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The NATO TG-25 Unattended Ground Sensors Field Experiment 2002

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Sensors and Electron Devices Directorate, ARL
# The NATO TG-25 Unattended Ground Sensors Field Experiment 2002

In October 2002, the U.S. Army Research Laboratory (ARL) participated in the NATO TG-25 unattended ground sensors experiment held in Bourges, France. The field experiment was a joint international signature collection and vehicle tracking exercise with nine participating NATO countries. The experiment consisted of nine different ground vehicles that covered the heavy-tracked, light-tracked, heavy-wheeled, and light-wheeled class of ground vehicles. The vehicles were run in single vehicle and convoy formations. This report describes the raw signature data that was collected by the ARL during the TG25 field experiment. The raw signature data collected include acoustic array data at two geographic locations, three-axis seismic data at two geographic locations, and still infrared images of the vehicles at one location.

## Distribution/Availability Statement
Approved for public release; distribution unlimited.

## Subject Terms
- unattended ground sensors (UGS)
- acoustics
- seismics
- ground vehicles (heavy-track, light-track, heavy-wheeled, light-wheeled)
- NATO

## Security Classification of:
<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
<th>c. THIS PAGE</th>
</tr>
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## Limitation of Abstract
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## Contents

<table>
<thead>
<tr>
<th>List of Figures</th>
<th>iv</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>iv</td>
</tr>
<tr>
<td>1. Background</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Field Experiment Purpose and Goals</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Raw Data Collection Hardware</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Acoustic Sensors</td>
<td>3</td>
</tr>
<tr>
<td>1.4 Seismic Sensor</td>
<td>3</td>
</tr>
<tr>
<td>1.5 Infrared (IR) Sensor</td>
<td>3</td>
</tr>
<tr>
<td>2. Sensor Installations and Configurations</td>
<td>4</td>
</tr>
<tr>
<td>2.1 Z1: Sensor 6 (ARL Hardware Number)</td>
<td>4</td>
</tr>
<tr>
<td>2.2 Site Z1 Surroundings</td>
<td>4</td>
</tr>
<tr>
<td>2.3 Z3: Sensor 8 (ARL Hardware Number)</td>
<td>4</td>
</tr>
<tr>
<td>2.4 Site Z3 Surroundings</td>
<td>5</td>
</tr>
<tr>
<td>2.5 IR Camera: (Located at Z3)</td>
<td>6</td>
</tr>
<tr>
<td>2.6 Sensor Microphone Configurations and Seismic Configuration</td>
<td>6</td>
</tr>
<tr>
<td>2.7 Sensor Data Acquisition Parameters</td>
<td>8</td>
</tr>
<tr>
<td>2.8 Sensor 6 Failure During Test</td>
<td>8</td>
</tr>
<tr>
<td>3. Vehicle Test Matrix</td>
<td>9</td>
</tr>
<tr>
<td>4. Description of Raw Data</td>
<td>9</td>
</tr>
<tr>
<td>5. Field Calibration Files</td>
<td>15</td>
</tr>
<tr>
<td>6. Contact Information for Data Requests</td>
<td>15</td>
</tr>
<tr>
<td>Appendix A. Test Site Locations and Vehicle Trajectories</td>
<td>17</td>
</tr>
<tr>
<td>Appendix B. BL-1994 Sensitivity Specifications</td>
<td>19</td>
</tr>
<tr>
<td>Appendix C. GS-11D Sensitivity Specifications</td>
<td>21</td>
</tr>
<tr>
<td>Appendix D. ALPHA Infrared (IR) Camera Specifications</td>
<td>23</td>
</tr>
</tbody>
</table>
Appendix E. Vehicle Descriptions
Appendix F. Data Format Specifications
Appendix G. Sample MATLAB Program to Read Data Files
Appendix H. Gain Table for Signal Conditioning Boxes

List of Figures

Figure 1. ALPHA uncooled IR camera................................................................. 3
Figure 2. Locations of local Z3 surroundings .................................................. 5
Figure 3. IR camera position at Z3. ................................................................. 6
Figure 4. Array topology and signal connections. ......................................... 7
Figure A-1. Test site locations and vehicle trajectories............................. 17
Figure B-1. BL-1994 sensitivity specifications ........................................... 19
Figure C-1. GS-11D sensitivity specifications ............................................. 21
Figure D-1. ALPHA IR camera specifications .......................................... 23
Figure E-1. AMX-10P: Infantry combat vehicle. .................................... 25
Figure E-2. AMX-10RC: Reconnaissance vehicle. .................................... 26
Figure E-3. AMX-30 MBT: Medium battle tank ....................................... 27
Figure E-4. CBH P4: Armored personnel carrier ...................................... 28
Figure E-5. TRM 10000: 10,000-Kg truck ............................................... 29
Figure E-6. TRM 200: Truck ........................................................................ 30
Figure E-7. VAB: Armored personnel carrier .......................................... 31

List of Tables

Table 1. Test matrix ....................................................................................... 10
Table F-1. Packet header format ................................................................. 33
Table H-1. Gain table .................................................................................... 37
Table H-2. Cutoff frequency table ............................................................... 37
1. Background

1.1 Field Experiment Purpose and Goals

The North American Treaty Organization (NATO) research group SET-08/Task Group (TG)-25 on “Advanced Concepts of Acoustic and Seismic Technology” is involved in emphasizing acoustic and seismic concepts within Unattended Ground Sensors (UGS). The main objective of the group is to assess the potential technologies that can be cooperatively developed and assessed within NATO to provide low-cost battlefield sensors based on acoustic and seismic technology.

