

# Airborne Spectral Photometric Environmental Collection Technology

## ASPECT Texas Air Quality Survey Beaumont and Houston, TX 10 March 2021



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# Table of Contents

<b>Acronyms and Abbreviations.....</b>	<b>3</b>
<b>Background and Operational Overview .....</b>	<b>7</b>
<b>General Mission Objectives .....</b>	<b>13</b>
<b>Flight Conditions and Status .....</b>	<b>13</b>
Weather and Site Conditions .....	13
<b>Data Results .....</b>	<b>14</b>
Flight Paths .....	14
Line Scanner Data Results .....	16
FTIR Data Results .....	19
Aerial Photography Results .....	21
<b>Conclusion .....</b>	<b>23</b>
<b>Appendix A: File Names of Data Collected During Flight .....</b>	<b>24</b>
<b>Appendix B: ASPECT Systems .....</b>	<b>27</b>

## **Acronyms and Abbreviations**

Alt	Altitude (in feet)
AGL	Above Ground Level
cm	centimeter
CST	Central Standard Time
DEM	Digital Elevation Model
Digital	Digital photography file from the Nikon D2X camera
ft	feet
FTIR	Fourier Transform Infrared Spectrometer
igm	Spectral data format based on grams format
IR	Infrared
IRLS	Infrared Line Scanner
jpg	JPEG image format
kts	knots
mph	miles per hour
m/s	meters per second
MSIC	Digital photography file from the Imperx mapping camera
MSL	Mean Sea Level Altitude (in feet)
ppm	parts per million
UTC	Universal Time Coordinated

## Executive Summary

During the week of 15 February 2021, a strong Polar air mass extended over a large portion of the United States pushing temperatures into the negative digits. The State of Texas experienced frozen precipitation and low temperatures culminating in stress to the power grid resulting in brown and blackout conditions. Due to the widespread power loss within the State, most petrochemical and other Risk Management Plan facilities were forced to shut down. During the week of 22 February 2021 plans were made to restart many of these facilities with concern that the restarts may impact air quality. The U.S. Environmental Protection Agency Region 6 was requested by the State of Texas to deploy the ASPECT aircraft for the purpose of area-wide air monitoring over the Beaumont, Houston, and Corpus Christi regions commencing on 27 February 2021. This report provides a summary of the findings made during the survey.

ASPECT missions conducted on 27 Feb 2021 were hampered by poor weather and low cloud ceilings which prevented data collection in the Beaumont area. ASPECT was able to collect a limited set of data near Crosby, TX and 5 collection runs over the Corpus Christi area. No compounds were detected on these missions.

On 28 Feb 2021 ASPECT conducted an air monitoring mission for both the Corpus Christi and Houston areas with low levels of 1-butene, isoprene, 1,3-butadiene, acetone, and ammonia were detected at low levels in the collection areas. Visible and IR imagery both showed hot flare and steam vents suggesting that facilities are operational.

ASPECT conducted two flight missions (Flight 4 and 5) on 2 March 2021 including air monitoring survey collections over Corpus Christi, Freeport, Houston, Port Arthur, and Beaumont areas. Weather conditions for both flights was favorable with some elevated turbulence reported on the afternoon flight. Imagery (visible and IR) showed typical steam and cooling tower and flare signatures. Compounds detected in the Corpus Christi area consisted of acetone (1.536 ppm), isoprene (1.250 ppm) and 1-butene (1.391 ppm). Isobutylene was detected in the Beaumont area at a level of 1.577 ppm.

Two air quality surveys were collected on 3 March 2021 over Beaumont and Houston areas (Flight 6) and mission over the Corpus Christi areas (Flight 7). Weather conditions for both surveys was favorable for all types of data collection. Visible and IR imagery showed normal facility operations including elevated process unit piping and visible steam plumes. Compounds detected on the Beaumont and Houston flight showed detections of 1-butene (7.230 ppm), 2-butene (5.443 ppm), 1,3-butadiene (1.537 ppm), ethylene (2.075 ppm), isoprene (4.055 ppm) and isobutylene (5.267 ppm). On Flight 7 the following compounds were detected including sulfur dioxide (1.517 ppm), 1-butene (1.792 ppm), 1,3-butadiene (0.994 ppm), isoprene (1.232 ppm) and isobutylene (1.505 ppm).

The collection objectives for 4 March 2021 included a continuation of air monitoring collection activities at selected sites within the Beaumont, Houston, and Corpus Christi areas. Weather forecast in the collection areas were acceptable for all types of data collection. No chemical plumes were detected on any of the IR imagery. Compounds

detected on Flight 8 included acetone (0.793 ppm) and isobutylene (1.929 ppm) in the Corpus Christi area and ammonia (0.477 ppm), 1,3-butadiene (6.788 ppm), 1-butene (6.140 ppm), 2-butene (7.930 ppm), ethylene (0.845 ppm), isobutylene (3.299 ppm), isoprene (2.678 ppm) and sulfur dioxide (2.218 ppm) in the Freeport and Houston areas. Compounds detected on the second flight of the day over Beaumont showed 1-butene (1.766 ppm), 1,3-butadiene (0.983 ppm), and isobutylene (1.531 ppm).

ASPECT conducted two flight missions on 5 March 2021 including air monitoring survey collections over Houston (Flight 10) and Corpus Christi (Flight 11). Weather conditions were generally favorable with some clouds in the early portion of the Houston area. No chemical plumes were detected on IR imagery. IR imagery did indicate a possible sheen within a containment basin in the Houston area. Compounds detected as part of the Houston survey consisted of 1-butene (1.244 ppm), acetone (0.855 ppm) and isoprene (4.398 ppm). Compounds detected in the Corpus Christi area consisted of 1-butene (1.862 ppm), 2-butene (2.634 ppm), isobutylene (1.527 ppm) and isoprene (0.883 ppm). No chemical plumes were detected on any of the collection passes.

Flight objectives for 6 March 2021 included conducting air monitoring surveys over the Beaumont and Houston areas. Weather conditions were favorable for all types of data collection with exception of moderate to strong turbulence on the Houston data collection. Compounds detected in the Beaumont area (Flight 12) included 1-butene (1.656 ppm) and 1,3-butadiene (0.743 ppm). Flight 13 had an absence of targeted organics but the presence of peroxyacetyl nitrate (PAN) and ozone was frequently detected. Oblique imagery during the Houston flight indicated a haze of smog, consistent with the PAN observations.

Objectives for 7 March 2021 included surveys over the La Port and Corpus Christi areas (Flight 14) and a mission over Freeport (Flight 15). A single compound was detected in the La Porte area consisting of acetic acid (1.518 ppm) which was associated with a flare that appeared to be in the startup process. Compounds detected in the Corpus Christi area included acetone (0.984 ppm), 1-butene (1.912 ppm), 2-butene (2.198 ppm), isoprene (1.184 ppm) and isobutylene (1.736 ppm). Isobutylene (2.022 ppm) was the only compound that was detected in the Freeport area.

ASPECT conducted two flights on 8 March 2021 consisting of an air monitoring survey over the Houston area followed by an afternoon mission over the Beaumont/Port Arthur area. Compounds detected associated with the Houston mission (Flight 16) included acetone (0.642 ppm), 1-butene (1.283 ppm), and isoprene (1.846 ppm). Compounds detected on over the Beaumont/Port Arthur areas included 1-butene (1.711 ppm), isobutylene (1.703 ppm), isoprene (1.221 ppm) and SO<sub>2</sub> (1.612 ppm).

