Joint US EPA ASPECT and 64th CST Chemical and Radiological Field Exercise

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Deployment in Support of:
New Mexico 64th Civil Support Team
New Mexico Department of Homeland Security and Emergency Management

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Executive Summary

The US Environmental Protection Agency (EPA) CBRN Consequence Management Advisory Team (CMAT) Field Operations Branch (FOB) Airborne Spectral Photometric Environmental Collection Technology (ASPECT) Program participated with the New Mexico National Guard 64th Weapons of Mass Destruction Civil Support Team (CST) in a joint chemical and radiological field training exercise to simulate operational responses to a chemical release and a lost industrial radiological source. The common element to both simulations was the deployment of the ASPECT aircraft to remotely detect chemical and radiological signatures and send these near real-time detections to the 64th CST as a queuing capability for the planning and execution of their ground mission. Maj James Willis was the primary point of contact for this exercise.

The overall exercise objectives were:

1. Conduct a full integration of the ASPECT scientific reach back team with the CST field structure. All data validation and review were conducted with the 64th CST Science Officer and coordinated with the CST Team Commander.
2. Use the 64th CST commercial communication system to:
    - **a.** communicate with and retrieve data from the ASPECT aircraft for scientific reach back purposes,
    - **b.** disseminate all ASPECT data products after validation by the ASPECT scientific reach back team,
3. Conduct a simultaneous dissemination of ASPECT data products to the State of New Mexico Emergency Operations Center (EOC) and the US EPA Headquarters EOC in Washington DC.

The exercise consisted of two scenarios including a chemical release and a lost industrial radiological source. The chemical and radiological scenarios were conducted on 8 and 10 July 2014, respectively. The chemical scenario involved the controlled release of a calibrated concentration of anhydrous ammonia using CMAT's plume generator. The resulting plume was detected by the ASPECT system and the locations and concentration of the plume was relayed to the 64th Science Officer. The lost industrial radiological source scenario used two Cesium-137 sources hidden within a series of structures located on the test area. The ASPECT aircraft was flown over the site using a series of systematic flight lines, located the sources using the gamma ray detection systems and transferred this information to the CST for further ground investigation.

In general, all objectives outlined in the exercise were accomplished. In addition, Standard Operating Procedures (SOP) are being developed in close collaboration with the 64th CST to refine communications in future exercises. This report details a portion of the technical approaches and products used during the exercise and contains an after-action assessment in the conclusions.

1 ASPECT System Summary

The U.S. Environmental Protection Agency, CBRN Consequence Management Advisory Team fields a fixed-wing aircraft known as the Airborne Spectral Photometric Environmental Collection Technology (ASPECT). ASPECT is a 24/7/365 response-ready asset that can be airborne within an hour and collecting chemical, radiological and photographic data anywhere in the continental United States within nine hours of notification from its home base near Dallas, TX. A primary goal of the program is to provide actionable intelligence to decision makers within minutes of data collection while the aircraft is still flying via the aircraft satellite communication system.

The ASPECT sensor suite is installed into a Cessna 208B Caravan (Figure 1). The system uses two chemical sensors and three radiological sensors to detect and map chemical plumes and radiological deposition patterns and point sources. The ASPECT chemical sensors include a high resolution (0.5 meter pixels) multi-spectral infrared line scanner that produces a two dimensional image and a point detection Fourier transform infrared spectrometer (FTIR) that can be used to obtain detailed chemical information of any point in the plume. Radiological detections are made using sodium iodide (NaI; 25 L), lanthanum bromide (LaBr; 1 L) gamma detectors and a helium-based neutron (He3; 4 L) sensor using full geospatial registration. The neutron system will be upgraded in 2015 with a boron tri-fluoride straw detector system that will increase its current detection efficiency by about 40%. Visible imagery is collected using a high resolution digital camera system. All data are geo-referenced with embedded geographical coordinates and can be used in a variety of GIS systems. Collected data are processed using onboard algorithms while the aircraft is in flight and preliminary data results are sent using a satellite system to the ASPECT scientific reach back team for QA/QC analysis.

Figure 1. ASPECT Aircraft: Cessna 208B Caravan

2 Chemical Release / Photo Scenario

The primary objective of the chemical release scenario was to collocate members of the ASPECT scientific reach back team within the 64^{th} incident command structure and test the ability of both teams in sharing and consuming data generated by the ASPECT system. Accordingly, the overall design concept for the chemical release portion of the exercise was to generate a controlled release of anhydrous ammonia within the test field to simulate an accidental chemical release. The ASPECT aircraft was then used to detect the released agent and generate a series of standardized chemical reports that were examined and analyzed by the ASPECT/CST team for accuracy and ultimate use in planning a ground-based survey. The chemical release was conducted at the ROTC training compound located on the State of New Mexico National Guard training reservation (termed the test area). Figure 2 shows the overall location of the test area and Figure 3 shows the location of the EPA plume generator.

For the purpose of this exercise, a target discharge concentration of 10,000 ppm of anhydrous ammonia was released from the CMAT plume generator. Gaussian plume estimates indicated that this discharge concentration would decrease to less than 30 ppm at a downwind range of 100 meters thus providing a level of safety for all field personnel and eliminating any off-site concerns (Appendix A). A maximum quantity of 45.4 kg (100 lb.) was released over the course of approximately one hour. A detailed description of the plume generator and operation is contained in Appendix B.

To simulate an emergency response action, the ASPECT aircraft was stationed at the Santa Fe Regional Airport (KSAF) and remained on the ground until the order was given to initiate the exercise. At approximately 1320 (local time; 1930 UTC), the CST Commander requested that the ASPECT aircraft be dispatched to the exercise area. The ASPECT scientific reach back team contacted the flight crew and conducted a flight prebrief on the nature of the release and the anticipated location of the plume. At approximately 1325, the crew reported that they were airborne at which time the plume generator was started and a plume of ammonia was actively generated.

The aircraft made the first chemical detection pass while taking photos over the site at 1335 and continuously made successive passes over the area about every 5 minutes. The aircraft remained on station for about 1.5 hours and then returned to KSAF. Throughout the course of the exercise, the ASPECT aircraft flew a standard emergency response ladder pattern consisting of downwind cross plume passes at various distances and passes up the apparent plume axis. Each pass was conducted at an altitude of 2,800 ft. above ground level (AGL) using a ground speed of approximately 110 kts. After each pass, the aircraft automatically processed chemical and aerial imagery data which were subsequently extracted from the aircraft by the scientific reach back team using the satellite system. These results were then shared in near real-time with the CST Commander and Science Officer. A total of 15 passes were conducted during the course of the chemical exercise

Figure 2: New Mexico National Guard Test Area

Figure 3: Detail of Plume Generator Location
(ASPECT Aerial Image overlayed in Google Earth)

A number of standard ASPECT products were generated as part of the chemical scenario exercise including chemical detection plots, infrared imagery, aerial visible imagery and flight status information. All of these products were geo-rectified and made available in either Google Earth or ESRI formats. Since this was the first full scale exercise between the ASPECT Team and the 64th CST, a goal of the interaction was to determine whether these data products were immediately useful to the CST and identify which products might needed to be further developed to meet the CST needs. Accordingly, members of the ASPECT Team used the commercial wi-fi system of the 64th CST to view data products in the Google Earth format. Appendix C provides a description and instructions on how to use both Google Earth and Flex Viewer.

2.1 Chemical Results - FTIR

The initial set of products used consisted of those developed by extracting chemical specific information from the airborne FTIR and displaying the detection locations onto an image including the associated concentration estimates for each detection point. These products were generated using a background suppressed pattern recognition approach that permits rapid automatic identification of 78 chemical compounds including ammonia (with the ability to confirm 540 other chemicals). Figure 4 shows the FTIR ground track for file H08H1419_55A. Each box represents 10 sample points with the gray boxes represent sample locations having no chemical detections (termed background samples) and the yellow boxes representing active ammonia detections. Figure 5 shows a close-up of the same ammonia detection locations with the background sample points removed. This image shows that a linear series of ammonia detections were observed suggesting that the aircraft passed over an ammonia plume.

