STRUCTURAL AND ENVIRONMENTAL HEALTH MONITORING AND MANAGEMENT – SEHM^2

Development of a comprehensive framework for technological scenarios triggered by natural events (Natech) assessment in the chemical and process industries

Summary of yearly activities (a.y. 2018/19)

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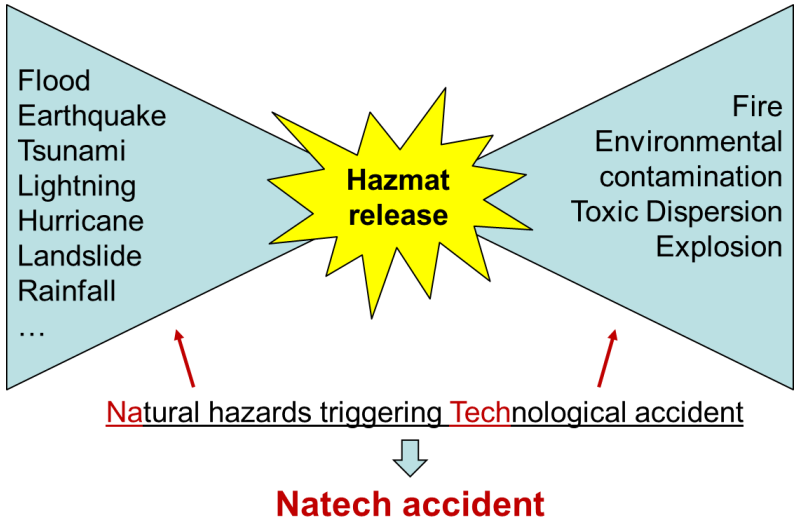
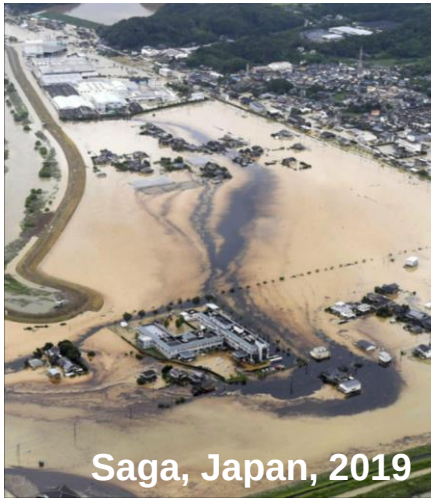
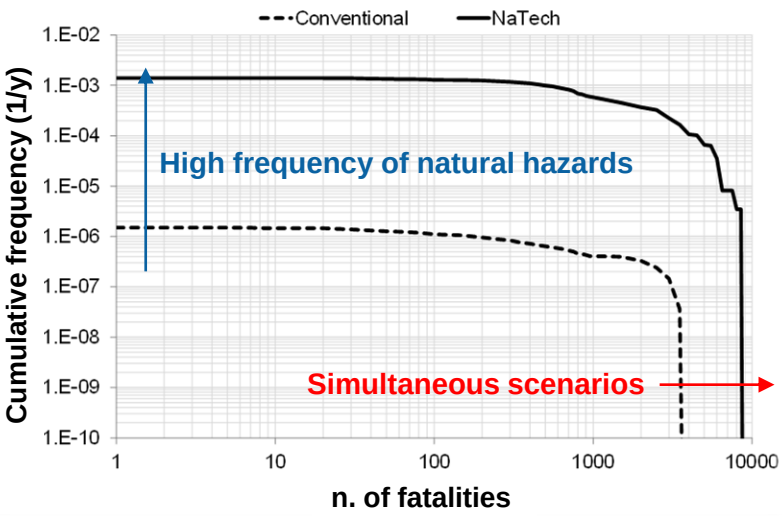
Introduction: Natech accidents







