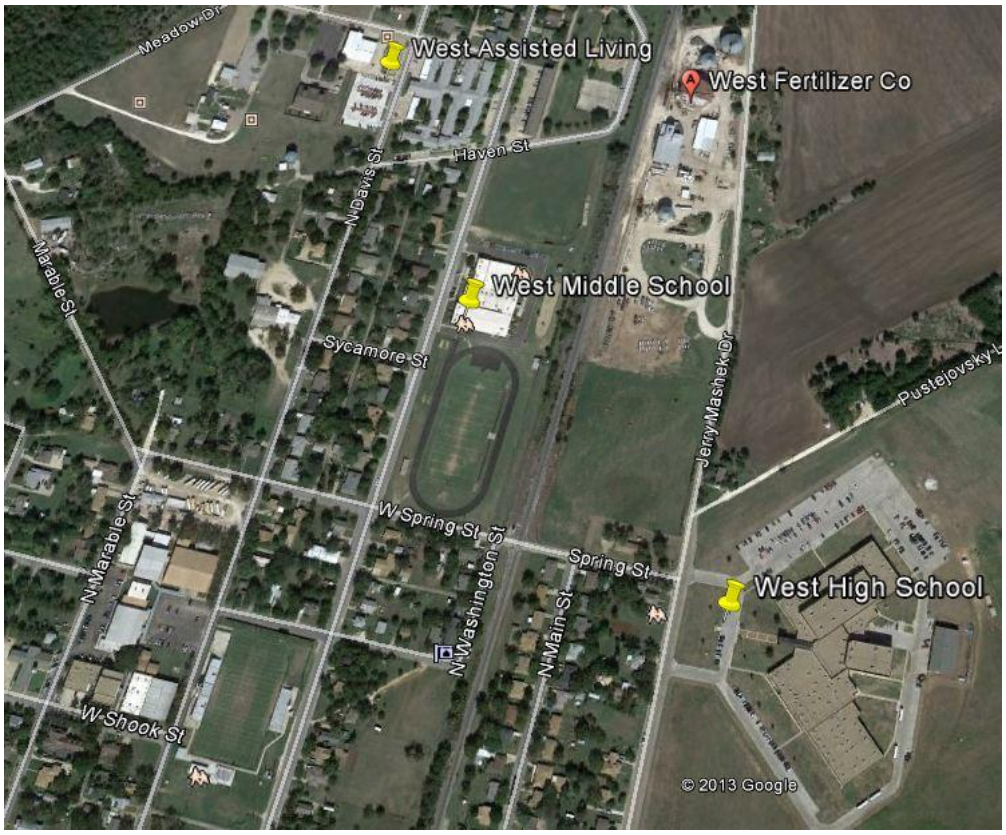
Field Report for Airborne Data Collected In Support of US EPA Region VI West, Texas Fertilizer Fire

Background

On 17 April 2013 the US EPA Region 6 Emergency Operations Center (EOC) requested that ASPECT mobilize to support air monitoring activities at the West, Texas Fertilizer fire located near West, Texas. Available media information concerning the site indicated that a large explosion and subsequent fire started on 17 April 2013 at approximately 2110 (local time) and a second explosion at 2150 (local time). Reports indicate that multiple injuries and deaths have occurred. The ASPECT aircraft was notified at approximately 2300 on 17 April 2013 and was airborne at 2345 and was on station at 0000 18 April 2013. Due to the close proximity of the fire to the aircraft's home base, the aircraft landed at Midway regional and uploaded data. The approximate coordinates of the fertilizer facility is 31.8157N 97.0879W.

ASPECT response to this Mission/Incident was in support of:
US EPA Region 6. OSC: Mark Hayes

Figure 1. Site Map of the West, Texas Fertilizer Facility



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ASPECT System

The US EPA ASPECT system was used to collect airborne infrared (IR) images and chemical screening data from a safe distance over the site. The ASPECT System is an emergency response aircraft permitting remote chemical detection in support of the first responder. The system consists of an airborne high speed Fourier transform infrared spectrometer (FTIR) coupled with a wide-area IR line scanner. The ASPECT IR systems have the ability to detect compounds in both the 8 to 12 micron (800 to 1200 cm-1) and 3 to 5 micron (2000 to 3200 cm-1) regions. The 8 to 12 micron region is typically known as the atmospheric window region since the band is reasonably void of water and carbon dioxide influence. Spectrally, this region is used to detect carbon—non- carbon bonded compounds. The 3 to 5 micron region is also free of water and carbon dioxide but typically does not have sufficient energy for use. This band does show use in high-energy environments such as fires. The Carbon – Hydrogen stretch is very common in this region.

Collected data is processed using onboard algorithms while the aircraft is in flight and preliminary data results are sent using a satellite system to the ASPECT reach back team for QA/QC analysis.

Sortie 1: 17-18 April 2013

Due to a low cloud ceiling on the first mission, the aircraft was flown at about 800 to 1000 feet above ground level (AGL) for the entire mission. The crew reported multiple fires and smoke in and around the facility, which included what appeared to be residences up to ¼ mile from the facility. During ASPECT over flights smoke/plume movement appeared to be to the Northwest.

Weather conditions at the time of data collection consisted of broken to overcast skies at 900 feet with winds from SE at 20 to 30 Kts. The surface temperature was 24°C with a relative humidity of 89%. The surface pressure was reported as 29.33 in Hg. Surface winds in Waco, Texas were reported to be from 160 Degrees at 20 Kts gusting to 30 Kts. The flight crew reported moderate to extreme turbulence and confirmed that winds were gusting from the south at the 800 foot flight level.

Flight Status

The order to launch the aircraft was given at 2300 local on 17 April 2013. The aircraft was airborne at 2345 and was on station at about 0000 on 18 April 2013. Flight information is summarized in Table 1 and Figure 2.