The approach adopted by TG-25 is as follows:

1. Evaluate emerging technologies for applicability to battlefield needs.
2. Develop cooperative efforts aimed at reducing costs to each participating country.
3. Evaluate potential of UGS to meet battlefield requirements.
4. Cooperate in known areas of overlap.
5. Cooperate on sensor environmental modelling.

The TG-25 has acquired participation from nine nations to include Canada, France, Germany, Italy, the Netherlands, Norway, Poland, the United Kingdom, and the United States. The group has worked on tasks with the primary objective of establishing quantitatively the military benefits that Acoustic and Seismic sensor systems offer. Although these technologies cover a wide range of applications, a few of these proposed topics will be selected for cooperation to include the following:

a. Propagation Modeling,
b. Signature Collection and Storage,
c. Standards,
d. Simulation and Modeling of Sensors,
e. Sensor Fusion,
f. Joint Field Experiments,
g. Unattended Ground Sensors, and
h. Sniper Detection.
In support of these tasks, a decision was made to further investigate the benefits of networking UGS systems and to demonstrate interoperability among participating nations. It was deemed necessary to organize a field-campaign in which each participant will collect data and provide real-time UGS system output to a network. Via the network, the UGS system output would be collected and visualized in real-time on a central server. Analysis of the collected data (i.e., data-fusion) would be carried out after the field-campaign.

In October 2002, under the auspices of the SET-08/TG-25 NATO research group, France hosted the Joint UGS field experiment campaign at the “Les Ormeaux” testing facility in Bourges. Appendix A shows the test site locations and the vehicle trajectories.

Apart from each team’s own objectives concerning the field-campaign, the following collective goals have been defined:

- **Centralized UGS system output.** During the field-campaign, output data from each participant’s UGS system(s) would be collected and displayed in real-time on a central server. This would demonstrate the potential of networked UGS systems, enabling the centralized and uniform collection of UGS systems' output.

- **Exchange of sensor data.** After the field-campaign, each TG-25 member would provide sensor data recorded during the field-campaign to other TG-25 members upon request.

- **Analysis of networked UGS systems.** After the field-campaign, the centrally collected UGS systems’ output data would be made available to TG-25 members to determine the benefits of networking UGS systems.

- **Field-campaign report.** A report would be written to provide participants and others with information about the field-campaign.

- **Demonstration for VIPs.** During the field-campaign, a number of invitees were given the opportunity to attend the field-campaign. The purpose was to demonstrate current developments and to gain support for the funding of research in networked UGS systems.

### 1.2 Raw Data Collection Hardware

The data collection hardware that was used by the U.S. Army Research Laboratory (ARL) is referred to as the Data Fusion Testbed (DFT). The DFT was developed by ARL to allow rapid in-field testing of various sensors and algorithms. The field-rugged, self-contained DFT can operate on battery or alternating current (AC) power, is remotely operated via wireless or RJ-45 network connection, and provides on-board recording of up to 56 channels of raw sensor data. The DFT can also host eight concurrent signal processing algorithms operating on the real-time data.

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sensor data. The algorithms can operate independently or fuze data locally prior to sending processed results to additional assets in the field. A final feature of the DFT allows remote clients to receive real-time sensor data. This allows high-level clients such as MATLAB or Labview clients to process field data and inject results into the network as if they were operating locally on the DFT. This feature avoids the costly step of porting software from a high level language for evaluation purposes. By using several DFTs, the backbone of a generic UGS field can be formed.

1.3 Acoustic Sensors

The acoustics sensors used were instrumentation-grade piezo-ceramic microphones. The specific microphones used were model number BL-1994 manufactured by Emkay Innovative Products. Emkay is a subsidiary company to Knowles, which is the common term used for the microphones. The sensitivity-vs.-frequency curve for the BL-1994 is shown in Appendix B.

1.4 Seismic Sensor

The seismic sensor used was a commercial tri-axial geophone. The specific unit is produced by Geo Space, LP, Inc. and contains three GS11D, 4.5-Hz, 4000-ohm coil resistance sensors packaged in a GSC-3C land case. The output sensitivity as a function of frequency is shown in Appendix C. Note curve C should be used due to the specific shunt resistor selected.

1.5 Infrared (IR) Sensor

IR images were collected for all of the vehicles used during the test. The images have various pass bye orientation to the camera and include both left and right turns in both approaching and receding directions. The IR sensor used for still image collection was the ALPHA uncooled IR camera, manufactured by Indego, Inc. The picture of the camera is shown in Figure 1. The specifications for the camera are shown in Appendix D.

Figure 1. ALPHA uncooled IR camera.

The images were collected using a commercial frame grabber card, associated software, and laptop. The frame grabber card was manufactured by Video Capture Essentials. The captured images are stored as Microsoft Windows Bitmap files and had the following properties: height
2. Sensor Installations and Configurations

Two ARL DFT sensors were installed to support the field experiment. The first sensor is sensor number 6 and was located at Bourges site Z1 (see map in Appendix A). The second sensor was sensor number 8 and was located at Bourges site Z3. The locations and network address follow:

2.1 Z1: Sensor 6 (ARL Hardware Number)

Location
- N 47.00484º
- E 2.68050º
- Alt: 191 m

Position estimated with Garmin Receiver (accuracy 4 m)
- IP Address: 192.168.10.40
- Sensor ID number used in NATO Messages: 120

Geodetic survey location:
- N 47º 0.29145 min
- E 02º 40.8274 min
- Alt: 238.2-m ellipsoid

Seismic sensor is 170 cm from the center of acoustic array. Acoustic array and seismic sensor are both aligned to True North.

