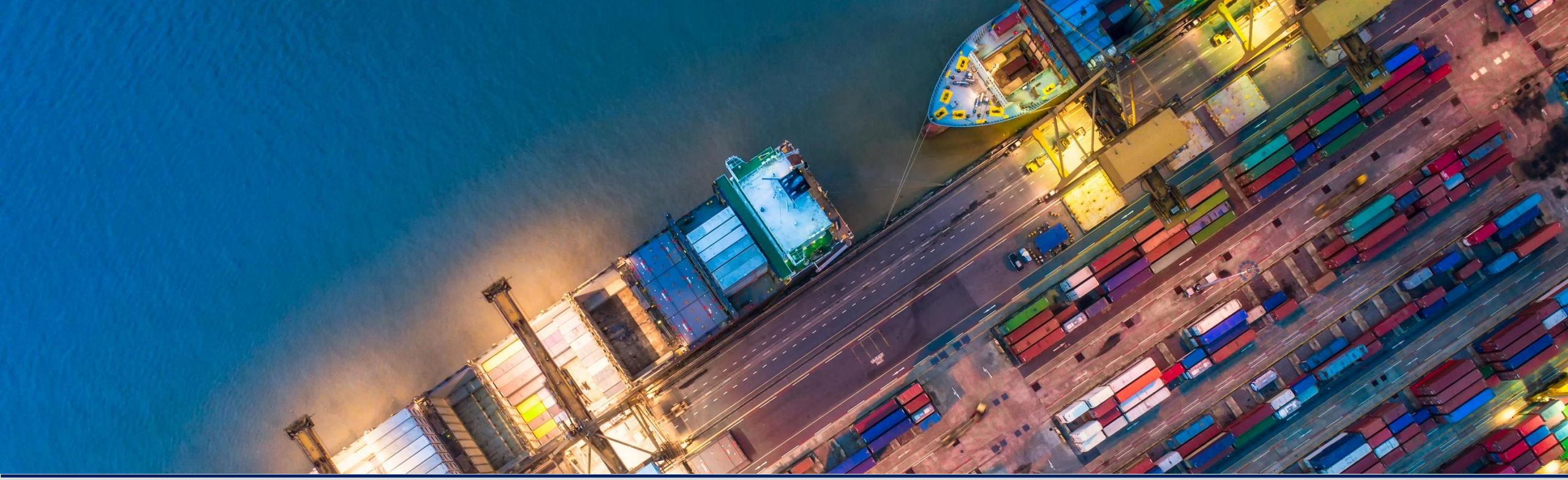


Port of Beirut Explosion – Analysis and Impacts

David Moore, PE, CSP
President & CEO
AcuTech Group, Inc.
www.acutech-consulting.com
Purdue Process Safety and Assurance Center (P2SAC)
11 May 2022

AcuTech
PROCESS RISK MANAGEMENT

Objectives of the Presentation

- The explosion of August 4, 2020, at the Port of Beirut was one of the largest industrial accidents in history.

- The impacts to an entire nation from a single industrial accident may be incomparable considering fatalities, injuries, and the economic impacts to GDP and public disruption to a major capital city and global nation.

- Lessons learned have widespread implications for facility siting and public risk management, handling of oxidizers, the management of chemicals in storage and transportation, and emergency management for large-scale emergencies

AcuTech
PROCESS RISK MANAGEMENT

The Incident

- On 4 August 2020, 2,750 tons of ammonium nitrate stored at the Port of Beirut (POB), Lebanon, exploded.
- Resulted in about 200 deaths, several thousand injuries, $10-15 billion USD in property damage, and leaving an estimated 300,000 people homeless, and a city and country in economic and political turmoil.
- Video of the Blast: https://twitter.com/i/status/1290694053550596102

AcuTech
PROCESS RISK MANAGEMENT

Explosion

- The explosion occurred on 4 August 2020, originating in Hanger 12.
- A fire in Hanger 12 was reported shortly before 18:00 local time, leading to an initial explosion at 18:07 local time, which most likely ignited some of the stored fireworks, and led to the ignition and detonation of the ammonium less than one minute later.
- The blast yield is estimated to be between 0.5 and 1.1 kilotons of TNT.

Photo: New York Times

AcuTech
PROCESS RISK MANAGEMENT

The Origin of the Hazard The Mission

- The cargo of ammonium nitrate had been stored in Hanger 12 at the POB, after having been confiscated by the Lebanese authorities from an abandoned ship, the MV Rhosus, in September, 2013

The MV Rhosus
Photo: Frank Behrends – http://www.shipspotting.com/gallery/photo.php?lid=3192824

AcuTech
PROCESS RISK MANAGEMENT

The Mission

- In response to this event, AcuTech participated in post-incident activities in close coordination with government and port authorities.

- AcuTech’s efforts focused on analyzing current roles and responsibilities concerning the management of dangerous goods at Lebanese ports, including the Port of Beirut and the Port of Tripoli, and Rafic Hariri Airport, and current practices within responsible agencies and partners that were potentially relevant to the incident and response.

