OVERVIEW OF SCIENCE AND TECHNOLOGY PROGRAM FOR JPG PHASE IV

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ABSTRACT

As part of an effort to bring closure to the UXO technology demonstrations at Jefferson Proving Ground (JPG), Indiana, JPG Phase IV includes a science and technology component to review and assess Phases I - III, thoroughly characterize the JPG sites, and conduct phenomenological modeling. The science and technology program is being executed by personnel at the U.S. Army Engineer Waterways Experiment Station (WES) and the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire; the Corps of Engineers team will also participate in the planning and execution of the JPG Phase IV technology demonstrations. The overall JPG Phase IV is directed by the U.S. Army Environmental Center, Aberdeen Proving Ground, Maryland, in cooperation with the U.S. Naval Explosive Ordnance Disposal Technology Center, Indian Head, Maryland.

Review of the previous phases of technology demonstrations at JPG for UXO detection concentrates on Phases II and III and examines factors such as depth distributions of ordnance and other objects, areal distributions of buried objects, comparisons of depths and distributions between phases, and demonstrator performance metrics. Phenomenological modeling will consist of magnetic, electromagnetic induction, and ground penetrating radar modeling to predict responses or signatures of the Phase II and III baseline target sets. Site characterization activities at the JPG sites are mostly completed and include electrical resistivity soundings to determine electrical resistivity as a function of depth at selected locations, electromagnetic "terrain conductivity" surveys to map the areal distribution of bulk, volume-averaged electrical conductivity, in situ measurements of complex dielectric permittivity at selected locations as a function of depth, and ground penetrating radar (GPR) surveys to study depth of investigation as a function of antenna center frequency and ability to detect localized objects (e.g., the buried ordnance). Soil samples were also acquired at selected locations. The soil samples are analyzed to determine soil types, water contents, engineering classifications, particle size gradation, and X-ray diffraction analysis for clay mineralogy. Laboratory complex dielectric permittivity measurements are planned on the soil samples over a wide frequency band and for three nominal water contents. Results of the site characterization are utilized in the assessments of Phases II and III and in the phenomenological modeling of GPR response as a function of environmental site conditions (specifically soil water contents) and depth of burial of ordnance item. Areal distribution of volume-averaged electrical conductivity is compared to ordnance distributions.

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INTRODUCTION

The status of capability for buried UXO detection, discrimination, and identification is summarized as follows: *(1) can detect UXO, within definable limits; (2) cannot effectively discriminate UXO anomalies from "false alarm" anomalies; (3) cannot identify UXO.* The definable limits for item 1 refer to combinations of ordnance size and burial depth that result in geophysical anomalies at the surface which can likely be detected relative to site-specific background noise (geologic background and cultural clutter). "False alarm" anomalies are caused by buried ordnance debris, other metallic objects, gravel and cobbles, soil heterogeneities, tree roots, and other natural and cultural features. Without significant discrimination capability, large numbers of false alarms that must be verified (dug up) are the dominant cost and time drivers for UXO site clean up (remediation).

The results of recent field demonstrations at the Jefferson Proving Ground (JPG) Technology Demonstrations (USAEC 1994, 1995, 1996, 1997; Altshuler et al 1995), exhibit buried ordnance detection probabilities exceeding 90% by Phase III (as shown in Tables 1 and 2). However, even with ordnance detection improving to acceptable rates, the number of false alarms is still unacceptably high, i.e., poor discrimination capability. For JPG Phase II, four demonstrators had ordnance detection rates >70%; the number of false alarms for each ordnance item detected, however, ranged from 3.4 to 20.7 for these demonstrators (Table 1). Even though JPG Phase III was easier for ordnance detection than Phase II, in that the ordnance items were consistently shallower (see Figure 1), it is notable that ordnance detection rates improved considerably. Four demonstrators for JPG Phase III *Scenario 2* (Table 2) had ordnance detection rates ≥90%; but the numbers of false alarms per ordnance item detected ranged from 1.4 to 20.2, still unacceptably high, although showing some improvement. The JPG and other field demonstrations exhibit extremely limited capability for ordnance identification or classification (item 3 above). Even classification into broad ordnance categories, such as bombs, projectiles, and mortars, is not possible reliably with presently fielded detection systems. Capability for verification of explosive content in *buried* ordnance does not presently exist.

