WHEN TRUST MATTERS

Improved consequence and risk modelling with Phast and Safeti 9.0

TORRENS Stephane

31 January 2024

Agenda

- Vision for the products
- Deep-dive into new features
  - Phast CFD dispersion
  - Batch runner
  - New ignition model
  - Points of interest
  - Exceedance curve – dynamic pressure
  - Further improvements
- Q&A

Our purpose

To safeguard life, property, and the environment

DNV

Summary of needs

To make a safety-related decision

To have confidence

To be cost-effective

Product vision statement

Make effective decisions with fit-for-purpose consequence and risk solutions

Make effective decisions with fit-for-purpose consequence and risk solutions

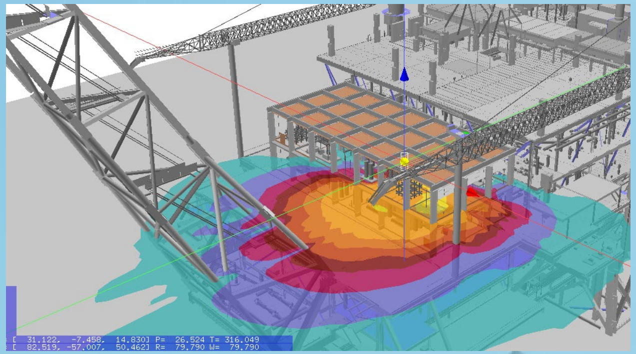
Provide the best, most validated modelling

Lower the barriers to entry

Live in the customer environment

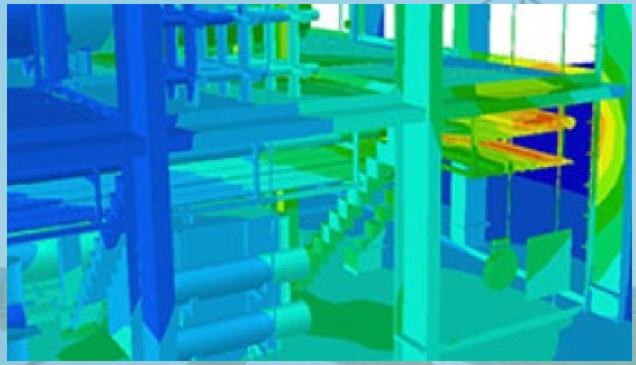
Leading consequence and risk modelling tools by DNV

PHAST™



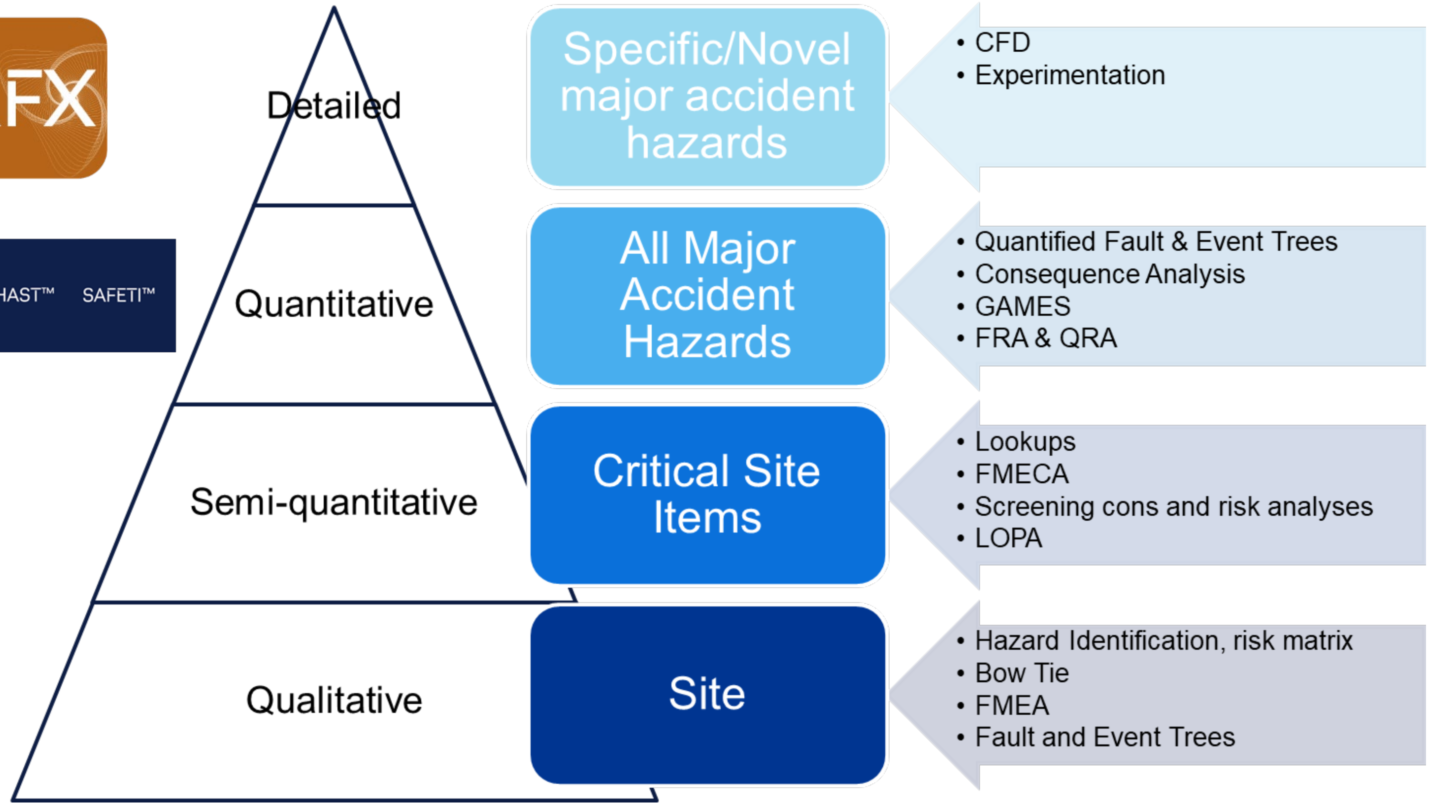
KFX

SAFETI™

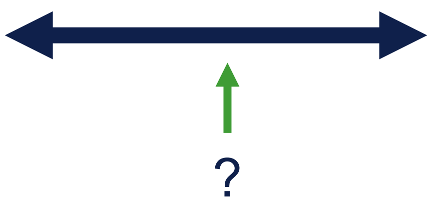


EXSIM

Possibilities for integration



- With this range of consequence and risk modelling capabilities, the end user is wanting the **right tool for the job**.
- Often Phast will be appropriate, but what about more complex situations?
- CFD can be out of reach for many…due to cost and complexity. But sometimes perception. How can we reduce these barriers?

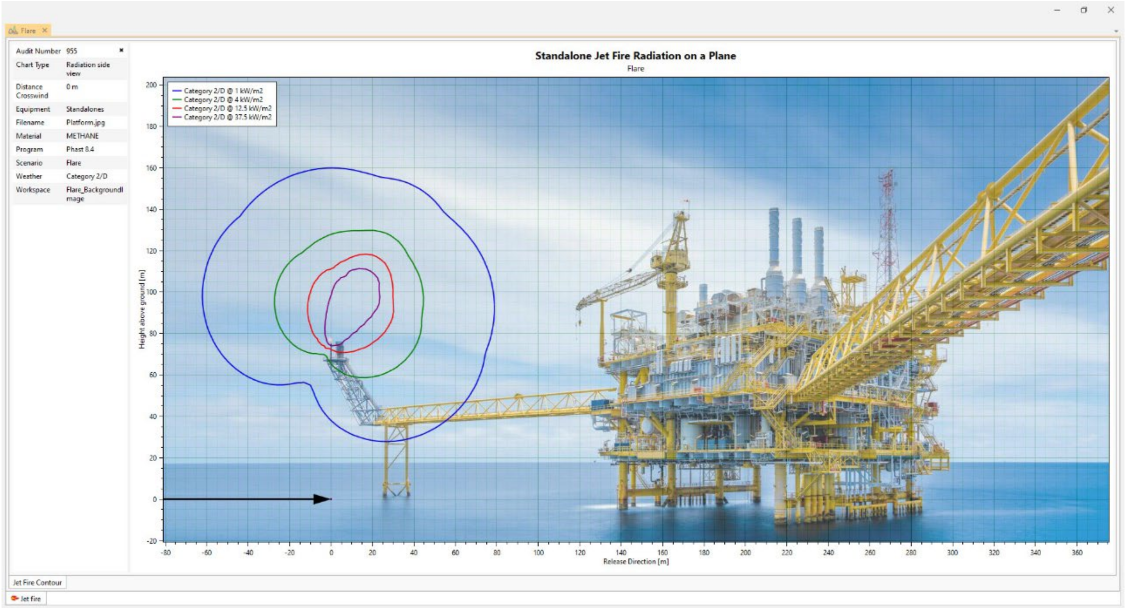


PHAST

Phast - Overview

A comprehensive hazard analysis software for all stages of process industry design and operation.

- Gas and liquid releases
- Pool model
- Two-phase releases
- Gas dispersion
- Fires



Provides clear illustration of the outcomes that may result from the hazards on your site

Assists in compliance with safety regulations

Enables more effective response to hazardous incidents by understanding their outcomes

Ensures safe optimization of plant and process design

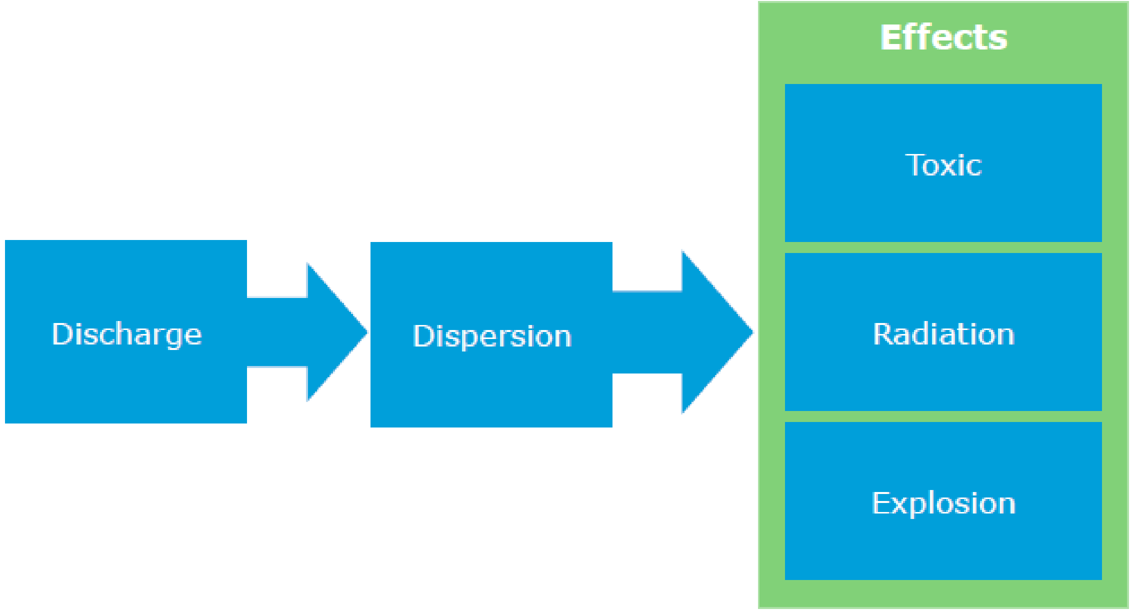
Phast – DNV’s Consequence Modelling Software

