Initial Investigative Facts in the West Fertilizer Explosion

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Abstract

On April 17, 2013, an explosion occurred at the West Fertilizer Company storage and distribution facility in West, Texas. The explosion at West Fertilizer resulted from an intense fire in the seed and storage area of the facility that led to the detonation of approximately 20-30 tons of ammonium nitrate stored inside a wooden receiving bin. The explosion occurred while emergency services personnel were responding to a fire at the facility and at least fifteen people were killed, more than 200 were injured, and numerous buildings were damaged or destroyed. The cause of the initial fire is still ongoing. This paper presents the initial evidence of our investigation into the cause and origin of the explosion event. In addition, the paper will also outline the current local, state and federal regulations regarding the storage and use of reactive chemicals such as ammonium nitrate.

Introduction

The West Fertilizer Company was owned by Adair Grain Inc. and located in West Texas. The Feed and Fertilizer building was built in 1958 and supplied (not produced) fertilizer and seed to farmers up until the date of the incident. In general, the company stored liquid fertilizers (including anhydrous ammonia) in tanks, seed in silos, and solid fertilizer and seed in the Seed and Fertilizer building, which can be seen at the site in **Figure 1** and **Figure 2**. **Figure 3** shows the layout of the Seed and Fertilizer building, which included ammonium nitrate in a storage bin fed by an elevator leg from rail shipments and transport trucks, an empty bin used for ammonium nitrate storage, a bin with ammonium nitrate, a bin for K-Mag (fertilizer mix of potassium, magnesium and sulfur), a bin for Potash, a bin for ammonium sulfate, a bin for DAP (diammonium phosphate), and a bin for potassium chloride.

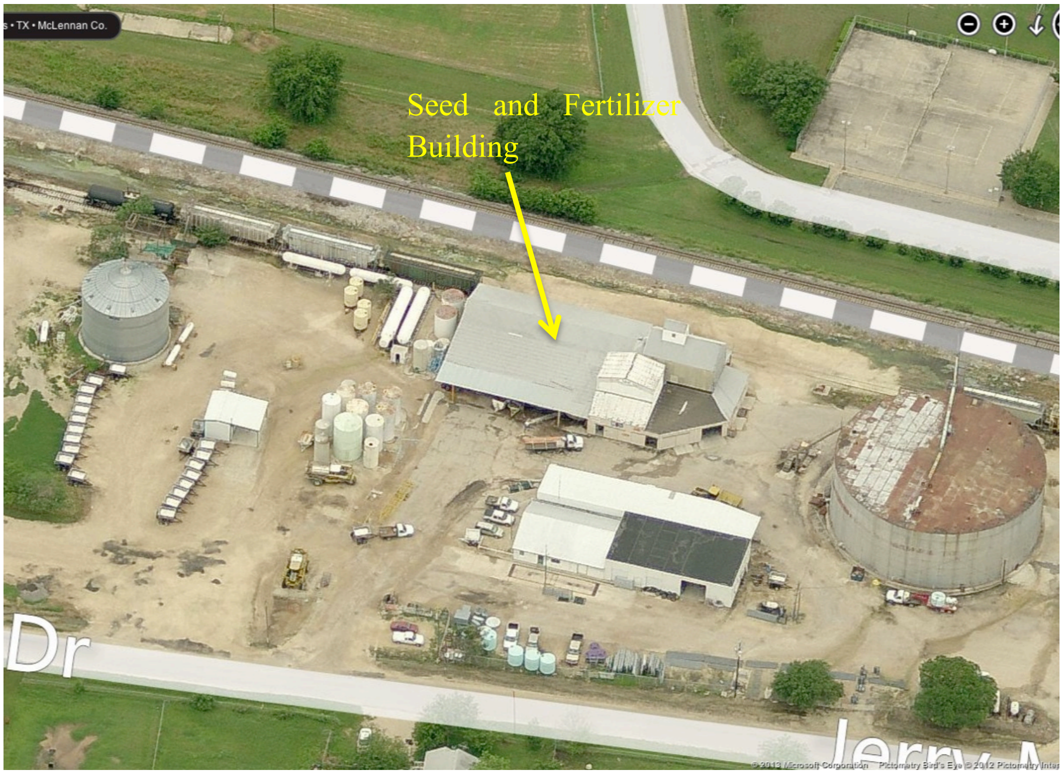

Figure 1: West Fertilizer Facility – viewed from the east

Figure 2: West Fertilizer Facility – viewed from the south

Figure 3: Layout and storage of the Seed and Fertilizer Building

On April 17, 2013, at approximately 7:30 pm, a fire was reported and fire fighters responded to the fertilizer plant. All operations were stopped and employees left the plant at about 5:30-6:00 pm. The temperature at the time of the incident was between 78-80°F, and the wind was coming from the SSE at approximately 19 mph (see **Figure 4**). GexCon obtained several videos that recorded the progression of the initial fire. The videos indicate that fire was localized on the northern section of the Feed and Fertilizer building. **Figure 5** to **Figure 7** show the initial fire as viewed from the east, while **Figure 8** and **Figure 9** is the fire as viewed from the west. The images clearly show that the fire is isolated to the northern section of the building, which includes the seed room and ultimately to the storage bin containing the 20-30 tons of ammonium nitrate that is fed from the elevator leg.

At approximately 7:50 pm, a massive explosion occurred at the fertilizer plant. **Figure 10** and **Figure 11** show the images from a video taken from the high school parking lot to the southeast, while **Figure 12** and **Figure 13** show the explosion as viewed from the middle school parking lot to the southwest.