Natech features go beyond “conventional” technological accidents

- ❑ Multiplicity of simultaneous failures
- ❑ Cascading scenarios: elevated possibility of domino escalation
- ❑ Natural hazards may impact safety systems, utilities and lifelines
- ❑ Compound disasters: Emergency intervention may be hampered

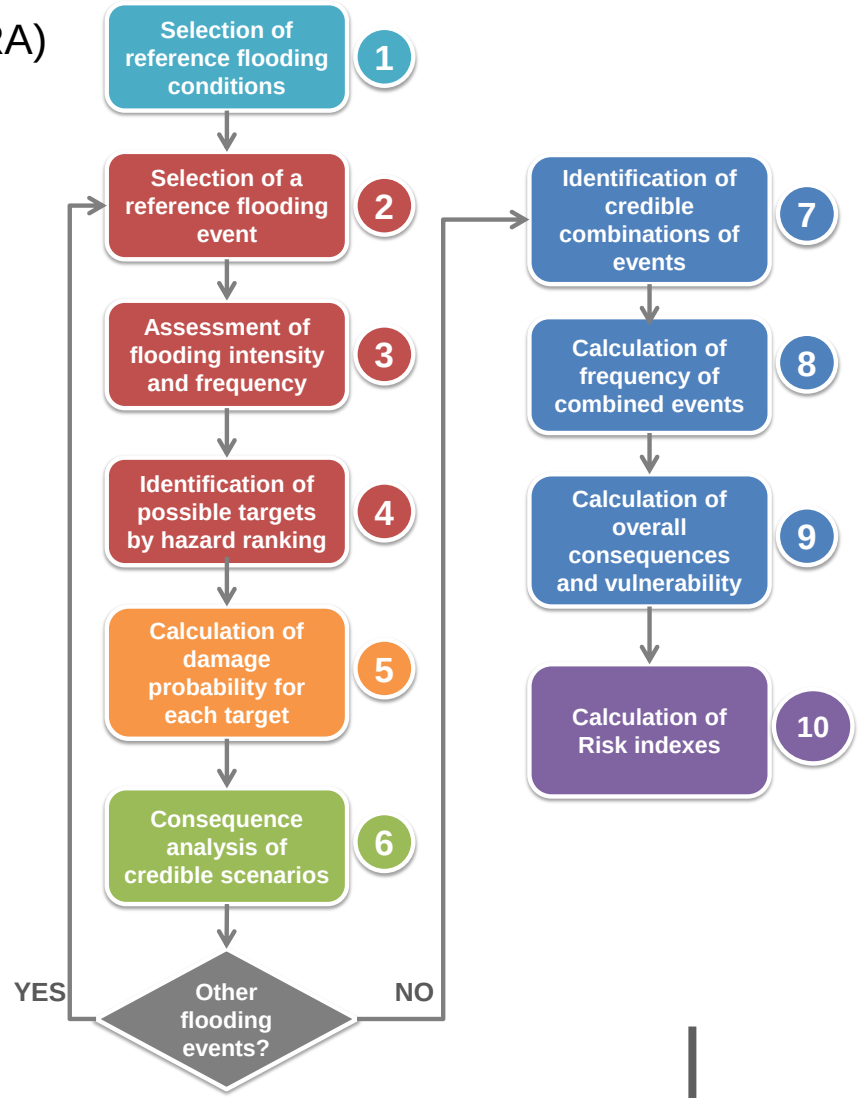
Gap analysis: safety barriers and domino effect

Example: **Flood** Quantitative Risk Assessment (QRA)

- QRA methodology for Natech accidents caused by floods *(Antonioni et al., 2015).*
- Vulnerability models for main equipment categories *(Landucci et al., 2012, 2014)*
- Similarity with domino effects, methodology for frequency of combined events *(Cozzani et al., 2014)*

What is still missing?