2.2 Site Z1 Surroundings

Sensor location 6, site Z1, had only one reflective source and that was the electronics hut. The hut was approximately the same separation as the array from site Z3, but at an angle of ~265º.

Sensor 6 at Z1 site is not operational on the last day of the field test, October 24, 2002. Sensor 8 at Z3 site remained operational for the entire series of tests on that same day.

2.3 Z3: Sensor 8 (ARL Hardware Number)

Location
- N 47.00293º
- E 02.68576º
- Alt: 183 m
Position estimated with Garmin Receiver (accuracy 4 m)
IP Address: 192.168.10.60
Sensor ID number used in NATO Messages : 370

Geodetic survey location:
N 47º 0.1768 min  
E 02º 41.14357 min  
Alt: 232.7-m ellipsoid

Seismic sensor is 193 cm from the center of acoustic array. Acoustic array and seismic sensor are both aligned to True North.

- Locations in WGS-84 coordinates
- NATO Sensor ID numbers were unique for all participants

2.4 Site Z3 Surroundings

Site Z3 has an old farm building ~100 m from the array. The walls were intact and created an efficient reflective source. The wall facing the array was parallel to the road between Z1 and Z3. The distances and locations of the surroundings at Z3 are mapped out in Figure 2.

Figure 2. Locations of local Z3 surroundings.

Controlling Computer “Magenta” was configured with IP Address 192.168.10.90.

Both sensors were configured to connect to the “Spider” socket server at IP Address 192.168.10.31 and port 1000.
2.5 IR Camera: (Located at Z3)

Camera Location: N 47.00269°
E 02.68582°
Alt: 172 m

Distance from camera perpendicular to middle of the track: 5.2 m
Distance from camera to center of intersection: 27.8 m
Angle from camera to intersection: 135° from magnetic north.

Figure 3 shows the IR camera position relative to the road.

![Figure 3. IR camera position at Z3.](image)

2.6 Sensor Microphone Configurations and Seismic Configuration

The sensor configurations for Sensor 8 site Z3 are as follows:

Group 0: Array of Microphones. The microphones were configured as a 7-element 4-ft circular array with topology shown in Figure 4.

Group 0 used junction box serial number (SN): 213(3 temp label)

- Channel 1: Mic SN 101
- Channel 2: Mic SN 117
- Channel 3: Mic SN 48
- Channel 4: Mic SN 63
- Channel 5: Mic SN 19
Figure 4. Array topology and signal connections.

Channel 6: Mic SN 122
Channel 7: Mic SN 26
Channel 8: No Connection

Group 1: 3 channels of seismic data from tri-axis seismometer with ARL SN 6.

  Group 1 used junction box SN: 2–15
  Channel 1: North
  Channel 2: East
  Channel 3: Vertical
  Channels 4–8: No Connections

The sensor configurations for Sensor 6 site Z1 are as follows:

Group 0: Array of Microphones. The microphones were configured as a 7-element 4-ft circular array with topology shown in Figure 4.
Group 0 used junction box SN: (C-1 and B-5 temp label)

Channel 1: Mic SN 85
Channel 2: Mic SN 32
Channel 3: Mic SN 107
Channel 4: Mic SN (no label)
Channel 5: Mic SN 24
Channel 6: Mic SN 38
Channel 7: Mic SN 6
Channel 8: No Connection

Group 1: 3 channels of seismic data from a tri-axis seismometer

Group 1 used junction box SN: (Not Recorded)
Channel 1: North
Channel 2: East
Channel 3: Vertical
Channels 4–8: No Connections

2.7 **Sensor Data Acquisition Parameters**

The settings for Sensors 6 and 8 were identical and are as follows:

Group 0 Sample Rate: 2048 Hz
Group 1 Sample Rate: 1024 Hz

Group 0 Gain 100× (33 in hardware setting): 10× in junction box 10× in mic preamp
Group 1 Gain 100× (44 in hardware setting): 100× in junction box no preamp on seismic

Group 0 Cutoff 625 Hz (66 in hardware setting)
Group 1 Cutoff 312 Hz (77 in hardware setting)

2.8 **Sensor 6 Failure During Test**

General Notes: On the evening of October 21, 2002 and into the morning of October 22, 2002, a severe thunderstorm went through the test area. The CPU in Sensor 6 was damaged. The sensor was replaced with the development system that was on site as a backup. All of the sensors remained in order so the data sets will have the same calibration files. There should be no noticeable difference in the data, but the change in sensors is noted for completeness.
3. Vehicle Test Matrix

Table 1 is the test matrix that provides a detailed record of the actual vehicle (Appendix E) runs during the field test. It records the number of runs that had taken place during the field test, the date when the runs occurred, the time when the vehicle(s) started their runs, the time when the vehicle(s) ended their runs, what type of target(s), the speed of the target(s), and how many targets were involved during the runs. It also provides the footnote that documents additional information that occurred during the runs.