Dispersion, fire and explosion simulations with Phast

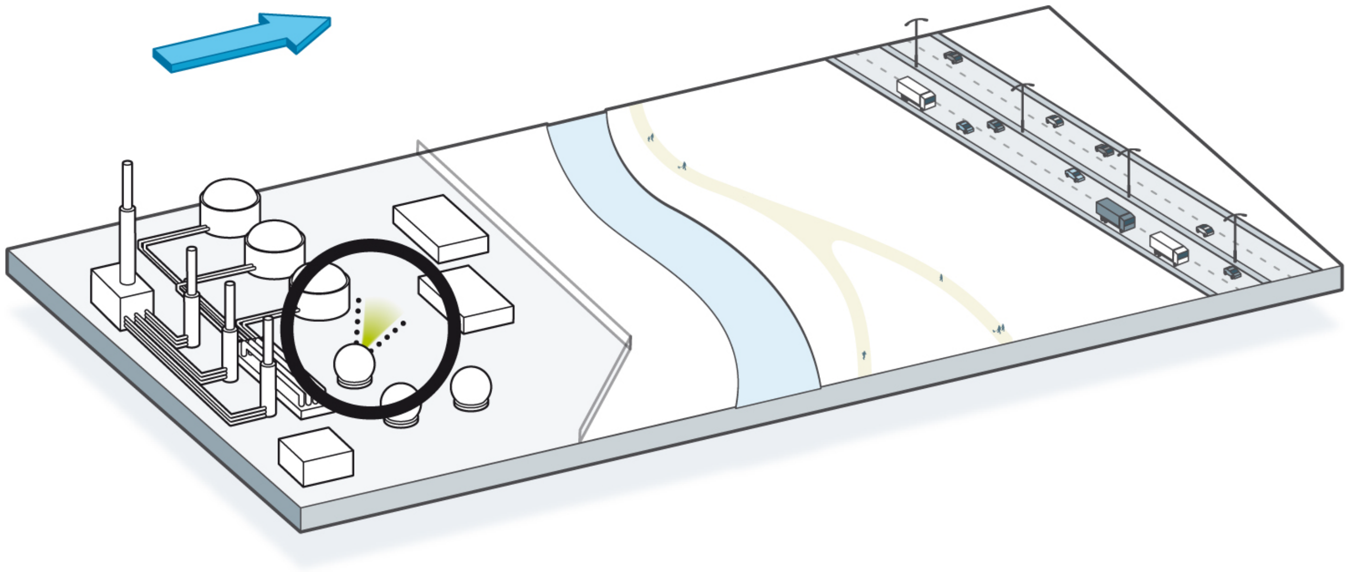
- Phast is used to analyse situations that present potential hazards to life, property and the environment and to quantify their severity. Consequences may then be managed or reduced by design of the process or plant, modification to existing operational procedures, or by implementing other mitigation measures.
- DNV continuously develops the UDM to ensure it is the industry standard by extensive research and development and experimental validation. Recent validation includes modeling of LNG, CO2 and Hydrogen.

Phast model path

- This is the overall model path through Phast



Discharge



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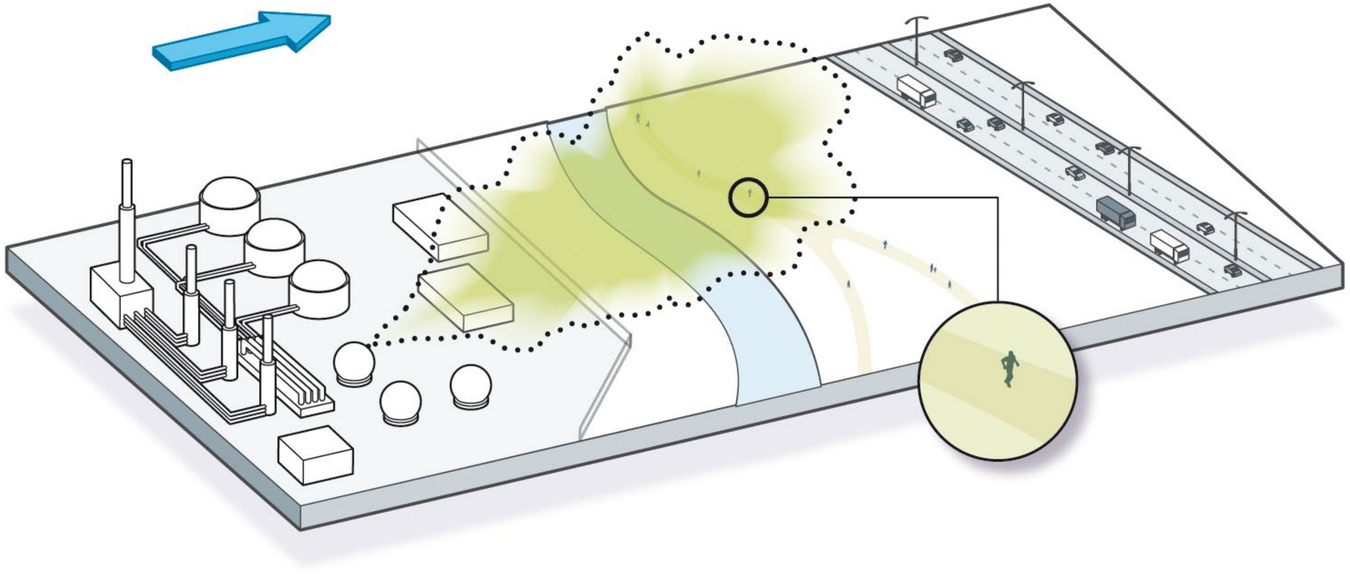
Dispersion



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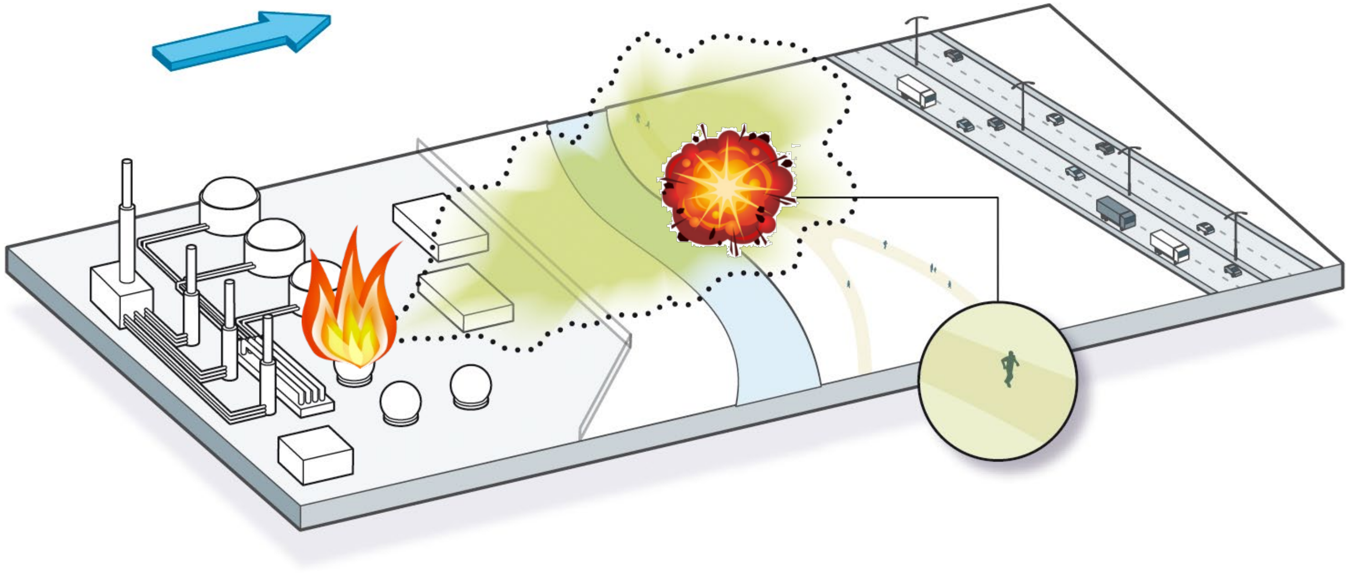
Effects (fire, explosion, toxic)



