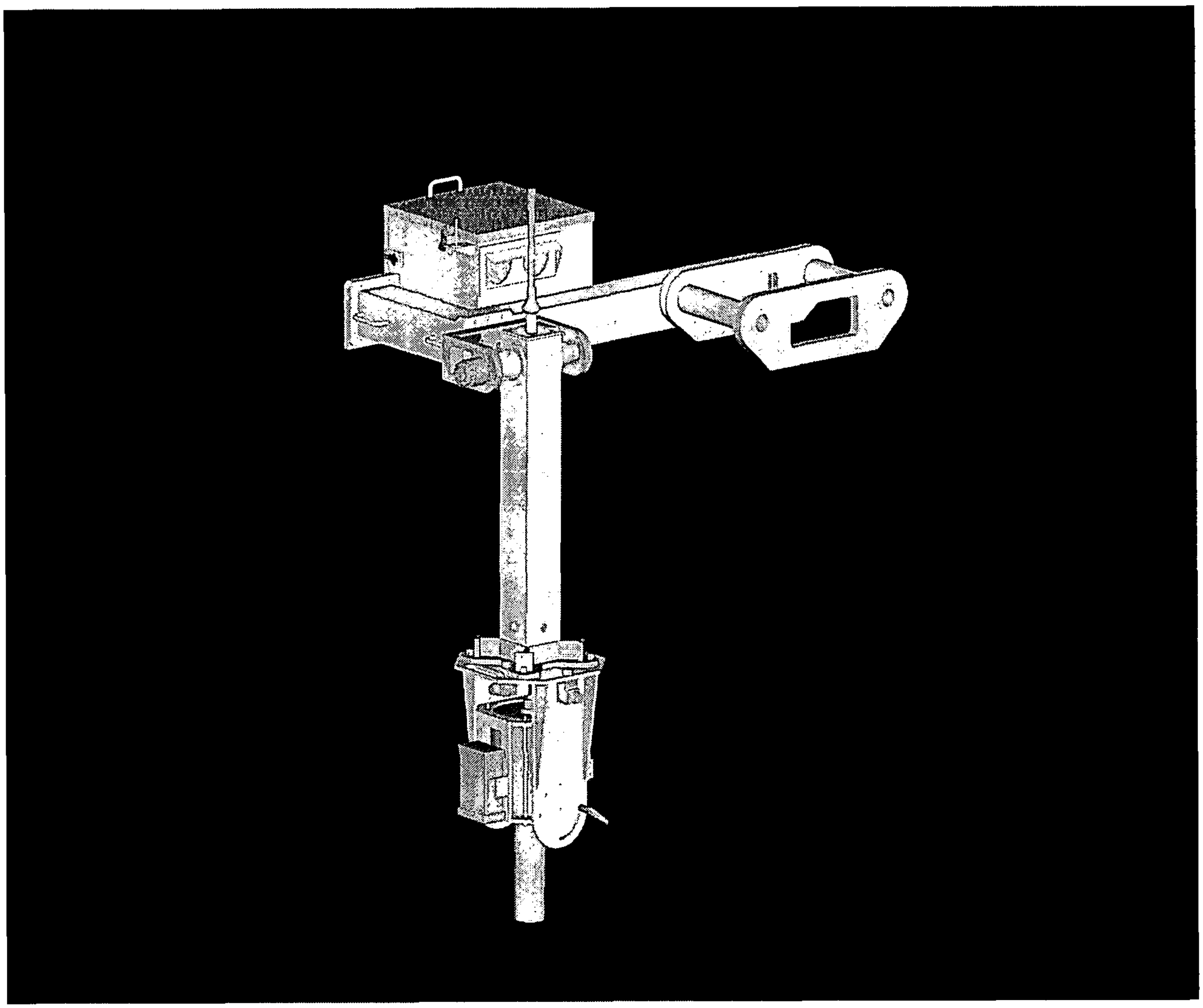

1.0 SCOPE OF WORK

1.1 A John Deere excavator operated by Fluor Fernald personnel will deploy the Idaho National Engineering and Environmental Laboratory (INEEL) supplied Excavation Monitoring System (EMSII) in several FEMP areas. The planned areas are in the Solid Waste Landfill, the West OMTA area North of the Plant One pad (Boneyard), the Building 10A Boiler Plant Basement and the Contaminated Oil/Graphite Burn pad 10D. In the Solid Waste Landfill and the OMTA areas there are specific points to be measured. The Burn Pad and time permitting the OMTA area will be scanned or statically measured to determine 100 percent soil characterization based on the ease of configuration. The Boiler Plant Basement foundation walls will be measured with the detector configuration at 90 degrees from the horizontal plane. The Solid Waste Landfill and the OMTA areas are to be measured by a reach-in approach. The Boiler Plant basement and Burn Pad will be accessed by placing the excavator in the radiological zone and reaching into and across the area to be measured.