Figure 4: Wind coming from the south-south east (SSE) at 19 mph

Figure 5: Close up of the Seed and Fertilizer Building (viewed from east)

Figure 6: Close up of the Seed and Fertilizer Building (viewed from east, ground level)

Figure 7: Close up of the Seed and Fertilizer Building during fire (viewed from east)

Figure 8: View of the next photo as viewed from the west

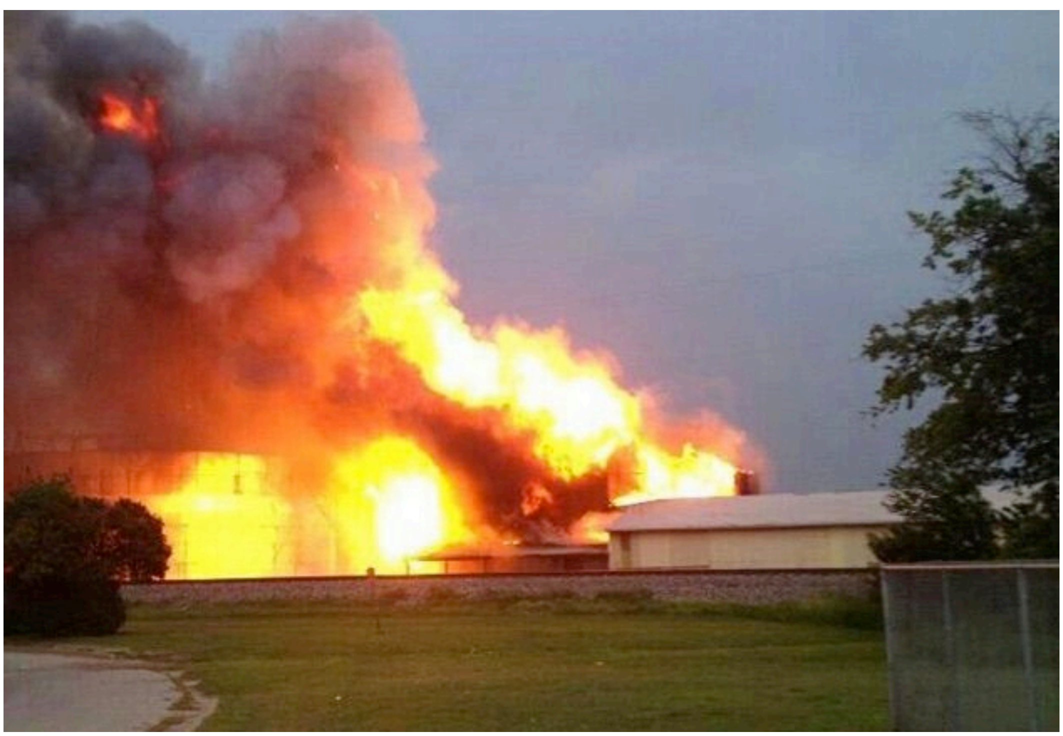

Figure 9: Close up of the Seed and Fertilizer Building during fire (viewed from west)

Figure 10: View of the next photo as viewed from the southeast

Figure 11: View of the explosion (viewed from southeast)

Figure 12: View of the next photo as viewed from the southwest

Figure 13: View of the explosion (viewed from southwest)

Fifteen people were killed as a result of the explosion, which included voluntary firefighters, and over 160 people were injured. Damage was extensive throughout the neighboring community, which included homes, schools, apartment building and a nursing home.

As the investigation into this incident is ongoing, GexCon will only provide initial facts as related to the cause and origin of the explosion. In addition, the results presented here are only preliminary and changes may occur due to new information that becomes available during the investigation

2. Investigative Evidence

Explosion damage

The blast at the fertilizer plant was massive. It completely destroyed the Seed and Fertilizer and office buildings, the neighboring silos, it knocked over a rail car with 100 tons of AN, it deformed the rail road as the blast propagated towards the neighborhood (see **Figure 14** and **Figure 15**). The blast caused a crater approximately 90 feet wide and 10 feet deep, directly under the storage bin containing the 20-30 tons of ammonium nitrate that is fed from the elevator leg as shown in **Figure 16** and **Figure 17**. The storage bin was constructed on a concrete slab.