- Safety barriers?
- Domino propagation?
- Utility systems?
- …



Natural hazards and safety barriers

Past accident analysis

Expert elicitation

Event tree analysis (ETA)

Way forward: FMEA/FMECA

Past accident analysis

Hurricane Harvey (Texas, 2017)

- About 100 chemical releases. **Power outage** was experienced in many cases. **Massive release from shutdown and emergency flaring**. (*Misuri et al., 2019a*)
- Arkema peroxide plant was flooded. **Power outage** interrupted the refrigeration units. **Inert gas system not available**. **Backup generators submerged.** Violent explosions. **Emergency intervention was hindered by floodwater**. *(CSB, 2018)*

Vltava River Flood (Czech Republic, 2002)

- Electrolysis plant was flooded. **Emergency retention sumps were flooded**. 80000t of chlorine were released in air and water. *(eMars)*

Koaceli Earthquake (Turkey, 1999)

- Multiple fires and chemical spills. **Power outage: firefighting water was not available in many sites. Foam-water systems for vapor suppression were not available. Containment dikes were damaged**. (*Steinberg, Cruz, 2004*)

San Jacinto River Flood (Texas, 1994)

- During flooding, 8 hydrocarbon pipelines ruptured, releasing LPG, gasoline, crude oil, diesel fuel and natural gas. Fire developed in multiple areas. **Manual interruption valves were submerged**. **Operator intervention hampered**. *(NTSB, 1996)*

Expert elicitation

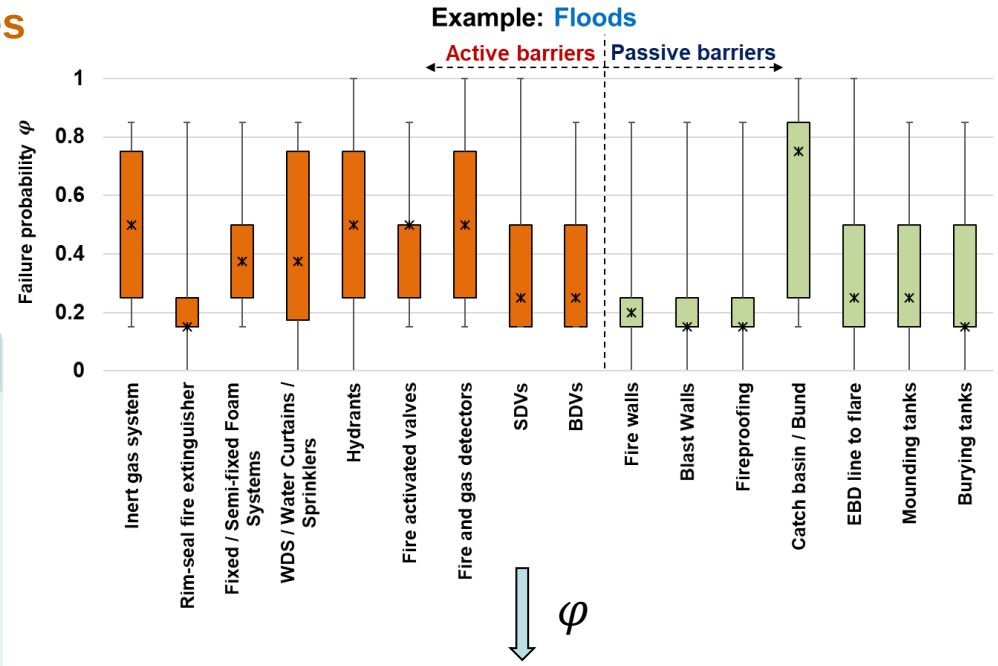
Expert elicitation *(Misuri et al., 2020)*:

- ❑ More than 40 experts involved
- ❑ Natural hazards: **Floods** and **Earthquakes**
- ❑ 16 safety barriers considered

Vulnerable systems highlighted

Floods	Earthquakes
• Blanketing systems • Fixed/semi-fixed foam systems • WDS/water curtains/sprinklers • Hydrants • Fire and gas detectors • Catch basins and bunds	• Blanketing systems • Rim-seal fire extinguishers • Fixed/semi-fixed foam systems • WDS/water curtains/sprinklers • Hydrants • Fire and gas detectors • SDVs • Fire walls • Blast walls • Catch basins and bunds • EBD line to flare