Table 1. Flight Status – Sortie 1, 17-18 April 2013

Run (Log Run #)	Time (GMT)	Altitude (AGL Ft)	Heading (Deg)	L/S File (2013_04_18 …)	FTIR File	Comments
1	0447	---	---	---	---	System Test All OK
2	0505	800		05_05_21_R02	H1305.05	Up the plume
3	0506	800		05_06_04_R03		
4	0506	800		05_06_36_R04		False system trigger
5	0509	800		05_09_05_R05	H1305.09	Up Plume
6	0509	800		05_09_42_R06		
7	0512	800		05_12_43_R07	H1305.12	½ mile downwind[1], Ammonia Detected.
8	0513	800		05_15_13_R08	H1305.15	1 mile downwind
9	0517	800		05_17_40_R09	H1305.17	2 mile downwind
10	0518	800		05_18_28_R10		2 mile downwind
11	0520	800		05_20_36_R11	H1305.20	3 mile downwind
12	0521	800		05_21_18_R12	H1305.21	4 mile downwind
13	0523	800		05_23_29_R13	H1305.23	Upwind of Fire
14	0526	800		05_26_26_R14	H1305.26	5 mile downwind
15	0527	800		05_27_04_R15	H1305.27	5 mile downwind
16	0528	800		05_28_39_R16	H1305.28	6 mile downwind
17	0529	800		05_29_18_R17	H1305.29	6 mile downwind
18	0530	800		05_30_47_R18	H1305.30	7 mile downwind
19	0531	800		05_31_27_R19	H1305.31	7 mile downwind
20	0534	800		05_34_04_R20	H1305.34	8 mile downwind
21	0535	800		05_35_48_R21	H1305.35	9 mile downwind

[1] Note: Run 7 is designated as ½ mile downwind but was flown at a 45 degree angle to the plume and ammonia was detected about 600 to 1000 feet downwind of the major fire.

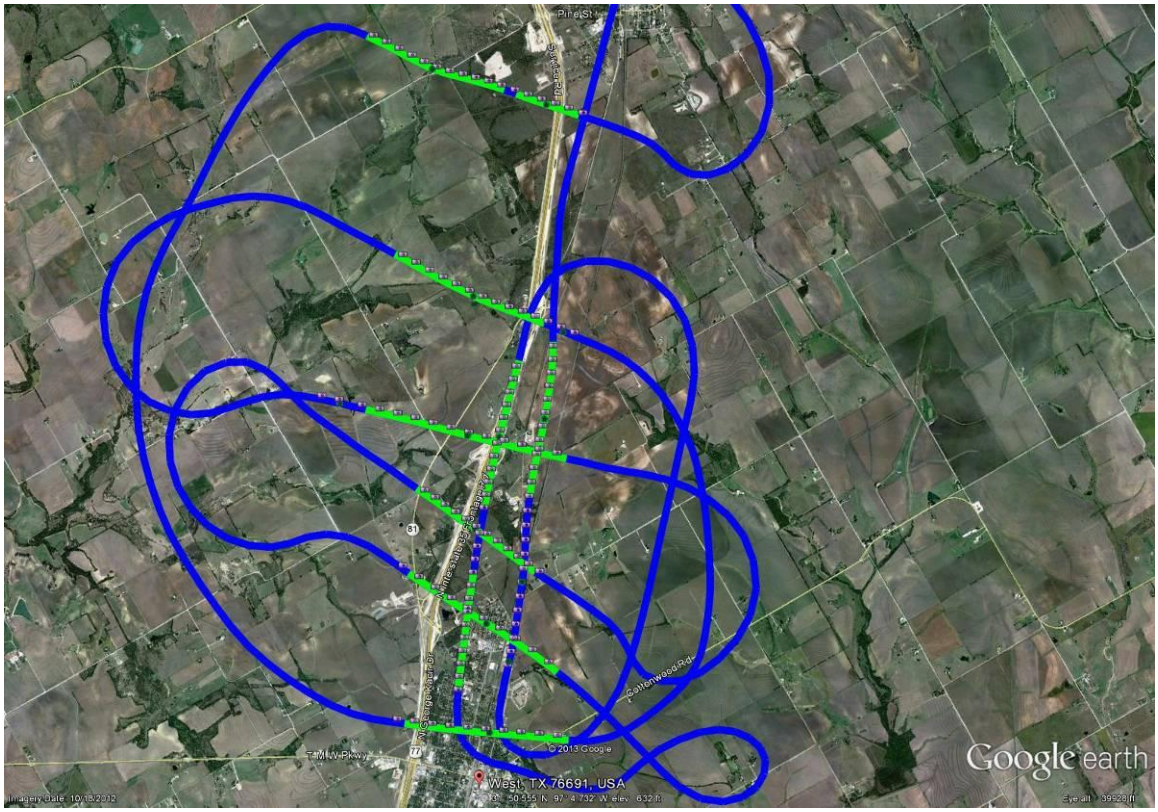

Figure 2 Flight Track, West, Texas Fertilizer Fire

Data Results

Line Scanner Data Results

A total of 20 data passes were made and an infrared line scanner image was generated for each pass. Figure 3 shows an IR image generated from Run 7 using three spectral band pass channels. The white area of the image shows the elevated temperature associated with the fire. Other than the elevated thermal signatures of the fire, no plume was observed in the IR imager. Normally, ASPECT flies at about 2800 feet above ground level and generates IR imagery that is about 3000 feet wide. During this survey, ASPECT had to fly between 800 to 1000 feet AGL due to the low cloud ceiling. Due to this lower altitude, the IR images were only about 800 feet wide.