Figure 14: Blast damage as viewed from the southeast

Figure 15: Blast damage as viewed from the west

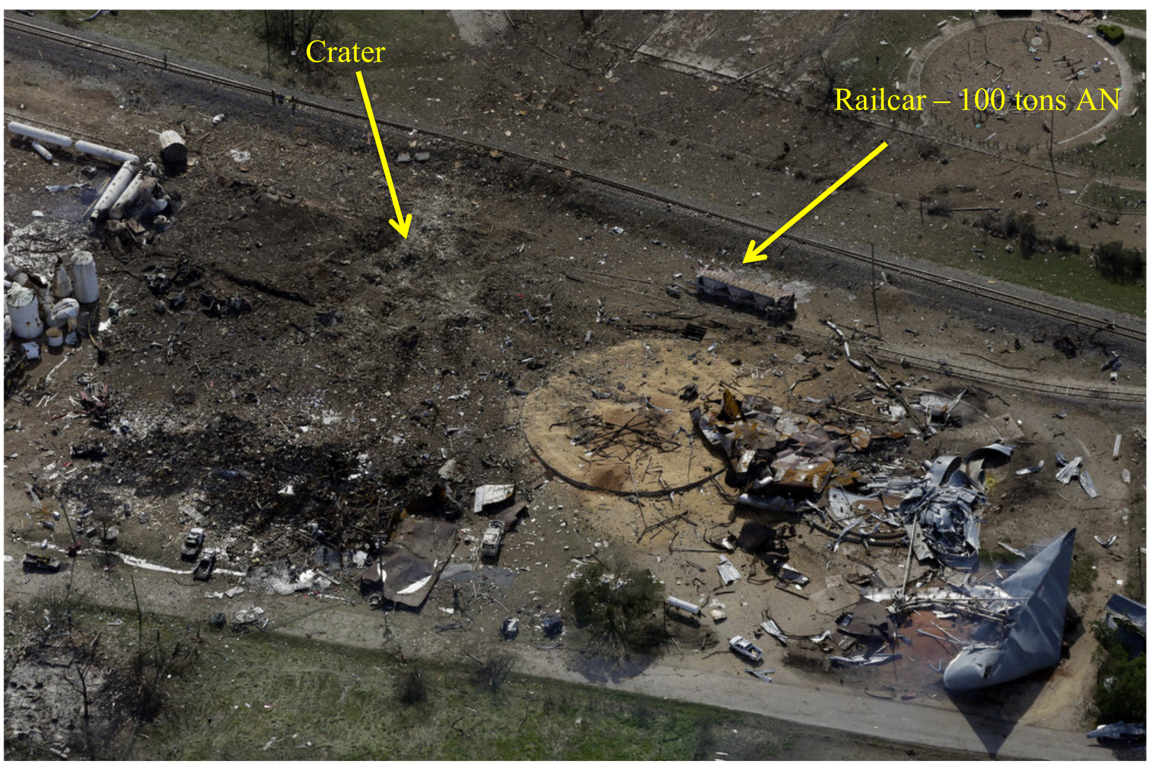

Figure 16: Blast damage as viewed from the northeast

Figure 17: Approximate crater dimensions as viewed from the west

The blast was so powerful that it caused significant damage to the town, which included multiple houses, schools, a nursing home and an apartment complex. **Figure 18** shows the damage to the apartment complex that was directly west of the facility, just over the train tracks. In addition, the explosion was so powerful that windows were broken in houses over a half-mile (~ 1 km) away from the explosion.

Figure 18: Blast damage to the basketball court and apartment complex west of the plant

Figure 19: Half-mile radius from the epicenter of the explosion

Figure 20: House with windows broken approximately 1 km from the incident

Fuel involved

Significant quantities of ammonium nitrate were present at the fertilizer plant. While the rail car contained 100 tons of ammonium nitrate and was significantly impacted by the blast (see **Figure 21**), the material did not ignite let alone combust or explode as a result of the blast.

Figure 21: Damaged rail car and silo after the blast

The crater of the explosion was centered on the loading and storage bin that is fed by the elevator from the rail cars (see **Figure 22**). All of the bins on the south wall of the building were like stalls and open so that a front loader could come and take the required quantities of the individual fertilizers. While not exact, **Figure 23** shows an example of a similar type layout. The loading and storage bin however was equipped with a solid door, and it is unclear if it was open or closed at the time of the incident. It was reported that there was 20-30 tons of the ammonium nitrate within the loading and storage bin, and the evidence suggests that it detonated during the explosion. There were numerous open bins of fertilizer material in the Seed and Fertilizer building (including an additional 20-30 tons of ammonium nitrate); however, the evidence suggests that none of the material in the open bins burned, let alone participated in the explosion.

Figure 22: Layout of the Seed and Fertilizer building with quantity of AN

Figure 23: Example of an "open" wooden bulk fertilizer bin

3. Preliminary blast modeling

As the investigation is ongoing, much of the information regarding GexCon's analysis cannot be presented. However, one area that GexCon is pursuing is to use FLACS to understand the energy of the blast and the damage that it caused to the surrounding area. FLACS is a leading CFD tool for the simulation of gas dispersion and vapor cloud explosion scenarios, and is extensively used for safety studies in the petrochemical industry. FLACS is capable of modeling gas and aerosol releases, dispersion of vapors, ventilation in structures, and ignition of flammable fuel-air mixtures to evaluate the flame front progression and the overpressures due to explosions. Sensor points and panels on structures can be placed within the computational domain to track the time history of relevant variables such as static or dynamic pressure, velocities, etc. FLACS also has a module, FLACS-Blast that is used to simulate the propagation of blast waves from the detonation of high explosives.

This section will briefly describe the FLACS-blast module, show the geometry module built for FLACS of the plant and surrounding neighborhood, and some preliminary simulation results.

3.1 FLACS-Blast

FLACS-Blast is a module of FLACS that simulates the propagation of blast waves from detonation of high explosives (Nolde and Skjold, 2010). The code does not model the actual detonation process, but solves the Euler equations with a conservative shock-capturing scheme, the so-called flux-corrected transport (FCT) scheme (Boris and Book, 1973). The FLACS-Blast solver uses the SOLA-ICE algorithm with 2nd order flux correction, instead of the SIMPLE algorithm used by the standard FLACS solver. Also, sub-grid contributions such as turbulence, drag, etc. are not included; therefore, the porosity filed is binarized (grid cells with less than 50% porosity are assumed to be fully blocked, the rest are fully open). The energy release from a specified amount of explosive material is transformed to a high-pressure and high-temperature region. FLACS-Blast treats the explosive like a bursting "balloon", which starts with the initial condition of a sphere of high temperature and pressure gases at zero velocity. This balloon analogue method has been described previously (Brode, 1959, Ritzel and Matthews, 1997, and Donahue, et al., 2004). The gases are treated as ideal, with a **g** (ratio of specific heats) equal to 1.4, which corresponds with air (or any other diatomic gas). The base state is estimated based on heat of reaction and temperature of products of combustion (for TNT detonations), which is then isentropically compressed to pressure of 808 bar (consistent with the TNT blast curve).

The equation of state is the ideal gas law. Standard TNT blast curves have been used to establish the empirical scaling relation for the source volume, which is proportional to the mass of explosive material. Since there is no case-specific calibration involved, it is possible to perform reasonably accurate predictions within the inherent limitation of the achievable grid resolution. FLACS-Blast has been demonstrated to match established data for TNT curves (see **Figure 24**). Since FLACS-Blast does not actually model the detonation process, but rather imposes an initial condition of high temperature and pressure gases, the timing of pressure traces with respect to experiments is likely to be advanced. That is to say that simulation peak pressures will likely be earlier than experimental results.