To confirm the detection, FTIR spectra extracted from this linear series were analyzed by the scientific reach back team using an independent spectral method. Figure 6 shows the spectrum for scan 717 which was located at the mid-point of the detection series. Infrared spectral analysis showed two negative peaks located at 930 and 960 wavenumbers which were consistent with ammonia and confirmed that ammonia was present. This type of data product was then shared with the CST Science Officer to show where ammonia was present in relationship to the release point.

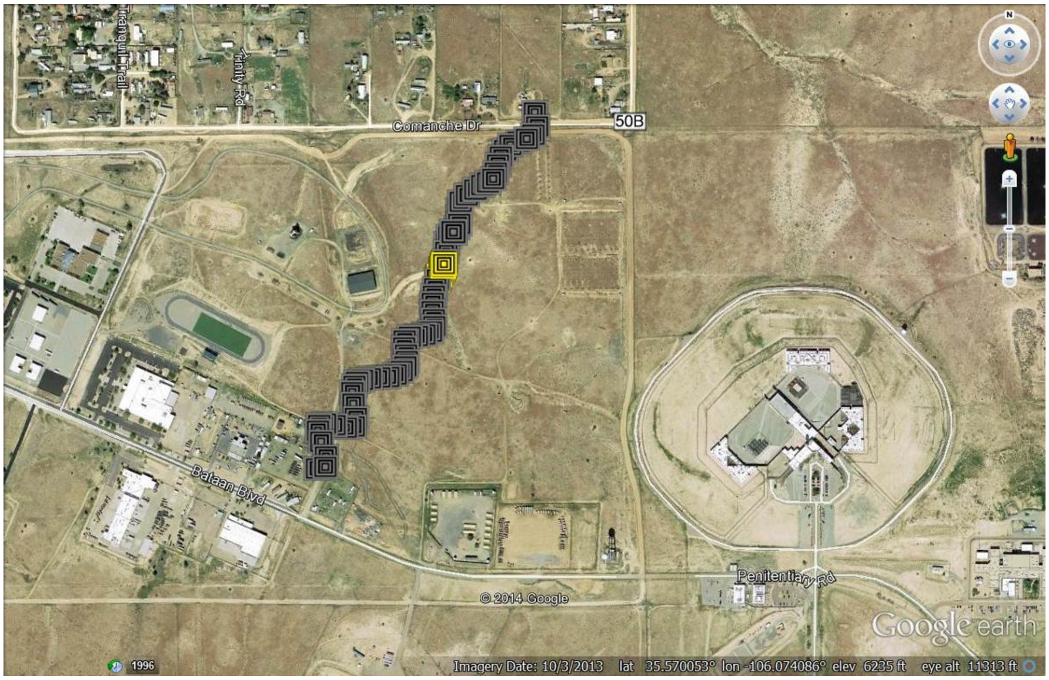

Figure 4. Ammonia Detection for File H08H14190_55A
(The zig-zag pattern is a result of turbulence on the aircraft)

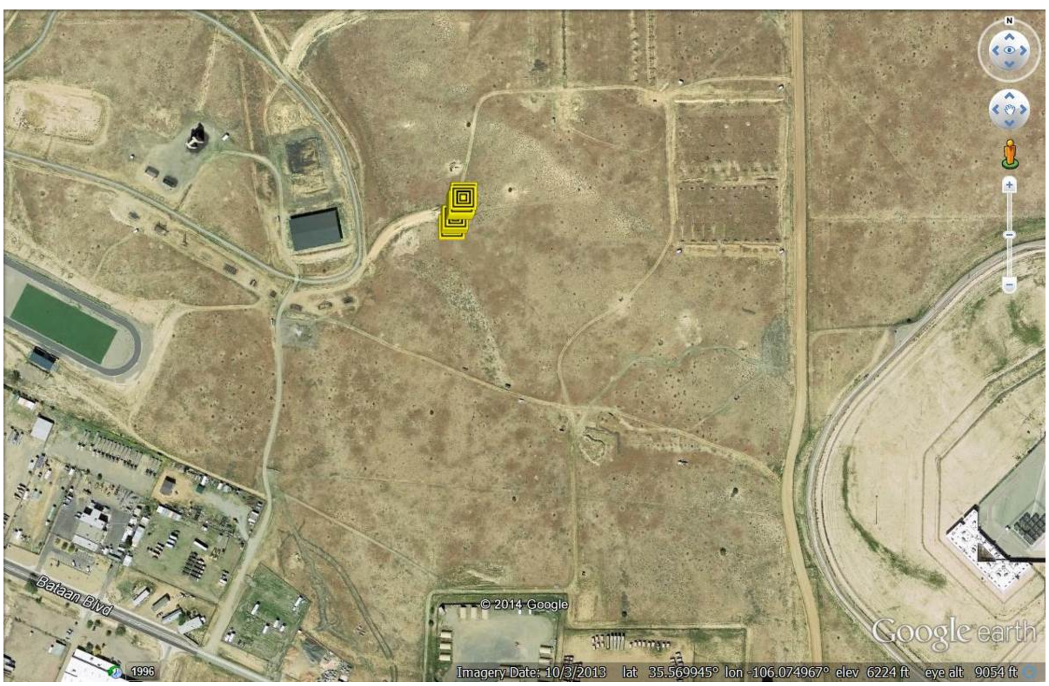

Figure 5. Close-up of Ammonia Detection for file H08H1419_55A
(Background detections removed)

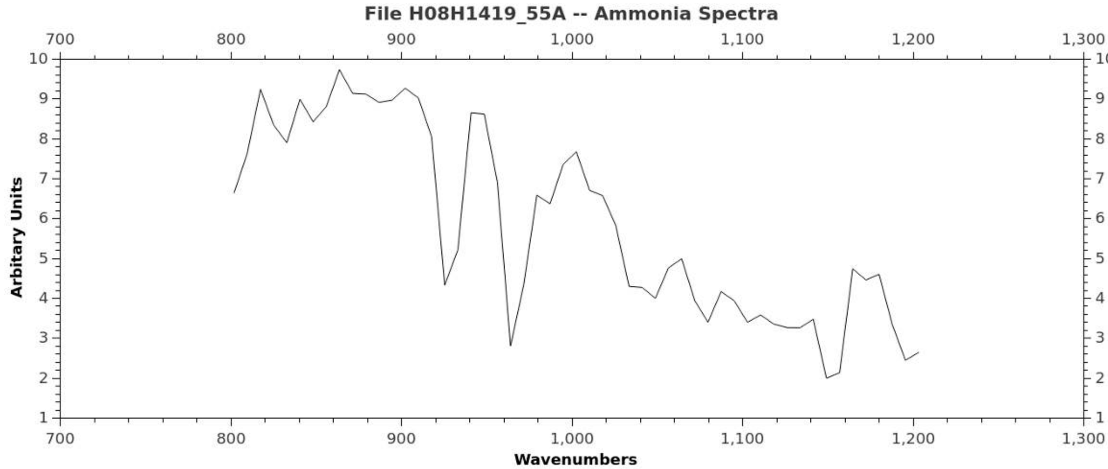

Figure 6. Ammonia Detection for File H08H1420_05A

The estimated concentration for each of the ammonia detection points was developed by scaling the discriminant score from the pattern recognition method (Figure 7). While only referenced to a scan number in this figure, each data point does contain unique latitude and longitude values which permit spatial statistical estimates to be developed for the plume structure.