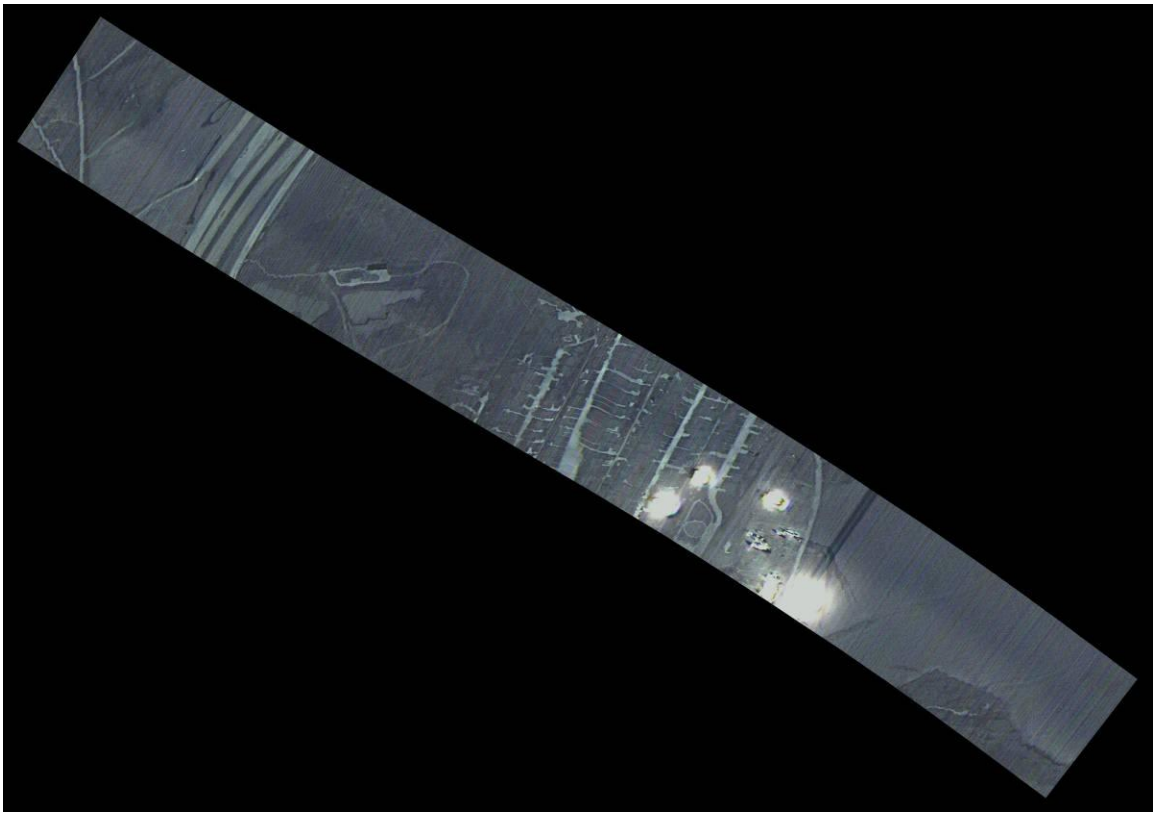

Figure 3, IR Image, West, Texas Fertilizer Fire, Sortie 1, Run 7
(Collected at 0012 Local on 18 April 2013)

FTIR Data Results

Spectral data was collected using the FTIR for each pass. A spectral resolution of 16 wavenumbers was used for all data passes. The following is a table summarizing the data sets generated during the flight.

ASPECT uses an automated detection algorithm to permit compounds to be analyzed while the aircraft is in flight. 71 compounds are included in this algorithm and the list and associated detection limits are given in Figure 4. In addition, collected data are also manually analyzed by comparing any detected spectral signatures to a collection of published library spectra.

Chemical Detection Algorithms

71 Automated

Detection limits (in ppm) referenced to a 10 meter path length

Acetic Acid (2.0)	Cumene (23.1)	Isoprene (6.5)	Propylene Oxide (6.8)
Acetone (5.6)	Diborane (5.0)	Isopropanol (8.5)	Silicon Tetrafluoride (0.2)
Acrolein (8.8)	1,1-Dichloroethene (3.7)	Isopropyl Acetate (0.7)	Sulfur Dioxide (15)
Acrylonitrile (12.5)	Dichloromethane (6.0)	MAPP (3.7)	Sulfur Hexafluoride (0.07)
Acrylic Acid (3.3)	Dichlorodifluoromethane (0.7)	Methyl Acetate (1.0)	Sulfur Mustard (6.0)
Allyl Alcohol (5.3)	1,1-Difluoroethane (0.8)	Methyl Ethyl Ketone (7.5)	Nitrogen Mustard (2.5)
Ammonia (2.0)	Difluoromethane (0.8)	Methanol (5.4)	Phosgene (0.5)
Arsine (18.7)	Ethanol (6.3)	Methylbromide (60)	Phosphine (8.3)
Bis-Chloroethyl Ether (1.7)	Ethyl Acetate (0.8)	Methyl Methacrylate (1.1)	Tetrachloroethylene (10)
Boron Tribromide (0.2)	Ethyl Formate (1.0)	MTEB (3.0)	1,1,1-Trichloroethane (1.9)
Boron Triflouride (5.6)	Ethylene (5.0)	Naphthalene (3.8)	Trichloroethylene (2.7)
1,3-Butadiene (5.0)	Formic Acid (5.0)	n-Butyl Acetate (3.8)	Trichloromethane (0.7)
1-Butene (12.0)	Freon 134a (0.8)	n-Butyl Alcohol (7.9)	Triethylamine (6.2)
2-Butene (18.8)	GA (Tabun) (0.7)	Nitric Acid (5.0)	Triethylphosphate (0.3)
Carbon Tetrachloride (0.2)	GB (Sarin) (0.5)	Nitrogen Trifluoride (0.7)	Trimethylamine (9.3)
Carbonyl Flouride (0.8)	Germane (1.5)	Phosphorus Oxychloride (2.0)	Trimethyl Phosphite (0.4)
Carbon Tetraflouride (0.1)	Hexafluoroacetone (0.4)	Propyl Acetate (0.7)	Vinyl Acetate (0.6)
Chlorodifluoromethane (0.6)	Isobutylene (15)	Propylene (3.7)	

Manual assessment of 500+ other chemical compounds

Figure 4. Automated ASPECT Detection Algorithm List and Detection Limits

Table 2. FTIR data set and detection notations

Run	Compound
1	System Test
2	No Detections
3	Not Collected
4	Not Collected
5	No Detection
6	Not Collected
7	Ammonia, 6.0 – 10.0 PPM
8	No Detections
9	No Detections
10	Not Collected
11	No Detections
12	No Detections
13	No Detections
14	No Detections
15	No Detections
16	No Detections
17	No Detections
18	No Detections
19	No Detections
20	No Detections
21	No Detections

Automated detection of ammonia was observed on data collection Run 7 and indicated moderate levels of ammonia 600 to 1000 feet downwind of the fire. Manual analysis of spectra for Run 7 showed characteristic absorption bands for ammonia at 960 and 920 wave numbers (figure 5). Initial estimates of ammonia air concentration based on the signal to noise ratio indicated that the highest levels of ammonia were approximately 6 to 10 ppm (volumetric) within the plume. Subsequent analysis of the data showed a slight reduction in concentration to a level of 6 ppm (volumetric). Figure 6 shows a plot of the ammonia detection as the aircraft flew over the plume for Run 7. Ammonia concentrations tended to remain fairly consistent across the plume and averaged about 5 ppm. No other compounds of significance were detected.