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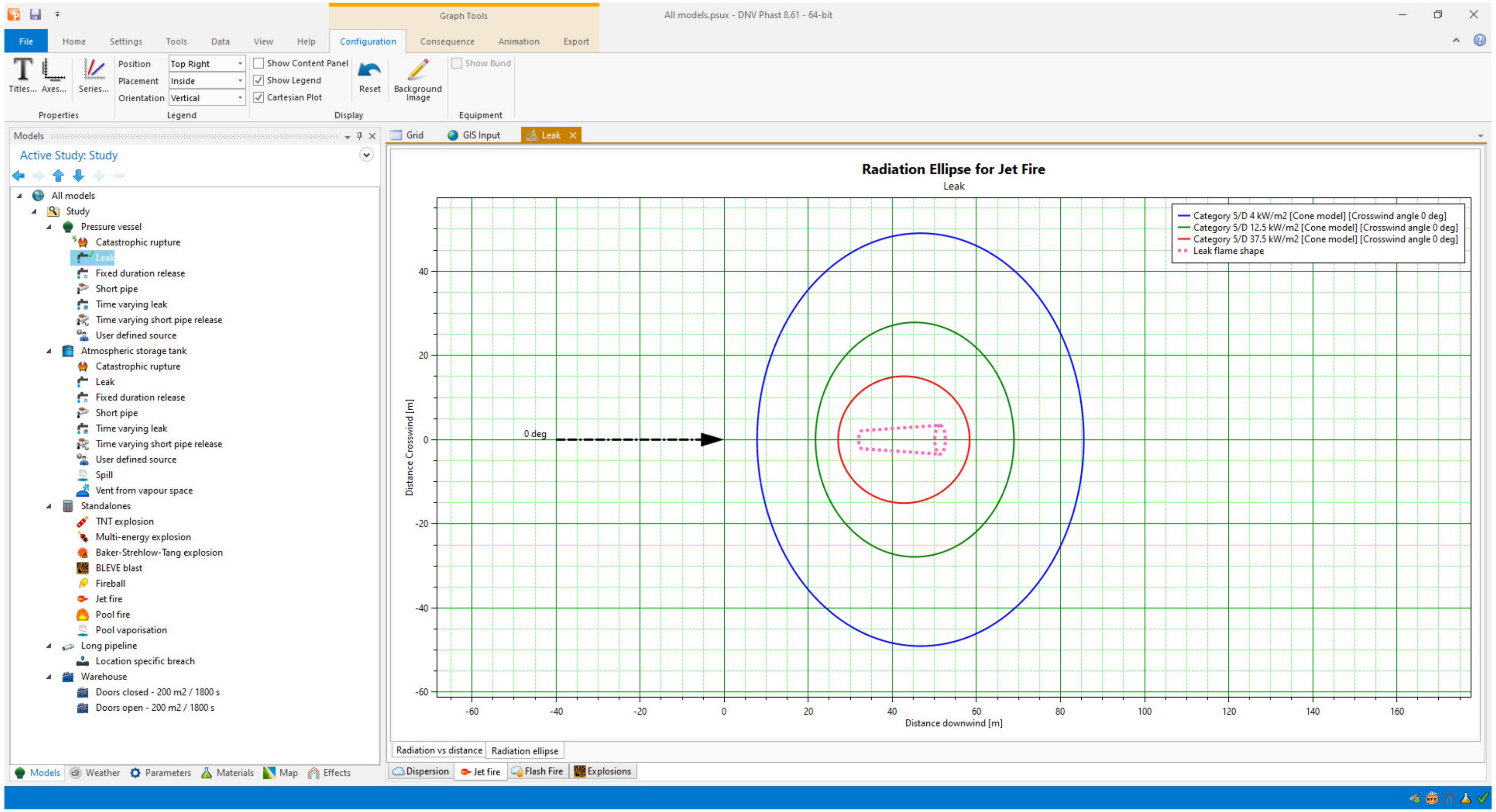
Thermal radiation contours on GIS

Radiation ellipse on a graph



Recent developments for Phast CFD

Provide the best, most validated modelling

Lower the barriers to entry

Live in the customer environment

Computational Fluid Dynamics (CFD)

- It involves long learning curves and significant expertise
- The complexity of CFD can often be a barrier
- CFD software license may involve major costs

DNV

Provide the best, most validated modelling

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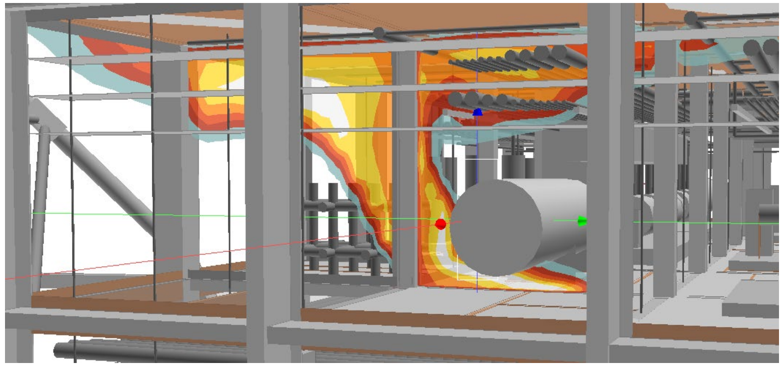
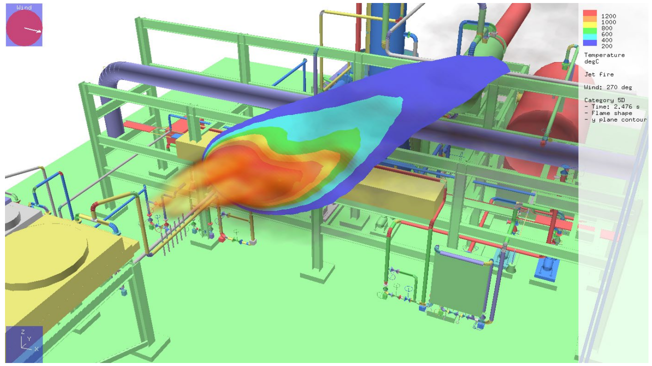
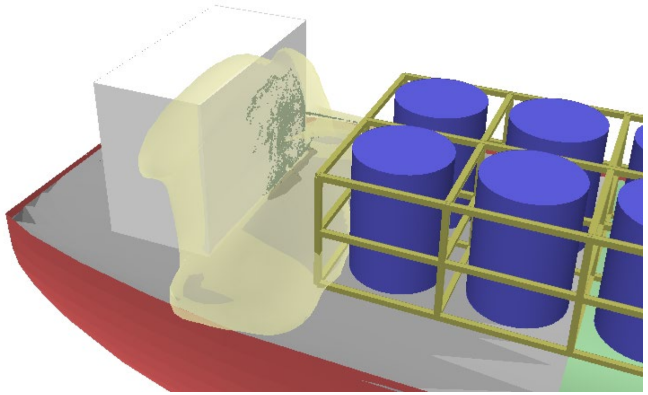
Live in the customer environment

Phast Computational Fluid Dynamics (CFD) extensions

Phast CFD – pool fire (8.6)	Phast CFD – jet fire (8.7)	Phast CFD – dispersion (9.0) NEW







Our journey to 3D (CFD)

2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024

2017 – KFX CFD code acquired by DNV

DNV acquired ComputIT, KFX become part of DNV software portfolio

2019 – Phast 3D Viewer

3D viewer is available in Phast 8.2, which can display 3D dispersion cloud and shielding effect for fires (non-CFD)

2021 – CFD – Pool fires

CFD simulation for pool fire is available in Phast 8.6 for 13 materials

2022 – CFD – Jet fires

CFD simulation for jet fire is available in Phast 8.7. More materials and mixtures are supported

2023 – CFD – Dispersion

CFD simulation for dispersion is being developed. Phast 9.0 is scheduled to be available in Q4 2023

2024 – CFD – Explosion

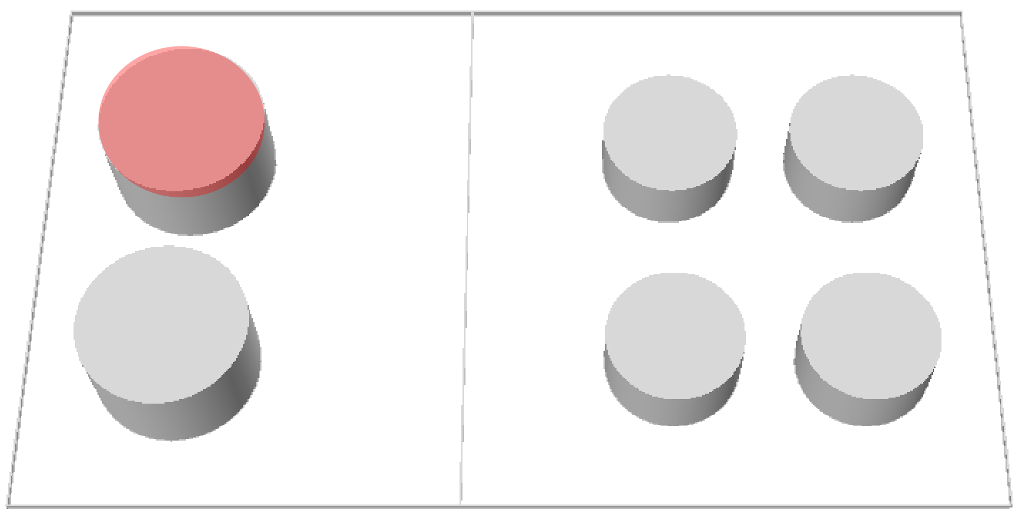
CFD simulation for explosion is planned in 2024

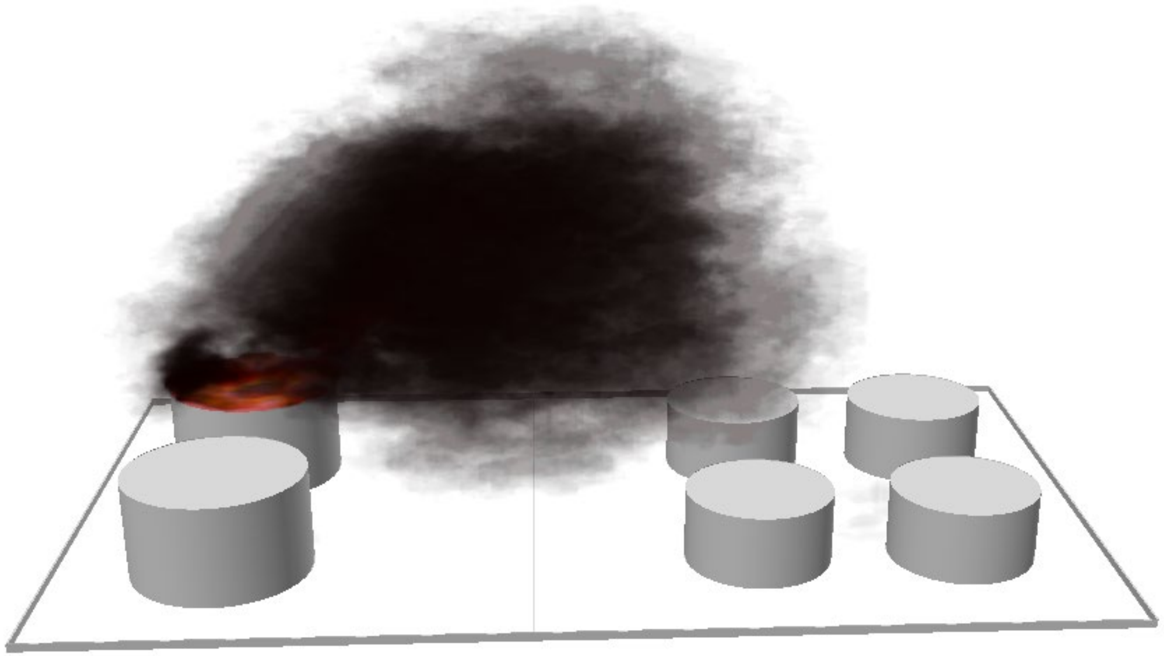
Phast CFD – Pool fires

CFD simulations for pool fires in Phast, powered by KFX	3D geometries and flames for visualisation	Circular pool fire modelling using CFD
Rectangular pool fire modelling using CFD	Temperature profiles	3D geometries used in the CFD calculations (Phast CFD – Pool fires license required)