Performance parameter elicited

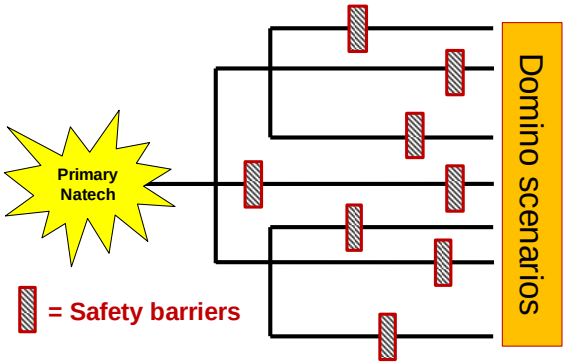


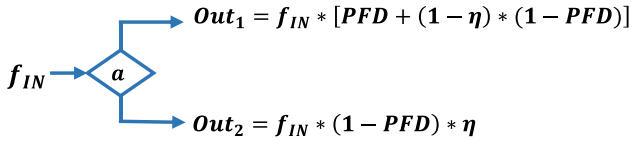
Barrier performance during natural hazards

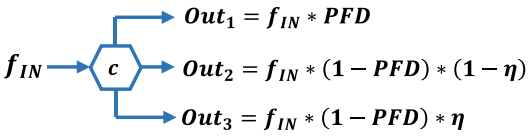
- ❑ Active: $PFD = 1 + (\varphi - 1)(1 - PFD_0)$, $\eta = \eta_0$
- ❑ Passive: $\eta = (1 - \varphi)\eta_0$

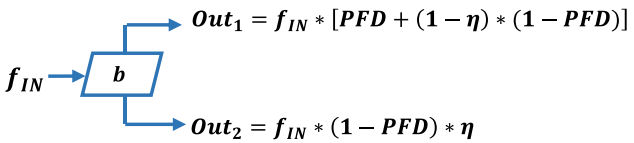
Event tree analysis (ETA)

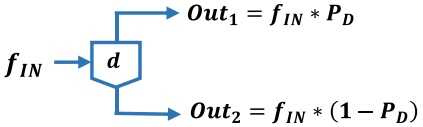
- Gate metrics for ETA of domino escalation (*Landucci et al., 2015; Misuri et al., 2019c*)