- The team also reviewed physical port security and disaster management and recovery.

AcuTech
PROCESS RISK MANAGEMENT

The Port of Beirut

- Opened in 1887.
- One of the 10 busiest ports in the Middle East and North Africa, handling approximately 60% of cargo entering Lebanon, roughly 1/3rd of which is transshipped regionally.
- Strategic access to three continents, Europe, Asia and Africa.
- The port is owned by Government of Lebanon and operated by Gestion et exploitation du port de Beyrouth.
- Centrally located in an urban setting, adjacent to downtown Beirut, with urban sprawl surrounding the port and no buffer zone.

AcuTech
PROCESS RISK MANAGEMENT

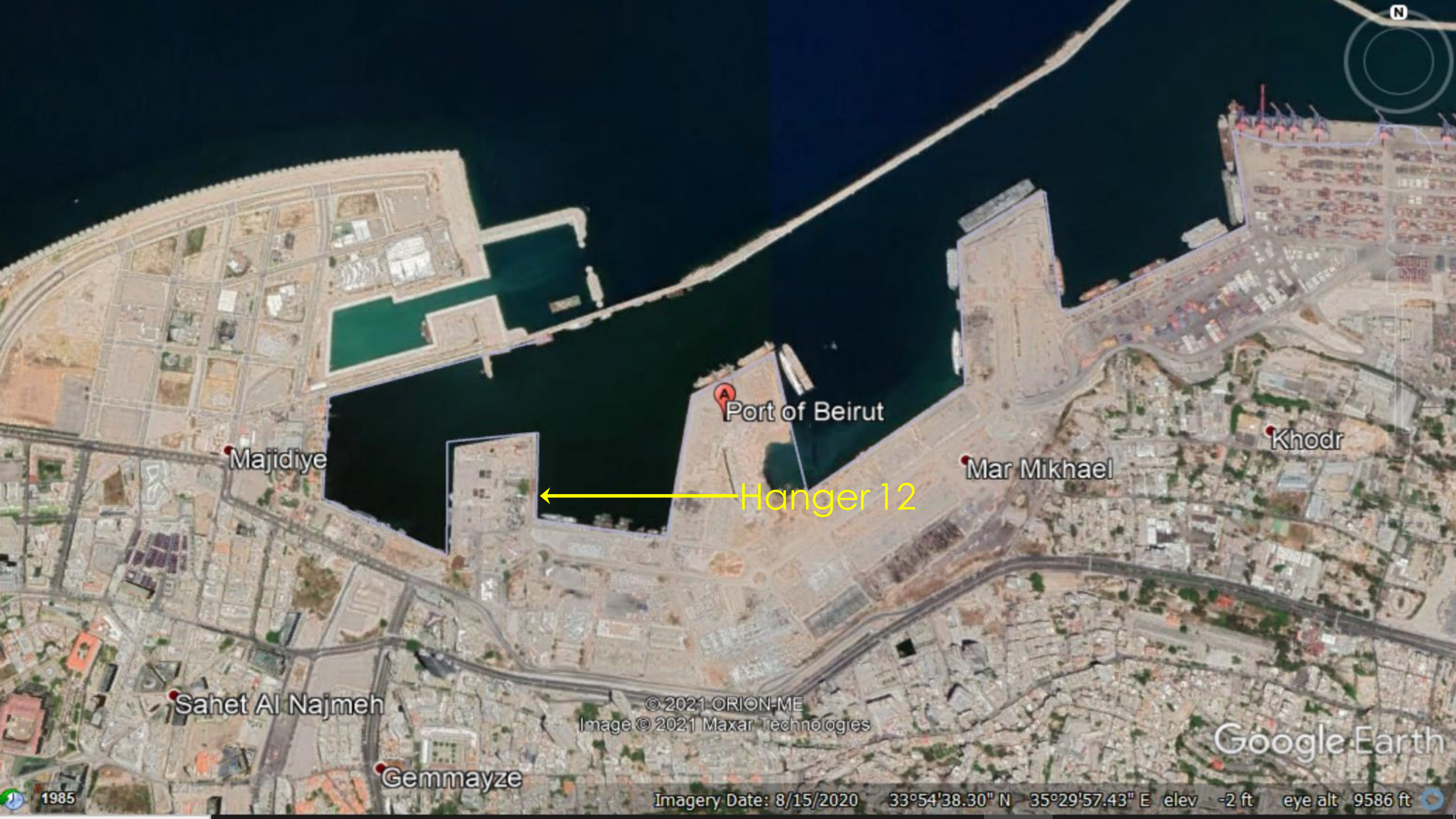
Factors in the Incident - Proximity to Urban Population

The expansion of business led to large quantities of bulk and container traffic and storage of some onsite especially when there were abandoned cargo.