Phast CFD – Pool fires
Tank fire

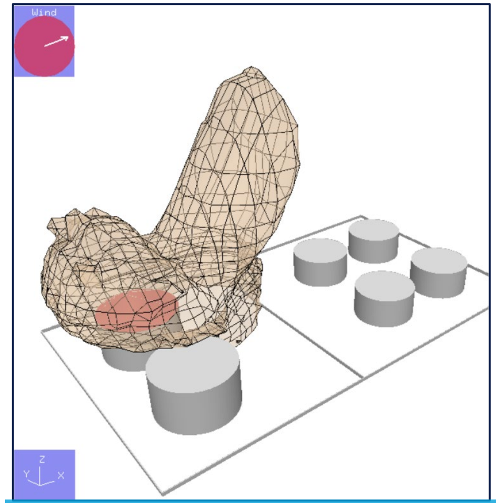
Wind direction



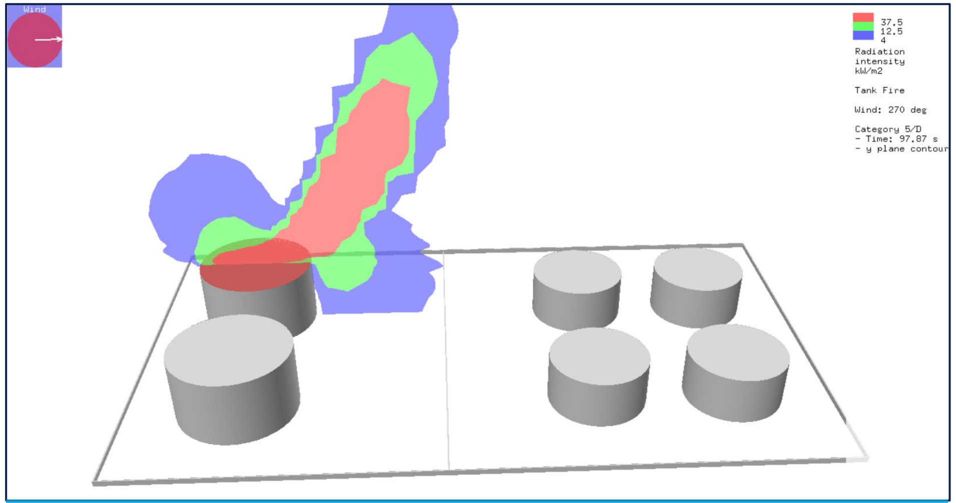


Octane tank fire

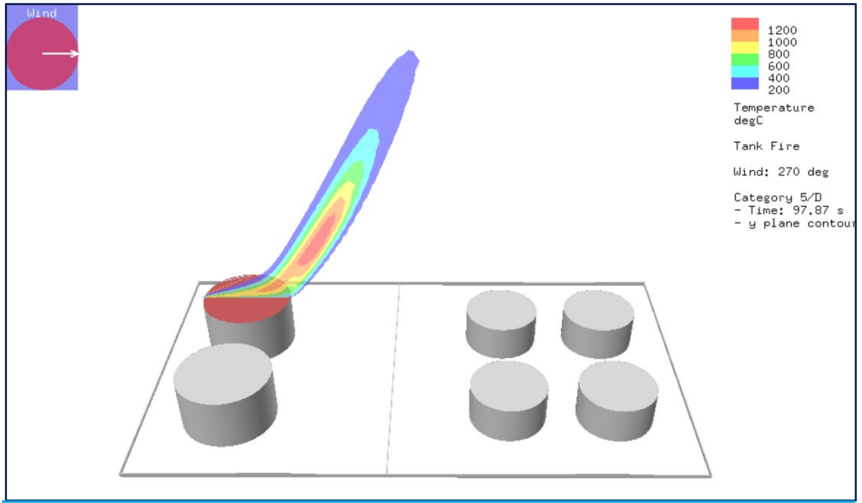
Phast CFD – Pool fires
Tank fire



Iso-surface for 3kW/m2

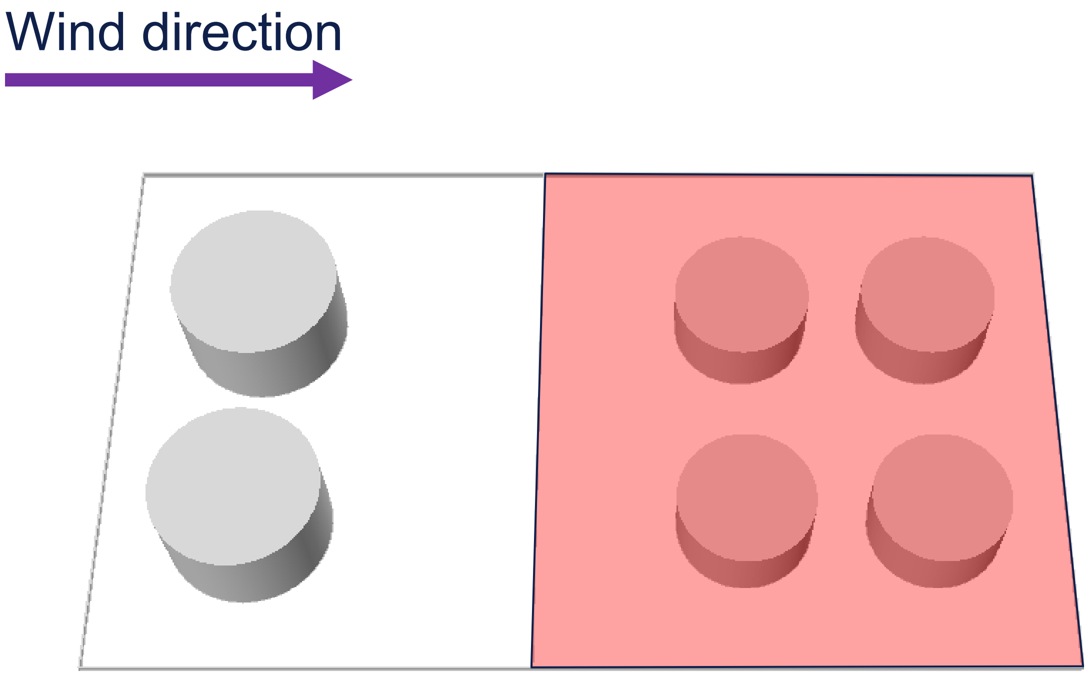


Radiation contours (y-plane)



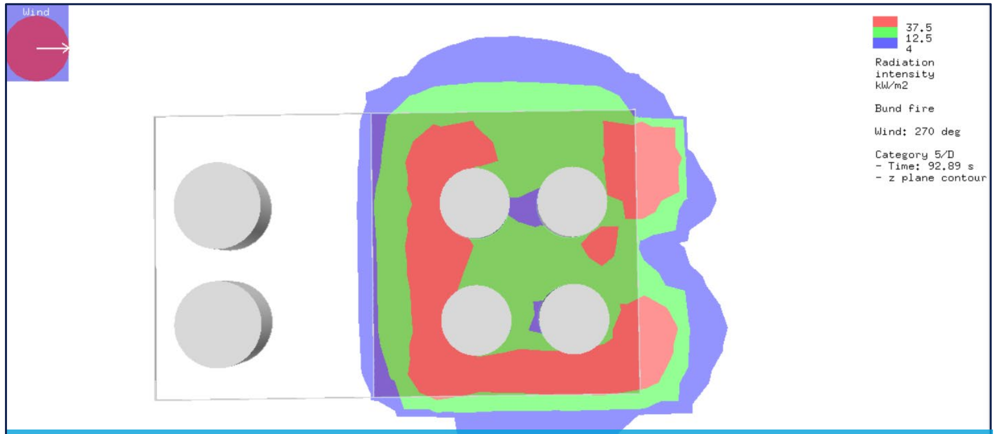
Temperature contours (y-plane)