Flights on 9 March 2021 included missions over Houston, Corpus Christi and the extended Corpus Christi areas. Compounds detected on Flight 18 (Houston and Freeport areas) included acetone (0.655 ppm), ammonia (10.19 ppm), 1-butene (1.250 ppm), 2-butene (1.921 ppm), 1,3-butadiene (0.514 ppm), isobutylene (1.788 ppm) and isoprene (0.682 ppm). Compounds observed over the Corpus Christi and extended areas on Flight 19

consisted of acetone (0.611 ppm), 1-butene (2.352 ppm), 2-butene (2.242 ppm), isobutylene (1.531 ppm), isoprene (1.016 ppm) and n-butyl alcohol (1.327 ppm).

Only one compound was detected on the morning mission Flight 20, 10 March 2021 over the Beaumont/Port Arthur areas and consisted of 1-butene (1.238 ppm). Flight conditions for an afternoon mission over the Houston area were marginal and forced the system to be operated at about 1200 ft AGL. No programmed compounds were detected but common air pollution compounds were observed in the FTIR system.

# **ASPECT Texas Air Quality Survey**

## **Beaumont and Houston, TX**

### **10 March 2021**

#### **Background and Operational Overview**

During the week of 15 February 2021, a strong Polar air mass extended over a large portion of the United States pushing temperatures into the negative digits. The State of Texas experienced snow, ice, and low temperatures. These conditions culminated in a stress to the power grid resulting in brown and blackout conditions in many parts of the State. Petrochemical facilities in many locations were forced to shut down. During the week of 22 February 2021 plans were made to restart many of these facilities with concern that the restarts may impact air quality. The U.S. Environmental Protection Agency Region 6 was requested by the State of Texas to deploy the ASPECT aircraft for the purpose of area-wide air monitoring over the Beaumont, Houston, and Corpus Christi regions commencing on 27 February 2021.

The overall objective of this survey was to examine the air quality of areas populated with Risk Management Plan (RMP) sites and petrochemical facilities using the ASPECT system. No specific sites were specified other than generic survey areas. Figures 1, 2, and 3 show those areas corresponding to the Beaumont/Port Arthur, Houston, and Corpus Christi survey locations. Within these areas, a series of guidance flight lines were developed to assist the flight crew in data collection using the ASPECT system. The ASPECT system has a set of automated compounds that can be automatically detected and if any of these compounds were detected, the location and approximate quality of the compound would be reported to EPA Region 6.

An ASPECT series of missions were flown on 27 Feb 2021 as part of a request from EPA Region 6 to support air monitoring within the Beaumont, Houston, and Corpus Christi areas. The ASPECT aircraft attempted to collect data at each of the general areas and was only able to obtain 1 collection pass near Crosby, TX and 5 collection runs over the Corpus Christi area. Poor weather hampered all collection activities due to low cloud levels and dark conditions. The limited FTIR data that was collected and analyzed showed no detections on any collection passes.

ASPECT conducted a mission on 28 Feb 2021 consisting of an air monitoring survey over selected areas of the Corpus Christi and Houston collection areas. Weather conditions in both locations were marginal due to low ceilings but a set of data was collected for both locations. Imagery collected showed that facilities appear to be operational with both

steam and active flares. Compounds including 1-butene (2.665 ppm), isoprene (3.065), 1,3-butadiene (2.56 ppm), acetone (0.688 ppm), and ammonia (0.440 ppm) were detected at low levels in the Houston area and 1-butene (1.219 ppm) and isoprene (1.012 ppm) were detected in the Corpus Christi area.

ASPECT conducted two flight missions on 2 March 2021 including air monitoring survey collections over Corpus Christi, Freeport, Houston, Port Arthur, and Beaumont areas. Weather conditions for both surveys was generally favorable with some elevated turbulence reported on the afternoon flight. Visible imagery collected showed what appears to be normal steam and cooling tower emissions. Examination of IR imagery showed numerous flares and hot process piping and units. Compounds detected on the flight over Corpus Christi included acetone (1.536 ppm), isoprene (1.250 ppm) and 1-butene (1.391 ppm) all associated with one facility. The flight over the Freeport and Houston locations showed no detections. Isobutylene was detected in the Beaumont area at a level of 1.577 ppm.

On 3 March 2021 air monitoring surveys were collected over the Beaumont and Houston areas (Flight 6) and a mission over the Corpus Christi areas (Flight 7). Weather conditions for both surveys was favorable for all types of data collection. Visible and IR imagery showed normal facility operations including elevated process unit piping and visible steam plumes. Compounds detected on the Beaumont and Houston flight showed detections of 1-butene (7.230 ppm), 2-butene (5.443 ppm), 1,3-butadiene (1.537 ppm), ethylene (2.075 ppm), isoprene (4.055 ppm) and isobutylene (5.267 ppm). On Flight 7 the following compounds were detected including sulfur dioxide (1.517 ppm), 1-butene (1.792 ppm), 1,3-butadiene (0.994 ppm), isoprene (1.232 ppm) and isobutylene (1.505 ppm).

ASPECT conducted two flight missions on 4 March 2021 including air monitoring survey collections over Corpus Christi and Houston areas (Flight 8) and a mission over the Beaumont/Port Arthur (Flight 9). Weather conditions were favorable for all types of data collection. No chemical plumes were detected on IR imagery. Compounds detected on flight 8 included acetone (0.793 ppm) and isobutylene (1.929 ppm) in the Corpus Christi area and ammonia (0.477 ppm), 1,3-butadiene (6.788 ppm), 1-butene (6.140 ppm), 2-butene (7.930 ppm), ethylene (0.845 ppm), isobutylene (3.299 ppm) isoprene (2.678 ppm) and sulfur dioxide (2.218 ppm) in the Freeport and Houston area. Flight 9 over the Beaumont area showed 1-butene (1.766 ppm), 1,3-butadiene (0.983 ppm), and isobutylene (1.531 ppm). As with flight 8, visible and IR imagery indicated that facilities are showing normal thermal signatures.

The ASPECT objectives on 5 March 2021 included two flight missions over Houston (Flight 10) and Corpus Christi (Flight 11). Weather conditions were generally favorable with some clouds in the early portion of the Houston area. No chemical plumes were detected on IR imagery. IR imagery did indicate a possible plume within a containment basin in the Houston area. Compounds detected as part of the Houston survey consisted of acetone (0.855 ppm) and isoprene (4.398 ppm). Compound detected in the Corpus Christi



area consisted of 1-butene (1.862 ppm), 2-butene (2.634 ppm), isobutylene (1.527 ppm) and isoprene (0.883 ppm). No chemical plumes were detected on any of the collection passes.

Flight objectives for 6 March 2021 included conducting air monitoring surveys over the Beaumont and Houston areas. Weather conditions were favorable for all types of data collection with exception of moderate to strong turbulence on the Houston data collection. Compounds detected in the Beaumont area (Flight 12) included 1-butene (1.656 ppm) and 1,3-butadiene (0.743 ppm). Flight 13 had an absence of targeted organics but the presence of peroxyacetyl nitrate (PAN) and ozone was frequently detected. Oblique imagery during the Houston flight indicated a haze of smog, consistent with the PAN observations.

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Focus areas of monitoring for 9 March 2021 included flights over Houston and the Corpus Christi and extended area. Compounds detected on Flight 18 (Houston and Freeport areas) included acetone (0.655 ppm), ammonia (10.19 ppm), 1-butene (1.250 ppm), 2-butene (1.921 ppm), 1,3-butadiene (0.514 ppm), isobutylene (1.788 ppm) and isoprene (0.682 ppm). Compounds observed over the Corpus Christi and extended areas consisted of acetone (0.611 ppm), 1-butene (2.352 ppm), 2-butene (2.242 ppm), isobutylene (1.531 ppm), isoprene (1.016 ppm) and n-butyl alcohol (1.327 ppm).