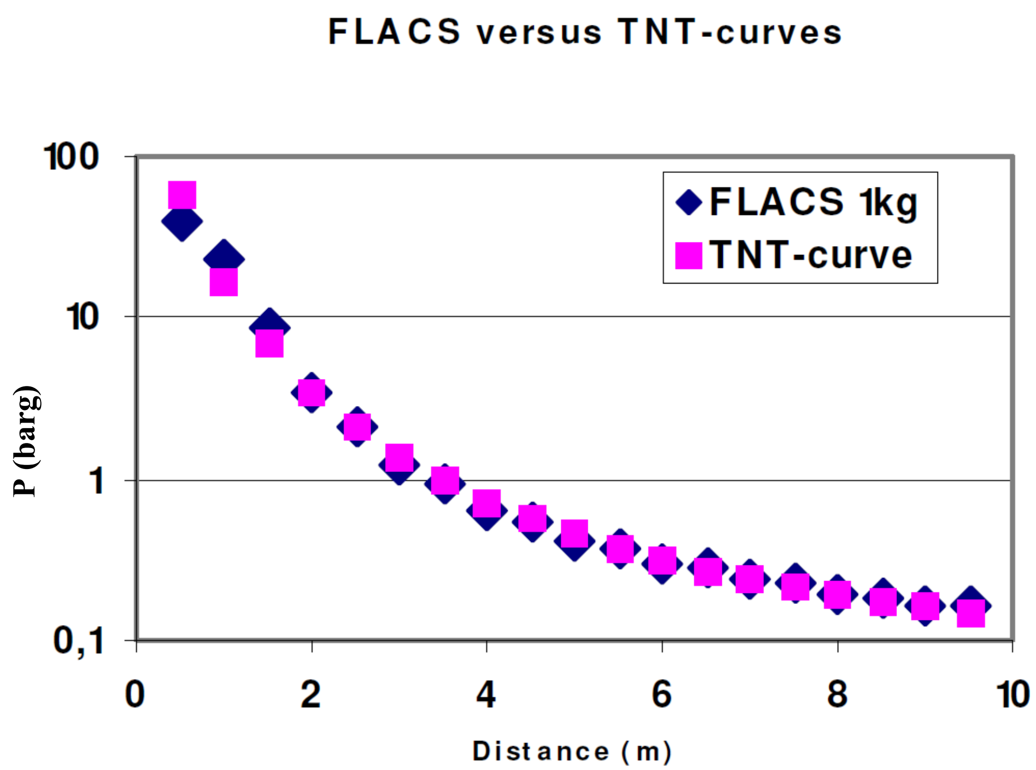

Figure 24: ***Comparison of maximum pressure from FLACS-Blast simulation of a 1 kg TNT explosion and a TNT curve from Lee's Loss Prevention in the Process Industries.***

3.2 FLACS geometry model of fertilizer and neighborhood

Using topographical data obtained from aerial flyovers and photographs taken of the site (e.g., Google or Bing), GexCon constructed a 3D model of the plant and surrounding neighborhood. The model included the plant, almost the entire town of West Texas and neighboring areas. **Figure 25** shows an overview of the 3D model constructed for FLACS simulations and **Figure 26** shows a close up of the Seed and Fertilizer building. The topography details from the aerial flyover can be seen in **Figure 27**, which include details of the crater caused by the blast. **Figure 28** compares photographs and model images for the area around the fertilizer building.