Subsequent data runs flown at increasing distances downwind from the fire failed to detect ammonia or other compounds of significance. This implies that considerable dilution was acting on the plume due to both the distance and high turbulent winds.

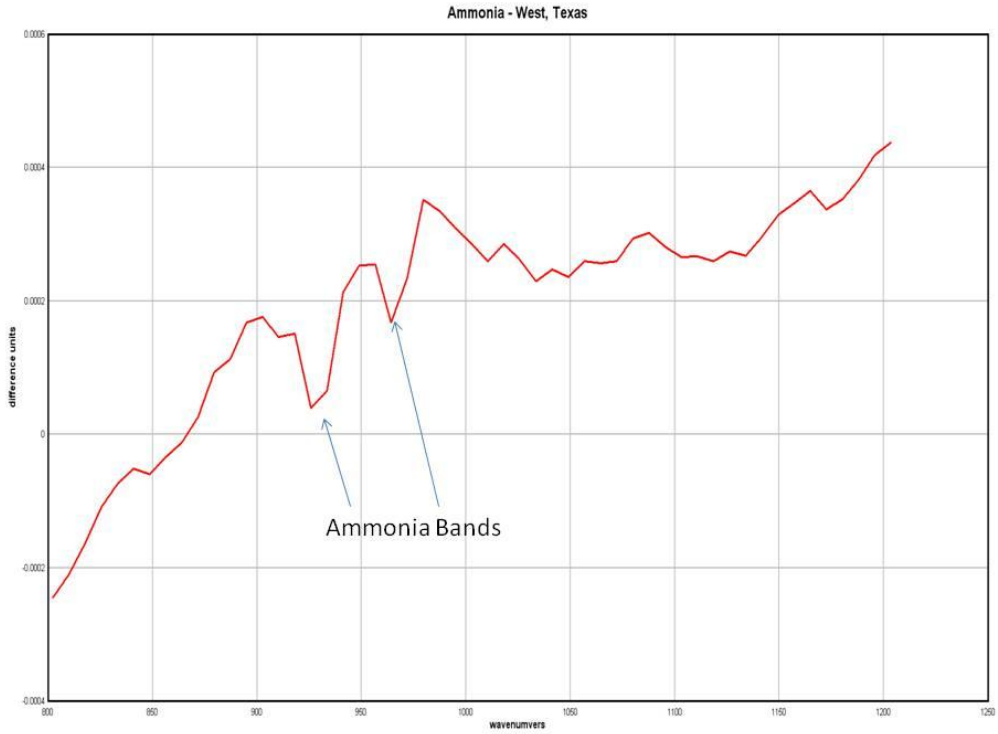

Figure 5. Ammonia Spectral Signature, West, Texas Fertilizer Fire

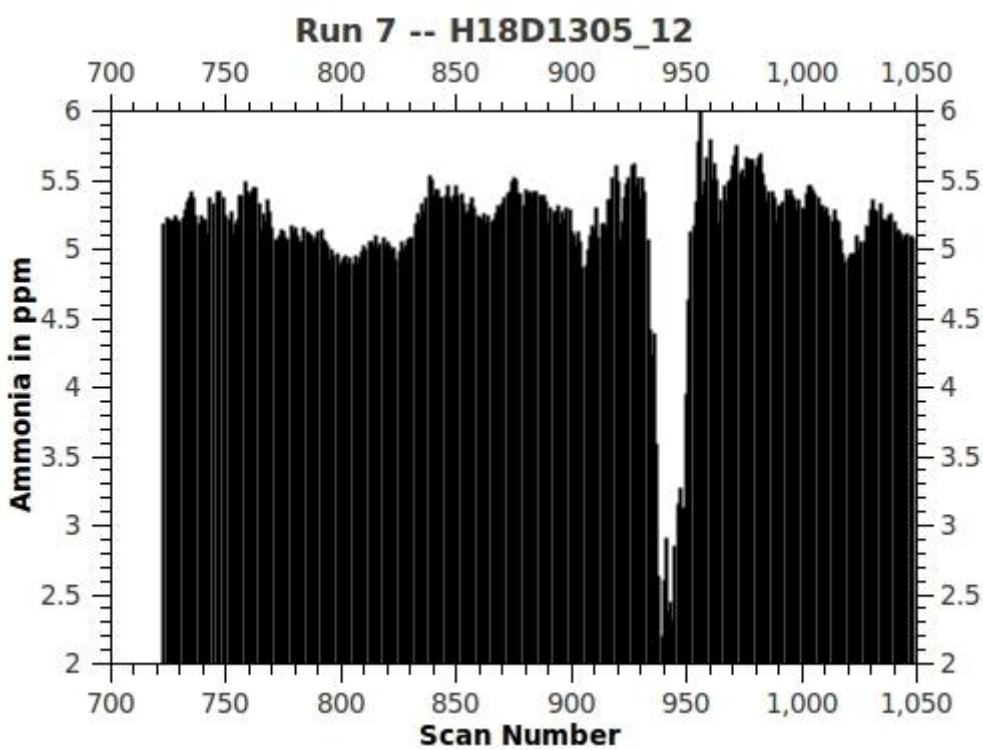

Figure 6. Concentration Profile for Ammonia, West, Texas Fertilizer Fire

Figure 7 shows the geographic location of the ammonia detections as observed with the ASPECT system. The wiggle in the line is a result of turbulence rolling the aiming point of the FTIR spectrometer.