4. Description of Raw Data

The raw acoustic and seismic data that were collected at the TG-25 field experiment have the same fundamental format specification. The data are organized into one file per eight analog signal channels. For each site, the first group (group 0) of channels contained the acoustic array data on channels 1–7 and the second group (group 1) contained the three-axis seismic data. The seismic group had three channels 1–3, containing the North, East, and Vertical components, respectively. Channels 8 on group 0 and channels 4–8 on group 1 had no sensor elements connected and should be ignored. During the tests, each vehicle run produced two data files per site location. The filenames have the basic format of year_month_day_hour_min_sec_SensorNumber_GroupNumber. The Sensor number indicates the site where the data were collected, and the group number indicates which set of eight analog channels are contained in the file.

The data within each file are stored in a binary file that is specified in Appendix F. The fundamental structure is a 40 byte header followed by a packet of raw data. The size of the raw data packet is calculated from the header information but is in this case 1 s of analog data for the eight channels specified by the group number. The blocks of headers followed by data repeat throughout the entire data file, which spans the entire vehicle run. The binary files are easily read into application by calculating the size parameters from the header fields, and an example MATLAB (Matrix Laboratory) program is included in Appendix G, which demonstrates the reading of the raw data files.
<table>
<thead>
<tr>
<th>Run #</th>
<th>Date</th>
<th>Raw Data Filename</th>
<th>IR Image Filename</th>
<th>Start time</th>
<th>Stop time</th>
<th>Target type</th>
<th>Num vehs</th>
<th>Speed kph</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>10/16/02</td>
<td>2002_10_16_08_27_10_Sens8_Grp0</td>
<td>Trial1_16Oct02_AMX30</td>
<td>0827</td>
<td>0840</td>
<td>AM × 30</td>
<td>1</td>
<td>20</td>
<td>Artillery fire: 8:32</td>
</tr>
</tbody>
</table>

| Run 1 | 10/16/02 | 2002_10_16_13_12_34_Sens6_Grp0 | Run1a_16Oct02_AMX30 | 1312 | 1344 | AM × 30 | 1 | 20 | Z1 is magnetic north. Z3 is True North. Magnetic North is offset by 2º 35 min counterclockwise from True North |

| Run 2 | 10/16/02 | 2002_10_16_13_56_02_Sens6_Grp0 | Run2a_16Oct02_AMX30_broadside | 1356 | 1427 | AM × 30 | 2 | 20 | Separation 75 m |

| Run 3 | 10/16/02 | 2002_10_16_14_54_37_Sens8_Grp0 | Run3a_16Oct02_VAB | 1454 | 1515 | VAB | 1 | 30 | Note: Run 1 is not Figure 8, on return driver skipped Z1 to Z3 path |

| Run 4 | 10/16/02 | 2002_10_16_15_33_46_Sens8_Grp0 | Run4a_16Oct02_TRM2000 | 1533 | 1554 | TRM2000 | 1 | 30 | — |

| Run 5 | 10/17/02 | 2002_10_17_12_31_10_Sens8_Grp0 | Run5a_17Oct02_AMX30 | 1231 | 1303 | AM × 30 | 4 | 20 | Separation 75 m, Z1 was rotated ~3º clockwise and is now pointing to True North. Z3 is True North. High winds |

| Run 6 | 10/17/02 | 2002_10_17_14_06_45_Sens8_Grp0 | Run6a_17Oct02_TRM10000 | 1406 | 1430 | TRM10000 | 1 | 30 | High winds |

| Run 7 | 10/17/02 | 2002_10_17_14_49_21_Sens8_Grp0 | Run7_1a_17Oct02_TRM10K_TRM2000_K | 1449 | 1501 | TRM10000 (1) TRM2000 (1) | 2 | 30 | Very high winds; Separation 75 m |

| Run 8 | 10/17/02 | 2002_10_17_15_42_53_Sens8_Grp0 | Run8a_17Oct02_AMX10RC | 1542 | 1606 | AM × 10-RC | 1 | 30 | Very high winds |
Table 1. Test matrix (cont’d).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Date</th>
<th>Test Matrix Details</th>
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<tr>
<td>9</td>
<td>10/17/02</td>
<td>Run9a_17Oct02_2xAMX10RC Run9b_17Oct02_2xAMX10RC Run9c_17Oct02_2xAMX10RC Run9d_17Oct02_2xAMX10RC</td>
</tr>
<tr>
<td>10</td>
<td>10/17/02</td>
<td>Run10a_17Oct02_AMX30 Run10b_17Oct02_AMX30</td>
</tr>
<tr>
<td>11</td>
<td>10/17/02</td>
<td>Run11a_17Oct02_2xAMX30 Run11b_17Oct02_2xAMX30</td>
</tr>
<tr>
<td>12</td>
<td>10/17/02</td>
<td>Run12a_17Oct02_VAB Run12b_17Oct02_VAB</td>
</tr>
<tr>
<td>13</td>
<td>10/17/02</td>
<td>Run13a_17Oct02_TRM2000 Run13b_17Oct02_TRM2000</td>
</tr>
<tr>
<td>14</td>
<td>10/17/02</td>
<td>Run14a_17Oct02_TRM10000 Run14b_17Oct02_TRM10000</td>
</tr>
<tr>
<td>15</td>
<td>10/17/02</td>
<td>Run15a_17Oct02_TRM10K_TRM2K Run15b_17Oct02_TRM10K_TRM2K</td>
</tr>
<tr>
<td>16</td>
<td>10/17/02</td>
<td>Run16a_17Oct02_p4 Run16d_17Oct02_p4</td>
</tr>
<tr>
<td>Trial 2</td>
<td>10/21/02</td>
<td>Tria4a_21Oct02_AMX10P Tria4b_21Oct02_AMX10P Tria4c_21Oct02_AMX10P</td>
</tr>
<tr>
<td>17</td>
<td>10/21/02</td>
<td>Run17a_21Oct02_AMX10P Run17b_21Oct02_AMX10P</td>
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Table 1. Test matrix (cont’d).