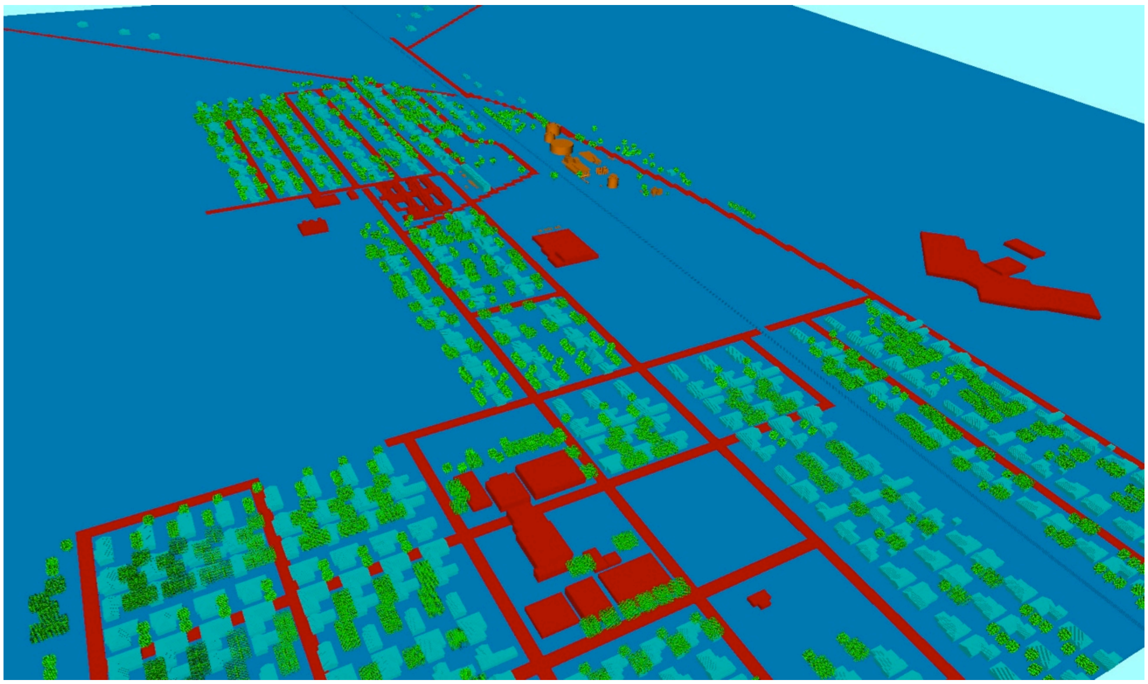

Figure 25: Overview of 3D model used in FLACS simulations

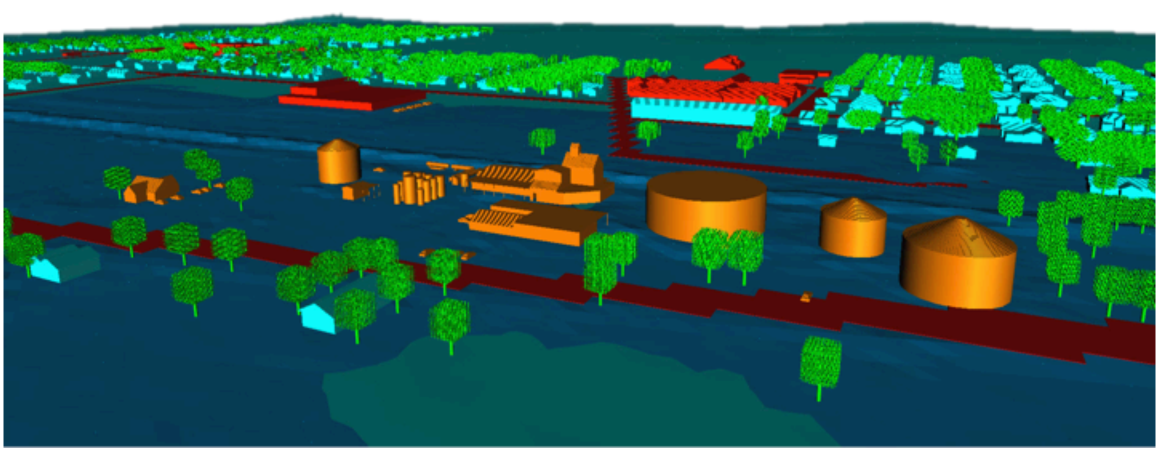

Figure 26: View of the model of the fertilizer plant as viewed from the east

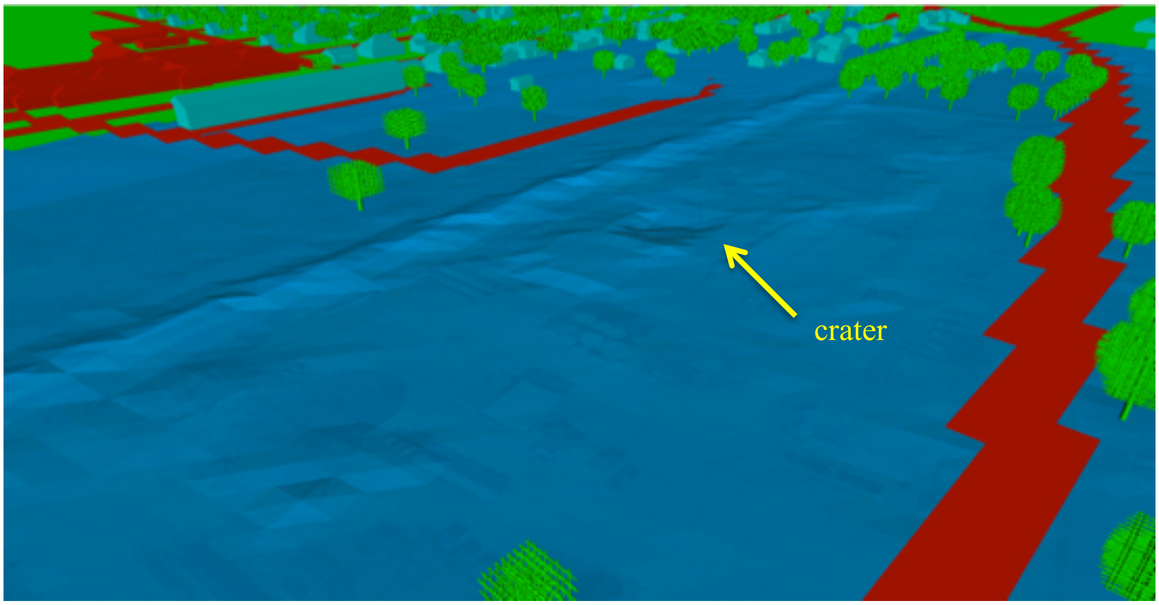

Figure 27: Topography details in the 3D model, which include the crater

Figure 28: Comparison of the Seed and Fertilizer building (photo - left, model - right)

3.3 FLACS – Preliminary simulations

By using FLACS-Blast, GexCon is currently evaluating the strength of the blast based on a given mass of detonating ammonium nitrate, and comparing results with the observed damage. This would include the damage to the plant equipment (including the silos), the overpressure damage to the apartment complex, nursing home and the various homes in West Texas. While not the exact replication of the AN blast, **Figure 29** shows an example of the resulting blast waves in 3D from the FLACS-Blast simulations of detonating ammonium nitrate; **Figure 30** shows similar pressure waves in 2D; **Figure 31** shows a blast wave hitting the apartment complex shown in **Figure 18**: the upper overpressure limit is set at 0.4 barg (~6 psig) that is the "completely destroyed building threshold" value; **Figure 32** shows a blast wave hitting the house shown in **Figure 20**: the lower overpressure limit is set at 0.01 barg (0.15 psig) that is the "typical broken window threshold" value; **Figure 33** shows the maximum distance reached by the blasting wave

1 second after the detonation of ammonium nitrate (the lower overpressure limit is set at 0.01 barg).