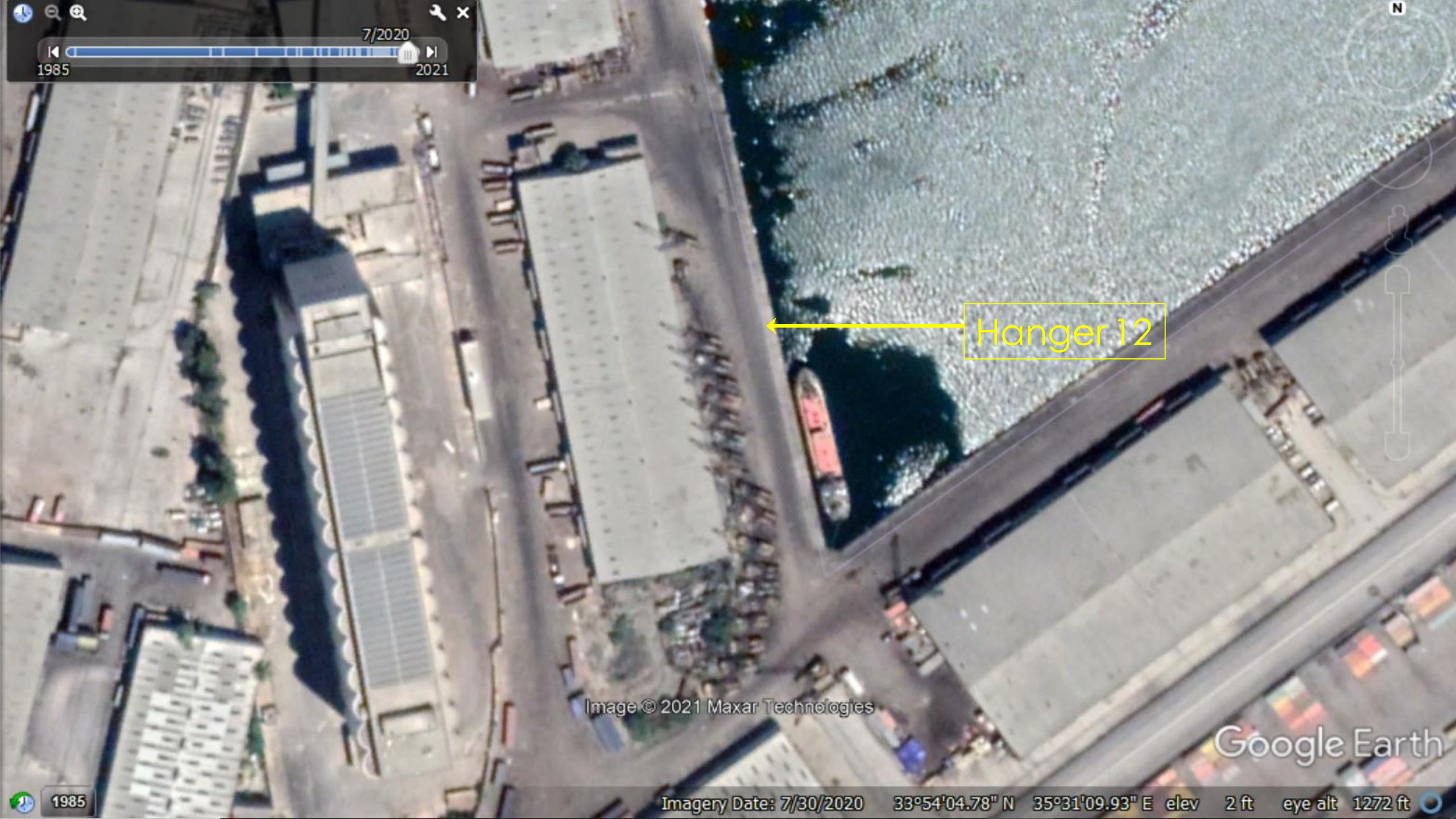
The distance from Hanger 12 to the city boundary was 0.4 KM.