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<th>Run</th>
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<th>Description</th>
<th>Distance</th>
<th>Gain</th>
<th>Weight</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>10/21/02</td>
<td>9:43</td>
<td>Run18a, 21Oct02-2xAMX10P</td>
<td>75 m</td>
<td>AM × 10P (2)</td>
<td>2</td>
<td>&lt;20</td>
</tr>
<tr>
<td>19</td>
<td>10/21/02</td>
<td>12:37</td>
<td>Run19a- 4xAMX30</td>
<td>75 m</td>
<td>AM × 30 (4)</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>10/21/02</td>
<td>13:46</td>
<td>Run20a- 21Oct02- P4</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>21</td>
<td>10/21/02</td>
<td>14:37</td>
<td>Run21a- 21Oct02- AMX10RC</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>10/21/02</td>
<td>15:19</td>
<td>Run22a- 21Oct02- 2xAMX10RC</td>
<td>—</td>
<td>AM × 10RC (2)</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>23</td>
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<td>08:27</td>
<td>Run23a- 21Oct02- Toyota Pickup</td>
<td>—</td>
<td>AM × 30 (2)</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>24</td>
<td>10/22/02</td>
<td>09:01</td>
<td>Run24a- 21Oct02- AMX10RC</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>10/22/02</td>
<td>09:43</td>
<td>Run25a- 21Oct02- AMX10RC</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>26</td>
<td>10/22/02</td>
<td>10:01</td>
<td>Run26a- 21Oct02- Toyota Pickup</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>27</td>
<td>10/22/02</td>
<td>10:27</td>
<td>Sensor 6 Up; Replaced with development unit. Plane 0854</td>
<td>—</td>
<td>AM × 10RC</td>
<td>1</td>
<td>20</td>
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Table 1. Test matrix (cont’d).

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Time</th>
<th>Sensors</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>10/22/02</td>
<td></td>
<td>2</td>
<td></td>
<td>0924 Toyota Pickup, 20 Both Sensors Up</td>
</tr>
<tr>
<td>29</td>
<td>10/22/02</td>
<td></td>
<td></td>
<td></td>
<td>1214 AM × 10RC, 1 AM × 10P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 Directions 1 &amp; 2: Did not record dir 1 during this run. Due to conflict of IP addr. Record the 2 direction at 1228.</td>
</tr>
<tr>
<td>30</td>
<td>10/23/02</td>
<td></td>
<td></td>
<td></td>
<td>1249 AM × 30, 1 AM × 10P, 1 AM × 30, 1 AM × 10P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 Directions 1 &amp; 2: Did calibration before this run. Sunshine, but high wind (8.1 m/s = 20–25 mph) Vehicles moving at 1253. The vehicles are interleave (amx 30, amx 10p, amx 30, amx 10p)</td>
</tr>
<tr>
<td>31</td>
<td>10/23/02</td>
<td></td>
<td></td>
<td></td>
<td>1402 AM × 10P, 1 AM × 10RC, 1 AM × 10P, 1 AM × 10RC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 Directions 1 &amp; 2:</td>
</tr>
<tr>
<td>32</td>
<td>10/23/02</td>
<td></td>
<td></td>
<td></td>
<td>1517 VAB, 1 AM × 10P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 Direction 1: Sensor 8 only site Z3 rest of runs</td>
</tr>
<tr>
<td>33</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1231 P4, 1 TRM2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 Sensor 8 Only Z3</td>
</tr>
<tr>
<td>34</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1256 P4, 1 TRM10000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 Plane will fly over until 1800. The vehicles are in order as labeled.</td>
</tr>
<tr>
<td>35</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1336 10RC, 1 vab, 1 trm2000, 1 trm10000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 Gain might be incorrect in group 0 of sensor 8 for runs 33–36</td>
</tr>
<tr>
<td>36</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1419 Pickup, 1 P4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 —</td>
</tr>
<tr>
<td>37</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1457 P4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 —</td>
</tr>
<tr>
<td>38</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1532 10RC (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 —</td>
</tr>
<tr>
<td>39</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1550 AM × 10RC, 1 AM × 10RC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 This 10RC is different than the one used in run 8.</td>
</tr>
<tr>
<td>40</td>
<td>10/24/02</td>
<td></td>
<td></td>
<td></td>
<td>1848 AM × 10P, 1 AM × 10P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20 —</td>
</tr>
</tbody>
</table>
Table 1. Test matrix (cont’d).