1.2 The deployment will test the design capabilities of the hybrid system for performance of radiological soil characterization during excavation activities. The deployment will also verify proper operation of laser range finding and GPS 3D position measurement equipment. Upon completion of the test the system and/or requirements will be modified if needed. The EMSII will be mounted on the excavator using a quick disconnect.

NOTES: **This EMS Demonstration Plan is written to document that the system design requirements as outlined in the attached checklist are met.**

Demonstrations planned, but not applicable will be documented with the comment "NA". Additional demonstrations if performed, will be documented under "other demonstrations" in this document.

Demonstrations may or may not occur in the order in which they are presented in this Demonstration Plan. Demonstrations may be combined if needed; demonstrations may be eliminated if not feasible.

2.0 SAFETY PRECAUTIONS

2.1 Supervisors shall read and understand the EMSII Acceptance Testing Plan and these safety requirements ensure any involved personnel have been briefed, and that all personnel sign the Plan acknowledgement sheet.

2.2 Understand and follow the requirements of all permits. All personnel should question any requirement they do not understand and provide recommendation to improve the safe performance of the work.

2.3 Required permits and training for the project:

a. General Site Worker (Rad II, GET, Site Worker)
b. Briefing on MSDS for chemicals used (if any)
c. Radiological work Permit in Contamination Areas (existing open permits for the Waste Storage Area, Area 3, and the Bulk Debris Storage Areas)
d. Site training and qualification for Heavy Equipment Operators

Note: Vendors, delivery personnel and visitors are to be escorted by project personnel who meet the above training requirements.

2.4 Personal Protective Equipment (PPE) Required:
Safety glasses, safety boots, hard hats, leather gloves (for workers performing work with potential for hand injury), hearing protection within 50 feet of operating equipment (unless posted otherwise) and orange vests when in work area, around equipment and/or vehicle traffic.

2.5 In the event of any unplanned occurrence, stop work and contact supervision. The appropriate supervision shall evaluate, re-plan, and revise this document, if necessary.

2.6 When working in areas where insects are present, take precautions to prevent ticks from getting on exposed skin by taping pants legs and wear long sleeve shirts. Utilize insect repellent for wasps, bees, etc. Workers should also be aware of possible poison ivy/poison oak. Use approved ivy block creams for prevention of both. Report known allergies to Supervision and Fluor Fernald Medical. Wash hands prior to taking breaks, including smoking breaks and lunch breaks, when using insect repellant or blocking creams.

2.7 If the situation arises that require personnel working under this scope to enter any other areas not covered in this plan briefing on applicable parts of the area(s) active safe work plan is required. Personnel will also be briefed on the applicable area daily work activities and associated hazards.

2.8 Fuels shall be stored away from the work site area. Fueling of equipment shall not be performed during periods of darkness unless lighting (greater than 5-foot candles general work area) has been provided. Fueling of equipment shall not occur until equipment has been turned off and an adequate time has been allowed for cooling of the equipment.

2.9 Prior to use, all equipment and tools shall be inspected by Fluor Fernald Safety and Health personnel and the equipment operator.

2.10 Equipment and machinery shall be inspected daily. Inspection sheets shall be completed by the operator and filed with the plan. Inspections shall be made in accordance with SPR 7-1 and 7-5.

2.11 A Safety Kick-off Meeting shall be held prior to the start of work to brief all personnel on safety requirements for the project. A daily safety meeting shall be held morning prior to start of work and, after lunch, and prior to the start of new activities.

2.12 Excavator-protection of the swing radius. Barricade the entire area to prevent access by any personnel other than the equipment operator(s). Swing radius barricading shall be consistent with SPR 7-5 Section 2.4.

2.13 Heat stress shall be administered in accordance with SPR-12-10. Documentation generated by compliance with SPR-12-10 shall be maintained with the plan.

2.14 Smoking is prohibited in all work areas and equipment. Smoking is only permitted in posted 'Designated Smoking Areas'. These areas shall be equipped with a 'cigarette end' receptacle (or approved equal), and be greater than 50 ft. from flammable and combustible storage. Smoking area(s) will be approved by the Fluor Fernald Health and Safety Officer.)

2.15 All personnel are to assemble at the appropriate Rally Point in the event of any site emergency or rally point accountability. The appropriate Rally Points will be discussed at the morning briefing and upon arrival at each work location. Possible Rally locations are T-96, T-191, T-139, or Rally Point #7. In addition, all directions provided by the Emergency Message System or radio instructions from the Communications Center shall be followed.

2.16 Vehicles and heavy equipment shall maintain a speed at or below 10 mph on all project roadways to control dust. Speed shall be reduced any time dust generation occurs as a result of vehicle/equipment operation. Control fugitive dust emissions.

2.17 A Fluor Fernald radio with Construction frequencies for emergency communication and weather alert notifications shall be available at all times when working in remote areas.

2.18 Electrical cords - Use of flexible cord sets with repairs to the cord is not permitted. Cord sets are to be routed overhead where possible to avoid damage. All flexible cords shall be UL listed industrial cords and rated for hard usage and damp locations. Cords rated at 120 volts shall be purchased assemblies.