The collection objectives for 10 March 2021 included a continuation of air monitoring collection activities at selected sites within the Beaumont/Port Arthur and Houston areas. Weather conditions for the Beaumont/Port Arthur collection area was forecast as favorable for all types of data collection. The weather prognosis for the Houston area was less favorable with some low clouds and rain forecast. This report summarizes the results of the mission.

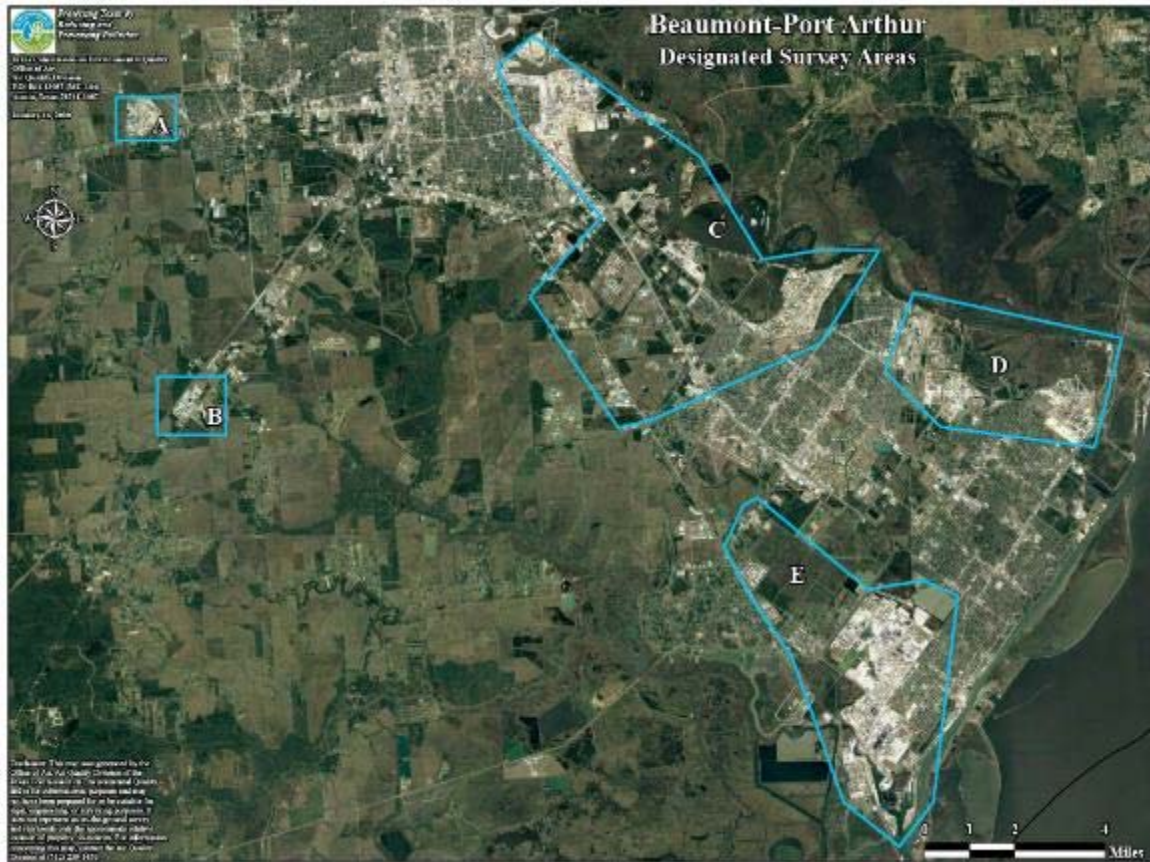
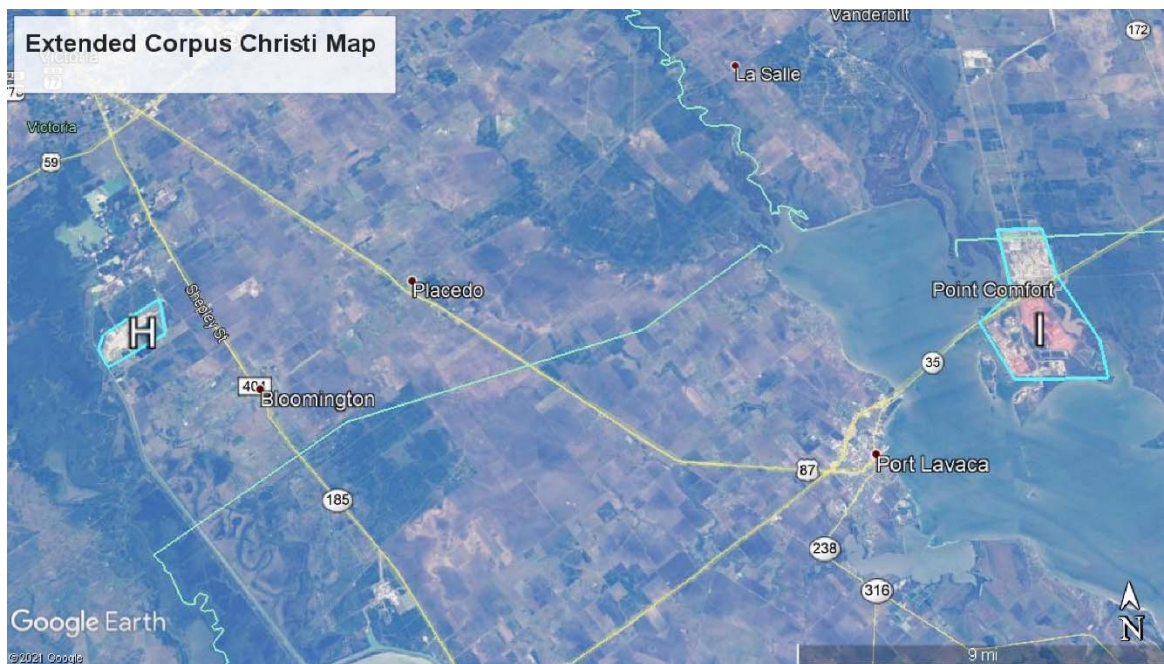
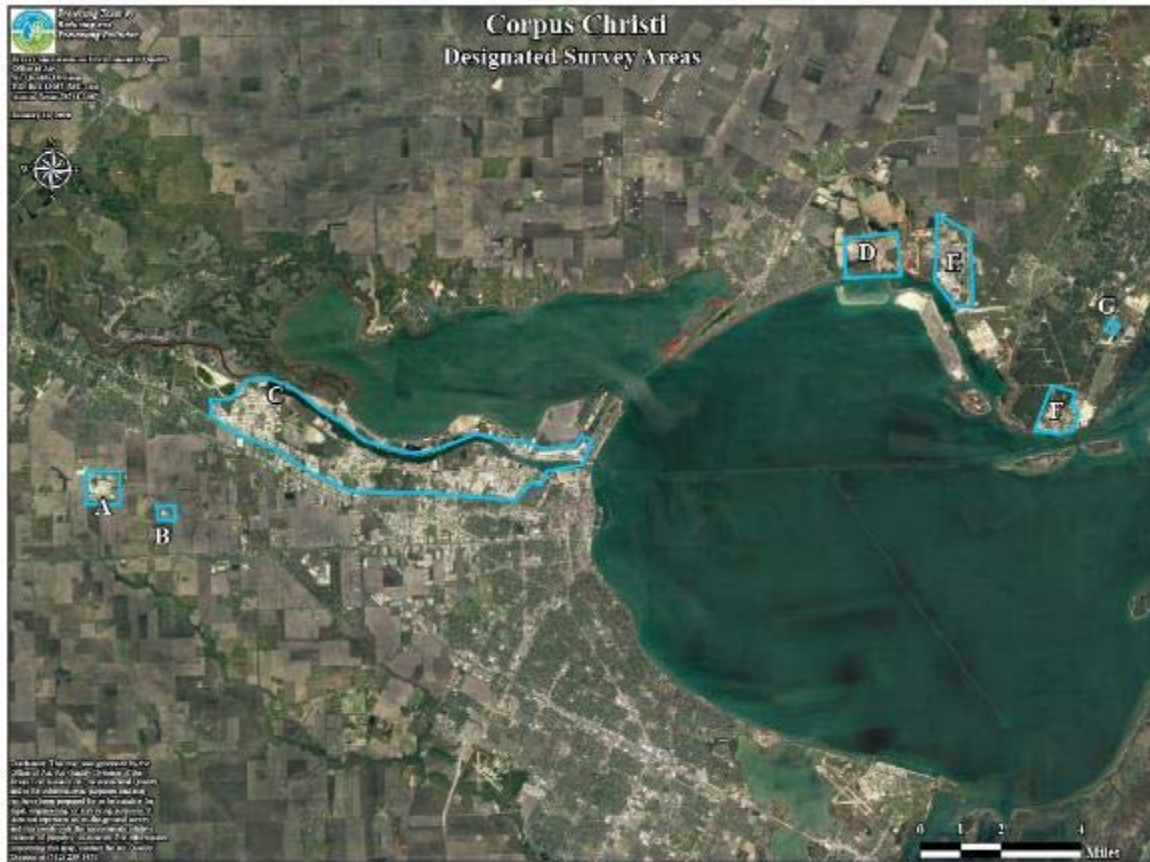