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>10/24/02</td>
<td>2002_10_24_19_11_20_Sen8_Grp0 2002_10_24_19_11_20_Sen8_Grp1</td>
<td>—</td>
<td>1911</td>
<td>1934</td>
<td>AM × 10P (2)</td>
</tr>
<tr>
<td>42</td>
<td>10/24/02</td>
<td>2002_10_24_19_56_55_Sen8_Grp0 2002_10_24_19_56_55_Sen8_Grp1</td>
<td>—</td>
<td>1956</td>
<td>2008</td>
<td>AM × 10RC type 1</td>
</tr>
<tr>
<td>43</td>
<td>10/24/02</td>
<td>2002_10_24_20_32_30_Sen8_Grp0 2002_10_24_20_32_30_Sen8_Grp1</td>
<td>—</td>
<td>2032</td>
<td>2048</td>
<td>AM × 10RC type 2</td>
</tr>
<tr>
<td>44</td>
<td>10/24/02</td>
<td>2002_10_24_21_15_08_Sen8_Grp0 2002_10_24_21_15_08_Sen8_Grp1</td>
<td>—</td>
<td>2115</td>
<td>2127</td>
<td>AM × 10RC (1) AM × 10P (1)</td>
</tr>
</tbody>
</table>
A key field in the header file is the gain specified for the associated data packet. The gain table values are specified in Appendix H and require some additional interpretation for between the acoustic channels and the seismic channels. The gain table shows a box gain and a mic gain. For the acoustic channels, the total gain is the product of the two. For the seismic groups, only the box gain has significance because there is no preamplifier (Mic gain stage) to be concerned with. This implies that the total gain on the seismic groups is just the box gain and is not affected by any setting on the mic gain. For this test, the mic gain on the seismic groups was set to unity so the box gain equals the total gain shown in the chart.

5. Field Calibration Files

Calibration files were collected for both sensor arrays in the field on 23 October 2002. A 1-KHz calibration tone was injected into the microphones for ~10 s/channel. The calibrator used was a 94-dBSPL unit. A single calibration file was collected for each sensor; therefore, the tones must be searched for in the data files to extract the time window in which a specific microphone was being stimulated. The two files are 2002_10_23_12_06_Sen6_Grp0.dat and 2002_10_23_12_16_Sen8_Grp0.dat. The units were reconfigured to have the following data acquisition parameters for the calibration files:

- Sample Rate = 4096 Hz
- Gain = 10×
- Cutoff Frequency = 1.25 KHz

Note that the meteorological conditions during the calibration collection were windy (gusts 20–25 mph and sustained winds of 15 mph).

6. Contact Information for Data Requests

Requests for the raw sensor data described in this report and information on any restrictions in its distribution, should be sent to the following address:

U.S. Army Research Laboratory
Attn: AMSRL-SE-SA
2800 Powder Mill Rd
Adelphi, MD 20783
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Appendix A. Test Site Locations and Vehicle Trajectories

Figure A-1. Test site locations and vehicle trajectories.
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Appendix B. BL-1994 Sensitivity Specifications

<table>
<thead>
<tr>
<th>MODEL NUMBER</th>
<th>SENSITIVITY AT 1kHz dB RE 1V/1Pa</th>
<th>DC SUPPLY</th>
<th>AMPLIFIER CURRENT DRAIN (µA)</th>
<th>&quot;X&quot; WEIGHTED NOISE (1 kHz EQUIVALENT SPL)</th>
<th>NOMINAL OUTPUT IMPEDANCE (OHMS)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL-1994</td>
<td>-69 +/- 3</td>
<td>3.0V</td>
<td>160</td>
<td>34.0dB MAX.</td>
<td>4000</td>
<td>BL-1785 WITH 38&quot; CABLE ASSEMBLY</td>
</tr>
</tbody>
</table>

Figure B-1. BL-1994 sensitivity specifications.
Appendix C. GS-11D Sensitivity Specifications

Figure C-1. GS-11D sensitivity specifications.
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Appendix D. ALPHA Infrared (IR) Camera Specifications

<table>
<thead>
<tr>
<th>ALPHA Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector type</td>
</tr>
<tr>
<td>Detector spectral range</td>
</tr>
<tr>
<td>Array format</td>
</tr>
<tr>
<td>Field of view (degrees)</td>
</tr>
</tbody>
</table>

Figure D-1. ALPHA IR camera specifications.
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Appendix E. Vehicle Descriptions

Figure E-1. AMX-10P: Infantry combat vehicle.

Combat weight: 14,500 Kg
Unloaded weight: 12,700 Kg
Track width: 425 mm
Length of track on ground: 2.93 m
Engine: Hispano-Suiza HS 115 V8 water-cooled supercharged diesel developing 260 hp at 3000 rpm
Transmission: preselective with four forward and one reverse gears
Suspension: torsion bar
Figure E-2. AMX-10RC: Reconnaissance vehicle.

Configuration: $6 \times 6$

Combat weight: 15,880 Kg

Unloaded weight: 14,900 Kg

Track: 2.425 m

Wheelbase: $1.55 + 1.55$ m

Engine: Baudouin Model 6F 11 SRX diesel engine developing 280 hp at 3000 rpm

Transmission: preselective with four forward and four reverse gears

Suspension: hydropneumatic
Figure E-3. AMX-30 MBT: Medium battle tank.