2.19 Ground Fault Circuit Interrupters (GFCI) shall be used on all 15 and 20 ampere, 120 volt. The GFCI shall be placed at the source of the electrical service to protect both the cord and the devices connected. Assured grounding programs are not acceptable. Power supplying cords to the EMS shall be secured tightly to the excavator along the entire path and in such a way as to prevent interference with normal equipment operations and eliminate any pinch points.

2.21 Class I lasers cannot emit laser radiation at known hazard levels. Users of Class I laser products are generally exempt from radiation hazard controls during operation and maintenance (but not necessarily during service).

Direct exposure on the eye by the beam of laser light should *always* be avoided with any laser, *no matter how low the power.*

3.0 EMS TEST DEPLOYMENT JUNE 2001 DETAIL SCOPE OF WORK

The table below may be used to document the results of the deployment in the field.

3.1 FIELD SET UP	**Document time, effort, skill level, problems, corrective actions needed, etc. as applicable to determine test success, test completion and effort for future deployment.**
3.1.1 At each of the 3 measurement locations, set up work zone barrier cones and tape. Document size and configuration of all work areas.	3.1.1 Area 1 (OMTA West) overall size 255' by average 22'. Broken into middle, east and west ends measuring 22'x31', 22'x144', and 22'x80' respectively.
3.1.2 Using standard surveying methods, survey the edges of each of the 3 work areas, set survey flags and record coordinates.	3.1.2 The OMTA West area is the only area used during the June 2001 evaluation. It was broken into thee segments. The coordinates bounding each segment are 1348611.4 by 481685.7, 1348610.6 by 481662.7, 1348702.3 by 481679.8, 1348701.6 by 481660.3, 1348733.2 by 481678.9, 1348732.6 by 481658.9, 1348887.8 by 481676.1, and 1348887.3 by 481655.1.
3.1.3 Using the laser system, establish laser grid for each of the three work areas. If only GPS is to be used at that location establish GPS benchmarks.	3.1.3 GPS was used to locate and measure the single point near the tree with the HPGe. GPS was used to scan the horseshoe shaped area around the tree with the HPGe. GPS was used to scan the east end of the OMTA area using NaI. The GPS system experienced lack of differential correction intermittently due to local interferences. The attempt to calibrate the laser system for scanning the West section using NaI failed. The West section was scanned with NaI using an uncalibrated local grid system. Only one of the three areas originally planned to be measured was visited.
3.1.4 Ensure the HPGe and NaI used for the deployment are calibrated and have passed all QC checks. Identify the detectors used and the file numbers for the daily checks.	3.1.4 On 6-28-01 the HPGe detector S/N 30687 was pre-operationally calibrated. The calibration spectrum identification is 3999.chn. The NaI detector likewise was calibrated prior to use spectrum ID 99.chn. The NaI detector is normally mounted on the Gator NaI system and was borrowed for this test. There was no specific NaI detector calibrated to the calibration pad mounted on the EMS/Excavator JD 690 used for this evaluation.

3.1.5 Document the amount of time, effort, and personnel skills needed to mount the EMS platform to the excavator arm and the HPGe and NaI detectors to the EMSII platform.	3.1.5 Attach HPGe mount and install and connect HPGe detector (35 min). Remove HPGe, install and remove 2-foot extension, install NaI mount and detector (25 min).
3.1.6 Document the amount of time, effort, and personnel skills needed to remove the EMS platform and assembly, particularly how a stand should be designed.	3.1.6 Remove and disassemble EMS and place in cargo vans (15 min). Platform construction should be built to accept the entire EMS assembly minus the HPGe or NaI detector carriage sections. The stand should be of lightweight construction designed to fit in a small pickup truck bed for easy transportation. The stand with EMS assembly should be designed to be forked easily with horizontal and vertical stability built in.
3.2 EMS OPERABILITY	**Document time, effort, skill level, problems, corrective actions needed, etc. as applicable to determine test success, test completion and effort for future deployment.**
3.2.1 Document the horizontal reach and vertical reach (i.e., depth) used for each location. Horizontal and vertical reach will depend on the particular excavator used for the demonstration. Identify the type of excavator used.	3.2.1 The horizontal reach of the JD 690 with EMS attached is 22"from the tracks to the centerline of the detectors with the excavator tracking in the East-West directions traversing the area. No vertical reach could be determined since schedule restraints prohibited access to the boiler plant basement test area.
3.2.2 Document the arc radius of the EMSII. Determine frequency of position coordinate marking.	3.2.2 The arc radius of the EMS attached to the JD 690 is 22'. The frequency of position coordinate marking was not performed as the desirable area was not accessed due to schedule restraints.
3.2.3 Complete an evaluation of each design requirement as listed in Attachment A.	3.2.3 See below.