Figure 1: Beaumont/Port Arthur, TX Survey Area



Figure 2. Houston, TX Survey Area





## General Mission Objectives

Once granted access to fly over the sites, the following general mission objectives were employed in conducting emergency response data collection with ASPECT:

1. To capture an overall, situational awareness of the incident using aerial photography with:
  - Oblique camera—photos taken by hand from the view/position of the co-pilot, and
  - MSIC photos—advanced camera mounted underneath the plane for a top-down view of the designated sites.
2. To qualitatively locate and characterize any the visible and non-visible components of a plume, as well as any areas on fire:
  - Using the Infrared Line Scanner (IRLS)
3. To screen for the presence and location of specific chemicals within ASPECT's automated chemical detection library:
  - Using the Fourier Transform Infrared (FTIR) Spectrometer

## Flight Conditions and Status

### Weather and Site Conditions

Prior to each flight, an updated status of the current and forecasted weather, site conditions and any potential flight obstacles including radio towers impacting safety is assessed by the crew. A complete timeline of the ground weather conditions during the two missions can be found in Tables 1 and 2.

**Table 1. Ground Weather for Beaumont, TX**

Time	755	855	955	1055
Wind direction	157.5 degrees SSE	157.5 degrees SSE	180 degrees S	180 degrees S
Wind speed	5.8 m/s (13.0 mph)	5.8 m/s (13.0 mph)	8.0 m/s (18.0 mph)	8.0 m/s (18.0 mph)
Temperature	20.6 C	22.2 C	23.9 C	23.9 C
Relative humidity	85%	76%	63%	66%
Dew point	17.8 C	17.8 C	16.7 C	17.2 C
Pressure	1021.7 mb	1022.7 mb	1023 mb	1023.3 mb
Ceiling	Broken 6000 Ft	Overcast 6000 Ft	Broken 5000 Ft	Broken 2500 Ft

**Table 2. Ground Weather for Houston, TX**

Time	1150	1250	1350	1450	1550
Wind direction	157.5 degrees SSE	157.5 degrees SSE	157.5 degrees SSE	157.5 degrees SSE	157.5 degrees SSE
Wind speed	8.0 m/s (18.0 mph)	8.0 m/s (18.0 mph)	10.3 m/s (23.0 mph)	10.3 m/s (23.0 mph)	7.6 m/s (17.0 mph)
Temperature	22.8 C	23.9 C	23.9 C	23.9 C	22.8 C
Relative humidity	74%	69%	69%	69%	74%
Dew point	17.8 C	17.8 C	17.8 C	17.8 C	17.8 C
Pressure	30.13 mb	30.09 mb	30.07 mb	30.05 mb	30.05 mb
Ceiling	Scattered 2300 Ft	Scattered 2500 Ft	Broken 2500 Ft	Broken 2500 Ft	Broken 2500 Ft

The aircraft departed Houston, TX at approximately 0755 CST and was on station in the Beaumont/Port Arthur area and was ready to collect data at 0817 CST. Winds were reported as 195° at 26 kts. Sky conditions reported from Beaumont showed some high clouds which did not impact data collection for the ASPECT system.

At 1227 ASPECT was airborne with a mission to conduct air monitoring in the Houston area. Ground weather observations from KEFD indicated scattered at 2300-2500 ft AGL but conditions aloft were reported as not optimal for data collection with ceilings at or below 2000 ft degrading to 1500 ft as the mission progressed. Collection altitudes (as reported from sensor systems) were at times on the order of 1200 ft AGL. The crew reported mild to heavy turbulence.

### **Data Results**

The following data is provided as a summary analysis. All data products are available for the Region to access on a shared FTP site. For a complete list of available products, see Appendix A. The data collected during these missions included a flight path summary, IRLS images, FTIR chemical identification and quantification, high resolution MSIC photos, and oblique photos.

### **Flight Paths**

Wide, slow turns are required to be made in between runs to keep the instruments stable. The blue lines indicate the flight path while the green lines indicate the specific sections of the flight where chemical data was collected and processed. On Flight 20 the Beaumont/Port Arthur was surveyed, and the flight path is shown in Figure 5. On the afternoon of 10 March 2021 ASPECT conducted a mission, Flight 21, over the Houston area which is shown in Figure 6.