Combat weight: 36,000 Kg

Unloaded weight: 34,000 Kg

Track: 2.53 m

Track width: 570 mm

Length of track on ground: 4.12 m

Engine: Hispano-Suiza HS 110 12-cylinder, water-cooled supercharged multifuel developing 720 hp at 2000 rpm

Transmission: mechanical with five gears in both directions

Suspension: torsion bar
Figure E-4. CBH P4: Armored personnel carrier.

Configuration: $4 \times 4$

Combat weight:

- Petrol engine: 3300 Kg
- Diesel engine: 3380 Kg

Max load: 1100 Kg

Track: 1.4 m

Wheelbase: 2.4 m

Engine: 4-cylinder diesel developing 76 hp or 4-cylinder intercooled diesel developing 110 hp

Suspension:

- (front) coil springs, antishay bar and double-acting telescopic hydraulic shock absorbers
- (rear) coil springs and double-acting telescopic hydraulic shock absorbers
Configuration: $6 \times 6$

Loaded weight: 29,000 Kg

Unloaded weight: 13,520 Kg

Track: 2.015 m

Wheelbase: 4.3 m + 1.4 m

Engine: Renault MIDR 06-20-45 9.839 liters 6-cylinder supercharged exhaust diesel developing 326 hp at 2000 rpm

Gearbox: Model B.9.150, nine forward and one reverse gears

Suspension:

(front) semi-elliptical leaf springs (auxiliary and main springs), mechanical stops, and telescopic shock-absorbers

(rear) semi-elliptical leaf springs, mechanical stops
Figure E-6. TRM 200: Truck.

Configuration: $4 \times 4$

Loaded weight: 13,500 Kg

Unloaded weight: 5490 Kg

Track: 1.96 m

Wheelbase: 3.85 m

Engine: MIDR 06-02-26 W
Figure E-7. VAB: Armored personnel carrier.

Configuration: $6 \times 6$

Combat weight: 14,200 Kg with limited amphibious capabilities

Unloaded weight: 11,400 Kg

Track: 2.035 m

Wheelbase: 3 m

Engine: Renault MIDS 06-20-45 in-line water-cooled turbocharged 6-cylinder diesel developing 220 bhp at 2200 rpm. Original engine was a MAN D.2356 HM 72 in-line water-cooled 6-cylinder diesel developing 220 hp at 2200 rpm

Transmission: Transfluide with five forward and three reverse gears
Appendix F. Data Format Specifications

F.1 Introduction

Every data packet will contain a header section and a data section. The header section comes with a fixed length of 40 bytes long. Depending on the sampling rate, the length of the data section is varied.

**HEADER:** Each field is a 16-bit unsigned integer in Little Endian Format (LSB) first.

Table F-1. Packet header format.

<table>
<thead>
<tr>
<th>Fields</th>
<th>Name</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Header ID</td>
<td>Distinguish different kind of data</td>
<td>2000 = acoustic data 0 = NULL data</td>
</tr>
<tr>
<td>2</td>
<td>Data type ID</td>
<td>Distinguish different type of data</td>
<td>0 = RAW data 1 = FFT data</td>
</tr>
<tr>
<td>3</td>
<td>Year</td>
<td>Years since 1900</td>
<td>99–</td>
</tr>
<tr>
<td>4</td>
<td>Month</td>
<td>—</td>
<td>1–12</td>
</tr>
<tr>
<td>5</td>
<td>Day</td>
<td>—</td>
<td>1–31</td>
</tr>
<tr>
<td>6</td>
<td>Hour</td>
<td>Hours after midnight</td>
<td>0–23</td>
</tr>
<tr>
<td>7</td>
<td>Minute</td>
<td>Minutes after hour</td>
<td>0–59</td>
</tr>
<tr>
<td>8</td>
<td>Second</td>
<td>Seconds after minute</td>
<td>0–59</td>
</tr>
<tr>
<td>9</td>
<td>Millisecond</td>
<td>Milliseconds after second</td>
<td>0–999</td>
</tr>
<tr>
<td>10</td>
<td>Sensor/group ID</td>
<td>Sensor ID/“signal condition” box ID</td>
<td>Sensor ID or w/ group ID</td>
</tr>
<tr>
<td>11</td>
<td>Sampling rate</td>
<td>Number of samples per second</td>
<td>2048 = Maximum sampling rate</td>
</tr>
<tr>
<td>12</td>
<td>Update rate</td>
<td>How often data are being transfer to host in hertz</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>Gain</td>
<td>Amplifier gain setting for “signal condition” box</td>
<td>Refer to Appendix C for gain table</td>
</tr>
<tr>
<td>14</td>
<td>Cutoff</td>
<td>Cutoff frequency setting for “signal condition” box</td>
<td>Refer to Appendix C for cutoff table</td>
</tr>
<tr>
<td>15</td>
<td>Full scale voltage</td>
<td>—</td>
<td>±5 volts</td>
</tr>
<tr>
<td>16</td>
<td>Number of channels per group</td>
<td>A/D channels</td>
<td>64 A/D channels that split into 8 channels per group</td>
</tr>
<tr>
<td>17</td>
<td>Days since sunday</td>
<td>Number of days from sunday</td>
<td>0–6</td>
</tr>
<tr>
<td>18</td>
<td>Board sampling rate</td>
<td>Used for calculating mux delays across groups</td>
<td>—</td>
</tr>
<tr>
<td>19</td>
<td>Active group mask</td>
<td>Bit 0–7 set indicates corresponding Group Active</td>
<td>—</td>
</tr>
<tr>
<td>20</td>
<td>Frame counter</td>
<td>Rolling counter used to detect lost frames</td>
<td>1–65535</td>
</tr>
</tbody>
</table>