3.2.4 Evaluate the operator's ability to control and maneuver the EMSII.	3.2.4 The operator was able to control and maneuver the system manually. There was no visual scan coverage available to the operator. The proximity screen lighting was insufficient for the cab on the 690. Correction of the detector standoff for the installed detector needed to be corrected.
3.2.5 Document time, effort and skill required to add available extension to the EMSII platform.	3.2.5 This task performance is estimated to take approximately 15 min. The task could not be evaluated due to the unavailability of tools to adjust the extension coupling clip lengths to the boom assembly hooks.
3.3 SOFTWARE COMMUNICATION	**Document time, effort, skill level, problems, corrective actions needed, etc. as applicable to determine test success, test completion and effort for future deployment.**
3.3.1 Document that EMSII hardware and software communicate with each other, i.e. , laser, etc.	3.3.1 This capability was achieved.
3.3.2 Document that software allows for HPGe and NaI communication with EMS.	3.3.2 This capability was achieved.

3.4 HPGe AND NaI DEPLOYMENT **Scan rates and count times may be adjusted during deployment.**	**Document time, effort, skill level, problems, corrective actions needed, etc. as applicable to determine test success, test completion and effort for future deployment.**
3.4.1 With **HPGe or NaI** attached, perform mobile or static counts in the area determined to be the most convenient for the system setup. - Perform EMSII mobile scans with the detector at a 1-foot above the grade surface. Secure as close to 100 percent coverage as possible. - Perform EMSII static counts with the detector at either the 1-foot level for NaI or at either the 1-foot or 1-meter position for the HPGe. The number of locations to be determined based on size of the location. Secure as close to 100 percent coverage as possible.	3.4.1 Mobile scans were performed with both the HPGe and NaI detectors. The detector standoff could not be determined via the system due to detector length correction input to the software being required. Coverage was not determined via the software in real-time due to lack of capability and intermittent differential correction. A static count was performed with the HPGe at an approximated 1-meter position. Coverage calculations were not determined due to schedule restraints prohibiting access to the desirable location to perform this activity.
3.5 OTHER DEMONSTRATIONS	
3.5.1 None	3.5.1

ATTACHMENT A
DESIGN REQUIREMENTS FOR EXCAVATOR MONITORING SYSTEM II

The following is a list of requirements that the new-design EMSII system should satisfy. (Evaluated during June 2001 deployment).

Requirements for EMS Structural Components

1. **Requirement:** The EMS system should use a "universal" coupler to mount the EMS sensors and electronics to the excavator arm to permit some degree of flexibility in choice of excavator to be used. The EMS system should be designed in modular fashion with one module attaching to the next to minimize the weight that personnel must handle at any one time.

   Comments: No "universal" coupler exists. A Hendrix hydraulically operated quick coupler was utilized to pick up the EMS boom assembly. The coupler is specifically fit for the John Deer 160LC and 590D model excavators. It is adaptable to models 690D and 200D without modifications. To adapt it to other models or makes would require fabrication modifications to the pickup plate pin size and distance of the EMS.

2. **Requirement:** Modules should exist containing electronic equipment such as computer and multichannel analyzer, and 4) detector platform module. The method of coupling one module to another should be some type of "quick disconnect" coupler, which does not require the use of hand tools. To minimize the chance of personnel injury, it would be desirable to limit the weight of each separate module to less than 40 pounds so that each could be handled by a single person. The 40-pound limit on each system component is a design goal that can be exceeded if necessary.

   Comments: Module weight for the EMS system is as follows: Mast assembly (45.63), HPGe carriage (25.47 lbs.), NaI carriage (21.20 lbs.),2' extension (21.90 lbs.), 4' extension (26.00 lbs.). Weights for the boom assembly and, Computer/Electronics/Communication module were not provided. All modules utilize quick clip coupling with the exception of the boom assembly and Computer/Electronics/Communication module these two components are attached with allen head machine screws.

3. **Requirement:** A vertical stand should be evaluated for design during this acceptance test to hold the EMS structure. The purpose of the stand will be to aid in storage and to support the weight of the EMS during assembly and disassembly of the various components and attachment to the excavator boom.

   Comments: The stand described above should fulfill the purpose of unit assembly when the excavator is not available and assembled transportation and storage of the Unit. The stand should be light weight yet sturdy enough to withstand the impact of the excavator using the quick coupler device to pick the assembly.

4. **Requirement:** The design of the detector platform module should permit rotation of the detector about a vertical axis so that the detector can be pointed in at least four rotational positions that are 90 degrees apart. The intent is to enable a side-looking detector to be pointed in north, south, east or west directions.

Comments: The detector carriages can be rotated through the horizontal plane at four discrete positions 90, 180, 270 and 360 degrees. Relocation of the connector positions of the proximity sensors is required to ensure proper video screen orientation. No software adjustments are required.

5. **Requirement:** EMS system design should provide adequate protection of multi-channel analyzer and other electronic modules from adverse weather conditions such as rain. The design should consider dissipation of heat generated by this equipment.