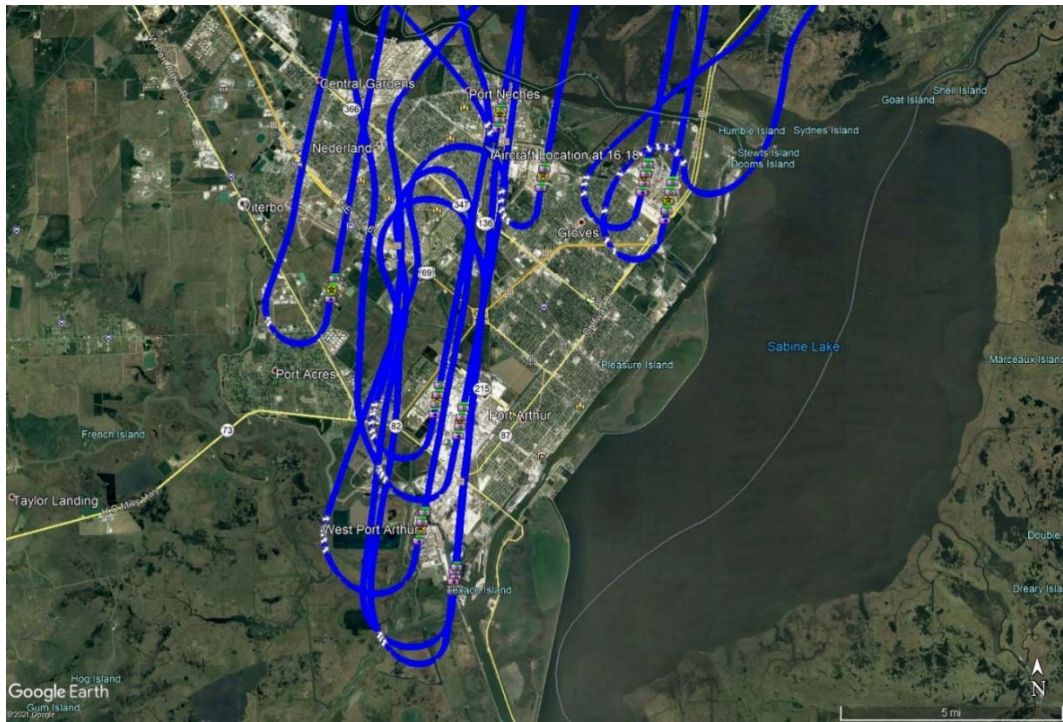


Figure 5. Data Collection Flight Path over the Beaumont/Port Arthur, Flight 20, 10 March 2021

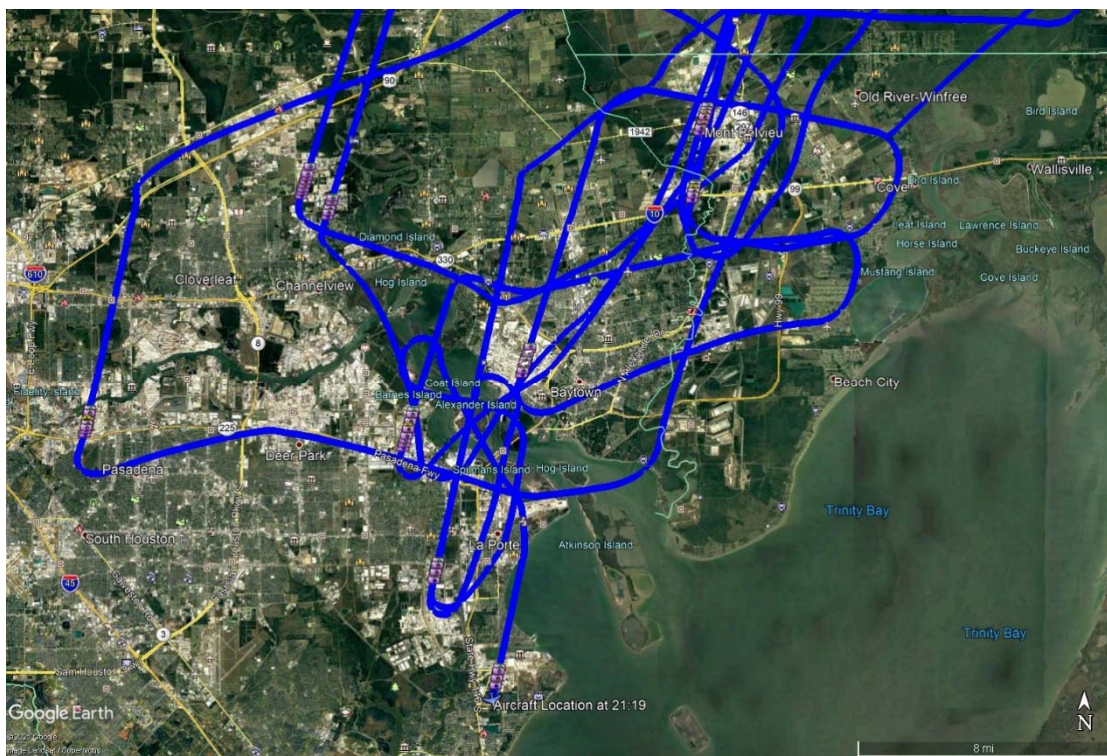


Figure 6. Data Collection Flight Path for the Houston Area, Flight 21, 10 March 2021

### Line Scanner Data Results

A total of 13 data collection runs were made over the Beaumont/Port Arthur areas and during each collection run an infrared line scanner image was generated. Figure 7 shows a 3-band infrared image collected over the Port Arthur area. Examination of the image shows a small flare on the right middle portion of the frame and hot process units and piping throughout the facility. No chemical plumes can be observed being emitted from the facility.

During the afternoon mission on 10 March 2021, ASPECT collected 10 IR images over selected sites within the Houston area. Due to a low ceiling, the imagery is distorted in the direction of flight. An image collected on pass 5 is given in Figure 8. Features of this image include one large and two small flares and many elevated thermal signatures of piping and process units. No chemical plumes can be seen being emitted from the facility.