OUTLINE OF JPG PHASE IV

Jefferson Proving Ground (JPG) Phase IV consists of three aspects: (1) technology enhancement projects; (2) technology demonstrations; (3) a complementary science and technology program. Both the technology enhancement projects and the technology demonstrations will focus on the discrimination and identification/classification requirements. Approximately 160 targets (ordnance and nonordnance targets) will be buried at the JPG 40 acre site. Demonstrators in both categories will have 40 hours to "interrogate" as many of the given target locations as possible. The demonstrators will make ordnance or nonordnance declarations for all target locations investigated in the allotted time, produce a rank ordering of the declarations in terms of confidence in the declaration, and details for the targets, particularly the declared ordnance targets, including depth, size (length, diameter, mass), orientation, ordnance type, etc. The technology enhancement projects are funded specifically to develop methods for increased discrimination capability, and then to demonstrate the enhanced capability at the 40 acre site. The technology demonstrators are funded just for the cost of the demonstration, using their existing technology.

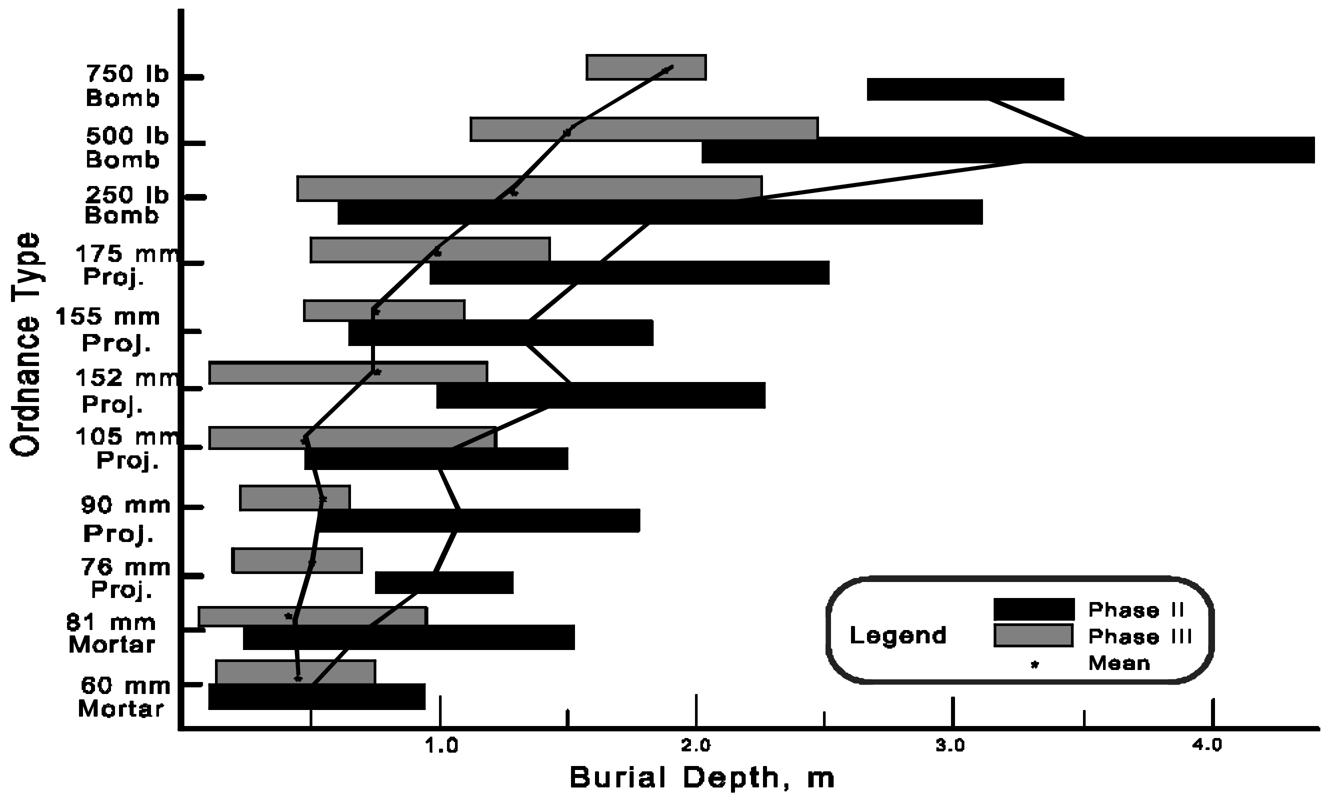

Figure 1. JPG Phase II and Phase III burial depth comparison for ordnance items.