   Comments: The Computer/electronics/communications module houses all electronic components described above in a weather resistant enclosure provided with two ventilation fans pulling in the same direction across the internals from intakes at the opposite side of the enclosure.

6. **Requirement:** EMS system should be capable of accepting both HPGe detectors (with liquid nitrogen dewars) and 4-inch by 4-inch by 16-inch NaI detectors (with PVC housings). Each detector platform should have at least three lockable tilt positions so that either type of detector can be pointed down at the ground (0-degree tilt) or sideways toward a vertical wall (90-degree tilt) or half way between the 0 and 90 degree positions (45 degree tilt). Positions with only three discreet tilt angles is acceptable.

   Comments: The HPGe carriage is capable of 0, 45, and90 degree positions in relation to the ground. These are pinned positions. The NaI carriage cannot rotate, but this is unnecessary as the detector could be turned in it's hanger to accomplish this requirement if desired.

7. **Requirement:** To permit the addition of a detector collimator at some time in the future, the EMS structure and couplings must be capable of supporting 100 pounds of weight over and above the weight of the gamma detector, the electronic equipment, the motion dampers and the structure suspended from the excavator arm. If a collimator is used in conjunction with an HPGe detector, the detector platform will NOT be tilted. That is, in reference to Item 6, a collimator will only be used with a detector tilt angle of 0 degrees.

   Comments: The system is capable of carrying at least an additional 100 lbs. The system should be adapted to retrofit the collimator assembly purchased from EG&G.

8. **Requirement:** The EMS design should include some type of housing to protect the HPGe detector crystal from incidental contact with the surfaces that are being characterized. Current plans for the NaI detectors are to use the existing PVC protective enclosure. The HPGe housing should offer some protection without severely attenuating the gamma flux incident on the detector. If possible, the protective housing should also provide some protection of the HPGe detector from adverse weather conditions such as rain.

   Comments: No protection was built into the design for the HPGe detector endcaps or detector can. The NaI PVC enclosure is intacked to protect the NaI crystal.

9. **Requirement:** The EMS design should permit the addition of a 2-foot or a 4-foot extension onto the detector platform to enable the detector to reach to the bottom of deep excavations. For design purposes, it may be assumed that the EMS system will only be used with the extension rods hanging in a vertical direction. Thus the extension rods will be subjected to longitudinal stretching forces created by the weight they support, but only minimal transverse forces perpendicular to the axis of the rods.

   Comments: Both a 2-foot and a 4-foot extension to the boom were constructed.

Requirements for EMS 3D Position Measurements

1. **Requirement:** The EMS hardware and software should be designed to incorporate both survey grade global positioning system (GPS) equipment and laser-based positioning equipment to determine xyz coordinates. The survey grade (3D GPS) will be the primary system for x,y,z position measurement. However, the laser-based system must be present as a backup to the GPS for those areas where GPS reception is inadequate.

   Comments: Both positioning systems were incorporated into the design. Although the conversion from one system to the other is simple this conversion could not be demonstrated due to difficulties with calibration of the laser grid setup.

2. **Requirement:** The position measurement equipment should have a minimum accuracy of ± 5 cm in the x and y directions (horizontal ground plane) and ± 10 cm in the z (vertical) direction.

   Comments: The GPS system accuracy is less than 1 cm in the x and y directions and less than 2 cm in the z. The ArcSecond laser system accuracy is less than 1 cm in the x, y, and z.

3. **Requirement:** To the greatest extent possible, the position measurement equipment should NOT be adversely effected by the position of the excavator itself. System design should allow the addition of extra position measurement modules if blind spots are found to exist.

   Comments: This requirement was put in place for the laser system. The laser system was not fully functional during the evaluation. Noted were areas of blind spots in the attempted setup. This will have to be evaluated and developed further mostly by system experience.

4. **Requirement:** The x,y,z coordinates determined by the 3D position measurements system should be those of the gamma sensitive detector. That is, it is NOT necessary that the x,y,z coordinates associated with any given spectrum be those of the surface being characterized. Proper determination of the detector coordinates may be accomplished with the entry of a z (vertical) offset into the 3D position measurement equipment or with the aid of software computations to correct for offsets. See software requirements for additional details. To simplify the problem, detector position errors introduced by tilting the detector away from the vertical (0 degree) position may be ignored.

   Comments: The positioning coordinates determined by the 3D system are those of the gamma sensitive detector with a built in offset for each type of detector HPGe or NaI.

Requirements for Ground Sensing (Range Finder) System

1. **Requirement:** The EMS system must have a laser based ground sensing (range finder) system to measure the distance from the surface being characterized (either trench floor or wall). The range finder reading will serve as a measurement of detector distance from the surface being characterized (i.e., detector height). The range finder system must be capable of feeding data to a proximity warning system that alarms when the detector moves closer to the scanning surface than a preset limit.