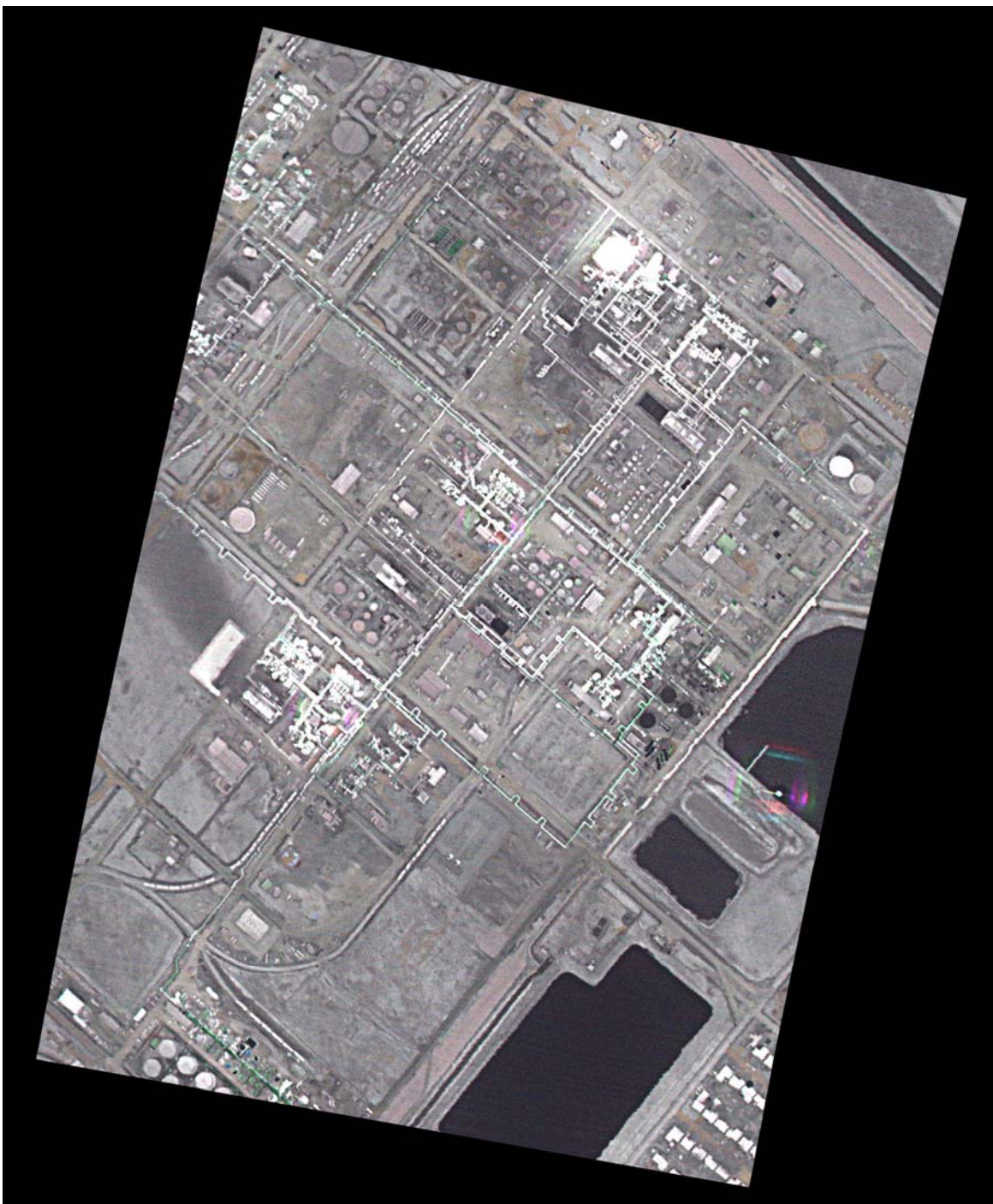


Figure 7. Three band IR image, Port Arthur Area, Run 12, Flight 20, 10 March 2021



Figure 8. Three band IR image, Houston Area, Run 5, Flight 21, 10 March 2021



## FTIR Data Results

FTIR spectral data at a resolution of 16 wavenumbers was collected for each run. ASPECT uses an automated detection algorithm to permit compounds to be automatically analyzed while the aircraft is in flight. Seventy-six chemical compounds are included in the airborne algorithm library (the list is provided in Appendix B, Table 1). In addition, collected data was also manually quality checked against a collection of published library spectra for each chemical detected.

Only one compound was detected on the mission over the Beaumont/Port Arthur areas and consisted of 1-butene (1.238 ppm). The location for this detection is given in Figure 9. A representative spectrum of 1-butene is given in Figure 10. Details of these detections can be found in Table 4.

ASTECT did not detect any programmed compounds (those found in Appendix B, Table 1) but the sensor did detect common air pollutants. Figure 11 shows peroxyacetyl nitrate (PAN) with the large feature centered at approximately  $1120\text{ cm}^{-1}$ . Details of the monitoring results can be found in Table 5.

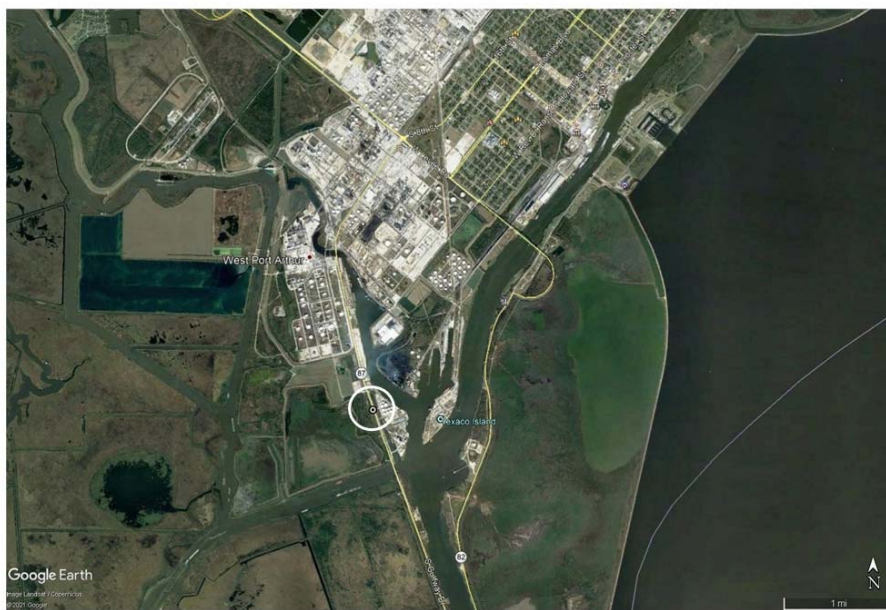


Figure 9. 1-Butene Detection Location, Beaumont/Port Arthur Areas, TX, Flight 20, 10 March 2021

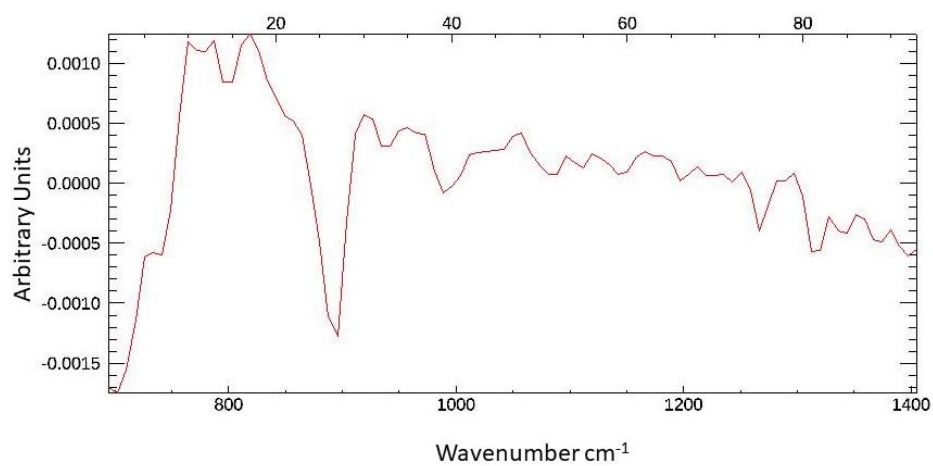


Figure 10. 1-Butene Spectrum, Beaumont/Port Arthur Areas, Flight 20,  
10 March 2021

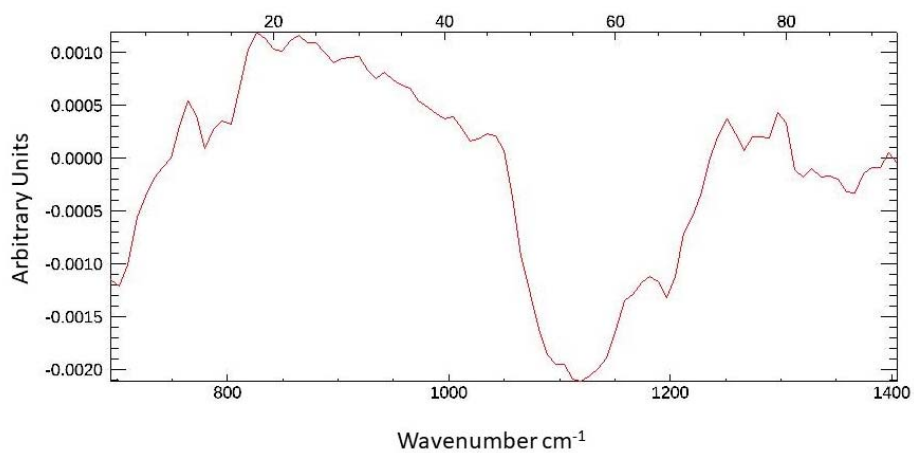


Figure 11. PAN Spectrum, Houston Area, Flight 21,  
10 March 2021

**Table 4. Chemical Results Summary  
Beaumont/Port Arthur Collection Area, Flight 20**

Pass	Date	Time (UTC)	Chemical	Max Concentration* (ppm)
1	2021-03-10	14:11:16	ND	ND
2		14:13:45	ND	ND
3		14:16:59	ND	ND
4		14:33:26	1-butene	1.238
5		14:43:09	ND	ND
6		14:52:28	ND	ND
7		15:00:38	ND	ND
8		15:12:37	ND	ND
9		15:23:39	ND	ND
10		15:41:51	ND	ND
11		15:54:35	ND	ND
12		16:05:57	ND	ND
13		16:17:41	ND	ND
ND = No Detection				