Table 1: A Synopsis of JPG UXO TD Phase II Results				
(160 UXO Targets Buried for Phase II)				
Contractor	**Targets Reports**	**Ordnance Detection Rate (%)**	**"False Alarms" Per Hectare**	**No. False Alarms Per Ordnance Item Detection**
Geophex	398	71	19.7	3.41
Geometrics	521	83	26.9	3.96
Parsons	602	85	32.5	4.68
Bristol	566	62	38.3	6.97
ADI (Mag)	569	63	31.7	8.88
ADI (Mag & EM)	598	65	34.5	9.35
Coleman	280	29	15.9	9.56
Scintrex	255	50	45.3	10.10
GeoPotential	168	11	12.0	13.00
Geo-Centers	1,409	72	84.0	20.70
Vallon	1,903	57	225.9	68.00

Table 2: A Synopsis of JPG UXO TD Phase III Results for Scenario 2				
Artillery and Mortar Range (Scenario 2) (117 Targets -- 67 Ordnance; 50 Nonordnance)				
Demonstrator	**Targets Reports**	**Ordnance Detection Rate (%)**	**"False Alarms" Per Hectare**	**No. False Alarms Per Ordnance Item Detection**
NAEVA	202	97	19.0	1.37
Geophex	174	67	21.1	2.20
Geometrics	282	90	38.4	3.00
Ensco	279	70	43.6	4.34
Geo-Centers	486	93	80.7	6.10
ADI	456	85	76.8	6.32
Rockwell	151	21	27.1	9.07
GeoPotential	23	3	4.3	10.00
GRI	1,319	90	258.2	20.15

The JPG Phase IV execution team, under the leadership of the U. S. Army Environmental Center, is as follows:

Army Environmental Center
Naval Explosive Ordnance Disposal Technology Division
Army Engineer Waterways Experiment Station
Army Engineering and Support Center, Huntsville

The science and technology program is executed by the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, and the U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. The major components of the science and technology Program are shown in Figure 2; further details are given below.

- Supplemental Site Characterization
  - -- 40 and 80 Acre Sites
- Establish and Characterize 1-Hectare Site
- Perform Independent Assessments
  - -- JPG Phases I - III
- Contractor self-assessments
  - -- Phase III Performance
- Participate in Phase IV demonstrations

Figure 2. Outline of Science and Technology Program.

Supplemental Site Characterization: 40 and 80 Acre Sites

The primary objective of conducting site characterization investigations at the JPG UXO Technology Demonstrations sites is to establish an archival documentation of the sites to support:

— Present and future demonstrator planning;
— Demonstration assessments;
— Phenomenological modeling;
— Future use of the JPG sites;
— Inter-site comparisons of the JPG sites with past and future UXO/landmine detection investigations at other sites.

The goal is to supplement existing site information to the maximum extent possible consistent with the existing site disturbance and buried objects.

The primary aspects of the supplemental site characterization are summarized in Figure 3. A synopsis of the existing site characterization information for the 40 and 80 acre sites is summarized in Figure 4.

Collection and synopsis of original site characterization data

Detailed topographic surveying

Additional soil sampling
- **Water Content**
- **Gradation; Soil Classification**
- **Clay Content Assessment**
- **Laboratory Electromagnetic Properties**

Vertical electrical resistivity sounding

DICON Probe EM Property Measurements

Electromagnetic induction (EM conductivity) surveys

Ground penetrating radar surveys

Figure 3. Outline of supplementary site characterization activities at JPG 40 and 80 acre sites .

Geophysical Surveys:

- Total Field Magnetic Survey, Both Sites, 100 ft Grid
- Electrical Resistivity Surveys, 40 Acre Site -- 3, 80 Acre Site -- 4
- GPR Surveys, 500 MHz; Unspecified Number of Lines; No Results Available
- Metal Detector Sweeps

Topographic (100 ft Grid) and Vegetation Survey

Soil Probing to Refusal Depth:

- 40 Acre Site -- 203 Probe Locations (1.1 - 7.3 m)
- 80 Acre Site -- 199 Probe Locations (0.9 - 6.5 m)

Geotechnical Investigations Soil Sampling:

- 20 Test Pits
- Continuous Soil Logging -- 8 Locations (40 acre site -- 3 ; 80 acre site --5)
- 20 Soil Samples

Figure 4. Synopsis of existing (prior) site characterization information.