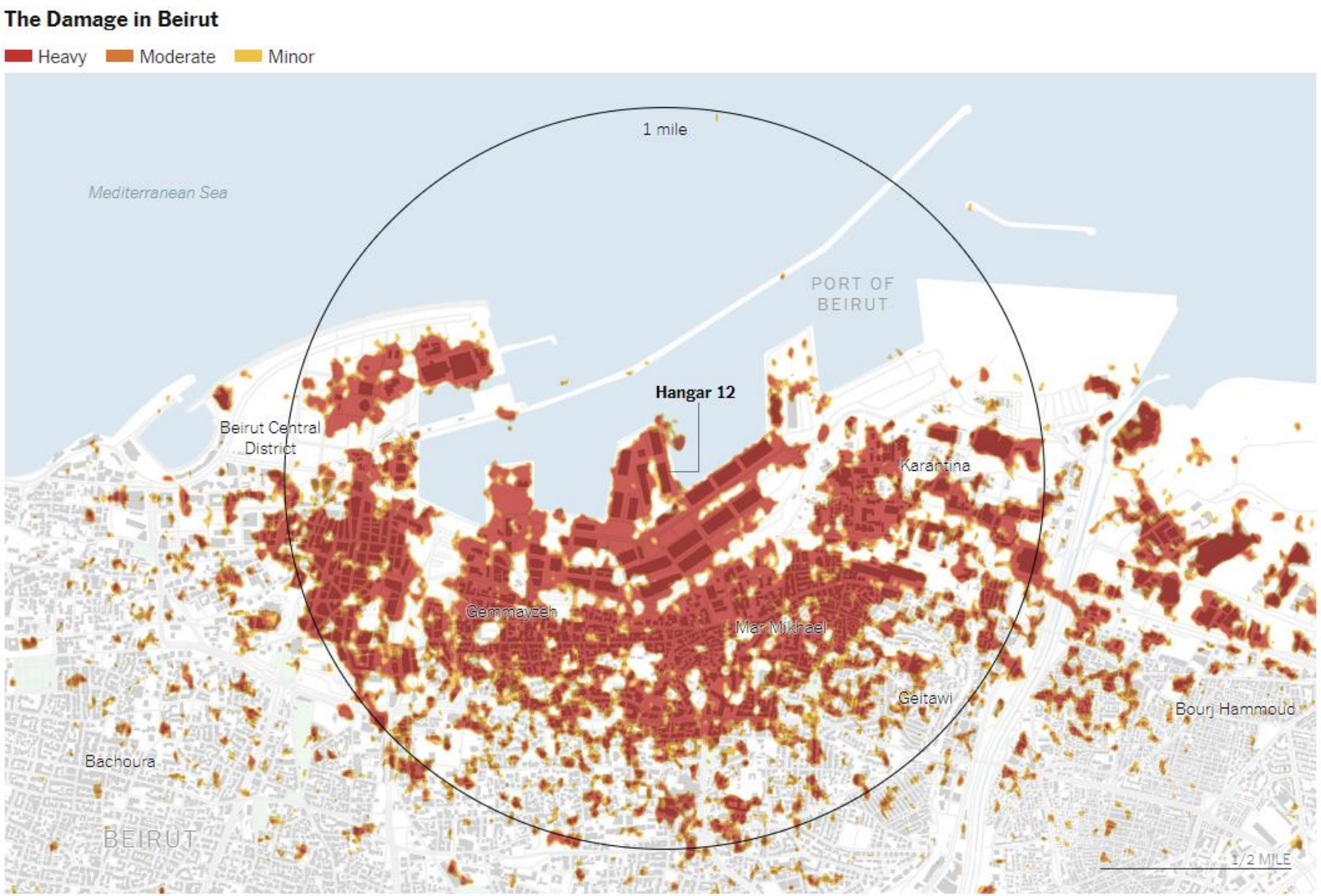
The port location and Hanger was unsuitable for the storage of large quantities of hazardous materials due to residential and businesses within the near vicinity.

AcuTech
PROCESS RISK MANAGEMENT


Port of Beirut
Majidiye
Hanger 12
Mar Mikhael
Khodr
Sahet Al Najmeh
Gemmayze
© 2021 ORION-ME
Image © 2021 Maxar Technologies
Google Earth
1985
Imagery Date: 8/15/2020 33°54'38.30" N 35°29'57.43" E elev -2 ft eye alt 9586 ft


Hanger 12


7/2020
1985
2021
Hanger 12
Image © 2021 Maxar Technologies
Google Earth
1985
Imagery Date: 7/30/2020 33°54'04.78" N 35°31'09.93" E elev 2 ft eye alt 1272 ft



The New York Times
Sources: Advanced Rapid Imaging and Analysis (ARIA), JPL-Caltech, Earth Observatory of Singapore (EOS), Nanyang Technological University (NTU), NASA Earth Applied Sciences Disasters Program. Contains modified Copernicus Sentinel data (2020). Street and building data from OpenStreetMap. Additional building data from the American University of Beirut.

AcuTech
PROCESS RISK MANAGEMENT

Factors in the Incident - Improper Storage Practices

The ammonium nitrate was a known hazard but delays in removing the seized cargo led to unnecessary exposure to the port and the public

The cargo was intermingled with a variety of other incompatible materials including fireworks and other combustible and hazardous materials

The AN was allowed to leak from bags and merge creating a larger exposed mass and contamination