**Table 5. Chemical Results Summary  
Houston Area, Flight 21**

Pass	Date	Time (UTC)	Chemical	Max Concentration* (ppm)
1	2021-03-10	18:41:13	ND	ND
2		18:44:42	ND	ND
3		19:01:07	ND	ND
4		19:14:11	ND	ND
5		19:37:10	ND	ND
6		19:58:24	ND	ND
7		20:18:27	ND	ND
8		20:34:12	ND	ND
9		20:46:39	ND	ND
10		21:08:31	ND	ND
11		21:19:05	ND	ND
ND = No Detections				

*\* The ASPECT FTIR is a standoff detector – measurements are taken >1,000 ft above the ground, and assumptions are made about the path length of the plume to calculate a concentration estimate. For this reason, these measurements should not be considered equivalent to volumetric measurement, but instead serve as a reasonable estimate of the concentration within the plume. They are not necessarily representative of concentrations at the ground level. Any measurements that appear out of the norm should be confirmed with ground measurements.*

### Aerial Photography Results

A full set of high-resolution aerial digital photography were collected as part of each data collection pass. Weather conditions over the Beaumont/Port Arthur areas allowed acceptable quality aerial images to be collected. Figure 12 shows a representative frame of a facility imaged during that air monitoring survey with a visible steam vent in the middle of the frame. Figure 13 shows an oblique image collected during the flight over Houston showing evidence that the plant is in operation.



Figure 12. MSIC Aerial Image, Port Arthur Area, Flight 20





Figure 13. Oblique Image, Houston area, Flight 21

## Conclusion

Only one compound was detected on the mission (Flight 20) over the Beaumont/Port Arthur areas and consisted of 1-butene (1.238 ppm). Flight conditions for an afternoon mission over the Houston area were marginal and forced the system to be operated at about 1200 ft AGL. No programmed compounds were detected but common air pollution compounds were observed in the FTIR system.

**Appendix A: File Names of Data Collected During Flight**  
**Beaumont/Port Arthur Collection Areas, Flight 20, 10 March 2021**

Run#	Time (UTC)	Altitude (MSL)	Velocity (knots)	MSIC Data Files	FTIR Data Files	IRLS Data Files	Gamma Files
1	14:11:16	2882	141	20210310141122475.jpg 20210310141127015.jpg 20210310141131555.jpg	20210310_141120_A.igm	2021_03_10_14_11_21_R_01 TA=11.4;TB=32.1;Gain=3	
2	14:13:45	2851	139	20210310141352290.jpg 20210310141358640.jpg 20210310141405005.jpg	20210310_141349_A.igm	2021_03_10_14_13_50_R_02 TA=11.3;TB=32.0;Gain=3	
3	14:16:59	2889	142	20210310141705678.jpg 20210310141712043.jpg 20210310141718393.jpg	20210310_141703_A.igm	2021_03_10_14_17_04_R_03 TA=12.5;TB=33.1;Gain=3	
4	14:33:26	2880	110	20210310143332613.jpg 20210310143338978.jpg 20210310143345327.jpg	20210310_143330_A.igm	2021_03_10_14_33_30_R_04 TA=13.5;TB=33.6;Gain=3	
5	14:43:09	2831	110	20210310144315514.jpg 20210310144321863.jpg 20210310144328228.jpg	20210310_144313_A.igm	2021_03_10_14_43_14_R_05 TA=8.6;TB=28.8;Gain=3	
6	14:52:28	2958	105	20210310145234793.jpg 20210310145241158.jpg 20210310145247507.jpg 20210310145253856.jpg	20210310_145232_A.igm	2021_03_10_14_52_34_R_06 TA=8.5;TB=28.6;Gain=3	
7	15:00:38	2949	104	20210310150044179.jpg 20210310150050529.jpg 20210310150056878.jpg 20210310150103243.jpg	20210310_150042_A.igm	2021_03_10_15_00_43_R_07 TA=17.6;TB=37.6;Gain=3	
8	15:12:37	2754	103	20210310151243254.jpg 20210310151249603.jpg 20210310151255968.jpg 20210310151303222.jpg	20210310_151241_A.igm	2021_03_10_15_12_42_R_08 TA=17.2;TB=37.1;Gain=3	
9	15:23:39	2797	105	20210310152345134.jpg 20210310152352388.jpg 20210310152358753.jpg	20210310_152343_A.igm	2021_03_10_15_23_44_R_09 TA=17.4;TB=36.9;Gain=3	
10	15:41:51	2811	105	20210310154157362.jpg 20210310154203727.jpg 20210310154210076.jpg 20210310154216425.jpg 20210310154222790.jpg	20210310_154154_A.igm	2021_03_10_15_41_56_R_10 TA=15.5;TB=35.7;Gain=3	
11	15:54:35	2811	103	20210310155441827.jpg 20210310155448192.jpg 20210310155454541.jpg 20210310155500906.jpg	20210310_155439_A.igm	2021_03_10_15_54_40_R_11 TA=17.4;TB=37.4;Gain=3	
12	16:05:57	2820	105	20210310160603681.jpg 20210310160610031.jpg 20210310160616396.jpg 20210310160622745.jpg	20210310_160600_A.igm	2021_03_10_16_06_02_R_12 TA=16.9;TB=37.0;Gain=3	
13	16:17:41	2793	104	20210310161747316.jpg 20210310161753665.jpg 20210310161800030.jpg 20210310161806379.jpg	20210310_161744_A.igm	2021_03_10_16_17_46_R_13 TA=18.4;TB=38.5;Gain=3	

**Houston Area, Flight 21, 10 March 2021**

Run#	Time (UTC)	Altitude (MSL)	Velocity (knots)	MSIC Data Files	FTIR Data Files	IRLS Data Files	Gamma Files
1	18:41:13	1522	140	20210310184118952.jpg 20210310184122586.jpg 20210310184126221.jpg 20210310184128951.jpg	20210310_184116_A.igm	2021_03_10_18_41_17_R_01 TA=21.8;TB=42.7;Gain=3	
2	18:44:42	1562	112	20210310184448667.jpg 20210310184452302.jpg 20210310184455937.jpg 20210310184459571.jpg	20210310_184446_A.igm	2021_03_10_18_44_46_R_02 TA=20.6;TB=41.0;Gain=3	