The approach for characterization of the 40 acre site is shown in Figure 5; a similar approach was followed for the 80 acre site, although there was less extensive coverage of the site. Results of the site

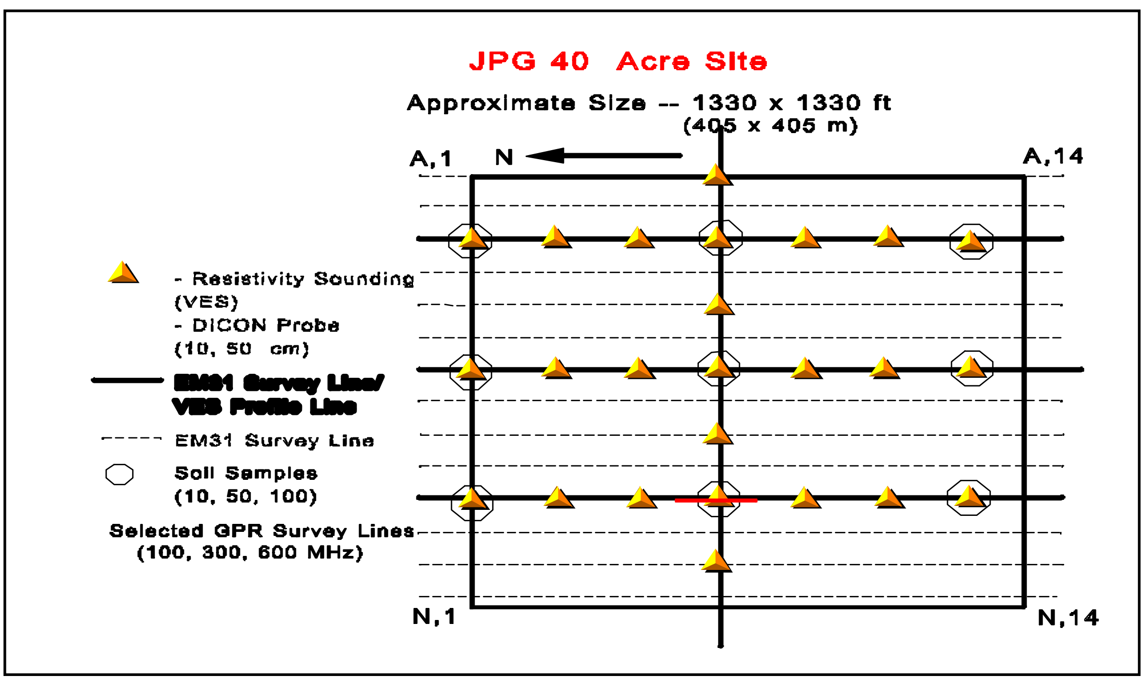

Figure 5. Layout and approach for 40 acre site characterization.

characterization investigations will be presented in detail in subsequent technical reports. A surprising result of the investigations is that the electrical resistivity (conductivity) is much higher (lower) than anticipated for the JPG sites. A synopsis of electromagnetic conductivity surveys of the 40 acre site under dry and wet site conditions is presented in Table 3. Due to persistent reports of poor ground penetrating radar performance at the sites and soils classifications as clays, the electrical conductivity was expected to be much higher. Also, the difference between conductivities during dry and wet site conditions was anticipated to be greater than indicated in Table 3. A synopsis of the results of laboratory visual and laboratory soils classifications is given in Figure 6, where the soils classify as CL and CH (low and high plasticity sandy clay). However, x-ray diffraction analyses of selected soil samples indicate very small quantities of clays present, particularly for samples from the 40 acre site. The soil mineralogy is predominantly quartz and feldspars and consists of very fine-grained silt- and "clay"-sized particles.

Table 3: Electromagnetic terrain conductivity survey statistics, JPG 40 acre site: Comparison survey results under dry and wet site conditions.