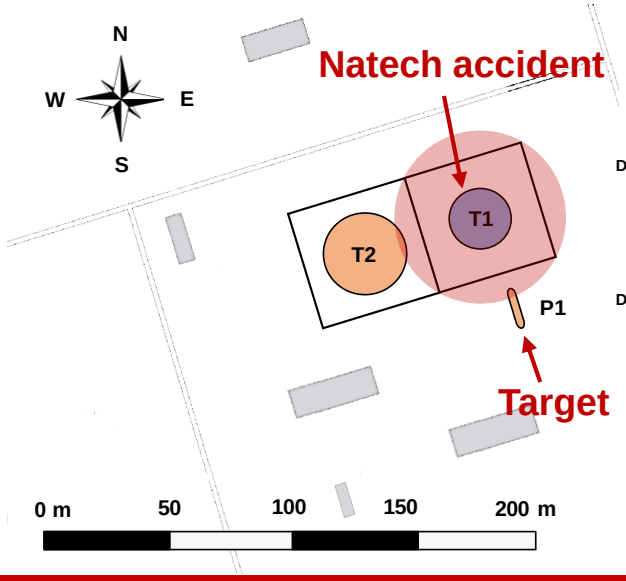


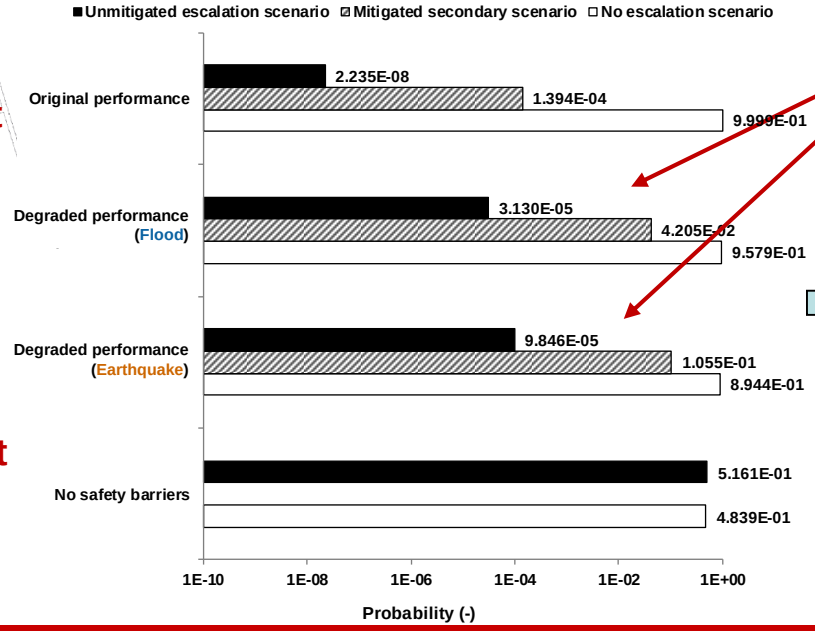






- Example of application: Domino escalation from Natech involving T1



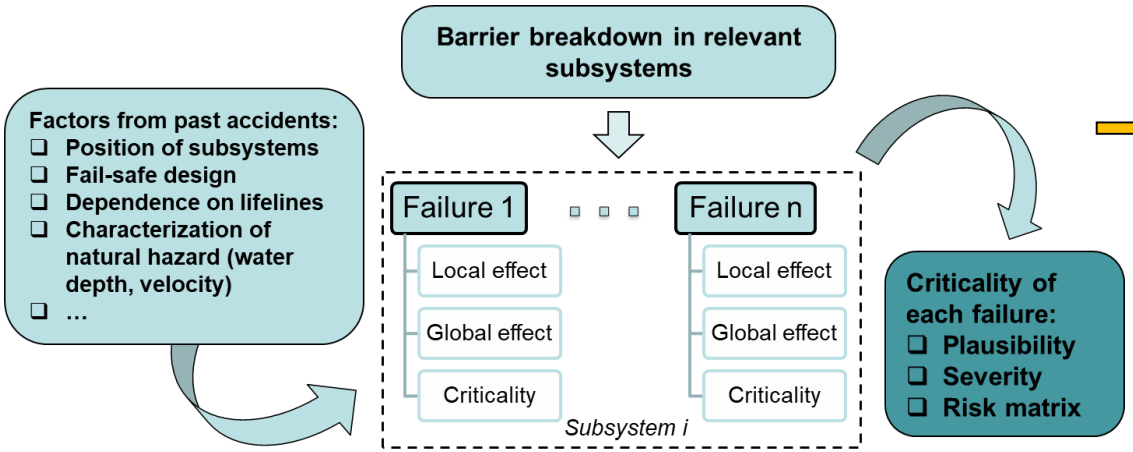


Likelihood of domino scenarios is significantly higher

Way forward: implementation in complete Natech QRA

Way forward: FMEA/FMECA

- Systematic method to identify the ways in which an item might potentially fail, and the effects of the mode of failure (EN IEC 60812:2018)