Phast CFD – Pool fires
Bund fire

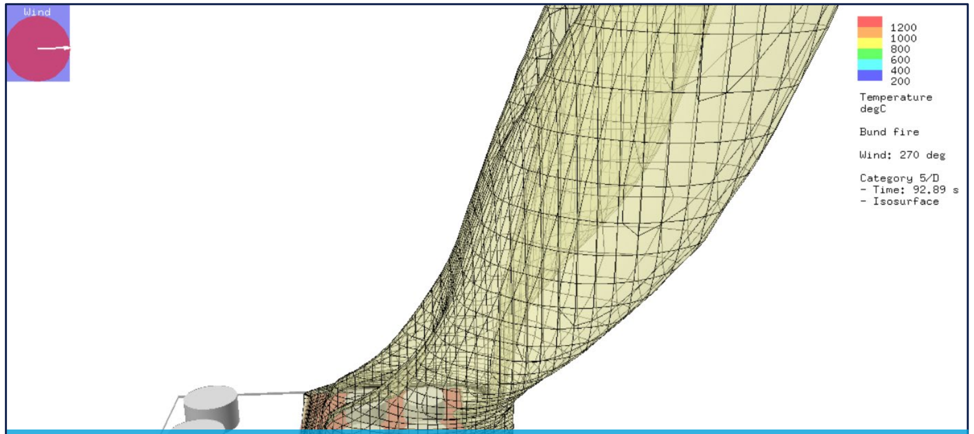


Octane bund fire

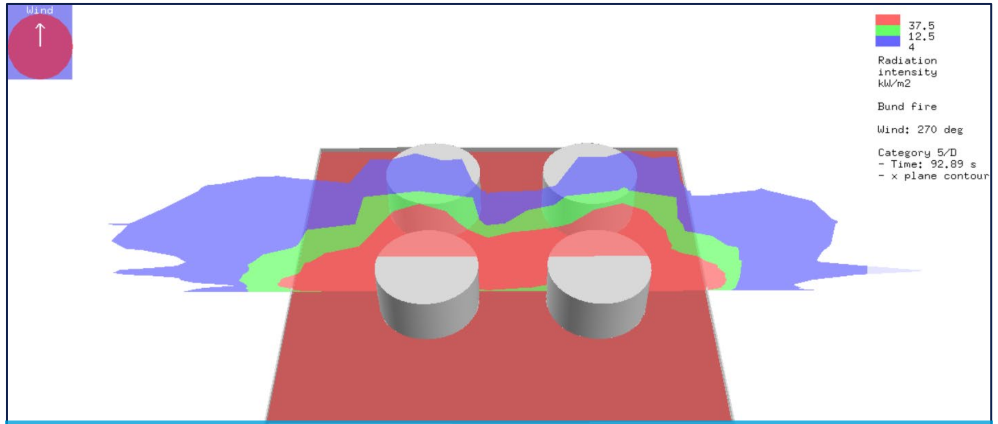
Phast CFD – Pool fires
Bund fire



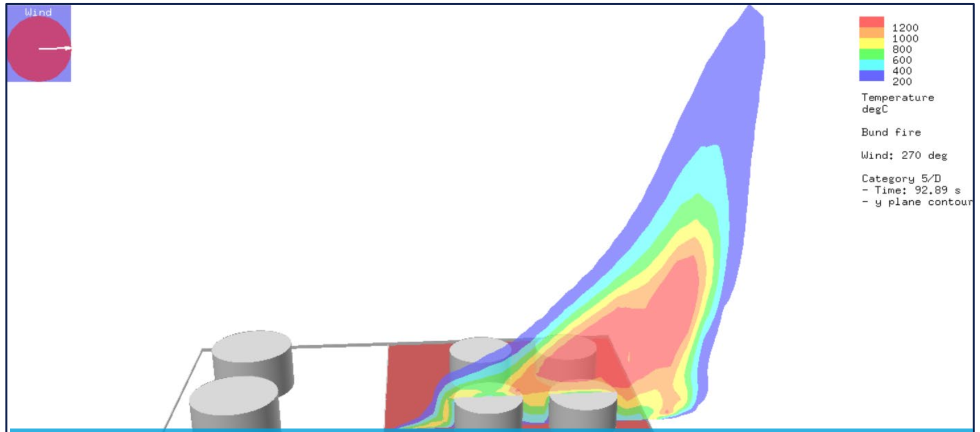
Radiation contours (z-plane)



Iso-surface for 100 degC

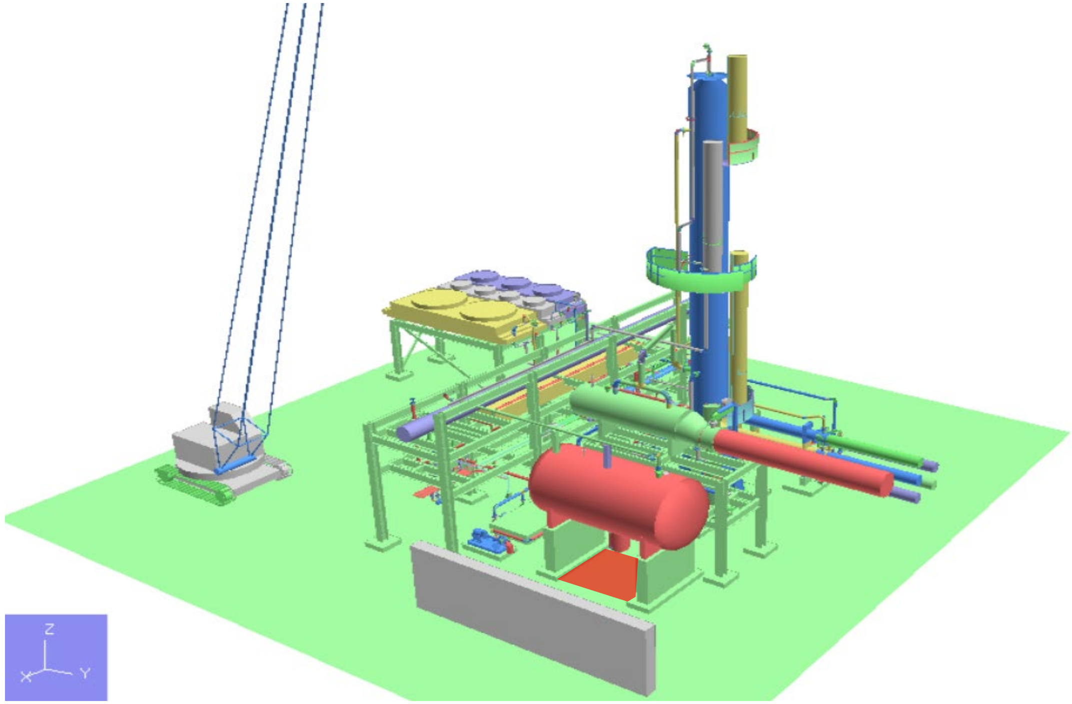


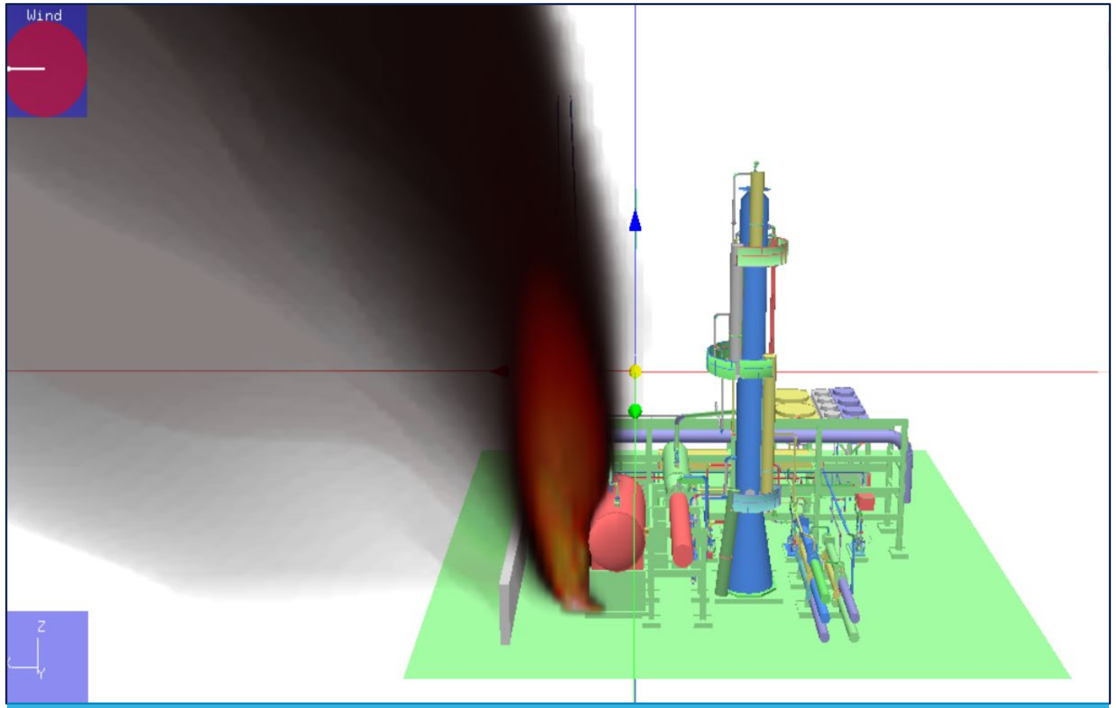
Radiation contours (x-plane)



Temperature contours (y-plane)

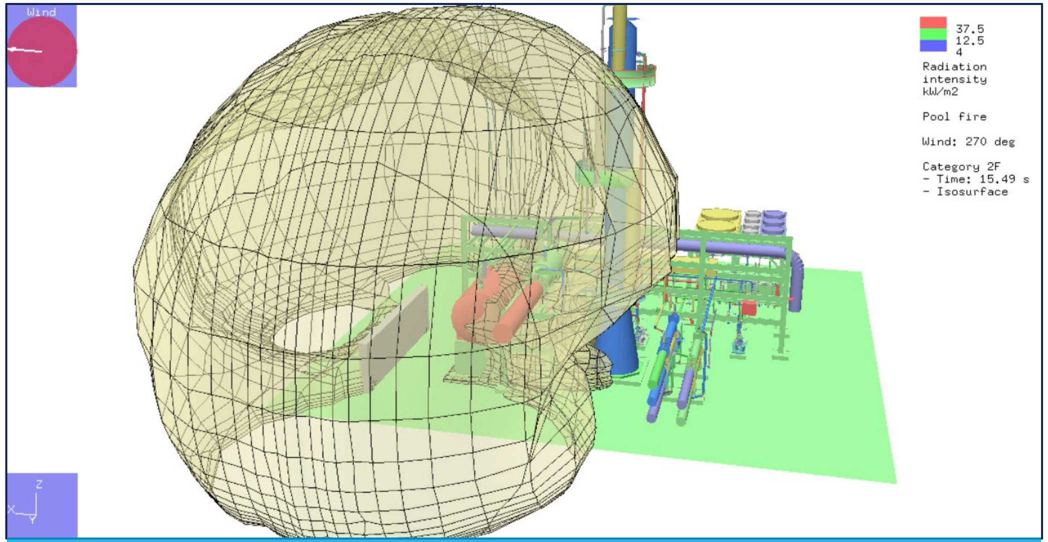
Phast CFD – Pool fires
Jet fire in process area



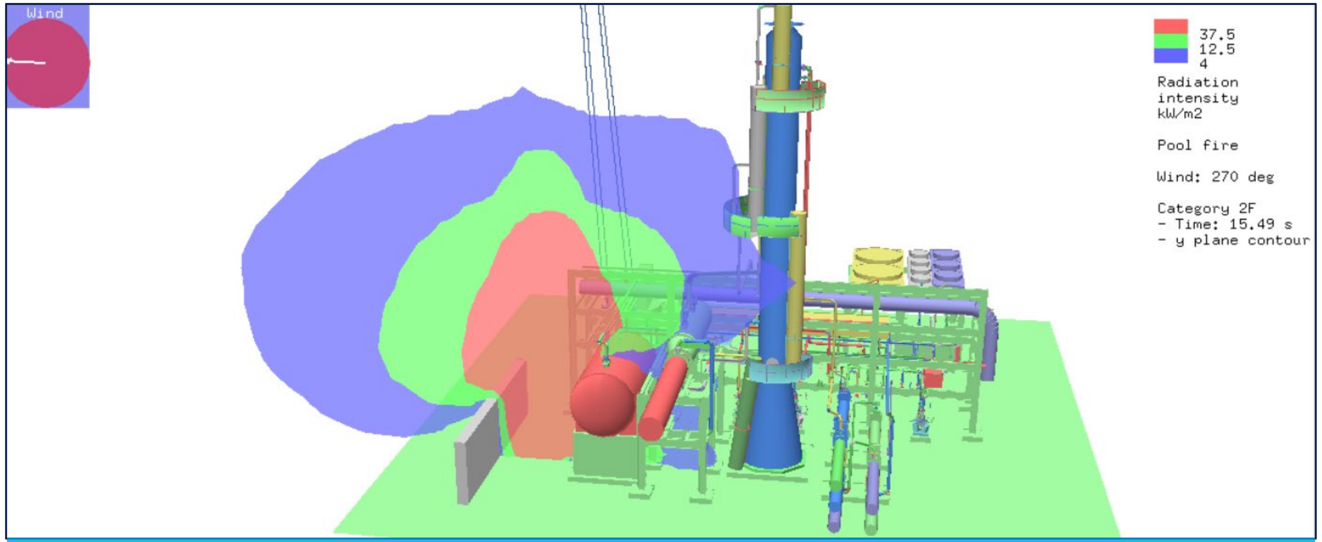


Heptane pool fire

Phast CFD – Pool fires
Jet fire in process area



Iso-surface for 3kW/m2



Radiation contours (y-plane)