Comments: The laser range finding system installed measures from the detector to the surface being measured. Some adjustment is needed to calibrate this setting as determined during the evaluation. The range finder feeds to an integrated proximity alarm system and display in both the excavator cab and control van. The preset alarm value was set at 15 inches with an accuracy of less than 1 inch.

2. **Requirement:** The range finder system should be capable of measuring distance with an accuracy of +-2 cm. If necessary, the specification for ±2 cm measurement accuracy may be relaxed.

   Comments: The laser range finder accuracy is better than 1 inch.

3. **Requirement:** The range finder system must function with both HPGe and NaI detectors and must not interfere with easy changing of detectors.

   Comments: The laser range finder functions by use of separate units with both HPGe and NaI detectors and does not interfere with detector changeout.

4. **Requirement:** In addition to the range finder system discussed in Item 1 above, which measures the distance of the detector from the surface being measured, the EMS design must also include proximity alarms that provide collision warning signals in four directions perpendicular to the vertical axis of the EMS system. The proximity alarm system must generate visible warning signals in the excavator cab and in the mapping van when the detector moves closer to a surface than a preset alarm distance. To permit scanning with a detector height of 1 foot, the minimum proximity alarm set point distance should be 6 inches. It should be possible to select any distance between 6 inches and 3 feet as the proximity alarm set point. Unlike the range finder system, the proximity alarm system does not need to provide distance readout, but simply warning signals when the detector gets too close to a surface.

   Comments: The horizontal plane proximity alarm system, made up of four ultrasonic sensors generates four independent visible alarms in the excavator cab and in the van. The setpoint of the four sensors is not related to the scan height but are independently settable between 6 inches and 3 feet. The distance readout on the screen is displayed in inches. The visibility of the cab display needs to be improved by replacement of the monitor with a high brightness display panel. The display should be mounted on an adjustable pivoting arm, which can be positioned to accommodate the operator's comfort and safety. An audible alarm should be added to inform the operator of the proximity status.

5. **Requirement:** The proximity alarm sensors must be capable of providing collision warnings in four perpendicular directions when the detector is pointing down at a trench floor and also when it has been rotated into its side-looking orientation to scan walls. When scanning the floor of a trench, two sensors would guard against collisions with opposite trench walls and the other two would point in opposite directions along the length of the trench. When scanning a wall, two sensors would point vertically up and down, and the other two would point left and right.

   Comments: The integrated proximity alarm system is only capable of sensing the distance from the detector endcap to the surface being measured using the laser range finder. In the case of measuring a vertical wall that surface would be the wall. It would also have three of the four ultrasonic sensors for use in determining proximity to the floor of a trench and to the right and left. The opposite trench wall direction would be unprotected.

Requirements for EMS Software

1. **Requirement:** The software for the EMS system should be as close as possible in function and appearance to current in-situ gamma spectrometry software.

   Comments: The EMS software is similar in function to the current gamma spec software with certain enhancements and added features specific to the EMS such as the capability to switch between detectors and modes and switch over to GPS or laser GPS systems.

2. **Requirement:** The EMS software should permit switching between HPGe and sodium iodide detectors without having to load software from an external device onto the main EMS computer.

   Comments: The EMS software has this capability within one code.

3. **Requirement:** The EMS software should be designed to gather gamma spectrometry data using static HPGe detectors and moving NaI detectors.

   Comments: The EMS software has the capability for static and mobile HPGe and NaI measurement modes.

4. **Requirement:** The EMS software should allow control of all data acquisition functions from a nearby untethered command center such as a mapping van. It should also permit the downloading of spectral data files in real time to the command center via wireless Ethernet technology. As much as possible, the wireless data transfer equipment must be compatible with current FEMP systems.

   Comments: The software did not have full function for starting detector high voltage and other "Gamma Vision" functions. The fix is minor however. Data downloading is automatic onboard the excavator and via wireless Ethernet to the control van. The current wireless Ethernet system is not compatible with the newer EMS system due to a company buyout and subsequent lack of support of the older system.

5. **Requirement:** The EMS software should incorporate all three position coordinates (x, y, and z) into the header string of each spectrum file.

   Comments: The EMS software has this capability.

6. **Requirement:** In the cab of the excavator, the EMS software should permit computer display of area coverage maps for both HPGe and NaI detectors, scanning speed in feet per second and easily noticeable proximity alarms from both the mechanical "curb feeler" system and the range finder system.

   Comments: The cab did not have the capability to display area coverage or scanning speed. Proximity alarms for both systems (laser and ultrasonic) were functional.

7. **Requirement:** If multiple display screens are necessary for the excavator operator, they should be accessible with the touch of one or two buttons. Because excavator operation requires almost constant attention to several control levers, access by computer touch screen or similar simple selection means is required.

Comments: Only one screen was necessary. If scan speed and area coverage are added and an additional screen is necessary this requirement will be re-evaluated.