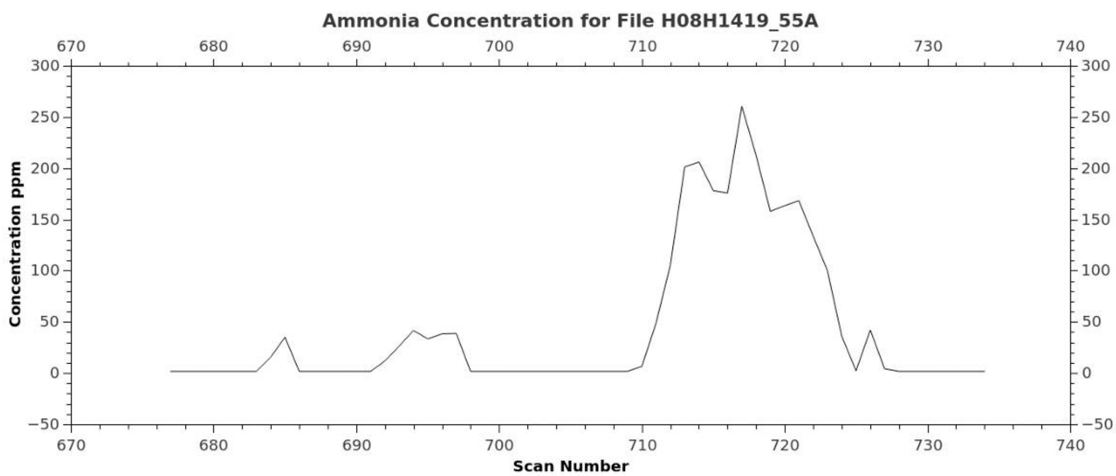

Figure 7. Estimated Ammonia Concentration vs Scan Number
File H08H1419_55A

Table 1 shows an example of statistical analysis developed from the concentration data extracted from file H08H1419_55A. In this example the plume was estimated to be 11.5 meters across, the maximum concentration was estimated to be approximately 260 ppm, and the total transected mass flux (emission rate) of the plume was estimated to be 49 grams per second. (The emission rate is useful in subsequent plume modeling since it effectively defines the "Q" or discharge rate of the source).

Table 1. Concentration Developed Statistics for File H08H1419_55A

H08H1419_55A: ammonia

Estimated Detection Limit = 20.0 ppm*M
Estimated Path Length = 11.5 Meters
Wind Speed =2.0 Meters per Second

Detections!!

Scan	Latitude	Longitude	Concentration ppm*M	ppm
684	35.570962	-106.075737	178.669	15.536
685	35.570969	-106.075734	402.926	35.037
692	35.571016	-106.075712	136.087	11.834
693	35.571023	-106.075709	303.050	26.352
694	35.571030	-106.075706	478.301	41.591
695	35.571037	-106.075703	384.495	33.434
696	35.571043	-106.075700	440.352	38.292
697	35.571050	-106.075696	445.270	38.719
710	35.571135	-106.075654	75.873	6.598
711	35.571141	-106.075650	565.247	49.152
712	35.571147	-106.075646	1216.397	105.774
713	35.571153	-106.075643	2314.471	201.258
714	35.571160	-106.075640	2370.131	206.098
715	35.571166	-106.075636	2049.056	178.179
716	35.571173	-106.075633	2022.100	175.835
717	35.571179	-106.075630	2994.146	260.360
718	35.571185	-106.075626	2444.298	212.548
719	35.571192	-106.075623	1816.010	157.914
720	35.571199	-106.075620	1879.610	163.444
721	35.571206	-106.075618	1934.939	168.256
722	35.571212	-106.075614	1537.164	133.666
723	35.571220	-106.075613	1149.270	99.936
724	35.571227	-106.075610	414.886	36.077
725	35.571234	-106.075608	25.975	2.259
726	35.571242	-106.075606	484.092	42.095
727	35.571249	-106.075603	48.875	4.250

Plume Statistics

Maximum Concentration

Scan	Latitude	Longitude	Concentration ppm*M	ppm
717	35.571179	-106.075630	2994.146	260.360

Plume Width = 11.5 Meters

Total Chemical Mass of Plume Section = 49.38 Grams

It should be noted that these results were not shared with the CST Science Officer during the exercise due to time constrains to develop the statistics. In post exercise discussions, the Science Officer indicated that having near real-time estimates of the release emission rate would be extremely useful since this estimate can be used as the plume source strength input (Q) used in the CST on-site Gaussian plume modeling system. Accordingly, this requirement was noted and will be included as a standard ASPECT product in the near future.

Figure 8 shows all of the ammonia detection locations observed during the exercise. Based on the scatter of the detection locations, a reasonable assumption can be made that the winds present during the exercise were variable. In particular, detection locations appear to be clustered in two areas, one north and a separate area to the west of the plume generator. These results suggest that over the course of the test, the winds were not only variable but also tended to show a distinct shift in direction. This image was shared with the Science Officer and was used to show how standard plume estimation techniques can misrepresent and/or under estimate the downwind hazard area especially if the model is not updated frequently or if inaccurate meteorological information is used to setup the model.

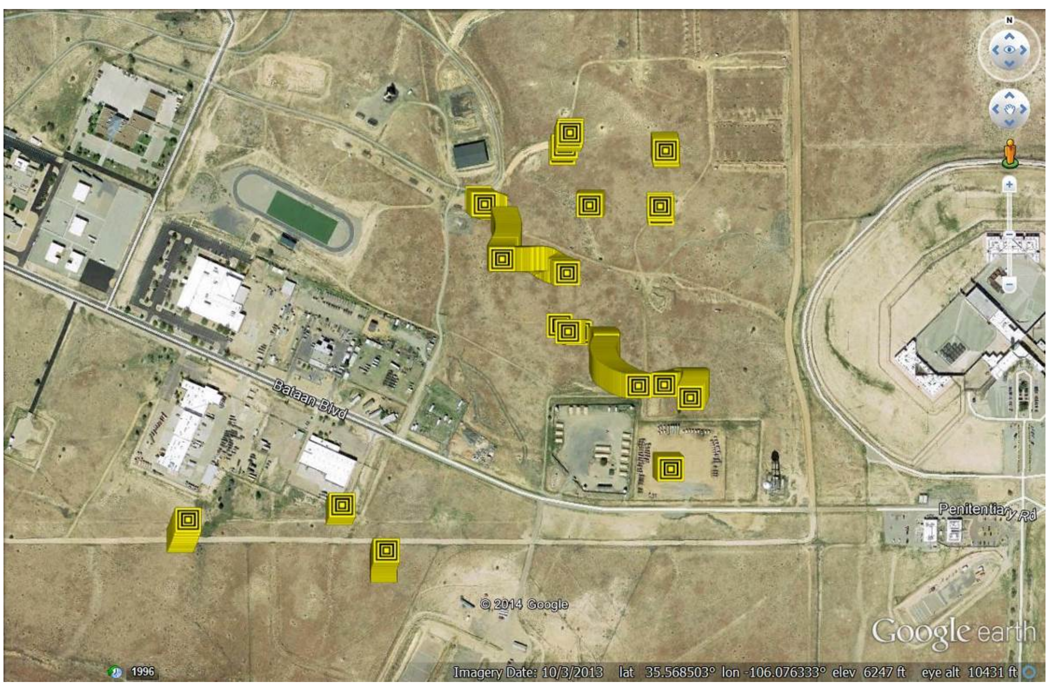

Figure 8. All Ammonia Detections

A review of the simple Gaussian model used by the ASPECT Team in designing the exercise (Appendix A) clearly shows significant deviation from what was actually measured by ASPECT. Specifically, due to assumed meteorological conditions (primarily a low wind speed with moderate directional variation) the model significantly underestimated the downwind concentration and the wide area impacted by the plume due to the change in wind direction. This result, coupled with the request by the CST to obtain near real-time emission estimates, clearly illustrates how ASPECT data can be used to refine the performance of air dispersion modeling systems.

Table 2 lists statistical results developed for all of the passes with positive ammonia detections.