Phast CFD – Jet fires

CFD simulations for jet fires in Phast, powered by KFX

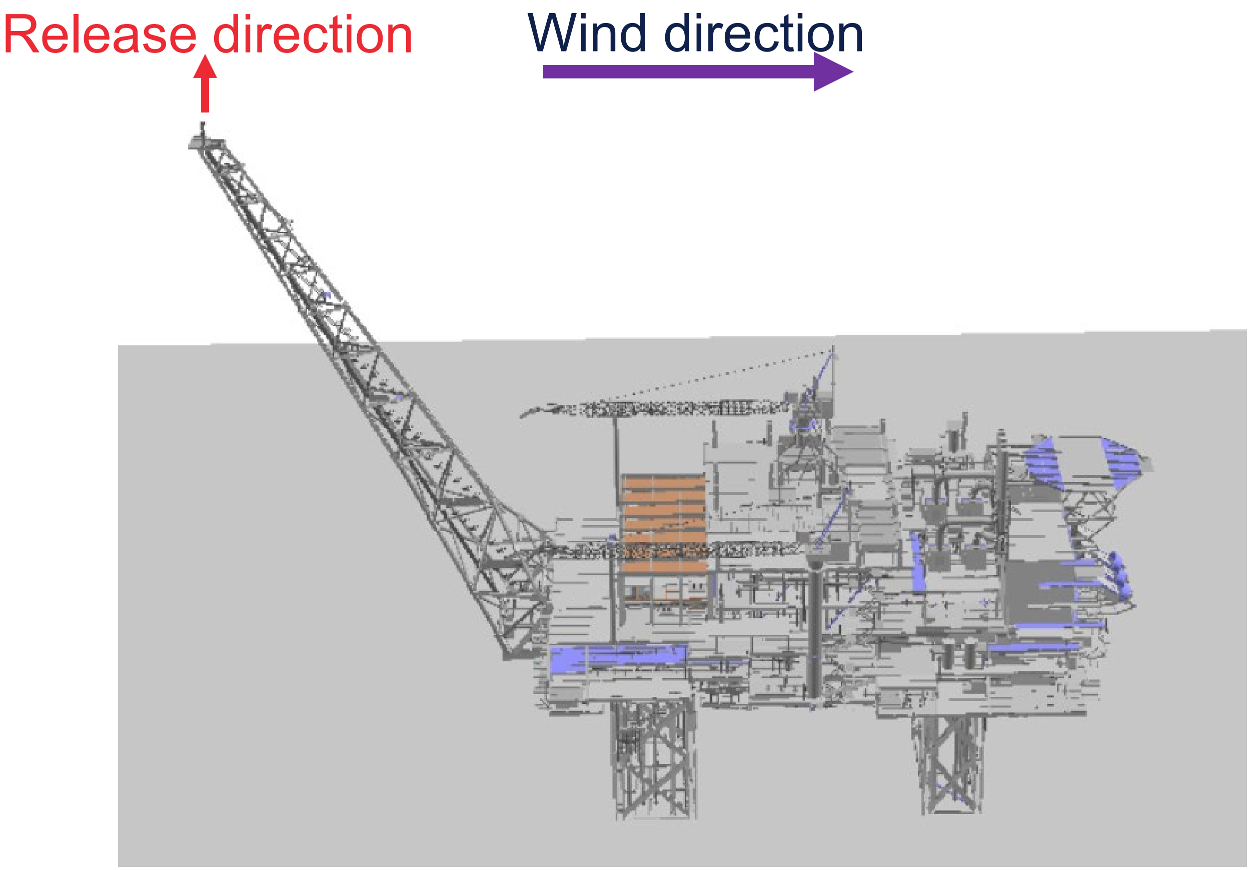
3D geometries and flames for visualisation

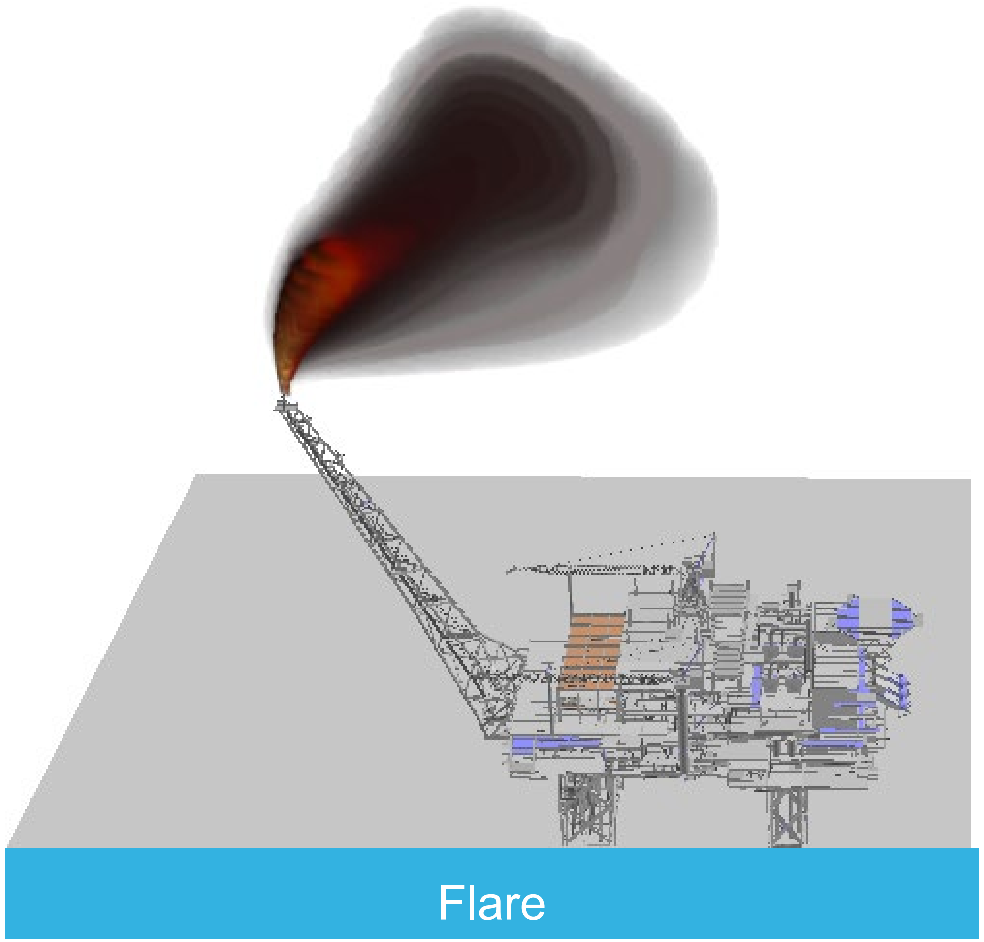
Independent release and wind directions

Temperature profiles

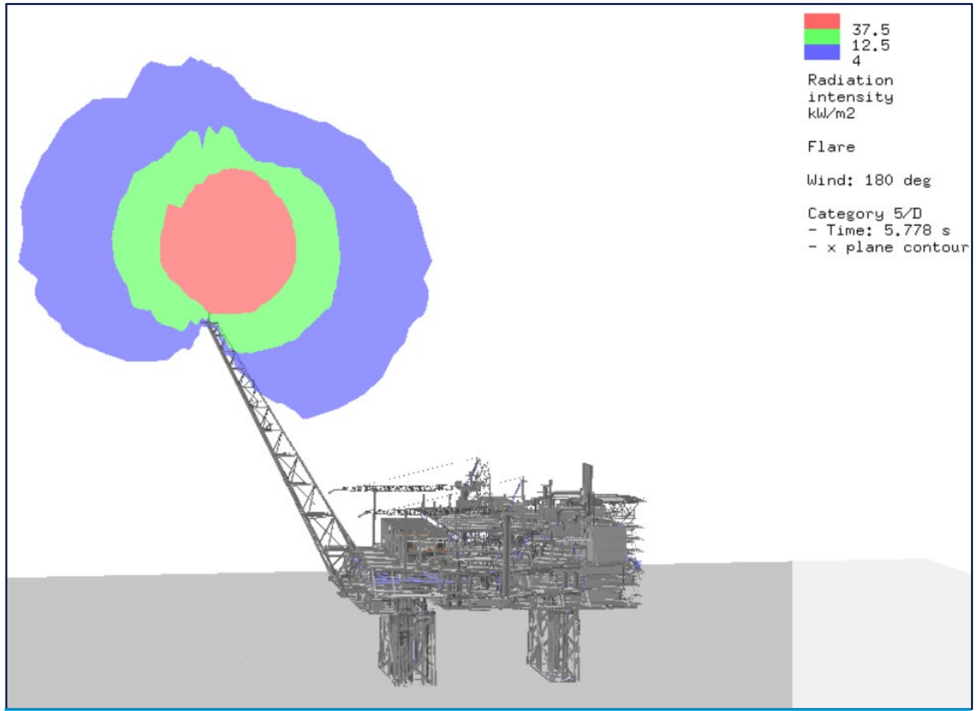
3D geometries used in the CFD calculations (Phast CFD – Jet fires license required)