8. **Requirement:** In the mapping van, the EMS software should permit the computer display of area coverage maps, isotopic concentration displays (on preloaded area base maps if possible), gamma spectral data, scanning speed in feet per second and easily noticeable proximity alarms from both the mechanical "curb feeler" system and the range finder system.

   Comments: The control van has the capability of isotopic display but not area coverage. Preloaded base maps were not used. Scan speed was not displayed. Proximity alarms and distance indicators were displayed.

9. **Requirement:** The computer displays generated by the software should be color-coded to represent variable ranges of isotopic contamination levels. The EMS software should permit selection of the isotopic concentration ranges that correspond to each color.

   Comments: This capability was achieved.

10. **Requirement:** The EMS software should permit entry or selection of an alarm level for detector height measured by the range finder ground proximity sensor.

    Comments: This capability was achieved.

11. **Requirement:** The EMS software should permit entry of a vertical offset distance to accommodate the use of "extension rods" in case such extensions are required for the detector to reach the bottom of a deep excavation.

    Comments: This capability was achieved.

12. **Requirement:** The EMS software should compute the scanning speed from the time rate of change of the position coordinates. Two significant figures should be used when displaying the speed. Speed values should be updated at least once per second.

    Comments: This function was not demonstrated on the displays.

13. **Requirement:** The EMS software should include subroutines to automatically check data quality indicators and generate warning flags when data quality parameters exceed preset limits. Specific data quality parameters and limits will be furnished at a later date. These are expected to be similar to the data quality checks in current real time software supplied by INEEL.

    Comments: The data quality indicators used in previous NaI and HPGe software were incorporated into the EMS version.

Miscellaneous EMS Requirements

1. **Requirement:** The EMS system design should include motion damping devices to reduce vibration and oscillation of the structure attached to the excavator boom. The damping system should allow the EMS structure to assume a vertical orientation under its own weight.

   Comments: This function was demonstrated and acceptable.

2. **Requirement:** The EMS design should minimize the use of custom-built items as a means of minimizing cost.

   Comments: "Off the shelf" components were used in the construction wherever possible.

3. **Requirement:** The design of the EMS system and any HPGe detector protective housing must minimize shielding of the detector.

   Comments: No HPGe protective housing was incorporated into the design.

4. **Requirement:** The EMS system should NOT make use of an external gasoline powered electrical generator. The preferred power source is the excavator electrical system, but other means of furnishing power may be acceptable. Cabling between excavator and EMS equipment should be minimized. The power source chosen must be capable of furnishing enough power to all EMS data collection and transfer equipment for 8 hours of continuous operation.

   Comments: Onboard 24-volt DC power was tapped and inverted to power the electrical components. Only one feed line was necessary to supply the boom components and one for the cab.

EMS System Software Features/Capabilities

Requirements:

1. Three-computer system networked via wireless Ethernet (EMS, Van, and Cab).
2. EMS computer communicates independently with the Van and Cab computers.
3. Van computer has complete command and control of EMS functions.
4. One Van control software package operates all EMS system configurations (i.e., NaI, HPGe, GPS, and ArcSecond combinations).
5. Menu-driven selection of hardware configuration for Sodium Iodide or Germanium spectrometer, and Global Positioning System or the ArcSecond Vulcan positioning system.
6. Menu-driven selection of data collection mode for continuous scanning or point-and-look modes for either NaI or HPGe hardware.
7. Scan modes may be changed between continuous scanning or point-and-look without shutting down the system.
8. Automatic creation of data directories based on date.
9. Automatic numbering of spectra for all modes and all hardware.
10. Automatic RTRAK-type analysis of Sodium Iodide spectra in both scan and point-and-look mode. RTRAK-style log file created.
11. Crude automatic analysis of HPGe spectra (counts per second) and creation of a separate HPGe log file.
12. Full spectrum display for both HPGe and NaI data.
13. Automated spectra location display of NaI and HPGe spectra.
14. Ability to adjust the ArcSecond gain on the fly.
15. Van-controllable communication of the EMS with the Cab computer. Van may toggle the communication on or off.

Comments: All listed software features were fully functional.

CAB Software Features

Requirements:

1. Automated spectra location display of NaI and HPGe spectra.
2. Large display of proximity sensors and detector standoff distances.
3. Proximity sensors and laser range finder sensor displays turn from green to red below predefined set points.

Comments: Spectra location, proximity sensor display and range finder distance with changing mode colored alarms were functional.