3	19:01:07	1519	104	20210310190113703.jpg 20210310190116432.jpg 20210310190120067.jpg 20210310190123702.jpg 20210310190127321.jpg 20210310190130051.jpg 20210310190133685.jpg 20210310190137320.jpg 20210310190140939.jpg	20210310_190111_A.igm	2021_03_10_19_01_11_R_03 TA=20.4;TB=40.6;Gain=3	
4	19:14:11	1529	109	20210310191418106.jpg 20210310191421740.jpg 20210310191424470.jpg 20210310191428089.jpg 20210310191431724.jpg 20210310191435359.jpg 20210310191438994.jpg 20210310191441708.jpg 20210310191445343.jpg 20210310191448977.jpg 20210310191452612.jpg	20210310_191415_A.igm	2021_03_10_19_14_16_R_04 TA=20.0;TB=40.2;Gain=3	
5	19:37:10	1612	106	20210310193716264.jpg 20210310193719898.jpg 20210310193722628.jpg 20210310193726263.jpg 20210310193729882.jpg 20210310193733517.jpg 20210310193736247.jpg 20210310193739881.jpg	20210310_193713_A.igm	2021_03_10_19_37_14_R_05 TA=20.9;TB=40.7;Gain=3	
6	19:58:24	1567	110	20210310195830945.jpg 20210310195834580.jpg 20210310195838199.jpg 20210310195840929.jpg 20210310195844564.jpg 20210310195848198.jpg	20210310_195827_A.igm	2021_03_10_19_58_29_R_06 TA=22.6;TB=42.6;Gain=3	
7	20:18:27	1363	109	20210310201832997.jpg 20210310201836631.jpg 20210310201840251.jpg 20210310201842981.jpg 20210310201846615.jpg 20210310201850250.jpg 20210310201853869.jpg 20210310201856599.jpg 20210310201900234.jpg	20210310_201830_A.igm	2021_03_10_20_18_31_R_07 TA=19.4;TB=39.6;Gain=3	
8	20:34:12	1410	113	20210310203418117.jpg 20210310203421751.jpg 20210310203424466.jpg 20210310203428101.jpg 20210310203431735.jpg 20210310203435370.jpg 20210310203438084.jpg 20210310203441719.jpg	20210310_203415_A.igm	2021_03_10_20_34_16_R_08 TA=18.0;TB=37.9;Gain=3	
9	20:46:39	1361	112	20210310204645321.jpg 20210310204648035.jpg 20210310204651670.jpg 20210310204655305.jpg 20210310204658939.jpg	20210310_204642_A.igm	2021_03_10_20_46_43_R_09 TA=20.0;TB=40.0;Gain=3	
10	21:08:31	1379	112	20210310210837225.jpg 20210310210840860.jpg 20210310210844495.jpg 20210310210847225.jpg 20210310210850844.jpg 20210310210854479.jpg	20210310_210835_A.igm	2021_03_10_21_08_35_R_10 TA=22.3;TB=42.4;Gain=3	
11	21:19:05	1362	108	20210310211911865.jpg 20210310211915484.jpg 20210310211918214.jpg 20210310211921849.jpg 20210310211925483.jpg 20210310211929103.jpg	20210310_211909_A.igm	2021_03_10_21_19_10_R_11 TA=18.6;TB=38.8;Gain=3	



## Appendix B: ASPECT Systems

The US EPA ASPECT system collects airborne infrared (IR) images and chemical screening data from a safe distance over the site (about 3,000 ft AGL). The system consists of an airborne high-speed Fourier Transform Infra-Red (FTIR) spectrometer coupled with a wide-area IR Line Scanner (IRLS). The ASPECT IR systems can detect chemical compounds in both the 8 to 12 micron (800 to 1200  $\text{cm}^{-1}$ ) and 3 to 5 micron (2000 to 3200  $\text{cm}^{-1}$ ) regions. List of chemicals and detection limits are listed in Table 1. 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.

An Imperx mapping camera (29 mega pixels; mapping focal plane array) is concurrently operated as part of all chemical collections. These images are often digitally processed in lower resolution, so they can be transmitted via satellite communication. All imagery is geo-rectified using both aircraft attitude correction (pitch, yaw, and roll) and GPS positional information. Imagery can be processed while in flight or approximately 600 frames per hour can be processed once the data are downloaded from the aircraft. The high-resolution images (>20 MB each) are pulled from the ASPECT after the sortie and are available at a later time.

All aerial photographic images collected by the ASPECT system are ortho-rectified and geospatially validated by the scientific reach back team. In general, this consists of conducting geo-registration using a USGS Digital Elevation Model (DEM) which promotes superior pixel computation and lessens topographic distortion. The image is checked by the team (using a Google Earth base map) for proper location and rotation.

Airborne radiological measurements are conducted using three fully integrated multi-crystal sodium iodide (NaI) RSX4 gamma ray spectrometers. Each RSX4 spectrometer contains four 4"x2"x16" doped NaI crystals each having an independent photomultiplier/spectrometer assembly. One RSX unit is configured with an additional upward NaI crystal utilized to provide real-time cosmic ray correction. Count and energy data from each crystal and pack is combined using a self-calibrating signal processor to generate a virtual detector output. All radiological spectrometer "packs" are further combined using a signal console controlled by the on-board central computer in the aircraft. Altitude correction data is provided by a radar altimeter with internal GPS systems within the packs serving as a backup. It should be noted that no radiological measurements were conducted on this mission.

Data is processed using automated algorithms onboard the aircraft with preliminary results being sent using a satellite system to the ASPECT scientific reach back team for QA/QC analysis. Upon landing, preliminary data results are examined and validated by the

scientific reach back team.

Table 1. ASPECT Automated Compounds

This table contains ASPECT's library of automated compounds.

Detection limits are for each chemical is found in parenthesis in units of parts per million (ppm)

Acetic Acid (2.0)	Cumene (23.1)	Isoprene (6.5)	Phosphine (8.3)
Acetone (5.6)	Diborane (5.0)	Isopropanol (8.5)	Phosphorus Oxychloride (2.0)
Acrolein (8.8)	1,1-Dichloroethene (3.7)	Isopropyl Acetate (0.7)	Propyl Acetate (0.7)
Acrylonitrile (12.5)	Dichloromethane (6.0)	MAPP (3.7)	Propylene (3.7)
Acrylic Acid (3.3)	Dichlorodifluoromethane (0.7)	Methyl Acetate (1.0)	Propylene Oxide (6.8)
Allyl Alcohol (5.3)	1,1-Difluoroethane (0.8)	Methyl Acrylate (1.0)	Silicon Tetrafluoride (0.2)
Ammonia (2.0)	Difluoromethane (0.8)	Methyl Ethyl Ketone (7.5)	Sulfur Dioxide (15)
Arsine (18.7)	Ethanol (6.3)	Methanol (5.4)	Sulfur Hexafluoride (0.07)
Bis-Chloroethyl Ether (1.7)	Ethyl Acetate (0.8)	Methylbromide (60)	Sulfur Mustard (6.0)
Boron Tribromide (0.2)	Ethyl Acrylate (0.8)	Methylene Chloride (1.1)	Sulfuryl Fluoride (1.5)
Boron Trifluoride (5.6)	Ethyl Formate (1.0)	Methyl Methacrylate (3.0)	Tetrachloroethylene (10)
1,3-Butadiene (5.0)	Ethylene (5.0)	MTEB (3.8)	1,1,1-Trichloroethane (1.9)
1-Butene (12.0)	Formic Acid (5.0)	Naphthalene (3.8)	Trichloroethylene (2.7)
2-Butene (18.8)	Freon 134a (0.8)	n-Butyl Acetate (3.8)	Trichloromethane (0.7)
Carbon Tetrachloride (0.2)	GA (Tabun) (0.7)	n-Butyl Alcohol (7.9)	Triethylamine (6.2)
Carbonyl Fluoride (0.8)	GB (Sarin) (0.5)	Nitric Acid (5.0)	Triethylphosphate (0.3)
Carbon Tetrafluoride (0.1)	Germane (1.5)	Nitrogen Mustard (2.5)	Trimethylamine (9.3)
Chlorodifluoromethane (0.6)	Hexafluoroacetone (0.4)	Nitrogen Trifluoride (0.7)	Trimethyl Phosphite (0.4)
Chloromethane (12)	Isobutylene (15)	Phosgene (0.5)	Vinyl Acetate (0.6)