Aerial Measuring System (AMS)/ Israel Atomic Energy Commission (IAEC) Joint Comparison Study

I. Halevy 1 and P. Wasiolek 2

1. Israel Atomic Energy Commission, Israel
2. U.S. Department of Energy National Nuclear Security Administration Remote Sensing Laboratory, USA

Israeli Team: I. Halevy, S. Dadon, M. Sheinfeld, A. Broide, S. Rofe and I. Yaar
American Team: AMS team – RSL LV
Piotr Wasiolek, Rusty Malchow, Carson Riland, Manuel Avaro, Ray Arsenault
Ed Zachman, Mike Lukens, Joe Keller, Jaz Stampahar and John Gelsthorpe

In support of the U.S. Department of Energy (DOE) International Emergency Management and Cooperation (IEMC/NA-46) Program, the comparison of the U.S. and Israeli Aerial Measuring Systems (AMS) study was proposed and accepted. The study, organized by the DOE/National Nuclear Security Administration (NNSA) Remote Sensing Laboratory (RSL), involved the DOE/NNSA Aerial Measuring System Project based at the RSL and operated under a contractor agreement by National Security Technologies, LLC (NSTec), and the Israel Atomic Energy Commission (IAEC) Aerial Measuring System. The operational comparison was conducted at RSL-Nellis in Las Vegas, Nevada, during week of June 24–27, 2013. The Israeli system, Air RAM 2000 (figure 1, down), was shipped to RSL-Nellis and mounted together with the DOE Spectral Advanced Radiological Computer System, Model A (SPARCS-A, figure 1 up) on U.S. DOE Bell-412 helicopter for a series of aerial comparison measurements at local test ranges, including the Desert Rock Airport and Area 3 at the Nevada National Security Site (NNSS). A four-person Israeli team from the IAEC, Nuclear Research Center – Negev (NRCN) supported the activity.

The main objective of this joint comparison was use the DOE/RSL Bell-412 helicopter aerial platform, perform the comparison study of measuring techniques and radiation acquisition systems utilized for emergency response by IEAC and NNSA AMS [1].

MEASURING SYSTEMS

One advantage of acquiring aero-radiometric measurements lies in the high collection rate of data over large areas and rough terrain. Typical aero-radiometric systems record and save gamma-ray spectra, correlated with the Global Positioning System (GPS) derived location information (latitude, longitude, elevation over GPS ellipsoid=GPS altitude) in regular time intervals of 1 to 2 seconds. Such data can be used to locate radiation anomalies on the ground, map ground contamination, or track a radioactive airborne plume. Acquiring spectral data of this type allows separation of natural radioactivity from that of man-made sources and identification of specific isotopes, whether natural or man-made.

During the acquisition the flight altitude is kept constant, with typical values recorded between 50 and 985 feet (ft) (15 and 100 meters [m]) above ground level (AGL). The helicopter ground speed is maintained constant, in the case of DOE Bell-412, 70 knots (130 km/h).

For the comparison study, AMS and IAEC used their emergency response radiation detection systems, Israel’s Air RAM 2000, and the DOE’s SPARCS. For altitude measurements the AirRAM 2000 system uses a barometric altimeter with the range of 0–8000 ft, which is calibrated at 1000 ft by a radar altimeter. The SPARCS system uses radar altimeters for vertical positioning (altitude over the ground) and Differential GPS for location.
Survey Aircraft
The DOE Bell-412 helicopter was used as the airborne platform to carry out the comparison study (figure 2). The Bell-412 is a twin engine utility helicopter that has been manufactured by Bell Helicopter since 1981. With a standard fuel capacity of 330 gallons, it is capable of flying for up to 3.7 hours, with a maximum range of 356 nautical miles and a cruising speed of 122 knots. However, with the AMS radiation survey configuration of 12 detectors, four crew members (two pilots, a mission scientist, and an equipment operator), with a survey speed of 70 knots (120 ft/sec) at survey altitude of 300 ft AGL, the Bell-412 was capable of 2.5 hours of flight time.
RESULTS
Attenuation and Sensitivity
Lake Mohave Calibration Line
The altitude spiral flight over the Lake Mohave Calibration Line was used to derive the local effective air attenuation coefficient, obtain the sensitivity of both acquisition systems, and estimate their inherent background. The altitude spiral consists of passes between two waypoints programmed into helicopter navigation system over the land calibration line and water line at several different altitudes. During the exchange, the altitudes were 50, 100, 200, 300, 750, 1500, and 3000 ft AGL. The path plots of the altitude spiral flight plotted independently by both groups are presented in Figure 3.