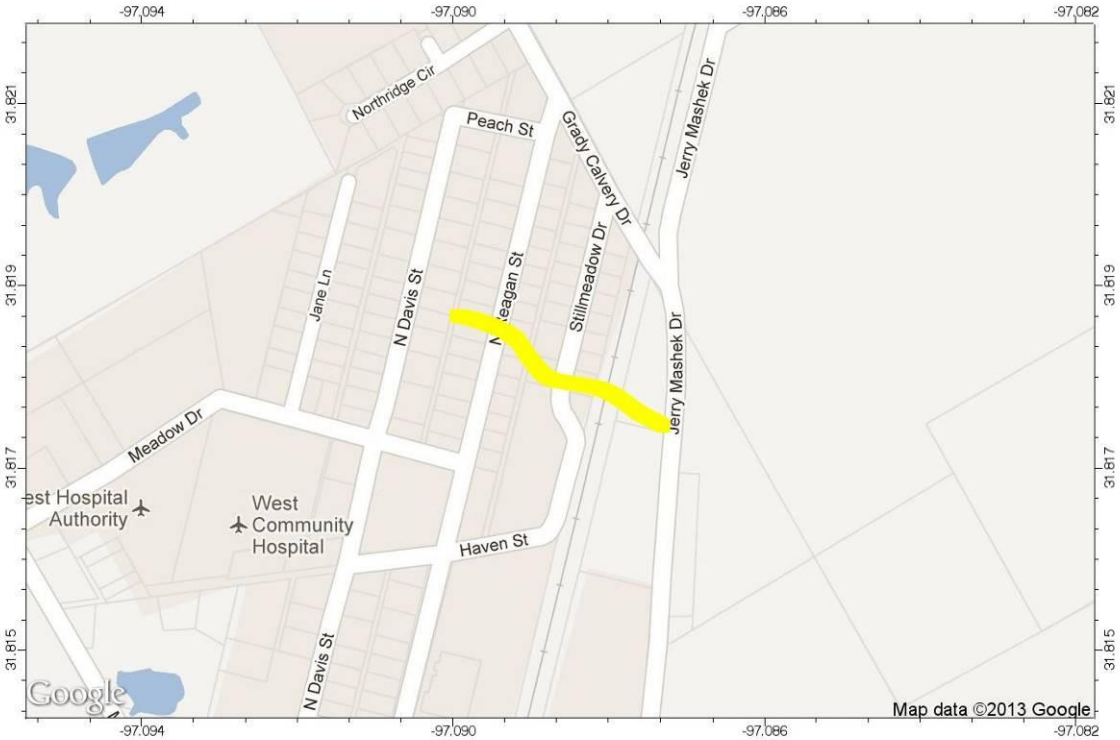

Figure 7. Ammonia Detection Locations, West, Texas Fertilizer Fire, Sortie 1, Run 7 (The detection track shown represents 323 detection data points)

Conclusions Sortie 1: 17-18 April 2013

The ASPECT aircraft was dispatched to the West, Texas Fertilizer Fire to support response activities due to an explosion and fire at the facility. Data collection over the site was initiated at 0000 on 18 April 2013 and included 20 data collection passes downwind of the primary fire. Reports from the crew and thermal features within the IR imagery, showed one large fire and several smaller fires, likely structure fires. Analysis of spectral data showed maximum levels of ammonia at about 6 ppm (volumetric) about 600 to 1000 feet downwind of the fire. Subsequent data collection at further downwind distances from the fire did not detect any hazardous compounds.

Additional flights are being planned for daylight hours of 18 April 2013 for the collection of aerial photographs and conducting follow-on chemical data collection.

Sortie 2: 18 April 2013

Flight Status

In order to provide visible aerial imagery and additional chemical screening data, ASPECT conducted a second sortie to the West, Texas facility on 18 April 2013. The aircraft was airborne at 1150 (local) and returned to base at 1240 (local) on 18 April 2013. Flight information is summarized in Table 3 and Figure 8.

Table 3. Flight Status – Sortie 2, 18 April 2013

Run (Log Run #)	Time (GMT)	Altitude (AGL Ft)	Heading (Deg)	L/S File (2013_04_18 …)	FTIR File	Comments
1	1652	---	---	---	---	System Test All OK
2	1708	1900		17_08_46_R02	H1317.08	24 Photos, Up the plume, fire 1
3	1709	1900		17_09_24_R03	H1317.09	Up the plume, fire 1, Ammonia Detected
4	1712	1900		17_12_03_R04	H1317.12	Up the plume, fire 2
5	1712	1900		17_12_39_R05		Up the plume, fire 2
6	1714	1900		17_14_03_R06	H1317.14	300 ft downwind, Ammonia Detected
7	1715	1900		17_15_06_R07	H1317.15	7 photos, upwind
8	1718	1900		17_18_30_R08	H1317.18	11 photos, 600 ft downwind
9	1721	1900		17_21_42_R09	H1317.21	12 photos, 900 ft downwind
10	1725	1900		17_25_16_R10	H1317.25	12 photos
11	1728	1900		17_28_57_R11	H1317.28	12 photos

Weather conditions present during sortie 2 consisted of brisk winds of 15 Kts gusting to 30 Kts from the northeast. The Temperature was constant at 10 degrees C with a high relative humidity of 80%. Pressure was 29.79 inches of Hg. The overall synoptic conditions included rain with a cloud ceiling of 1900 ft AGL.

The crew reported that two isolated fires were still burning at the site and the resulting plume, while weak in strength, were lofting into the cloud base at about 2000 ft. Winds at flight level were essentially the same as those on the surface. All emissions from the site were being blown to the southeast.