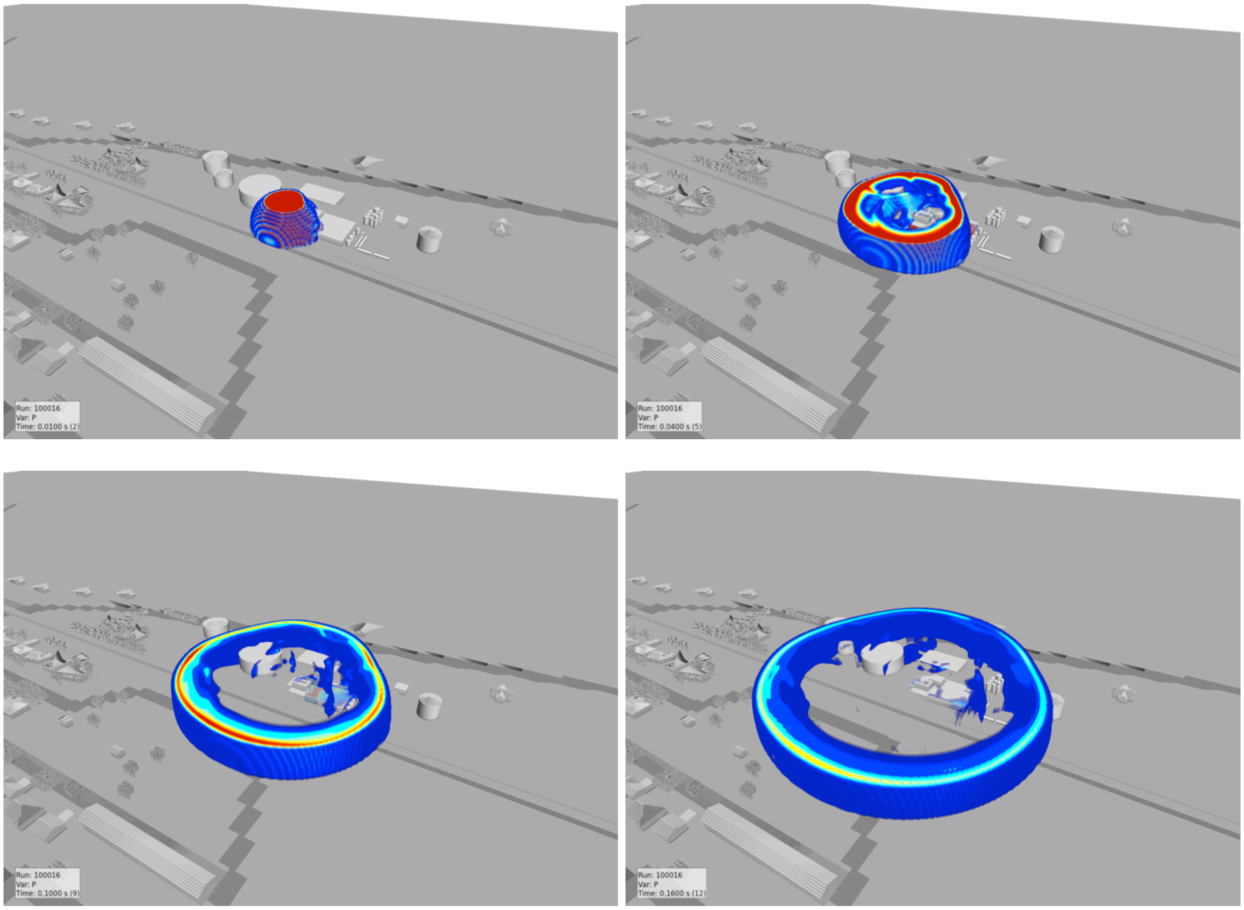

Figure 29: Simulations of a 3D blast wave propagating from detonating ammonium nitrate (red is pressures > 1.0 barg, and blue = 0.015 barg)