Phast CFD – Jet fires
Flare

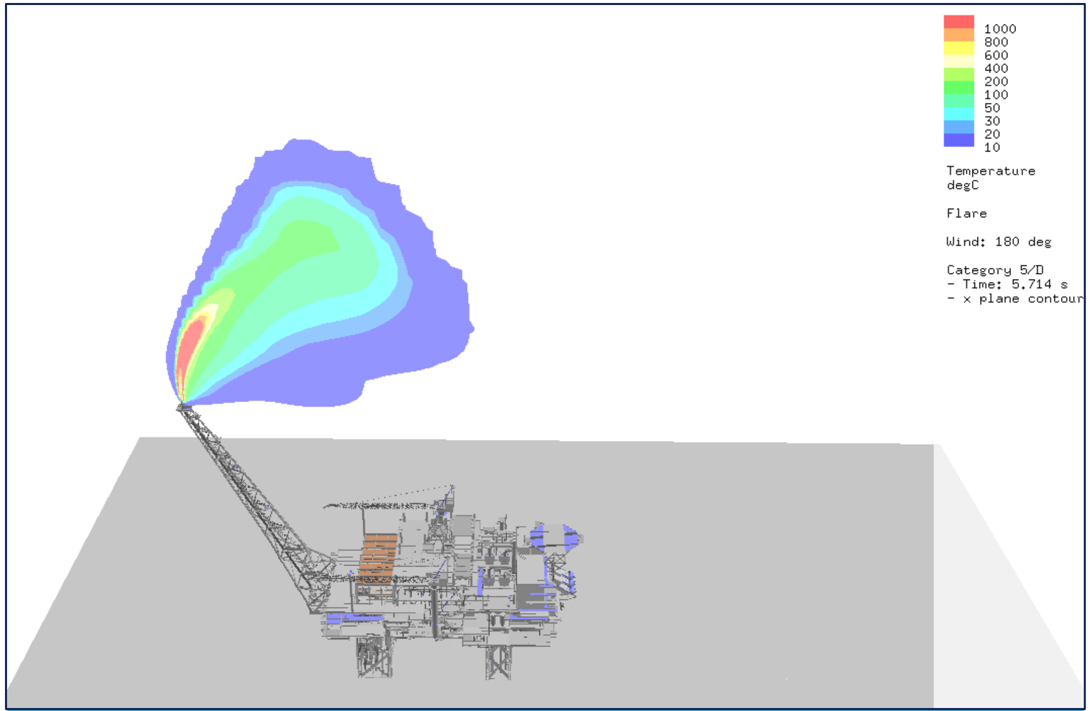




Phast CFD – Jet fires
Flare



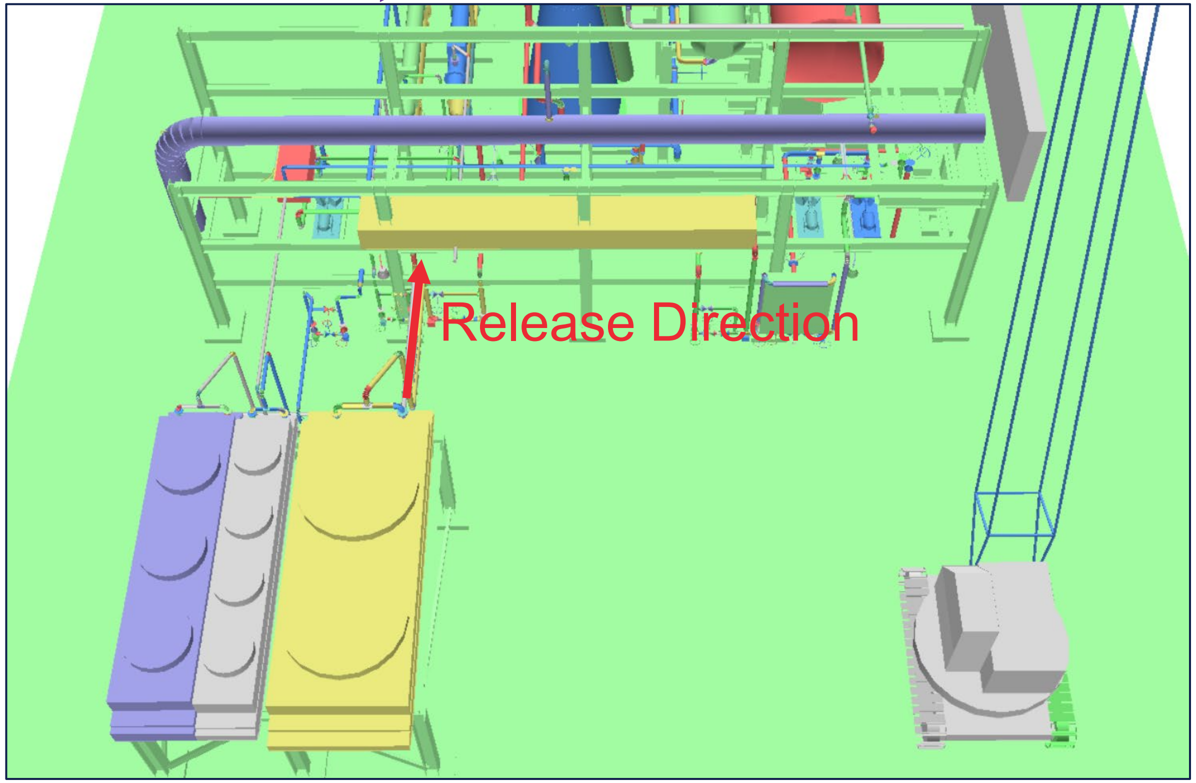
Radiation contours (x-plane)

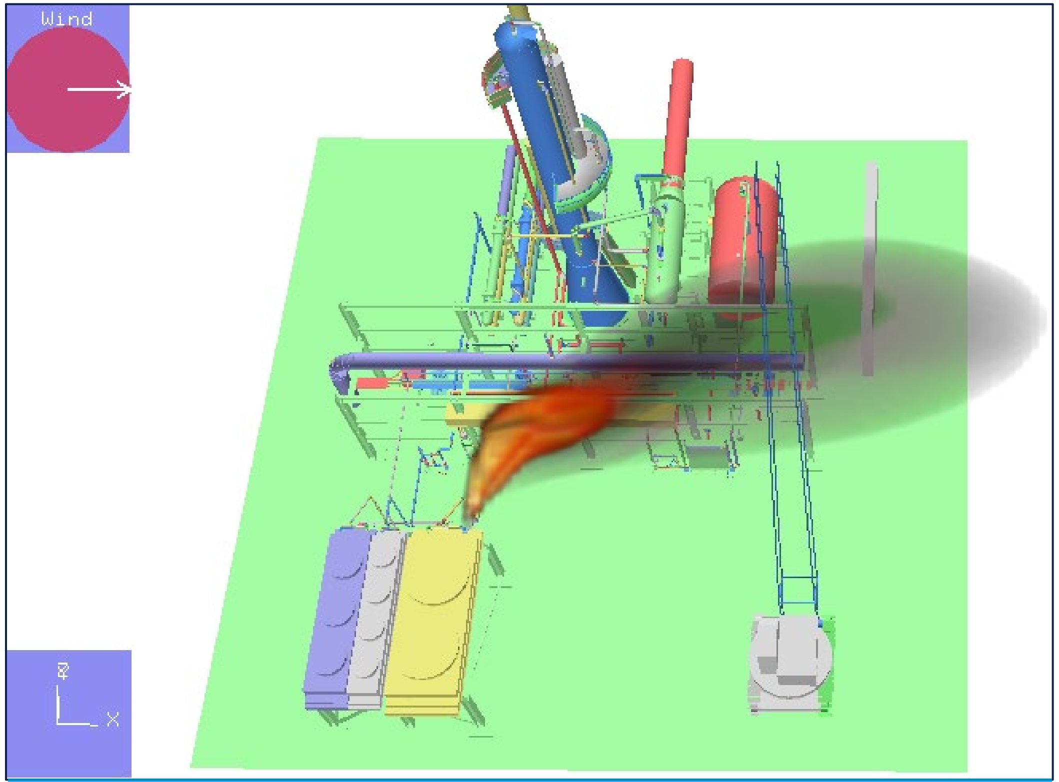


Temperature contours (x-plane)