Table 2. Plume Statistics

File	Latitude	Longitude	Concentration Ppm	Plume Width (meters)	Emission Rate (g/sec)
H08H1419_51A	**35.570987**	**-106.074125**	**2268.125**	**5.5**	**356.22**
H08H1419_53A	**35.565785**	**-106.078529**	**602.160**	**9.3**	**63.09**
H08H1419_55A	**35.571179**	**-106.075630**	**260.360**	**11.5**	**49.38**
H08H1419_57A	**35.566445**	**-106.079192**	**446.125**	**4.0**	**8.92**
H08H1420_00A*	**35.567977**	**-106.073665**	**1766.287**	**436**	**Up Plume**
H08H1420_02A	**35.566139**	**-106.081670**	**169.067**	**10.8**	**32.30**
H08H1420_05A	**35.570306**	**-106.075292**	**605.223**	**2.4**	**5.21**
H08H1420_10A	**35.570208**	**-106.074190**	**129.539**	**4.2**	**5.17**

*This collection pass corresponded to a track up the axis of the plume and does not represent an accurate estimate of emission rate.

Figure 9 was generated by plotting ASPECT estimated ammonia emission rates in relation to the elapsed time from the start of the plume generation. The operators of the plume generator reported that as ammonia was released, the supply pressure of the ammonia rapidly decreased resulting in a corresponding decrease in emission rate. About midway through the exercise, the supply tank was repositioned which resulted in a temporary increase in ammonia flow followed again by a progressive decrease in emission rate. An examination of the emission rates developed based on the ASPECT data show a close correlation to the reported flow rate of ammonia from the plume generator.

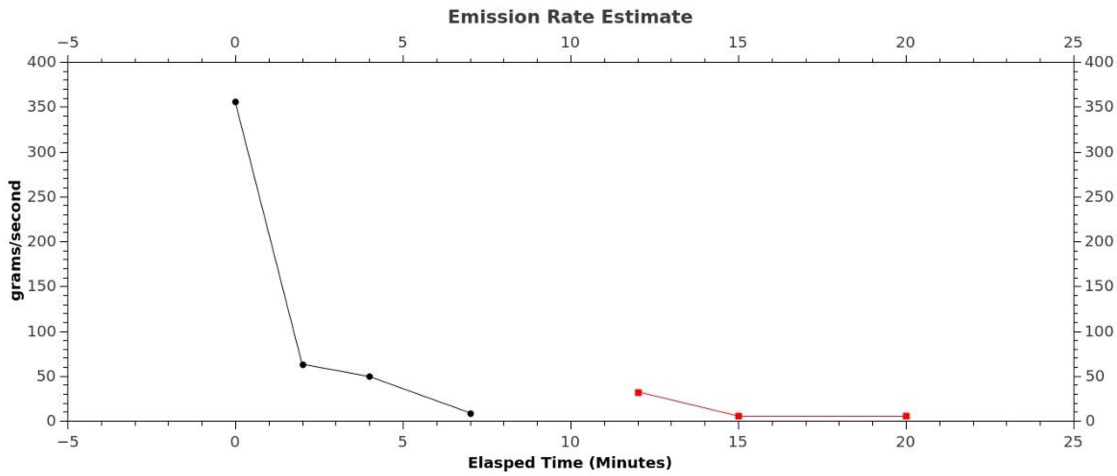

Figure 9. ASPECT Developed Ammonia Emission Rates

2.2 Chemical Results – IRLS Imagery

During each chemical collection pass, a 16 detector multi-spectral infrared image was collected using the IRLS RS800 line scanner. Each detector (channel) in the RS800 system is equipped with a cold optical filter that permits a band pass (window) of the infrared energy to be measured. If compounds are of high enough concentration, the system can generate an image that permits the plume to be displayed. Figure 10 shows a typical image that was collected during the exercise. This image was generated by assigning the red, blue and green primary colors respectively to two ammonia IR channels and one broadband IR channel. Analysis of the image does not show any structure of an ammonia plume. While this is unfortunate, this version of the RS800 tends to have fairly noisy ammonia channels and due to the age of the sensor does not easily show narrow-band gases such as ammonia. The broadband performance of the system is strong and clearly shows ground and structural features around the test area. The wavy features present on the right side of the image are due to extreme turbulence swamping the gyro-stabilization of the system. It should be noted that this imaging system is being replaced in 2015 and will have better performance for narrow feature gases like ammonia.

Figure 10. 3-Band IRLS Image

2.3 Photographic Results – Aerial Visible Imagery

The ASPECT system is designed to collect concurrent digital aerial imagery at regular intervals during all chemical data collection. Each collected image is automatically processed to account for geo-position and aircraft attitude to generate a fully orthorectified image. During the 64th CST exercise, 58 aerial photographs were collected and processed while the aircraft was on-station. Periodically, the collocated ASPECT Team would extract an image from the aircraft and share the image with the CST Science Officer. Figure 11 shows a typically image collected during the exercise. While there was little changing content from frame to frame, the CST agreed that having the capability to view near real-time aerial imagery, especially in a dynamic emergency response situation, would greatly benefit there planning and entry execution. In addition, imagery of this type would assist the CST in generating their technical products (i.e., reports, maps, etc.) provided to the response incident commander.

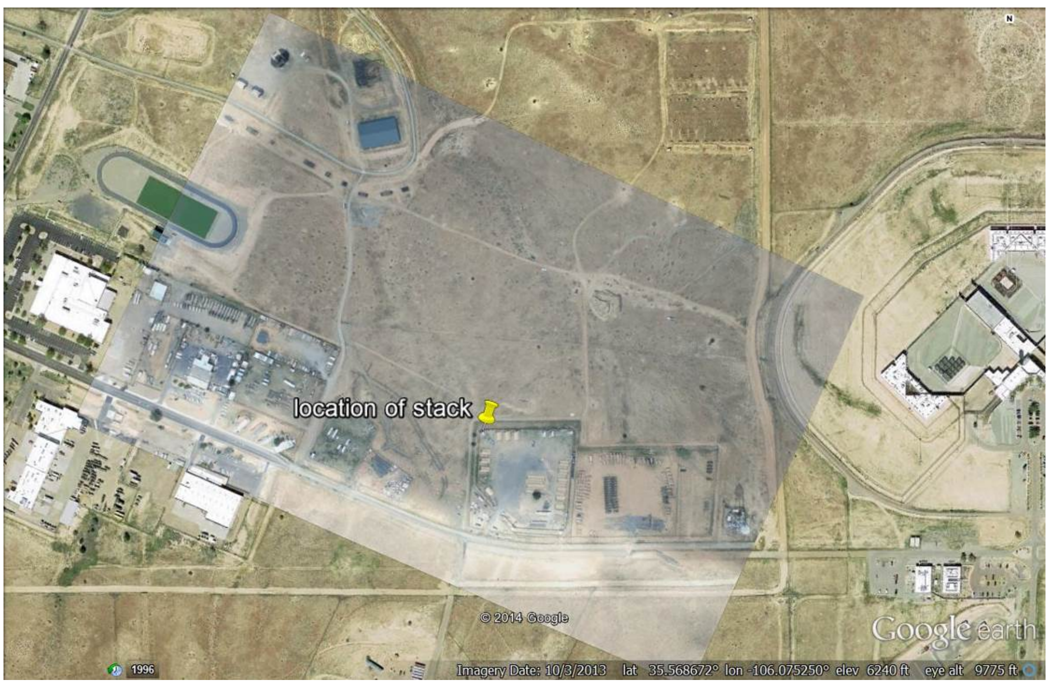

Figure 11. Georectified Aerial Image

3 Radiological Exercise Scenario

The radiological exercise was conducted on 10 July 2014 and represented a lost industrial source scenario. It consisted of hiding two Cesium-137 sources (5 and 10 mCi) in various locations within the test area and using ASPECT detection capabilities to locate the sources and provide guidance to the 64th CST for further ground investigation. Two ASPECT Team members were posted in the State EOC and two members served on the scientific reach back team.

After all sources were hidden, a general survey area of approximately ½ square mile was provided to the ASPECT scientific reach back team. A series of flight lines 300 ft apart was generated and sent to the ASPECT flight crew via email. A flight briefing was then conducted over the phone and the aircraft was released to conduct the radiological survey at an operational altitude of 300 ft AGL. The aircraft conducted the survey and its crew used automated algorithms to generate preliminary products that were reviewed by the ASPECT scientific reach back team and then provided to the 64th CST.