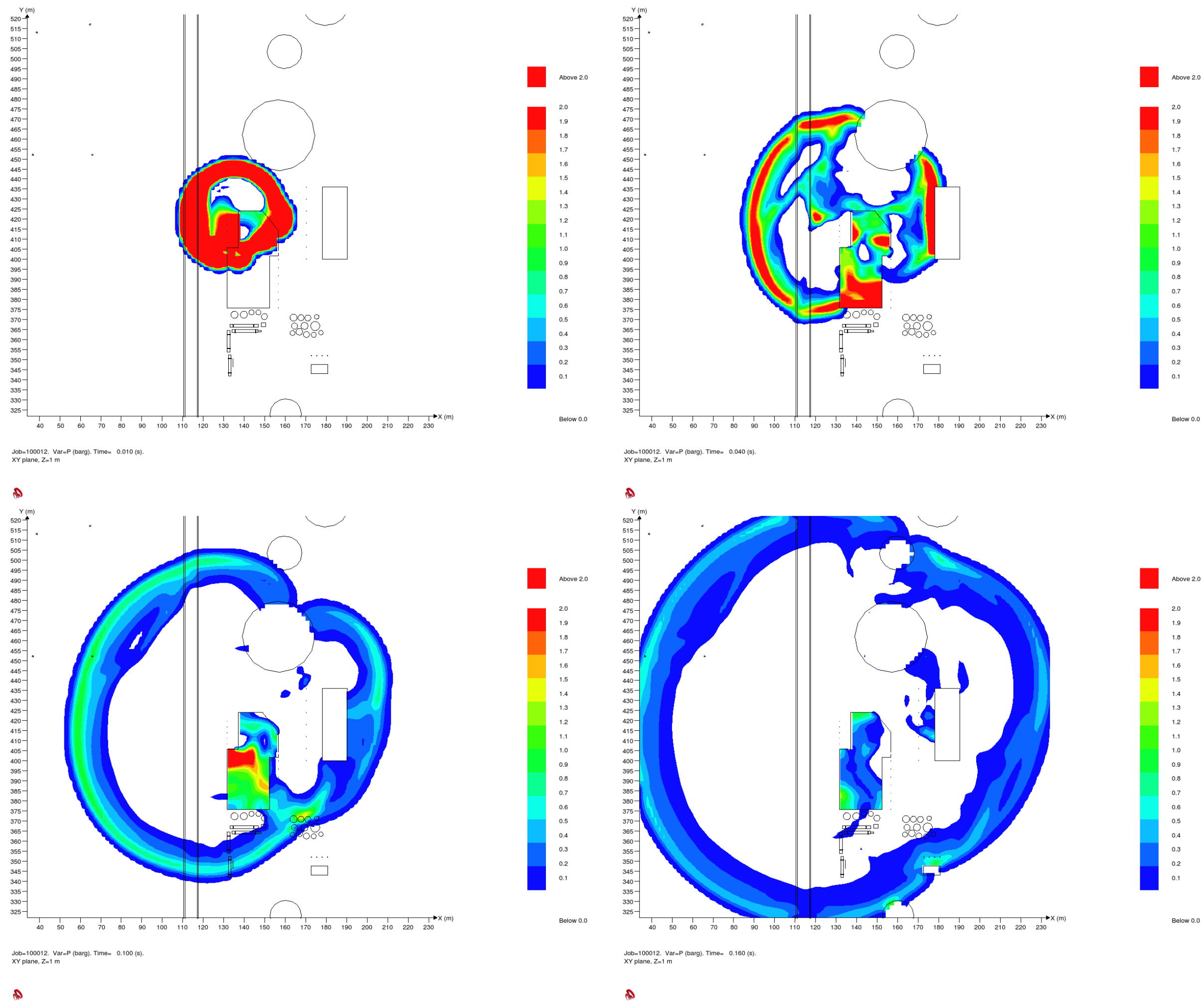

Figure 30: Simulations of a 2D blast wave propagating from detonating ammonium nitrate (red is pressures > 2.0 barg, and blue = 0.015 barg)

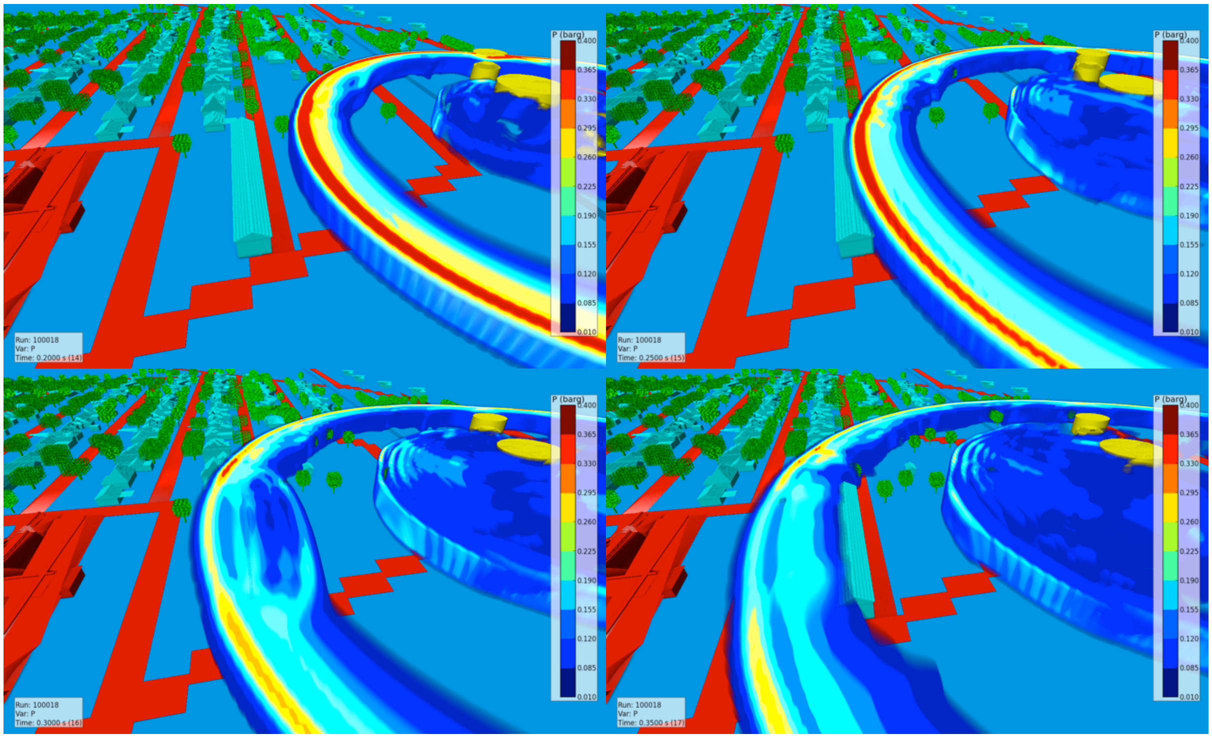

Figure 31: Simulations of a 3D blast wave propagating from detonating ammonium nitrate (red is pressures > 0.4 barg, and blue = 0.01 barg).