![Figure 3. The AirRAM 2000 inside the DOE Bell-412 helicopter](image)

The count rate ratio of the SPARCS single 2″ × 4″ ×16″ NaI detector to the AirRAM 2000 two 2″ × 2″ inch detectors of about 18 (Table 1) compares very well with the ratio of volumes between systems of 16 [128 inch³ (2″ × 4″ × 16″)/8 inch³ (2″ × 2″ × 2″)].

From the altitude spiral, the effective air attenuation coefficient and sensitivity of the detectors can be derived by plotting each altitude flight’s net gross counts versus altitude on a semi-log plot (Figure 4) and exponentially fitting the gross counts expression:

\[
Calt = CGC \times \exp[\mu_{air} \times (H - H_{avg})]
\]

Where:

- \(Calt\) = gross counts normalized to the averaged survey altitude, (cps).
- \(CGC\) = total terrestrial count rate or gross counts, (cps).
- \(\mu_{air}\) = gamma ray air attenuation coefficient, ft\(^{-1}\).
- \(H, H_{avg}\) = average radar altitude, ft AGL.

The difference in sensitivity between the SPARCS single 2″ × 4″ ×16″ NaI detector to the AirRAM 2000 two 2″ × 2″ inch detectors is remarkable, ~18 times.
Table 1. Average count rate from different detectors at the calibration line

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Count rate (cps)</th>
<th>Count Ratio</th>
<th>Count rate (cps)</th>
<th>Count Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPARCS NaI 2″×4″×16</td>
<td>AirRAM two NaI 2″×2″</td>
<td></td>
<td>SPARCS NaI 2″×4″×16</td>
</tr>
<tr>
<td>50</td>
<td>2620</td>
<td>151</td>
<td>17</td>
<td>159</td>
</tr>
<tr>
<td>100</td>
<td>2450</td>
<td>141</td>
<td>17</td>
<td>155</td>
</tr>
<tr>
<td>200</td>
<td>2139</td>
<td>118</td>
<td>18</td>
<td>165</td>
</tr>
<tr>
<td>300</td>
<td>1887</td>
<td>102</td>
<td>18</td>
<td>172</td>
</tr>
<tr>
<td>750</td>
<td>993</td>
<td>53</td>
<td>19</td>
<td>190</td>
</tr>
<tr>
<td>1500</td>
<td>405</td>
<td>22</td>
<td>18</td>
<td>173</td>
</tr>
<tr>
<td>3000</td>
<td>223</td>
<td>13</td>
<td>17</td>
<td>196</td>
</tr>
</tbody>
</table>

The slope in figure 4 is the gamma ray air attenuation coefficient (0.00186 ft⁻¹).
From the graph it is clear that the heights altitude for detecting 8.5 µR/hr is ~1950 ft.

Figure 4. Results of the curve fit of the altitude spiral data collected with AirRAM and analyzed by IAEC.

Desert Rock Airport Sources Overfly
Three radioactive sources listed in Table 2 were placed approximately 1500 ft (450 m) apart along the runway at the Desert Rock Airport (Figure 5). Using the visual flight rules, several passes directly over the sources (marked with orange cones) were executed. To study the response of the SPARCS and AirRAM, the flight altitude and speed were varied from 50 to 150 ft AGL and from 35 to 150 knots. The results of the source flyover are presented in Figure. The SPARCS data (gross counts from the 2″ × 4″ × 16″ NaI crystal) show an elevated count rate at any combination of flight altitude and speed tested, from 50 ft AGL at 50 knots to 150 ft AGL at 100 knots. The AirRAM, due to much lower detector volume, failed to detect the smaller 60Co source at 100 ft and both 60Co sources at 150 ft AGL. A higher flight speed of 100 knots, combined with lower sampling frequency (sample every 2 seconds) affected the AirRAM capability to spatially locate the sources.

Table 2. Activity and location of the radioactive sources used in the study

<table>
<thead>
<tr>
<th>Activity (mCi)</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>137Cs</td>
<td>20.6</td>
<td>-116.028605</td>
</tr>
<tr>
<td>60Co</td>
<td>3.6</td>
<td>-116.031402</td>
</tr>
<tr>
<td>60Co</td>
<td>1.7</td>
<td>-116.034129</td>
</tr>
</tbody>
</table>
Contours

Natural Background
To compare responses of the SPARCS and AirRAM to variable natural radiation background, the AMS test/evaluation area (Government Wash) was surveyed using standard AMS techniques of flying uniformly spaced parallel lines over survey area. The actual flight lines flown during the exchange are shown in Figure 6.

Figure 6. Gross-count contour of the natural background area (Government Wash) created using IAEC AirRAM detection system and AMS data processing techniques