AcuTech
PROCESS RISK MANAGEMENT

Factors in the Incident – Inadequate Fire Protection and Emergency Response

Inadequate hot work during repairs on a door is a suspected cause

The building did not have an automatic sprinkler system

Fireworks caused the accelerant to initiate the explosion

The firefighters were unaware of the hazards they were facing

The terminal and city were not evacuated following the initial fire

AcuTech
PROCESS RISK MANAGEMENT

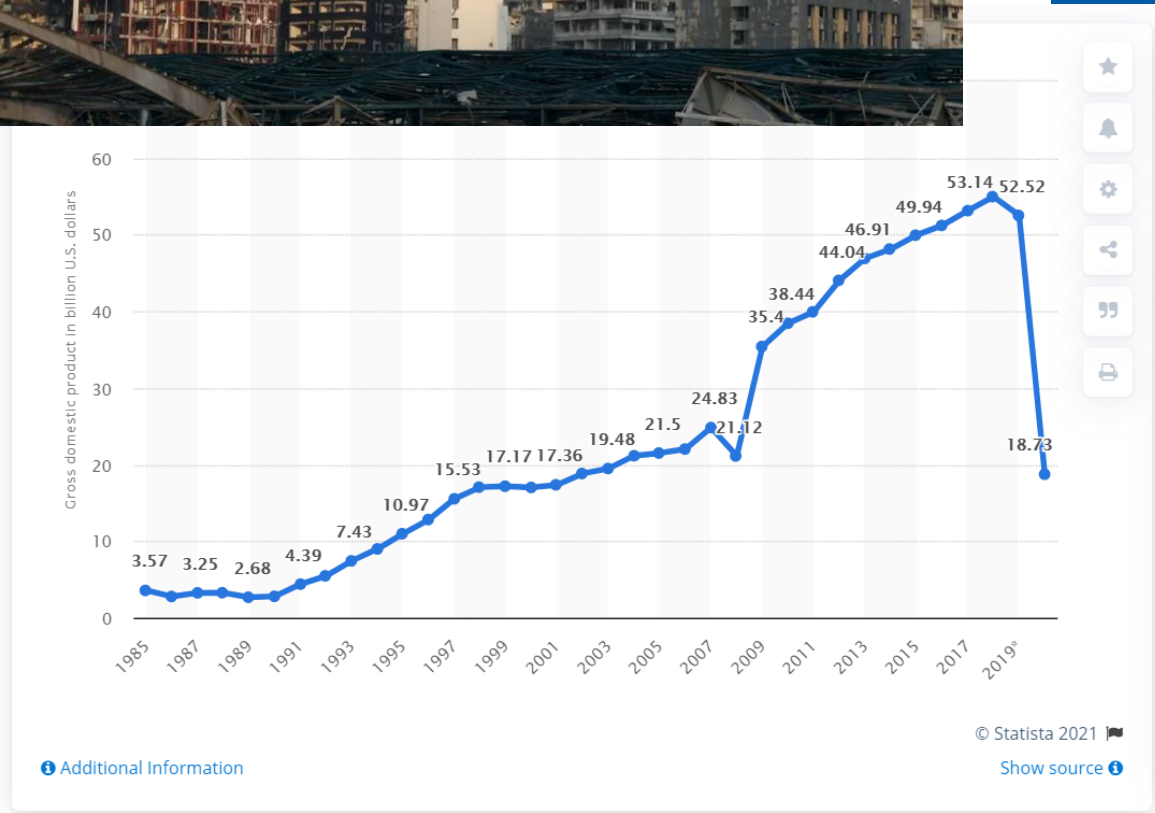
Onsite Impacts

- Multiple fatalities and injuries to personnel, 10 city fire fighter fatalities.
- Destruction of all port operational buildings on the west side of the port.
- Loss of most all warehouse space.
- Eight ships declared as casualties.
- Loss of perimeter security and associated buildings.
- Damage to gantry cranes.
- Port closure (Container port 10 days to limited operation).