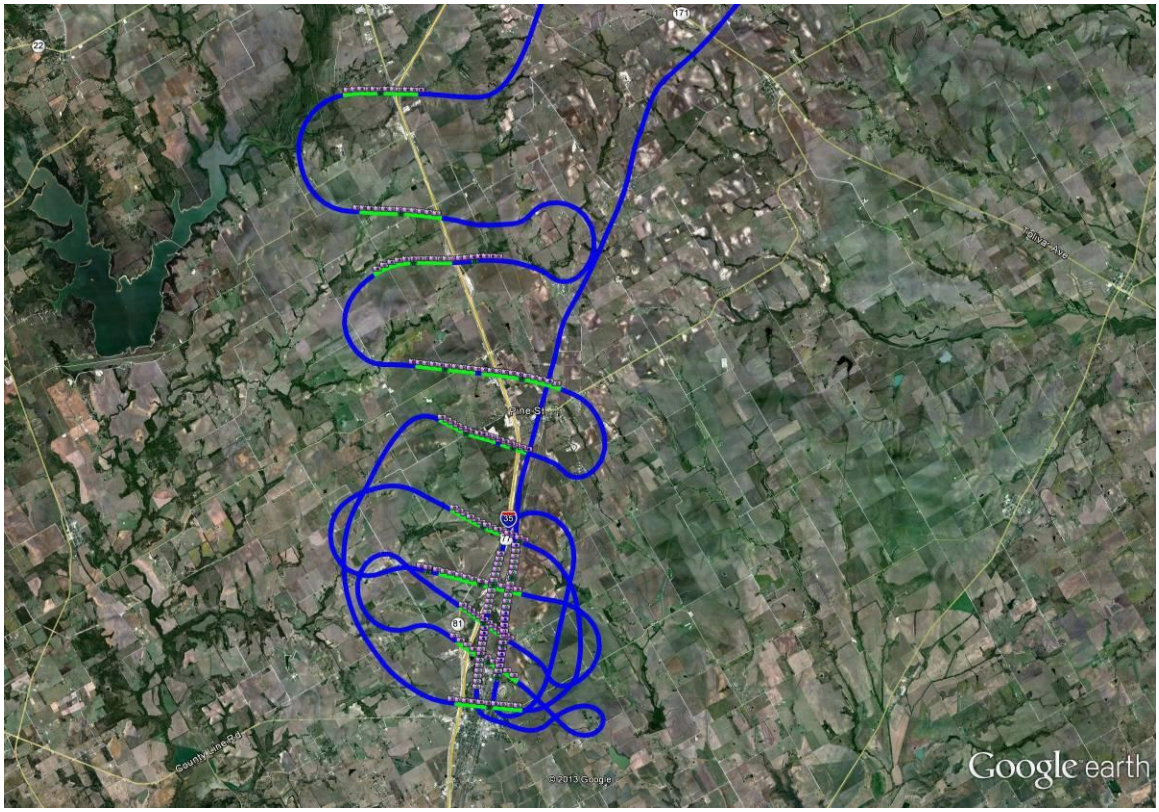

Figure 8 Flight Track, Sortie 2, West, Texas Fertilizer Fire

Data Results

Aerial Photography

As part of the normal daylight ASPECT data collection protocol, ortho-rectified aerial images are produced concurrently with the chemical sensor data collection. Since sortie 2 was conducted in daylight, a series of down looking aerial and oblique photographs were collected.

Figure 9 is an example of the ASPECT ortho-rectified imagery produced. Examination of the image clearly shows the destruction of the former facility and surrounding damage. Figure 10 is representative of the oblique imagery collected by the system. This perspective shows that explosion and fire damage directly impacted structures up to ¼ mile away from the center of the facility.