Figure 12 shows the location of the Cs-137 sources overlaid on an aerial photograph taken by the ASPECT aircraft during the chemical exercise. During the first sortie, both sources were placed on the back of an EPA vehicle to represent a 15 mCi Cs-137 point source. The colored dots in this image represent a preliminary product called a "sigma plot." Each dot in the sigma plot represents a one second measurement that is geospatially positioned in the mid-point between the distance flown by the aircraft during that second (about 200 ft).

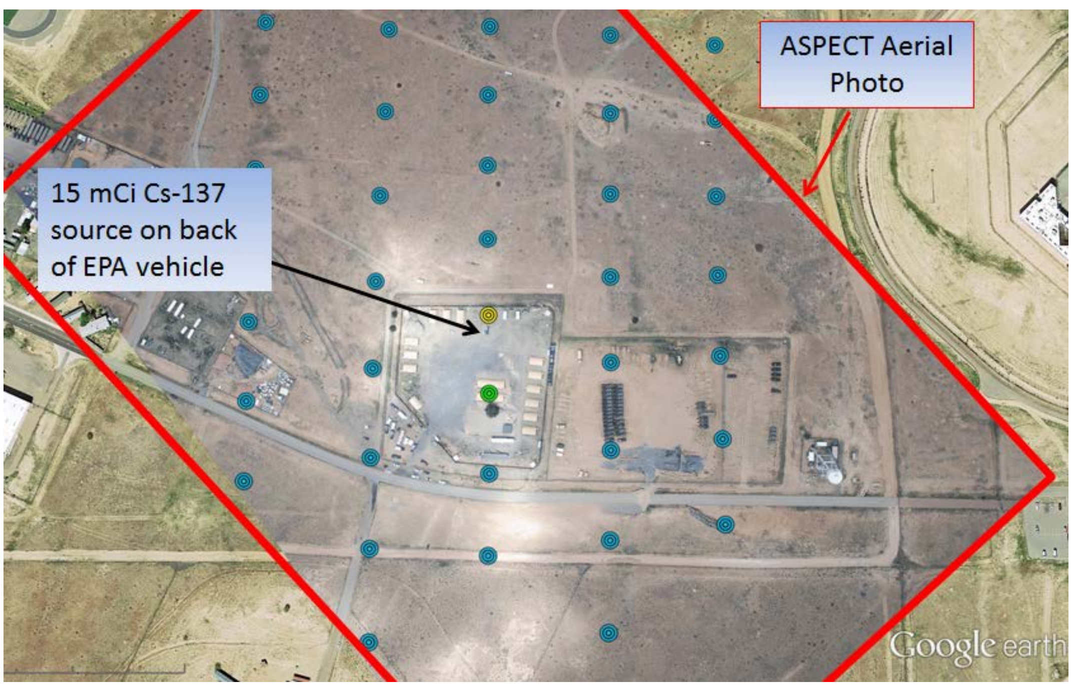

Figure 12. Cs-137 Sigma Plot product on aerial photo

The sigma plot provides a statistical comparison of every data point relative to a background location which is known not to contain any radiological contamination. For this exercise, the background location was about 1,000 ft west of the survey area. Light blue dots are within 2 standard deviations (e.g. sigma) when compared with the background location, green dots are >2 and <4 sigma; yellow is >4 and <6 sigma; and red is >6 sigma. Any deviation from background greater than 4 sigma is usually an initial indicator that the area may warrant a more detailed ground assessment. Any areas greater than 6 sigma almost certainly warrant further ground investigation and initiate a more intense assessment of the spectral data to identify the isotope(s). In this case, the isotope was known to be Cs-137.

The sigma plot is an adequate tool to quickly screen data values for further investigation. However, based on this exercise and through discussions with the 64th CST, the ASPECT Team determined that additional tools are necessary to assist the 64th CST in locating a source quickly. For example, by using the sigma plot and a gamma count-rate contour for the Cs-137 region-of-interest, a product can be developed very quickly to locate the source to within about 25 meters around a datum point on the sigma plot (Figure 13). This information can then be relayed to the 64th CST as the starting point for a ground survey.

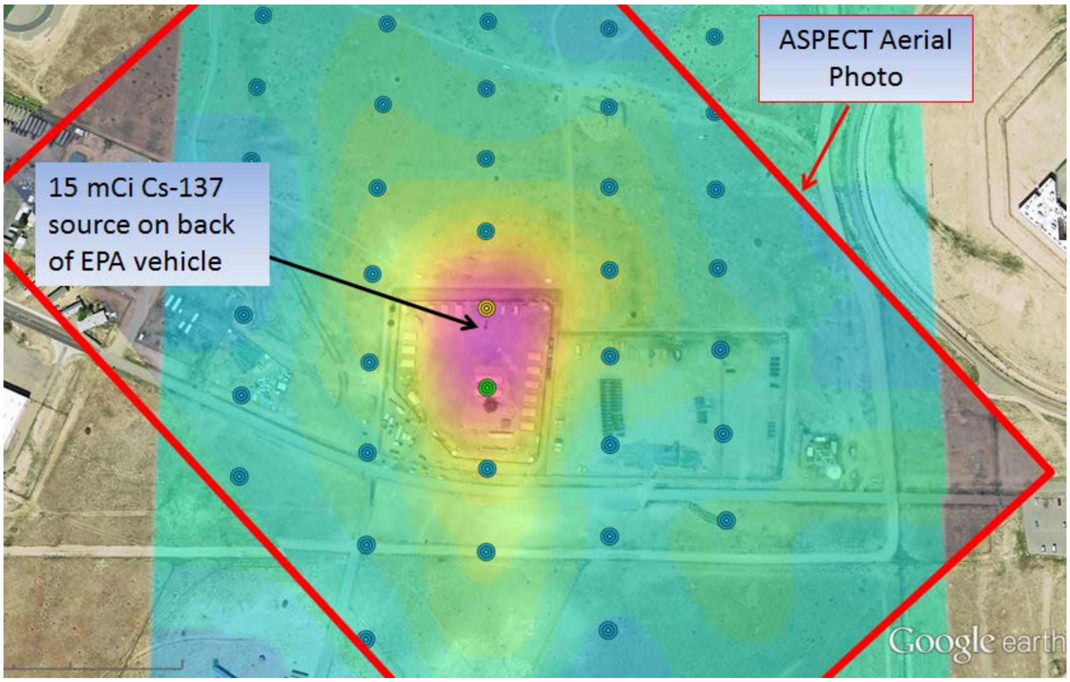

Figure 13. Cs-137 region-of-interest count-rate contour overlaid on the sigma plot. This product can be produced within minutes and can be used to plan a ground-based survey.

At the conclusion of the first survey, the aircraft was placed into a holding pattern and the sources were moved to a different location. A second survey was conducted using the same flight lines and results were provided to the CST to support their ground exercise.

Figures 14 & 15 show the source locations during the second sortie. The sources were hidden inside a tent structure in the test area. One source (10 mCi) was place underneath a Troxler gauge inside the tent and the other (5 mCi) was hidden just outside the tent on the ground. The EPA sources were positioned about 20 ft apart which made appear like a single source in the ASPECT products but were discovered as two separate sources on the ground by the 64th CST. The radioactive sources inside the Troxler gauge were never removed from their shield since the New Mexico Department of Transportation NRC License did not permit the use of these sources for training purposes.