AcuTech
PROCESS RISK MANAGEMENT

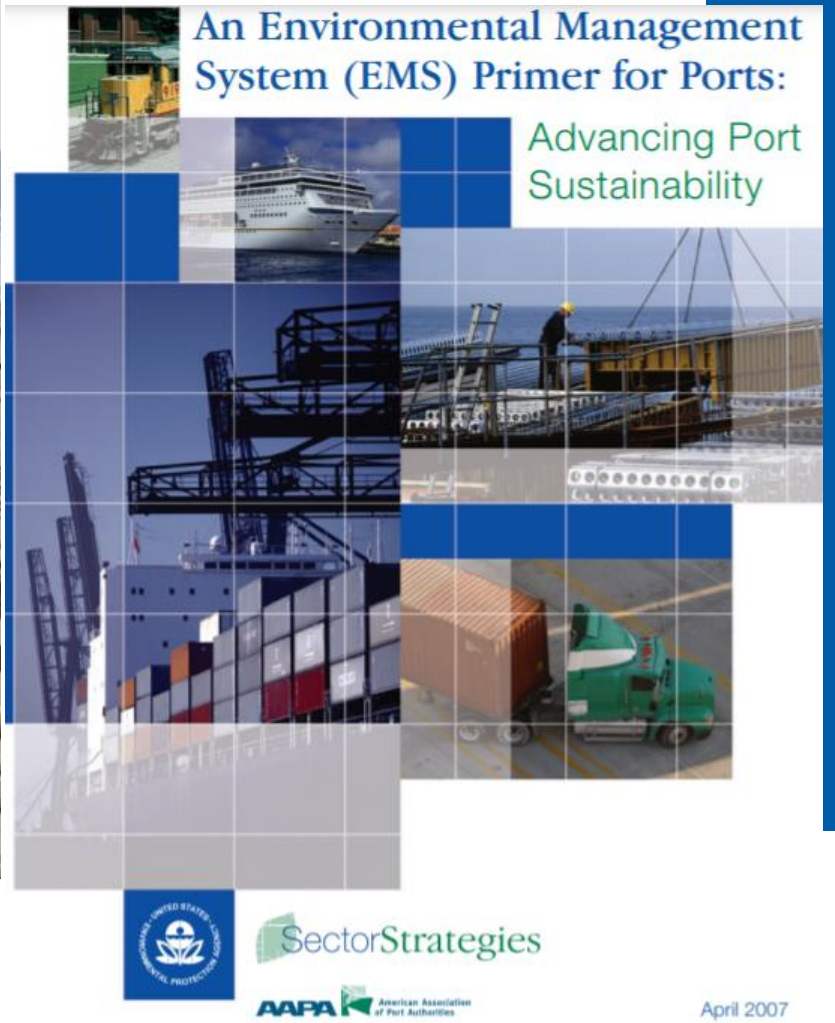
Offsite Impacts

- Disruption to port, businesses, city and national economy.
- $15B+ in estimated damages with unknown impacts on future GDP.
- Abut 200 fatalities and over 6,500 injuries and over 300,000 left homeless.
- Infrastructure damage including the city's primary grain silos, 17 hospitals and 178 schools.
- Led to the collapse of the sitting government.



Operational Impacts and Resiliency

- The site was not entirely damaged (the container port had limited damage due to distance from the hanger).
- Given lesser demand due to COVID-19 and general economic conditions demand could be met despite damaged gantry cranes.
- Major gaps in other operations and needed to shift to other ports or means of transportation.
- Incident highlights the need for risk assessment, emergency preparedness, and resiliency and sustainability planning.



Ammonium Nitrate Historic Accidents

Figure 1 - The consequences of explosion caused by blasting of hardened fertiliser, Opau, Germany, 1921 (French Ministry of Sustainable Development, 2008)

Location	Year	Fatalities
Texas City, USA	1947	581
Oppau, Germany	1921	561
Beirut, Lebanon	2020	200
Tessenderlo, Belgium	1942	169
Tianjin, China	2015	165
Ryongchon, N. Korea	2004	160
Monclova, Mexico	2007	57
Tolouse, France	2001	30
Brest, France	1947	29

Source:

- Han, Zhe (2016) Thermal Stability Studies of Ammonium Nitrate, Texas A&M
- Braithwaite, Martin (2008) Ammonium Nitrate – Fertilizer, Oxidiser and Tertiary Explosive

AcuTech
PROCESS RISK MANAGEMENT

NFPA 400 (2019) - Storage, Separation and Housekeeping Principles

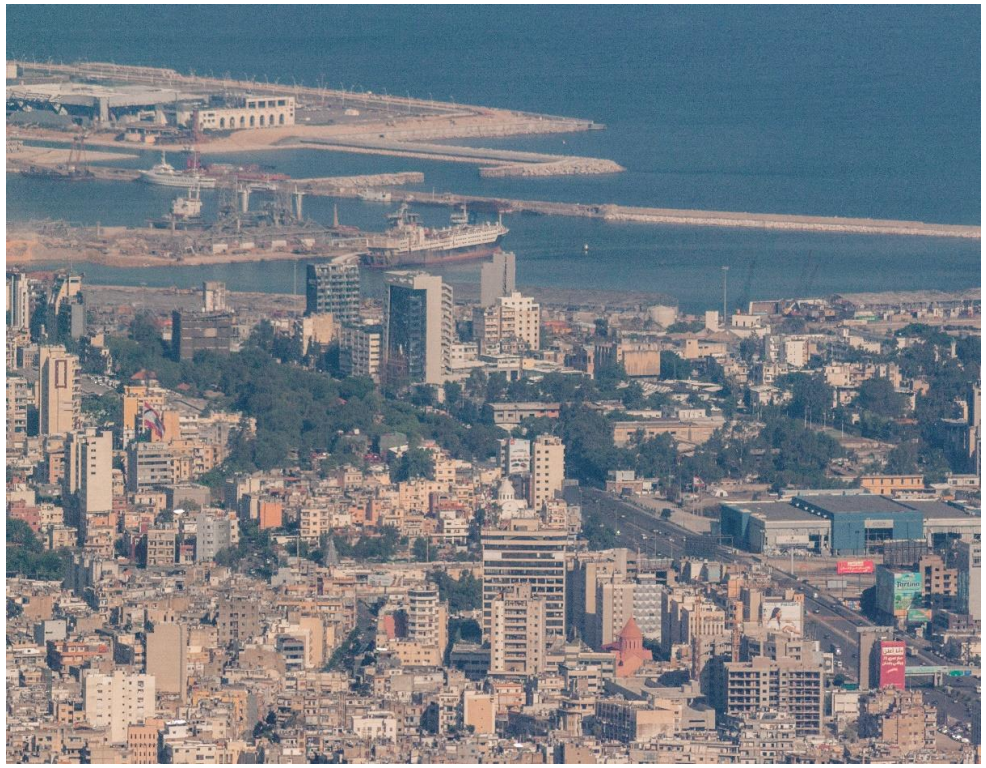
- Maximum Allowable Quantities per control Area
- Ammonium nitrate shall be isolated in a separate room by fire barrier walls constructed of concrete block having a minimum fire resistance rating of one hour from:
  - Organic materials
  - Phosphorus, etc.
- Explosives and blasting agents in a separate building
- Spills shall be contained and properly disposed of immediately
- Damaged containers removed
- Policy and procedures to ensure separation and good housekeeping
- No storage of combustibles in AN storage areas