Note: The size of each data packet can be calculated as follows:
RAW data packet (in bytes):
$$(((Header.Sampling Rate \times Header.Number of Channels) / Header.Update Rate) \times 2) + 40$$
NULL data = Contains only the header data
RAW data = Unprocessed data
FFT data = Fast Fourier data
F.2 Mux Delay Calculation

In applications using multigroup data, the mux delay between groups is calculated using Header Fields 18 and 19. The groups are scanned at the board sample rate making the base mux delay 1/board sample rate. The total delay is the base delay * the number of active groups between groups of interest, which is shown in field 19. Note that only active groups add to delay calculations. For example, an active group mask of $0 \times 0B$ groups 0, 1, and 3 is active. The delay between 0 and 3 is a 2*base mux delay and the delay is 1*base mux delay between 0 and 1 and 1 and 3.

F.3 Data Block Specifications

Raw Data:

The raw data sent to the host is in individual blocks for each group. Within the block, the eight channels are stored as signed 16-bit integers (Little Endian) in an interleaved fashion. The interleave pattern is ([channel 1, 2, 3, 4, 5, 6, 7, 8][channel 1, 2,...]). Note that within a sub-block (channels 1–8), the samples are simultaneous and each sub-block represents one sample event.
Appendix G. Sample MATLAB Program to Read Data Files

```matlab
% Initialize look-up vector for gain factors as read from packet header
% Gain values range from 0 to 7 and map as follows:
% 0=10, 1=100, 2=100, 3=1000, 4=1000, 5=10000, 6=10000, 7=100000
gain_vector = [1;10;10;100;100;1000;1000;10000];
file_name = '2000_09_28_18_40_06_Sen2_Grp0.dat';
number_of_seconds = 7;
% All data are 16 bit unsigned int store in Little Indian Format
input_fd = fopen(file_name,'r','l');
% Each data block preceded by a packet header
[Header,count] = fread(input_fd,20,'ushort');
sample_rate = Header(11);
update_rate = Header(12);
% loop through file extracting the data and stripping of packet headers
data=[];
for j = 1:number_of_seconds
% Extract current gain values for packet. The gains are stored in the low byte
% with the top nibble containing the gain value for the low channel group (1–4)
% and the low nibble used for the high channels. The gain values stored are
% converted to real values via the gain lookup vector
    gain_channel_1to4 = gain_vector(bitshift(bitand(Header(13),hex2dec('000000f0')),-4)+1);
gain_channel_5to8 = gain_vector(bitand(Header(13),hex2dec('0000000f'))+1);
% All of the data is read in as a two dimensional array with the row
% count set to the number of channels (8) and duration of 1 packet = sample rate/
% update rate
    clear temp
    [temp,count] = fread(input_fd,[8,sample_rate/update_rate],'short');
temp(1:4,:) = temp(1:4,:)/gain_channel_1to4;
temp(5:8,:) = temp(5:8,:)/gain_channel_5to8;
data = [data,temp];
% Grab next header
[Header,count] = fread(input_fd,20,'ushort');
end
% convert to voltage full scall is +/- 5 volts
data = (data .*5.0)/2^15;
fclose(input_fd)
```

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Appendix H. Gain Table for Signal Conditioning Boxes

H.1 Gain Table for Signal Conditioning Boxes

Gain value selects the gain used in the signal conditioning boxes. It is a hex pair with the top nibble effecting the low four channels and the low nibble effecting the high four channels. The nibble values map to gains as in Table H-1.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Box Gain</th>
<th>Mic Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>1000</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1000</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>AGC ch0</td>
<td>AGC ch0</td>
</tr>
<tr>
<td>B</td>
<td>AGC ch4</td>
<td>AGC ch4</td>
</tr>
</tbody>
</table>

Notes: AGC = Automatic gain control
The A or B options enable AGC on respective group of Channels with the reference channel indicated above. Any other valid gain sent to the group will disable AGC.

H.2 Cutoff Values for Signal Conditioning Boxes

Cutoff value selects the cutoff frequency used in the signal conditioning boxes. It is a hex pair with the top nibble effecting the low four channels and the low nibble effecting the high four channels. The nibble values map to frequencies as in Table H-2.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Cutoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Change</td>
</tr>
<tr>
<td>1</td>
<td>20 kHz</td>
</tr>
<tr>
<td>2</td>
<td>10 kHz</td>
</tr>
<tr>
<td>3</td>
<td>5 kHz</td>
</tr>
<tr>
<td>4</td>
<td>2.5 kHz</td>
</tr>
<tr>
<td>5</td>
<td>1.25 kHz</td>
</tr>
<tr>
<td>6</td>
<td>625 Hz</td>
</tr>
<tr>
<td>7</td>
<td>312 Hz</td>
</tr>
<tr>
<td>8</td>
<td>156 Hz</td>
</tr>
<tr>
<td>9</td>
<td>78 Hz</td>
</tr>
<tr>
<td>A</td>
<td>39 Hz</td>
</tr>
<tr>
<td>B</td>
<td>19 Hz</td>
</tr>
<tr>
<td>C</td>
<td>10 Hz</td>
</tr>
</tbody>
</table>
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