STATISTIC	DRY (AUG 1997)	WET (APR 1998)
Minimum	10.5	12.2
Maximum	32.5	94.9
Average (Mean)	19.9	20.8
Median	19.6	20.2
Mode	18.2	19.2
Variance	13.2	22.9
Standard Deviation	3.6	4.8

Visual Soils Classification --
Sandy Clay -- CL and CH

Natural Water Content (%) -- August 1997
11 - 26 (Increasing with depth)

Liquid Limit Range -- 25 - 44

Plasticity Index -- 4 - 23
(All samples plot just above the A-Line in Cassagrande's Plasticity Chart)

Gradation -- 80 - 95 % Fines (< 0.075 mm)

X-Ray Diffraction Analyses (40 & 80 Acre Sites)
Predominant Minerals Present -- Quartz, Na- and K-Feldspars
Only Trace Amounts of Clays (Slightly more on 80 acre site)

Figure 6. Synopsis of soils classifications for 40 acre site and x-ray diffraction analyses for selected samples from the 40 and 80 acre sites.

Establish and Characterize 1-Hectare Site

A 1-hectare size site has been established approximately 60 m north of the 40 acre site at JPG. The 1-hectare site has identical layout to four sites established at Fort A.P. Hill, Virginia (two sites), and Fort Carson, Colorado (two sites), for the Defense Advanced Research Projects Agency (DARPA). Activities involved in this aspect of the science and technology program consist of (1) locate 125 x 100 m site, (2) conduct topographic, vegetation, and site features surveys, (3) conduct geophysical surveys and soil sampling, (4) establish side bars and center square, and (5) bury inert ordnance, calibration targets, and registration targets (no inert landmines or simulants buried at the JPG 1-hectare site). The JPG 1-hectare site complements the four DARPA sites in terms of site conditions and soil type, and will enhance the utility of the JPG technology demonstrations by establishing a backgrounds characterization for JPG similar to the four DARPA sites.

Assessments of JPG Phases I - III

Assessments of prior JPG phases consist of baseline ordnance item comparisons, site layouts, demonstrator assessments, and phenomenological studies. The phenomenological studies are a major aspect of the science and technology program. Electromagnetic (time domain EM), magnetic, and ground penetrating radar modeling of the baseline ordnance target set is being conducted. Key questions addressed by the phenomenological modeling are detectability of the ordnance items relative to site background, resolution of closely spaced targets by the different geophysical methods, required measurement spacing to detect and resolve targets, and the effects of environmental variables (primarily water contents of the soils) on detection and resolution.

Demonstrator Self-Assessments

One of the shortcomings of the prior JPG phases was the lack of a feedback mechanism to allow demonstrators to analyze their performance based on knowledge of the baseline target set. The demonstrators knew how well they performed overall, but not what targets they detected and did not detect, what targets they misclassified (ordnance or nonordnance), and which of their target declarations were false alarms. As part of the science and technology program selected demonstrators will be funded to perform critical self-assessments of their performance in JPG Phase III. The objective and format of the self-assessments is summarized below:

Objective: Establish a feedback mechanism for selected JPG Phase III demonstrators

Format:

— Demonstrators will document all equipment, procedures, rationale, etc., used during Phase III demonstration
— Government will provide baseline target set details
— Demonstrators will conduct a critical self-assessment of performance relative to the target baseline
— All data (raw and processed) acquired during the demonstration will be submitted

CONCLUSIONS

This paper contains only a brief overview of plans and some preliminary results of a Science and Technology Program component of JPG Phase IV. A number of products of the science and technology investigations will be available for dissemination, and it is the sincere plan of all involved that there will be significant value-added enhancement to JPG Phase IV. The following tabulations summarize the products and planned value-added contribution.

Products

— Supplementary Site Characterization of JPG 40 and 80 Acre Sites

— Phenomenological Modeling of Baseline Targets

— Assessment of JPG Demonstration Results Including a Demonstrator Self-Evaluation

— Input to Targeted Technologies and Demonstrator Selection for Phase IV Demonstrations Directed to UXO Discrimination / Identification

— Input to Phase IV Test Plans, Metrics, Deliverables, and Execution

— Development of Standard 1-Hectare UXO Test Site for Future Use: UXO Test Sites Spanning Broad Range of Climatologic and Geologic Conditions

Value-Added

Geophysical and Environmental Characterization of Demonstration Sites to

— Support Future Phenomenological Modeling
— Support Environmental and Sensor Performance Assessments
— Place the JPG Sites in Perspective with Other UXO Test Sites

Scientifically Defensible Phase IV Demonstrations Using Targeted Technologies and Demonstrators Under Carefully Controlled Test Conditions

Phenomenological Modeling Linking Target Signatures to Sensor Performance

Scientific Closure to the JPG Experience — Maximizing Return on Investment

Well-Documented, High-Resolution Data Sets to Support Multi-Sensor Data Integration Algorithm Development

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