Bags of ammonium nitrate were piled haphazardly in Hangar 12, some torn and spilling their contents. The New York Times

AcuTech PROCESS RISK MANAGEMENT

NFPA 400 (2019) - Process Safety Issues

- NFPA 400 requirements would apply (Chapter 11) for this installation.
- A public quantitative risk assessment is not required but the Authority Having Jurisdiction has siting decision responsibilities.
- NFPA 551 Guidelines for Evaluation of Fire Risk Assessment can provide guidance
- AN is not regulated under 29 CFR 1910.119 or 48 CFR Part 68 but is regulated per OSHA's Explosive Standard (29 CFR 1910.109) and 49 CFR § 176.410.



AcuTech
PROCESS RISK MANAGEMENT

NFPA 400 (2019)-
Fire Protection and Public Safety Siting Principles

- 2019 Edition requires retroactive automatic sprinkler systems in all buildings of Type III, IV, or V construction or for any type with combustible content.
- Requires noncombustible building construction and compartment construction.
- Emergency action plans are required including that fires beyond the incipient stage should not be approached by facility personnel.
- In both new and existing facilities that store ammonium nitrate, a fire alarm system with fire detection is required with an approved public. notification/ siren system.
- Building occupants should be notified of the need to evacuate the building faster than they would during an ordinary combustible fire.
- Individuals in the surrounding area need to be notified to evacuate.

AcuTech
PROCESS RISK MANAGEMENT

NFPA Fire & Life Safety Ecosystem

Fire & Life Safety Ecosystem Individual components or "cogs"

Learn more about each component and the roles necessary to help maintain and promote a system to protect people and property against evolving safety threats.

Maintaining an effective policy and regulatory environment, supporting fire, electrical, building, and life safety.

Using the latest codes and standards developed by experts from across the world.

Applying all standards referenced (PDF) within the primary fire, life safety, building and electrical codes and standards, including the International Building Code® (IBC®) and International Fire Code® (IFC®).

Prioritizing safety across the board.

Promoting the development of skilled professionals to apply the codes and standards.

Supporting effective code enforcement.

Providing effective preparedness and response capabilities to deal with fire, electrical, and related hazards.

Educating the public about the dangers posed by fire, electrical, and related hazards.