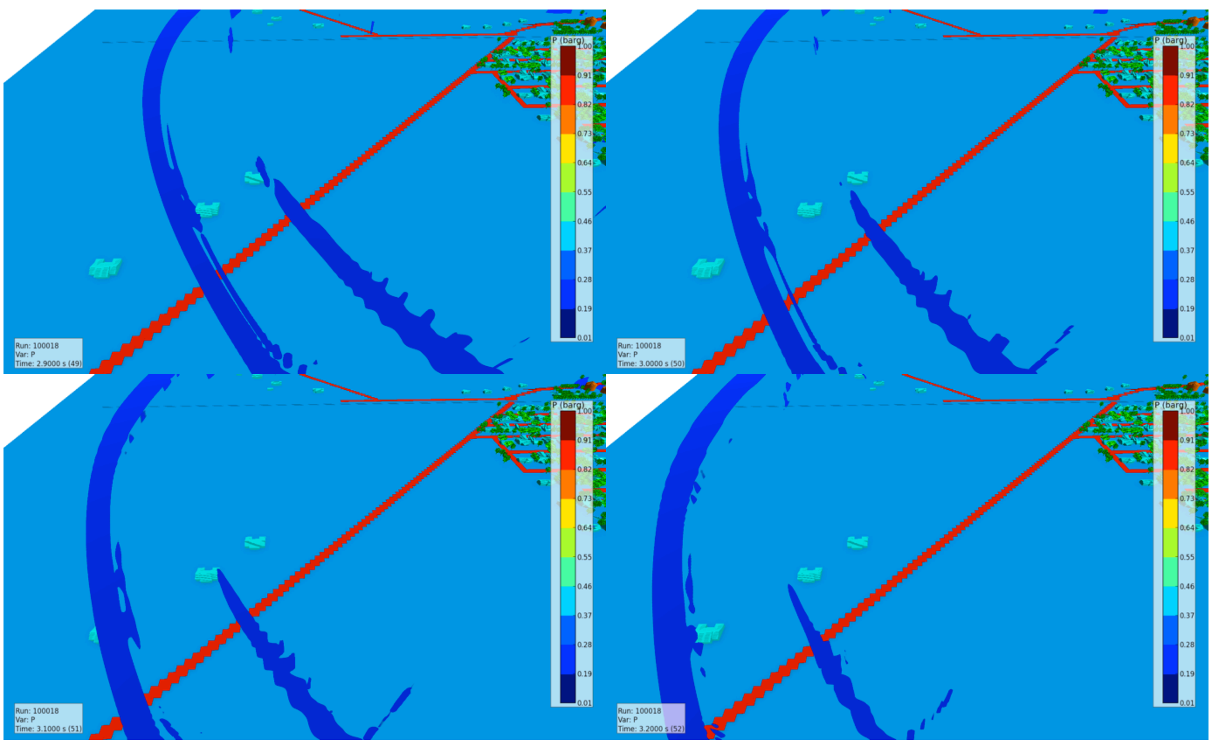

Figure 32: Simulations of a 3D blast wave propagating from detonating ammonium nitrate (red is pressures > 1 barg, and blue = 0.01 barg).

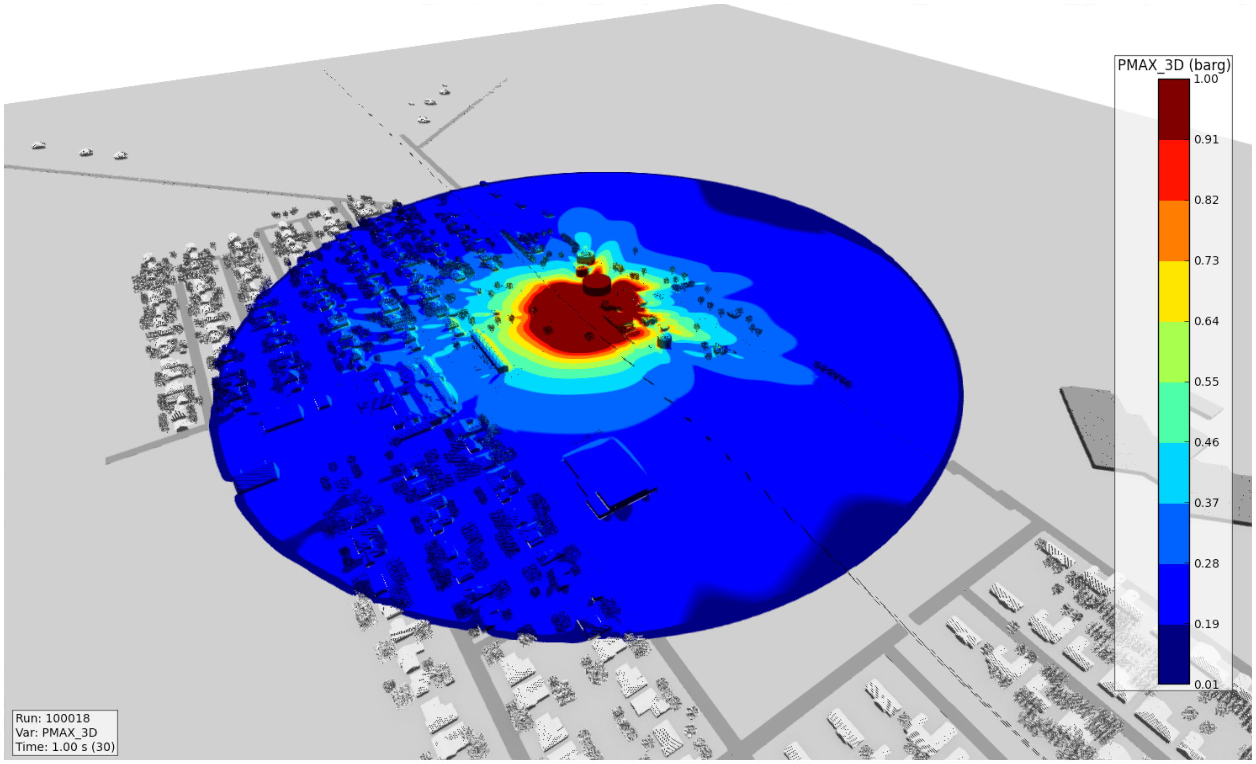

Figure 33: Simulations of a 2D blast wave propagated from detonating ammonium nitrate (red is pressures > 1 barg, and blue = 0.01 barg).

Using this and other analyses, GexCon will further corroborate the quantity of AN that participated in the devastating blast.

5. Summary

This paper summarizes the initial investigative facts into the massive explosion that occurred in West Texas on April 10, 2013. The investigation is ongoing and the results will be updated as the necessary work progresses. The work is focusing on the cause of the initial fire observed in the Seed and Fertilizer building, which includes: (1) intentionally set fire; (2) rechargeable golf cart; (3) other electrical causes; and (4) potential contamination.