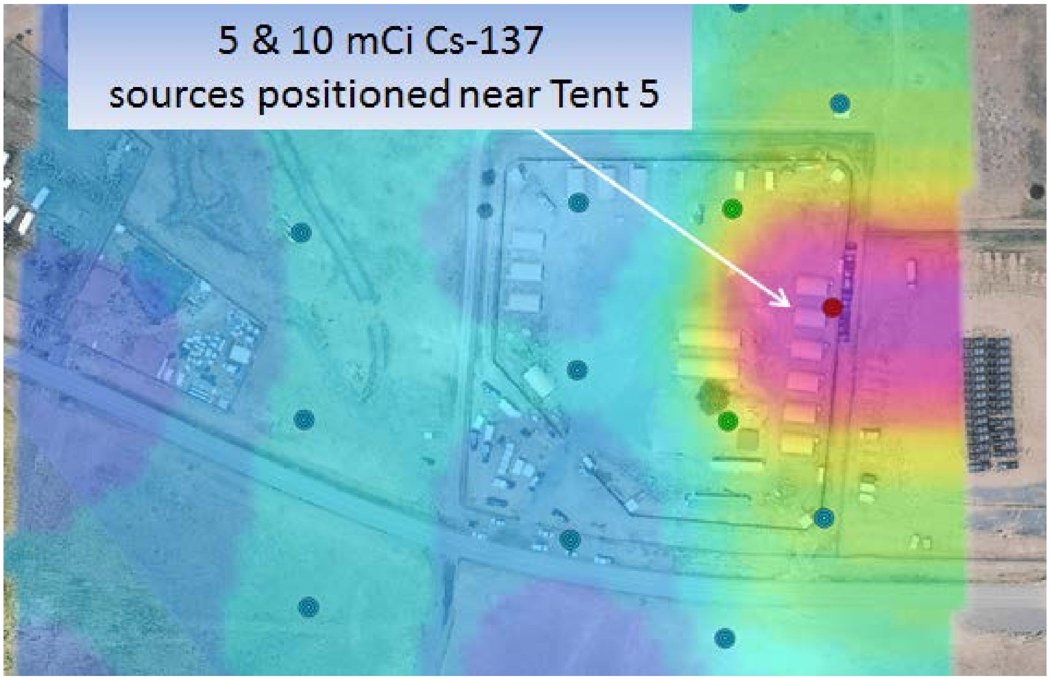

Figure 14. Cs-137 region-of-interest count-rate contour overlaid on the sigma plot after the sources were moved to the new location.

The contour in this image does not extend further east since there were no data collected. Consequently, the contouring algorithm abruptly ends and does not reflect the actual gradient from the source.

Figure 15. Photo of the 64th CST responders searching for the radioactive sources. The officers in uniform were controllers and prevented unnecessary radiation exposures to the exercise players. ASPECT Team members provided source control and safety oversight.

4 Post Exercise Assessment

At the conclusion of the joint ASPECT/64th CST exercise, the ASPECT Team conducted an after action assessment to determine if the exercise objectives were met, what operational and/or technical gaps were identified and how these gaps can be closed to better work with the 64th and other CST organizations. This assessment uses the overall exercise objectives as metrics and examined the chemical and radiological scenarios as separate events. The exercise objectives were:

1. Conduct a full integration of the ASPECT scientific reach back team with the CST field structure. All data validation and review were conducted with the 64th CST Science Officer and coordinated with the CST Team Commander.

2. Use the 64th CST commercial communication system to:
    a. communicate with and retrieve data from the ASPECT aircraft for scientific reach back purposes,
    b. disseminate all ASPECT data products after validation by the ASPECT scientific reach back team,
3. Conduct a simultaneous dissemination of ASPECT data products to the State of New Mexico EOC and the US EPA Headquarters EOC in Washington DC.

4.1 Chemical Exercise

Results for Objective 1.

1. From the CST perspective, the primary objective of this phase of the exercise was to determine whether ASPECT Team members could be integrated into their structure and whether chemical products could be used to help guide their team operations and to help develop products useful for senior emergency management usage. This objective was met.

2. The ASPECT scientific reach back team was able to integrate into the 64th CST command structure and was able to conduct a scientific reach back mission with the 64th CST communication connection. Discussion where held with the CST Science Officer and Commander concerning data content and meaning. Consequently, objective 1 was fully satisfied.

Gaps for Objective 1.

1. The chemical products developed by ASPECT were not optimal for the CST mission. While ASPECT products clearly showed points of positive detection of ammonia on multiple passes and the data provided excellent spatial information on the position of the ammonia plume, the team was not able to provide concentration data quickly due to time limitations. Post exercise discussion with the CST Science Officer highlighted that detailed and timely information related to plume location, concentration, and emission factor would greatly benefit the CST mission.

2. The ASPECT aircraft was collecting and developing preliminary data faster than the ASPECT scientific reach back team could process. Additional scientific reach back team members could have assisted with faster quality assurance reviews. In addition, the limited team only focused on chemical detection data and did not provide aerial imagery products or IR products. The primary focus of the CST is to provide hazard recommendations to the IC. Accordingly, the ASPECT data, while fertile in data content, was in the wrong product format for the CST usage. The 64th indicated that they needed a downwind hazard depiction based on real world measurements including spatial and emission rate data related to the plume.

Solutions for Objective 1 Gaps.

1. The ASPECT program will install an improved airborne spectrometer into the aircraft in 2015. This system will provide real-time concentration data and will solve the need to conduct ground-based concentration processing.
2. The ASPECT scientific reach back team needs to include a flight director and two data specialists with one focused on FTIR spectral data and the other focused on imagery.
3. Chemical data collected during the 64th CST exercise will be used to develop a hazard-based data product focused on providing plume parameter data. This product

will show chemical ID, downwind concentration, hazard information and direction/distances of the hazard. In addition, this product will provide specific information needed as input for various air dispersion models.

4. An aerial image and IR image needs to be used to reference the collected chemical data.
5. All chemical detection results and products will be summarized in a two-page report and emailed to the CST Science Officer.

Results for Objective 2

1. The ASPECT scientific reach back team was successful in using the 64th CST open internet system to conduct both data retrieval from the aircraft and push data to the EOC. All team computers were able to connect with the given password but data transmission speeds were slow.

Gaps for Objective 2

1. Due to the limited number of scientific reach back team members integrated with the 64th CST, the slow connection speeds prevents the ASPECT Team's ability to provide the entire suite of ASPECT data products to the 64th CST and to the EOC.
2. Some difficulty was observed with scientific reach back team members emails due to the type of connection used by the CST.

Solutions for objective 2 Gaps.

1. Additional team members are required to offset the slow internet speeds available with the 64th CST package.
2. Team members must be ready to force email systems to work.

Results for Objective 3.

1. The ASPECT Team was able to provide limited data products to the State of New Mexico EOC. The Washington DC EOC was not active during the exercise.
2. The exercise did demonstrate that the ASPECT scientific reach back team can be collocated with the 64th CST and use their communication system to provide a remote EOC with ASPECT data products.

Gaps for objective 3.

1. As with the other gaps, the small number of scientific reach back team members did not have enough time to process data, brief the 64th CST and move all relevant data products up to the EOC.

Solution for Objective 3.

1. Additional team members are needed to fully supply an EOC with relevant data products.

4.2 Radiological Exercise

Results for Objective 1.

1. ASPECT was able to provide the 64th CST with detailed information on the location of the test sources for each of the surveys. Information including the latitude and longitude and guidance on where to focus ground search efforts was successful.

Gaps for Objective 1.

1. The initial communication of the locations of the sources was provided to the 64th CST through latitude and longitude. This format was not optimal for the team. The ASPECT Team next provided the distance and azimuth of the source locations from the gate of the compound. This was much more useful for usage by the 64th CST.
2. The only radiation product that was used by the ASPECT scientific reach back team was the sigma plot. While this provided adequate information for the exercise, an isotope specific count plot with contours would have been more desirable to showing the 64th CST the most probable locations to search.
3. As with the chemical phase of the exercise, the ASPECT scientific reach back team was limited in number and was unable to fully provide ALL rad products within a targeted time frame of just a few minutes.

Solution for Objective 1 Gaps.

1. A single product consisting of a modified total count or isotope specific plot showing a 25 meter area-of-interest will be developed by the ASPECT Program. This product will also be referenced to common points (roads, gates, etc.) and will have indicated distances from the given reference points.
2. Additional ASPECT scientific reach back team members will be used to support a radiological survey for the 64th CST. One member will focus on flight operations and two members will focus on product extraction from the aircraft and report generation.
3. A two page report will be prepared and submitted to the CST Science Officer after a given survey is completed.