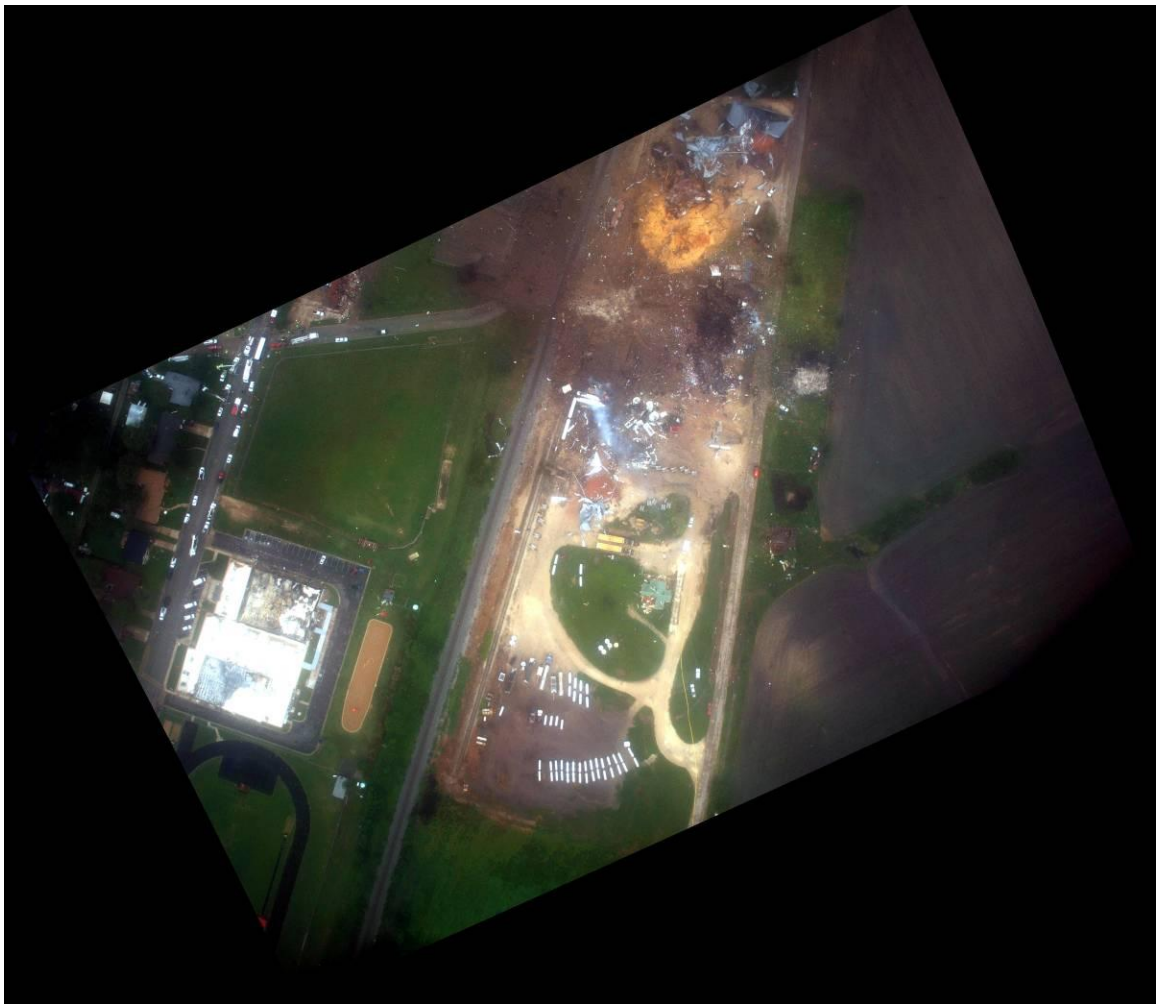

Figure 9. GeoRectified Aerial Image, West, Texas Fertilizer Fire

Figure 10. Oblique Image, West, Texas Fertilizer Fire

Sortie 2: Line Scanner Data Results

A total of 10 data passes were made and an infrared line scanner image was generated for each pass. Figure 11 shows an IR image generated from Run 3 using three spectral band pass channels. The white areas highlighted correspond to elevated temperatures and are associated with the two active fires. As with images collected during sortie 1, no plume was observed in the IR imager. A comparison of this image and that of Figure 3 indicates that while fires still exist at the site, the magnitude and extent are greatly diminished.

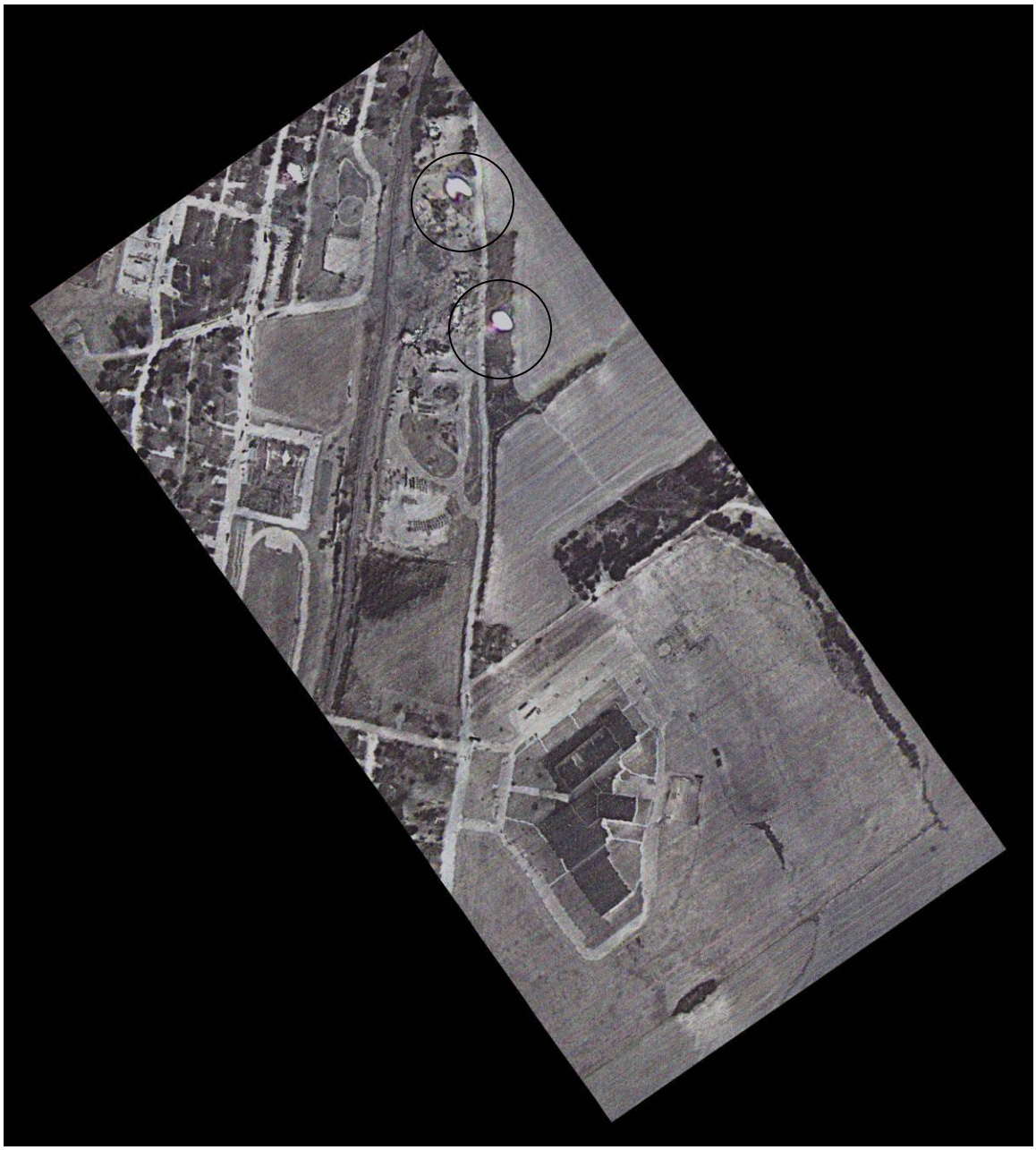

Figure 11, IR Image, West, Texas Fertilizer Fire, Sortie 2, Run 3
(Collected at 1209 Local on 18 April 2013)

Sortie 2: FTIR Data Results

Spectral data was collected using the FTIR for each pass. A spectral resolution of 16 wave numbers was used for all data passes. The following is a table summarizing the data sets generated during sortie 2.

Table 4. FTIR data set and detection notations

Run	Compound
1	System Test
2	No Detections
3	Ammonia, 6 ppm max
4	No Detections
5	Not Collected
6	Ammonia, 3 ppm max
7	No Detection
8	No Detection
9	No Detection
10	No Detection
11	No Detection

Automated detection of ammonia was observed on data collection Run 3 and Run 6. For both passes, ammonia was detected about 650 feet southeast of the residual fires and was consistent with the wind direction during the mission. As with the first sortie, manual analysis of spectra showed the characteristic absorption bands of 960 and 920 wave numbers (figure 12). Run 3 showed the highest maximum concentration of approximately 6 ppm (volumetric). Run 6 showed a maximum concentration of about 3 ppm. Figure 13 shows the concentration profile of the ammonia for Run 3. No other compounds of significance were detected at greater downwind distances from the site.