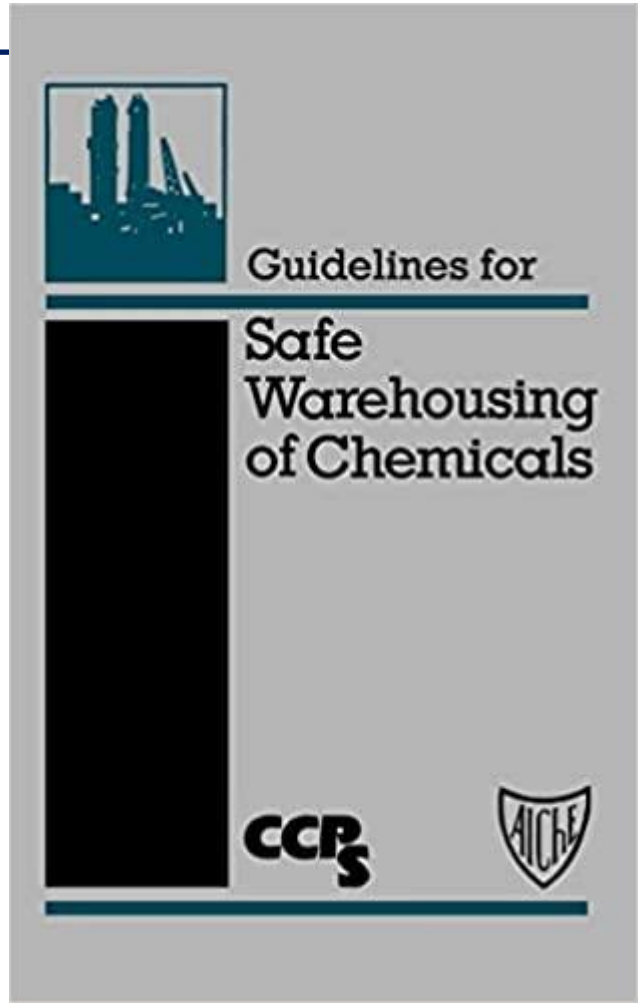
https://www.nfpa.org/ecosystem

AcuTech
PROCESS RISK MANAGEMENT

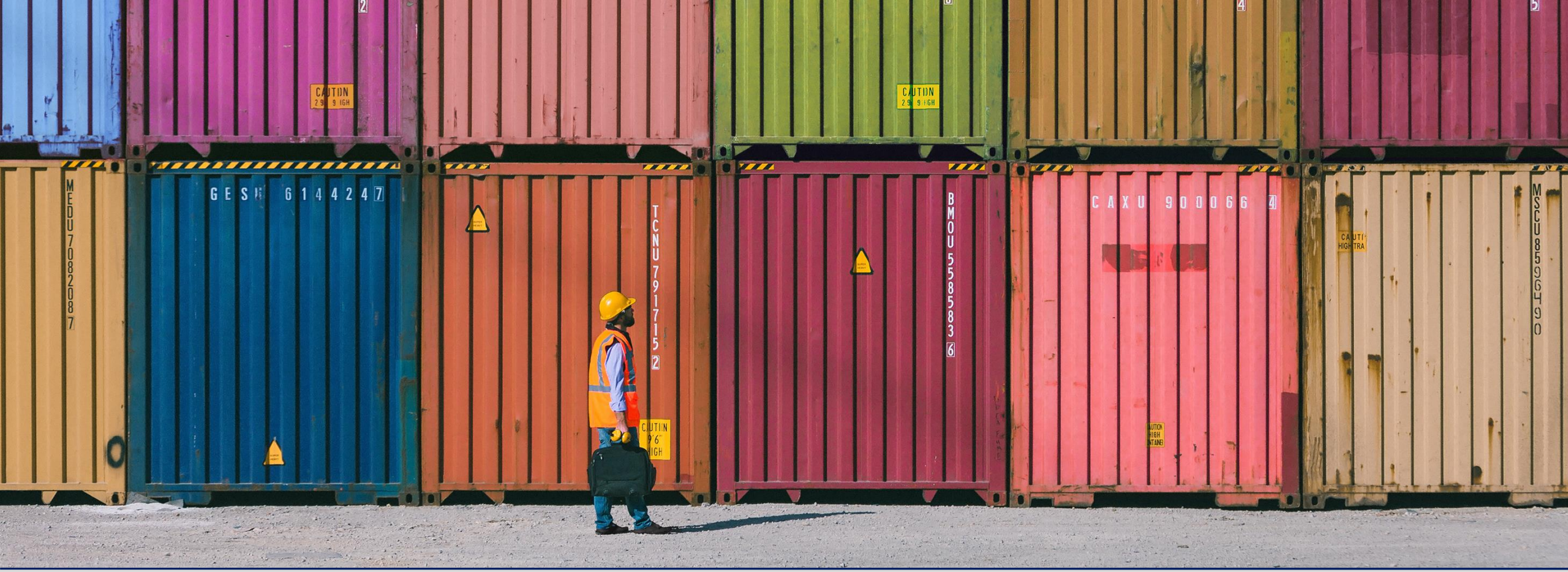
Summary

The lessons learned from the Port of Beirut incident include:

- The need for compliance with best practices for AN storage including NFPA 400 and CCPS Safe Warehousing of Chemicals.
- Transportation facilities having AN in transport, storage, temporary confinement, or abandonment need to properly handle and store and rapidly remove the chemical from the site, to have adequate fire and emergency management plans.
- The principles of process safety management (including the CCPS RBPS model) and risk and resiliency planning represent a superior way to oversee the hazards given the need for management of change, hazard and risk assessment, facility siting, operational discipline, emergency planning, and other relevant elements to assure RAGAGEP.
- Best practices and lessons learned are applicable not only to ports and facilities handling ammonium nitrate, but all facilities handling hazardous materials operating in challenging urban environments, and which maintain complex interdependencies with critical infrastructure.



AcuTech
PROCESS RISK MANAGEMENT



Questions?

https://www.linkedin.com/in/acutech/

https://www.linkedin.com/company/acutech-consulting-group

David Moore, PE, CSP
AcuTech Group, Inc.
dmoore@acutech-consulting.com
www.acutech-consulting.com

AcuTech
PROCESS RISK MANAGEMENT