Results for Objective 2 & 3 were the same as the chemical phase.

5 Follow Up Actions

1. Software modifications to the standard ASPECT products need to be implemented to fully support the 64th CST data requirement. These changes will include generating:
   a. a chemical hazard zone product based on data developed with the FTIR,
   b. a new radiological product specifically designed to permit ground surveys to be rapidly vectored to suspected lost source locations.

2. Dedicated scientific reach back team slots need to be filled to effectively provide information to the 64th CST command structure in a timely fashion. In general this requirement can be met with a three person scientific reach back team structure.

3. An SOP needs to be developed which will outline and map how ASPECT will interact with the 64th CST and what standard products will be provided. SOP development needs to be conducted in concert with the 64th CST to make certain that the SOP meets overall CST/DOD requirements.

4. A follow on field exercise is required with the 64th CST to test and further refine the SOP and methods of integration. Subsequently, a similar exercise with a different CSTs is required to test the SOP and modes of interaction.

Appendix A: Ammonia Gaussian Plume Estimate

SITE DATA:
Location: SANTA FE, NEW MEXICO
Building Air Exchanges Per Hour: 0.41 (unsheltered double storied)
Time: June 10, 2014 0935 hours MDT (using computer's clock)

CHEMICAL DATA:
Chemical Name: AMMONIA Molecular Weight: 17.03 g/mol
AEGL-1 (60 min): 30 ppm AEGL-2 (60 min): 160 ppm AEGL-3 (60 min): 1100 ppm
IDLH: 300 ppm LEL: 150000 ppm UEL: 280000 ppm
Ambient Boiling Point: -38.4° C
Vapor Pressure at Ambient Temperature: greater than 1 atm
Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
Wind: 3 meters/second from 180° true at 4 meters
Ground Roughness: open country Cloud Cover: 5 tenths
Air Temperature: 30° C Stability Class: C
No Inversion Height Relative Humidity: 5%

SOURCE STRENGTH:
Direct Source: .756 kilograms/min Source Height: 4 feet
Release Duration: 60 minutes
Release Rate: 756 grams/min
Total Amount Released: 45.4 kilograms
Note: This chemical may flash boil and/or result in two phase flow.
Use both dispersion modules to investigate its potential behavior.

THREAT ZONE:
Model Run: Gaussian
Red : LOC is not exceeded --- (1100 ppm = AEGL-3 (60 min))
Note: Threat zone was not drawn because
the ground level concentrations never exceed the LOC.
Orange: 37 meters --- (160 ppm = AEGL-2 (60 min))
Note: Threat zone was not drawn because effects of near-field patchiness
make dispersion predictions less reliable for short distances.
Yellow: 88 meters --- (30 ppm = AEGL-1 (60 min))

Appendix B: Plume Generator Operations

A portable plume generator supplied and operated by the ASPECT Team was used to generate and release a heated plume of ammonia that served as the target gas for the chemical exercise (Figure 16). The plume generator consisted of an integrated propane fueled burner coupled to a closed loop analyte boiler/superheater all contained in 0.4 meter (16 inch) duct. A 57 m^3/min (2000 ft^3/min) fan is used to generate an output plume having an exit velocity of 12 m/sec (40 ft/sec). Liquid and/or gaseous target analytes are injected into the system through a set of pressurized tanks and are subsequently controlled using a serial based distributive control system. System control is accomplished using a multiple loop control package tethered to the plume generator over a twisted wire RS-485 communication link. Full system details are contained in Table 3.

Figure 16. ASPECT Chemical Plume Generator. During this exercise, a controlled release of ammonia was used for the chemical agent.

TABLE 3– Plume Generator Technical Specifications

System:	ASPECT mobile Plume Generator
Discharge Temperature:	User adjustable from 150 to 400 C
Fuel:	Liquid propane using an onboard 250 gal tank
Heat Capacity	Up to 2.5 million BTU
Bore Diameter	0.4 meters
Analyte Types	Non corrosive compounds with boiling points lower than 400 C
Number of Analyte Channels:	2
Discharge Velocity:	12 m/sec
Discharge Rate (air):	57 m^3/min
Discharge Concentration:	Up to 5000 ppm
Control System:	Remote distributed control

Typical plume generator operations require about 1 hour to set up the system and ready the test analytes. Approximately 10 minutes prior to active plume generation, the unit is started and a stable plume temperature of 250 ^{o}C is established using water as the boiler coolant. When the order is given to establish the chemical plume, the chemical feedstock (ammonia) is injected into the unit while the water feed to the boiler is reduced. Depending on the size and concentration of plume required, chemical input flow rates are adjusted to provide an estimated discharge concentration. Under normal conditions, a stable chemical plume is formed in less than 2 minutes. When the order is given to stop the plume generation, the chemical feed is removed and substituted with water. Depending on wind speeds, the test range is normally clear of any chemical residuals in about 5 minutes.

Appendix C: How to use Google Earth and ESRI Flex Viewer to view ASPECT products.

A significant objective of this joint exercise was developing a method to distribute and view products generated by the ASPECT program. Due to the nature of the CST program and the associated DOD requirements on network security, all data were transferred from the ASPECT Team to the CST using either email or CD/R media. Accordingly, the CST did not actively use a data viewer during the exercise and instead used static products generated by the ASPECT Team for their reporting purposes. A future action item that is planned between the ASPECT Team and the 64th CST will consist of detailed training on using the Google Earth and ESRI data viewing systems with their open source computer and commercial internet connection. The following information is presented to describe how the ASPECT Team examined data using the Google Earth software package. The ESRI package provides a similar capability.

Google Earth Instructions

The Google Earth software package permits data to be viewed and analyzed in a straight forward fashion with minimal training and/or computer hardware requirements. A free version of Google Earth (downloadable from the internet) is all that is required to use this package.

The ASPECT Program processes all data into a format that can be accessed through Google Earth using an "nlink" script. This small file permits full access to all data associated with a particular mission and/or deployment and greatly aids in near real-time situational awareness (Figure 17). This script can be obtained directly as an email or pulled from the deployment specific website. The following instructions detail how to install the script and use the system:

1. Download the provided KML file to your desktop if you received it through email. If provided on a memory stick, simply copy the KML file to your desktop.

2. To open the kml, double click the file located on your desktop. This will automatically bring up your Google Earth Program, and the ASPECT airplane icon will appear and zoom to the geographic area of the mission. The ASPECT airplane icon provides total access to all of the data available for the mission.

3. Double Click the airplane and a balloon will expand listing all of the relevant information for the particular ASPECT mission. The relevant information available may vary from mission to mission. All of the sections depicted in blue are links to data on the ASPECT mission servers. The following is a brief description of each section:

a. **Brief Mission Description.** This section contains details of the overall mission and specific details of the current mission which will open up in a separate browser window.

b. **Sensor suite capabilities.** This browser window contains a description of the sensors used on ASPECT aircraft. When finished with this section, close the browser window.

c. **Color aerial photography.** Clicking the color aerial photography section permits georectified NADAR images to be displayed and/or downloaded using the Google Earth. Once selected, available images from the last mission will be displayed as transparent outlines on the main screen. *Note: By default, only outlines from the last mission are displayed. Additional images collected on prior missions can be selected under the places menu on the left side of the Google Earth tool.*

   To load the actual imagery into Google Earth, click on a camera icon in one of the polygons. A photo balloon will open and a thumb nail of the non-georectified photograph will be displayed. Two options are given at the bottom of the image:

   Download Image Overlay into Google Earth

   Download High Resolution Image into Web Browser

   By clicking on the "Download Image Overlay into Google Earth" the image will be imported into the Google Earth imagery database and the georegistered image will be shown on the screen. Repeat this process for as many images as you are interested in. *Note: each time you execute this procedure the referenced aerial photograph frame will appear in blue in you temporary places pane on the left hand side of the Google Earth window. Should you want to view a full resolution image of this frame, click on the option "Download High Resolution Image into Web Browser". The full resolution image will be displayed in a separate browser window.*

d. **Mosaic Aerial Photography (By Date).** Selection of a color mosaic will load a georectified color mosaic into Google Earth. Selected of the appropriate image is referenced to the date of collection. Due to the large size of these files, several minutes may be required to fully download the file.