ATTACHMENT B
ACCEPTANCE TEST REQUIREMENTS FOR EXCAVATOR MONITORING SYSTEM II
(Evaluated during December 2001 deployment)

B.1 SOFTWARE FUNCTIONALITY	
B.1.1 EMSII hardware and software communicate with each other, 1.e., laser, etc.	X pass fail
B.1.2 Document that software allows for HPGe and NaI communication with EMS.	X pass fail
B.1.3 The EMS software is able to successfully initialize and report the initialization of the ORTEC™ multi-channel buffer (MCB) library and the current high voltage setting of the MCB.	X pass fail
B.1.4 The survey configuration items of the EMS software function correctly. These are switches for NaI or HPGe detectors, use of the GPS or Vulcan positioning system, scan or point-look survey, and the number of extension pieces on the EMS.	X pass fail
B.1.5 The EMS terminates properly when the shutdown command in remotely issued from the control van.	X pass fail
B.1.6 The EMS software acquires and displays spectra properly. This includes the ability to change preset times, initial and stop scans, and initiate point-look operations.	X pass fail Completed 12-5-2001
B.1.7 The EMS software reports and allows the operator to change the ArcSecond Vulcan system gain parameter.	X pass fail
B.1.8 The EMS software "Draw Scaled Coverage" feature operates satisfactorily.	X pass fail

B.1.9 The EMS software is able to display and change the display from Total U, Th-232, Ra-226, and Tot CPS properly (for NaI spectra only).	X pass fail
B.1.10 The EMS software is able to exit and restart a scan sequence (switching from scan to point-look and vise-versa) properly.	X pass fail
B.1.11 The EMS software system shuts down the EMS and the control van software properly and orderly.	X pass fail
B.1.12 The EMS software incorporates all three position coordinates (x, y, and z) into the header string of each spectrum file.	X pass fail
B.1.13 In the cab of the excavator, the EMS software permits computer display of area coverage maps for both HPGe and NaI detectors, scanning speed in feet per second and easily noticeable proximity alarms from both the mechanical "curb feeler" system and the range finder system.	X pass fail
B.1.14 In the mapping van, the EMS software permits the computer display of area coverage maps, isotopic concentration displays, gamma spectral data, scanning speed in feet per second and easily noticeable proximity alarms from both systems.	X pass fail
B.1.15 The EMS software permits entry of a vertical offset distance to accommodate the use of extensions.	X pass fail
B.1.16 The EMS software permits entry or selection of an alarm level for detector height measured by the range finder ground proximity sensor.	X pass fail

B.1.17 EMS software computes the scanning speed from the time rate of change of the position coordinates. Two significant figures should be used when displaying the speed. Speed values should be updated at least once per second.	X pass fail Smoother added to make readout more stable
B.2 GENERAL SYSTEM OPERATION	
B.2.1 The control van computer, EMS computer and excavator cab computer are able establish network communications reliably and promptly (i.e., less than one minute after all machines are turned on).	X pass fail
B.2.2 The control van operator is able to adjust and apply high voltage power to the detector on the EMS remotely from the control van.	X pass fail
B.2.3 Document the amount of time, effort, and personnel skills needed to assemble and remove the EMS platform in relevance to stand design.	Previously demonstrated.
B.2.4 Document the arc radius of the EMSII.	25.5 ft. Side tracking (track to detector) 24 ft. Tracking forward (track to detector)
B.2.5 Document the stability of the excavator system hydraulics to maintain a fixed detector height, and the ability of the operator to stabilize or compensate for the hydraulic leak-off if required.	One-inch drift downward noted during 5-minute static acquisition at normal engine idle. Operator able to compensate for hydraulic leak-off and downward drift during static counts by adjusting diesel engine idle. Counting statistics performed on the calibration pad with the NaI detector to assess the difference between drift-based measurement and non-drift-based measurement, no discernable difference noted.
B.3 POSITIONING SYSTEM HARDWARE FUNCTIONALITY	
B.3.1 The control van operator is able to successfully transfer ArcSecond Vulcan calibration data to the EMS computer. This assumes that the Vulcan system has been successfully calibrated.	X pass fail

B.3.2 The EMS is able to communicate with either the ArcSecond or Global Positioning System hardware and successfully acquire valid position data.	X pass fail
B.3.3 The control van operator is able to adjust Vulcan gain setting successfully from the control van.	X pass fail
B.3.4 Both position systems, ArcSecond and GPS, report Ohio State coordinates properly to within 0.25 ft of a known datum.	X pass fail
B.4 COLLISION AVOIDANCE HARDWARE	
B.4.1 The four ultrasonic sensors (both NaI and HPGe mounts) operate properly and report stand-off distances accurately to within two inches when using a flat-surfaced object of acceptable acoustic characteristics.	X pass fail Front = 0.95 ft. Right = 1.01 ft. Rear = 0.85 ft. (recalibration required) Left = 1.01 ft.
B.4.2 The laser range finder (both NaI and HPGe mounts) reports distance to ground surface accurately to within 2 centimeters when using a matte or satin finished flat-surfaced object.	X pass fail
B.4.3 The proximity alarm system generates visible warning signals in the excavator cab and in the mapping van when the detector moves closer to a surface than a preset alarm distance.	X pass fail
B.4.4 It is possible to select any distance between 6 inches and 3 feet as the proximity alarm set point.	X pass fail

B.4.5 The proximity alarm sensors are capable of providing collision warnings in four perpendicular directions when the detector is pointing down at a trench floor and also when it has been rotated into its side-looking orientation to scan walls.	X pass fail