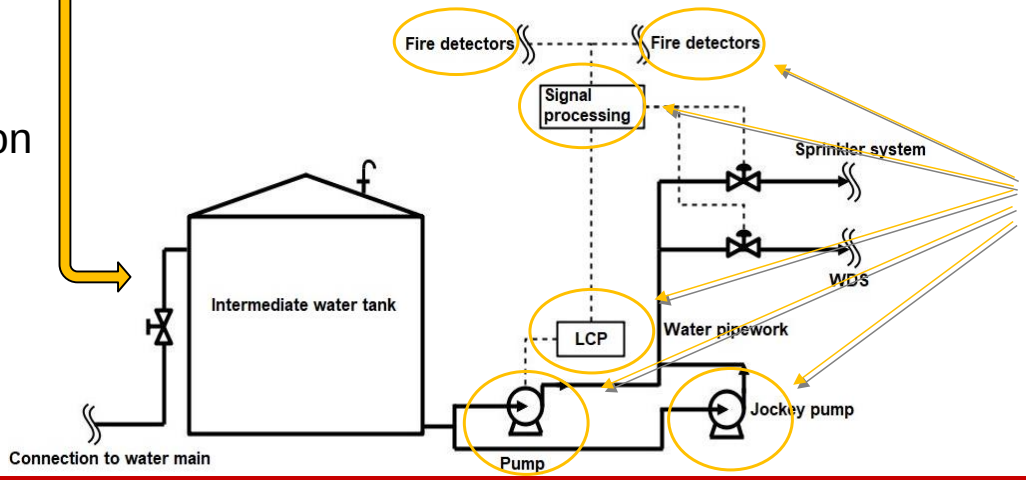


Ongoing work:

- Retrieving detailed data from Tohoku Earthquake and Tsunami (2011) for validation and testing

Visiting period at Kyoto University (September – December 2019)

Preliminary application of the methodology *(Misuri et al., 2019b)*



Power outage has been identified as the most critical failure mode for firefighting water network during floods.

References

- *Antonioni et al., 2015, Quantitative assessment of risk due to NaTech scenarios caused by floods, Reliability Engineering and System Safety, 142:334-345.*
- *CSB, 2018, Organic Peroxide Decomposition, Release, and Fire at Arkema Crosby Following Hurricane Harvey Flooding, Washington, DC: U.S. Chemical Safety and Hazard Investigation Board.*
- *Cozzani et al., 2014, Quantitative assessment of domino and NaTech scenarios in complex industrial areas, Journal of Loss Prevention in the Process Industries, 28:10-22.*
- *eMars,* https://emars.jrc.ec.europa.eu/en/emars/content
- *Landucci et al., 2012, Release of hazardous substances in flood events: Damage model for atmospheric storage tanks, Reliability Engineering and System Safety, 106:200-216.*
- *Landucci et al., 2014, Release of hazardous substances in flood events: Damage model for horizontal cylindrical vessels, Reliability Engineering and System Safety, 132:125-145.*
- *Landucci et al., 2015, Quantitative assessment of safety barrier performance in the prevention of domino scenarios triggered by fire, Reliability Engineering and System Safety, 143:30-45.*
- *Misuri et al., 2019a, Lessons learnt from the impact of hurricane Harvey on the chemical and process industry, Reliability Engineering and System Safety, 190:106521.*
- *Misuri et al., 2019b, Risk-based Vulnerability Analysis of Chemical Facilities Affected by Flooding, Conference paper, 16th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Delft, NL.*
- *Misuri et al., 2019c, Risk assessment of escalation scenarios triggered by extreme flooding events: the role of safety barriers, Conference paper, 29th European Safety and Reliability Conference, Hannover, DE.*
- *Misuri et al., 2020, Assessment of safety barrier performance in Natech scenarios, Reliability Engineering and System Safety, 193:106597.*
- *NTSB, 1996, Evaluation of pipeline failures during flooding and of spill response actions, San Jacinto River near Houston, Texas, October 1994, Washington, DC: National Transportation Safety Board.*
- *Steinberg, Cruz, 2004, When Natural and Technological Disasters Collide: Lessons from the Turkey Earthquake of August 17 1999, Natural Hazards Review, 5(3):121-130.*