e. **Oblique Photography.** Viewing of oblique color aerial photography is accomplished by selecting the oblique photography item. Once selected, available oblique images for the last flight will be displayed as a collection of arrows. These arrows represent the location that the aircraft was positioned and the direction the camera was pointed when the frame was collected (about

2 o'clock of the heading looking about 45 degrees down). As the cursor is moved over the respective arrows, the frame number will be highlighted. If an arrow is double clicked a thumb nail of the image will be displayed. The user has the option of downloading the image in a browser.

f. **Infrared Color Imagery.** Multi-channel color infrared imagery is selected using this option. Once selected, transparent outlines of available images from the last flight will be displayed. Operation and manipulation of IR imagery is identical to procedures used to view color aerial photography.

g. **FTS Confirmed Detection.** This section contains the locations of confirmed remote sensed chemical detections for the last mission. Detections will be displayed as an icon. Each detected compound will be displayed as a unique icon. As with other data, data from prior missions can be selected under the places menu.

h. **Chemical Report Retrieval.** Chemical data associated with FTS confirmed detections is contained in this section. Each report shows a listing of compounds which are automatically scanned by ASPECT. The number of detections, maximum concentration, and the coordinates of the collection line are given in the report.

i. **Aircraft Flight Tracks (By Date).** Flight track information for the last mission is available using this selection. Once selected, a color flight path will be displayed. Multiple tracks can be displayed by selecting additional paths from other missions.

j. **New Data Additions.** As new data are added to the mission website the provided Google Earth link will permit full access to the new data. You must periodically close the Google Earth program and re-open it again using the Google Earth icon on your desktop. When you exit the program, Google Earth will prompt whether to save your "temporary places". Select discard. Depending on the amount of data being collected and uploaded to the mission server, reloading the Google Earth program once each hour will permit access to the new data.

k. **Troubleshooting.** If you are having problems with multiple ASPECT airplane icons appearing on the screen do the following:

1. Locate the Places Box on the upper left hand side of Google Earth.
2. Locate the line labeled as My Places.
3. Right click on My Places and select Delete Contents
4. Close Google Earth and reopen using the Google Earth Icon on your desktop

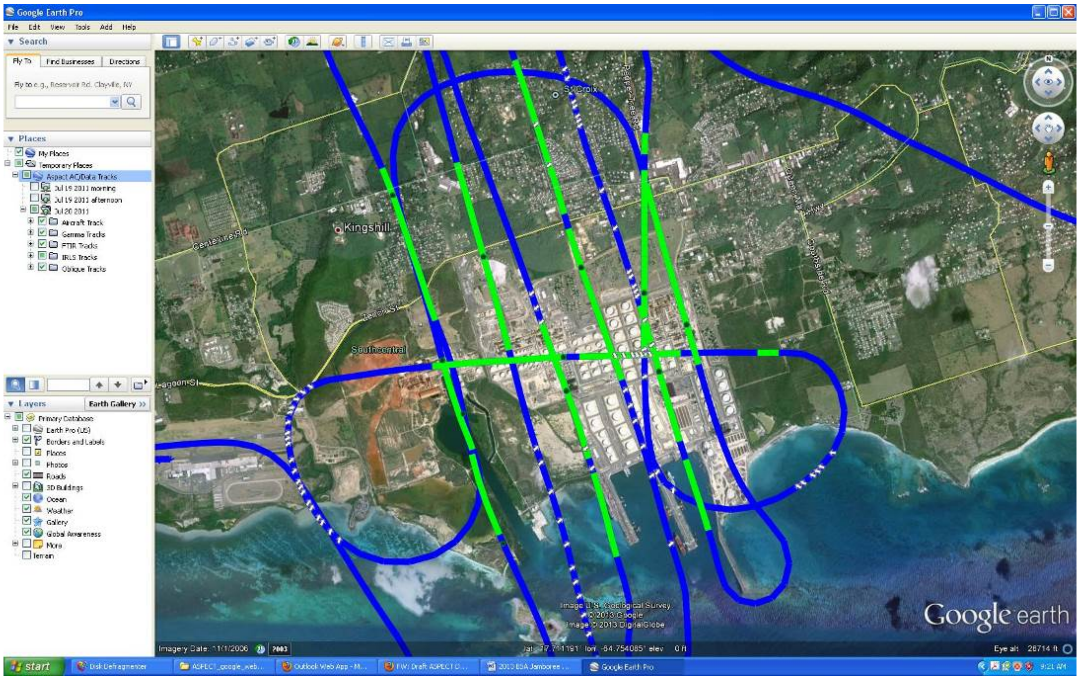

Figure 17. Google Earth Display of ASPECT Aircraft Tracks. The green tracks indicate when a chemical sensor was actively taking measurements.

Flex Viewer Instructions

To support of the users of the ESRI GIS system, the ASPECT Program generates products that can be viewed using the ESRI Flex Viewer package. As with the Google Earth nlink, a similar interface link can be provided to the user or the link can be obtained from the deployment specific website.

The Flex Viewer product allows data display of various layers through the use on the “more” operational layer buttons. All of the ASPECT layer data are initially turned off and the user is required to turn on layers of selected data. Available layer data includes chemical and rad detection layers, a flight line layer, an aircraft track layer, oblique photos, and downward geo-corrected digital images. An example of the ASPECT Flex Viewer product is shown in Figure 18.

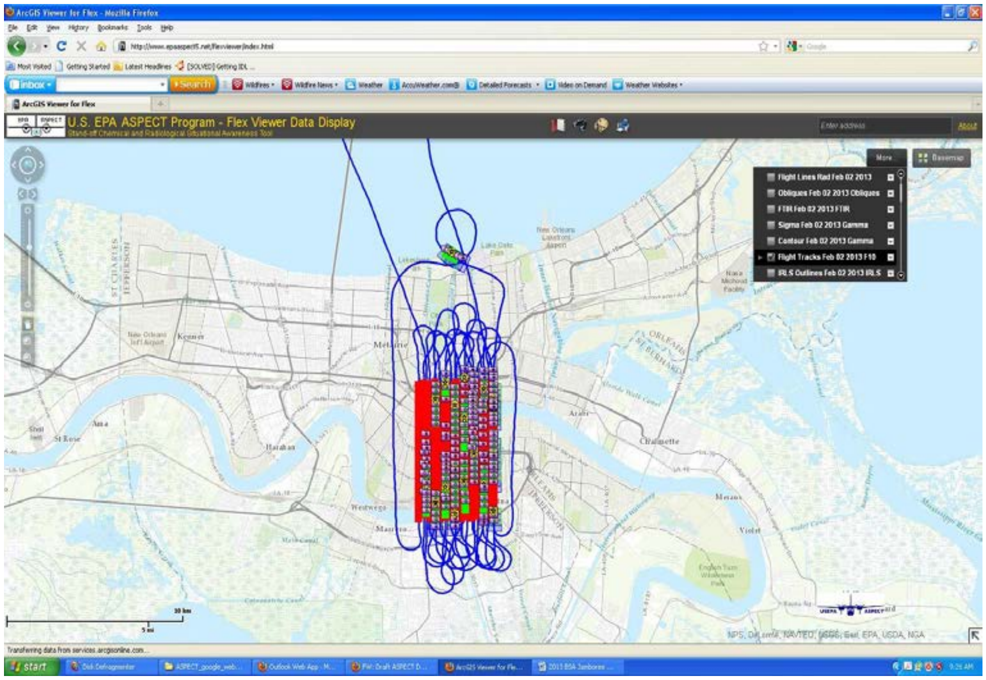

Figure 18. Sample ESRI Flex Viewer Display of ASPECT Aircraft Tracks. The red tracks indicate when radiological sensors were actively taking measurements.