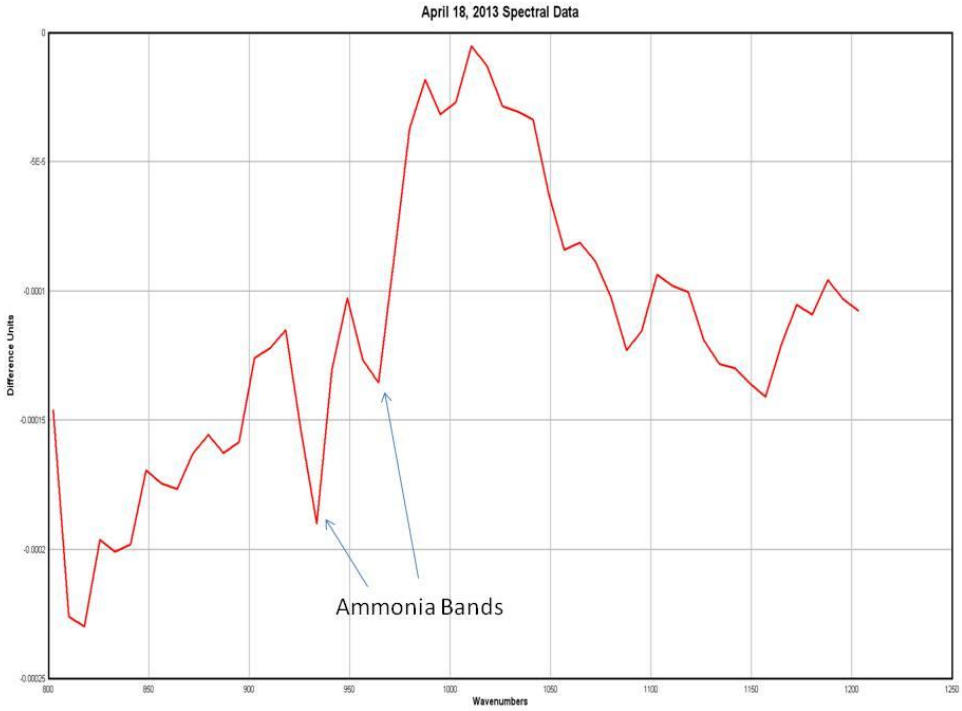

Figure 12. Ammonia Spectral Signature, West, Texas Fertilizer Fire

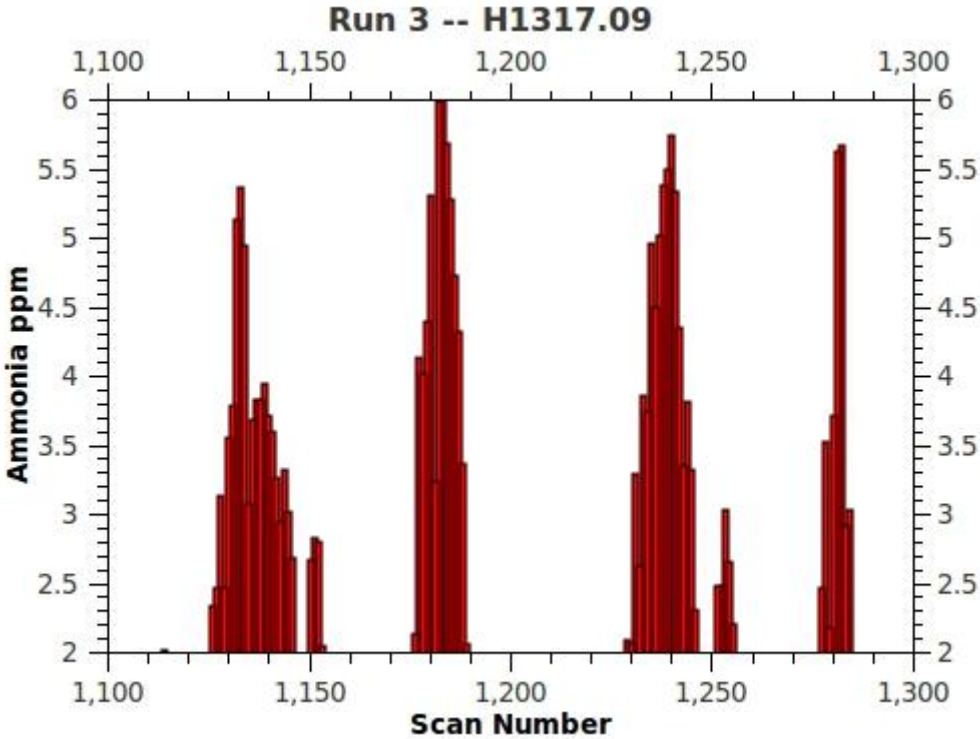

Figure 13. Concentration Profile for Ammonia, West, Texas Fertilizer Fire

Figure 14 shows the geographic location of the ammonia detections as observed with the ASPECT system. The observed detection locations are southeast of the site and are consistent with the shift in wind direction from the previous mission.

Figure 14. Ammonia Detection Locations, Sortie 2, West, Texas Fertilizer Fire
(The detection track shown represents 75 detection data points)

Conclusions

At the request of the Region, ASPECT conducted a Sortie 2 of the West, Test Fertilizer facility to collect additional chemical data and aerial and oblique images. Data collection over the site was initiated at 1208 (local) on 18 April 2013 and included 10 data collection passes downwind of the site. Two isolated fires were still burning during the mission; the magnitude and extent of these fires are greatly diminished. Collected aerial chemical data continued to show ammonia being emitted from the site. A maximum concentration of 6 ppm was detected about 650 feet southwest of the site. Subsequent data collection at further downwind distances from the site did not detect any additional hazardous compounds.