Phast CFD – Jet fires
Jet fire in process area

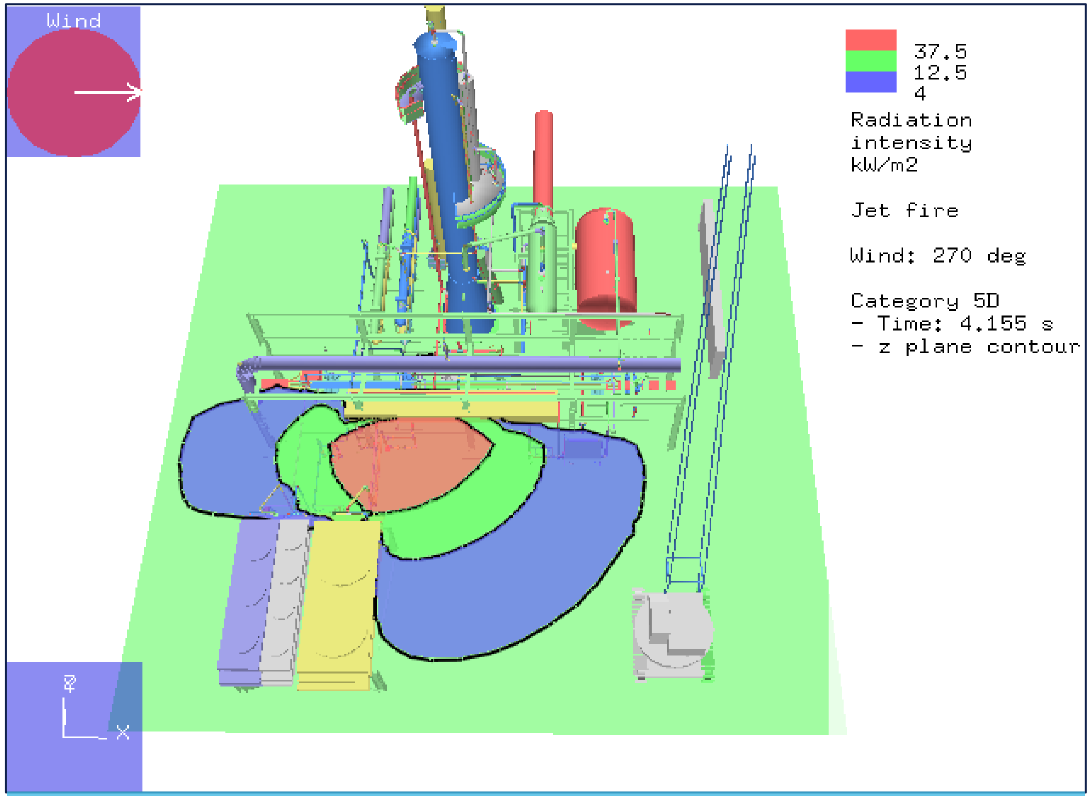
Wind direction



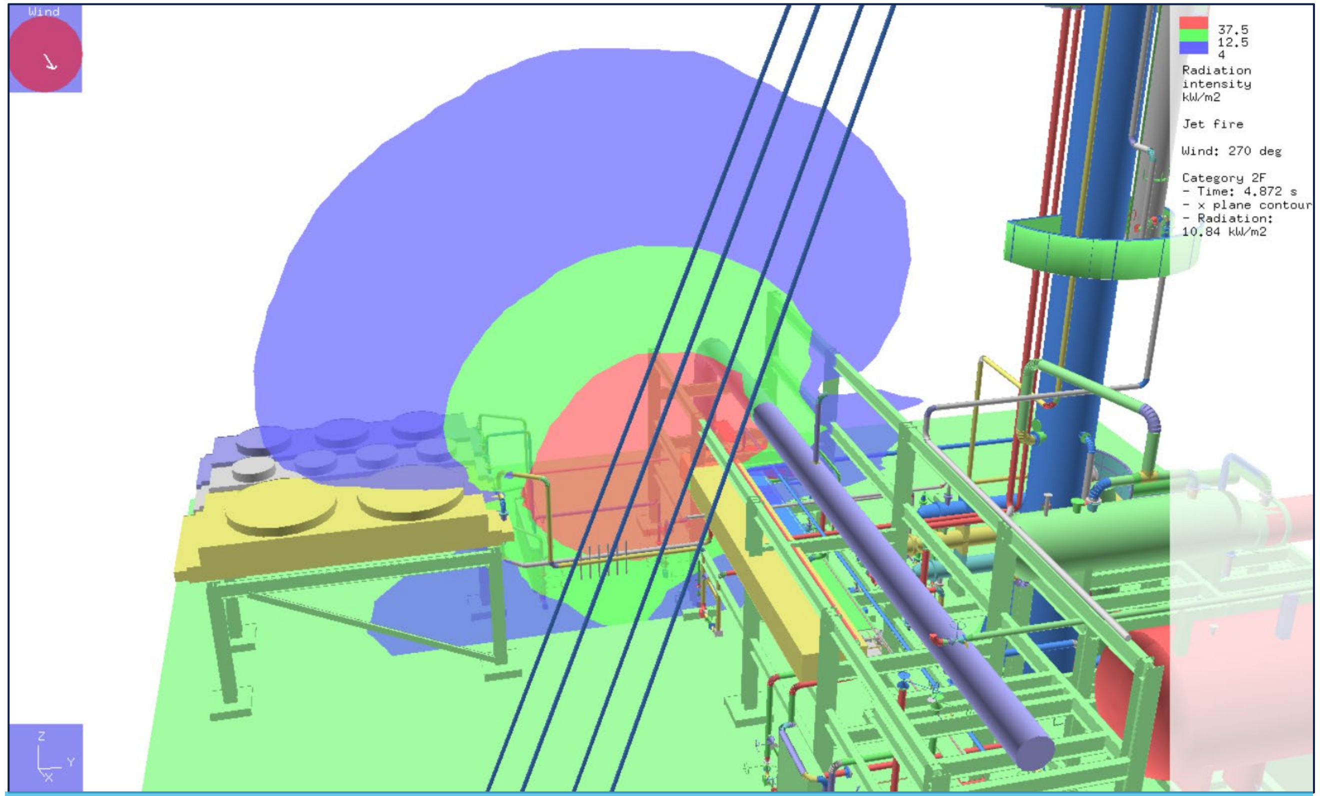


Methane cross-wind jet fire

Phast CFD – Jet fires
Jet fire in process area



Radiation contours (z-plane)



Radiation contours (x-plane)

Phast CFD – Dispersion

CFD simulations for material dispersion in Phast, powered by KFX

3D geometries and gas cloud for visualisation

Modelling the dispersion behaviour of an unignited release*

Cloud temperature and concentration profiles

3D geometries used in the CFD calculations (Phast CFD – Dispersion license required)

For liquid and two-phase releases: spray droplets and liquid (spread) pool area visualisation

* This will currently be limited to flammable materials only in the Phast v9.0 release.

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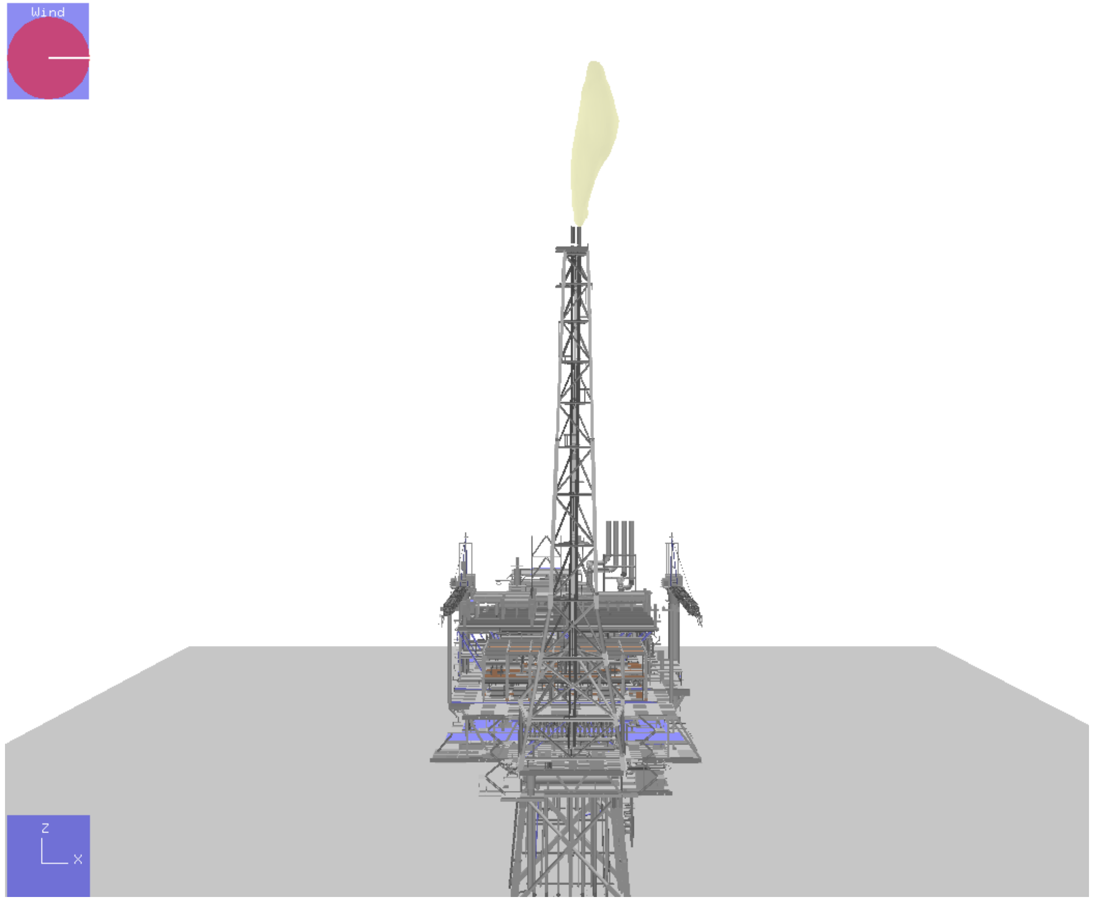
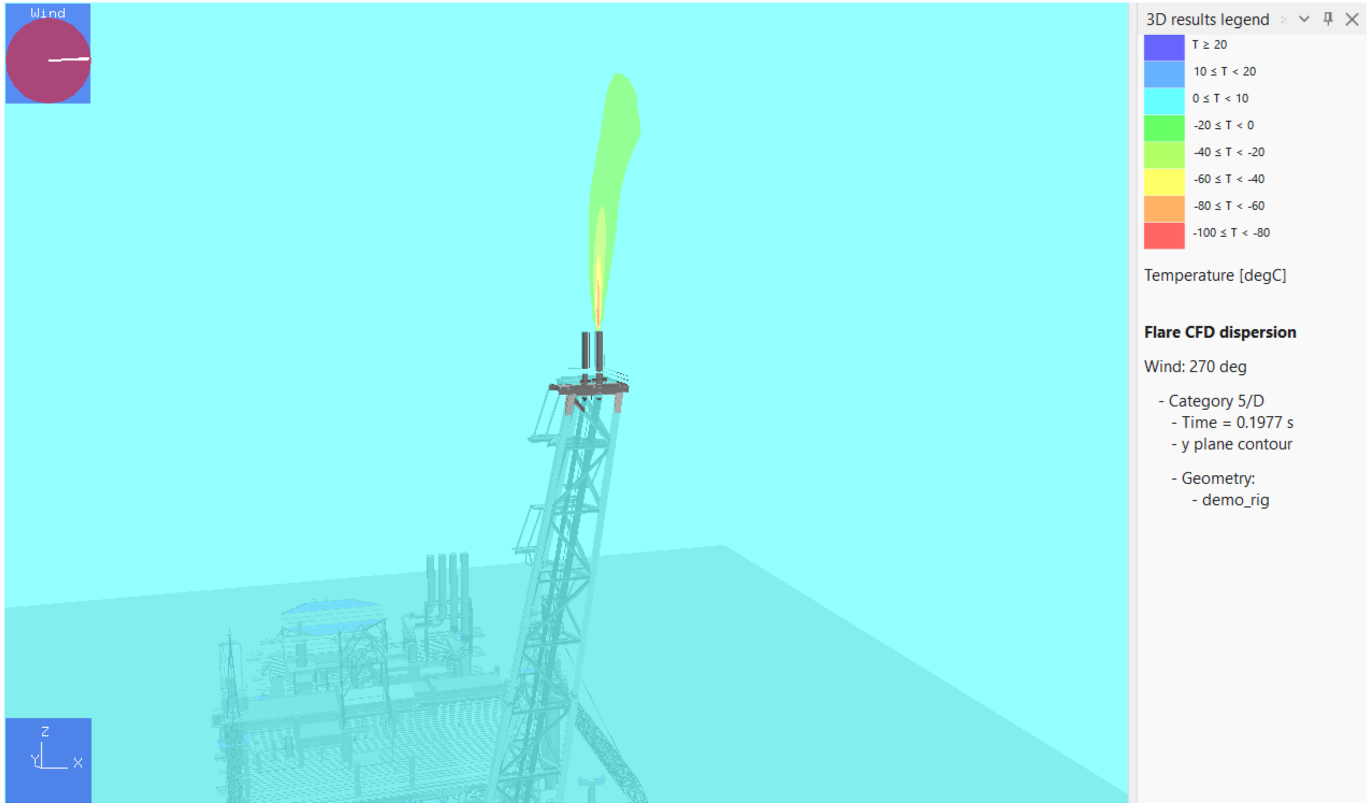
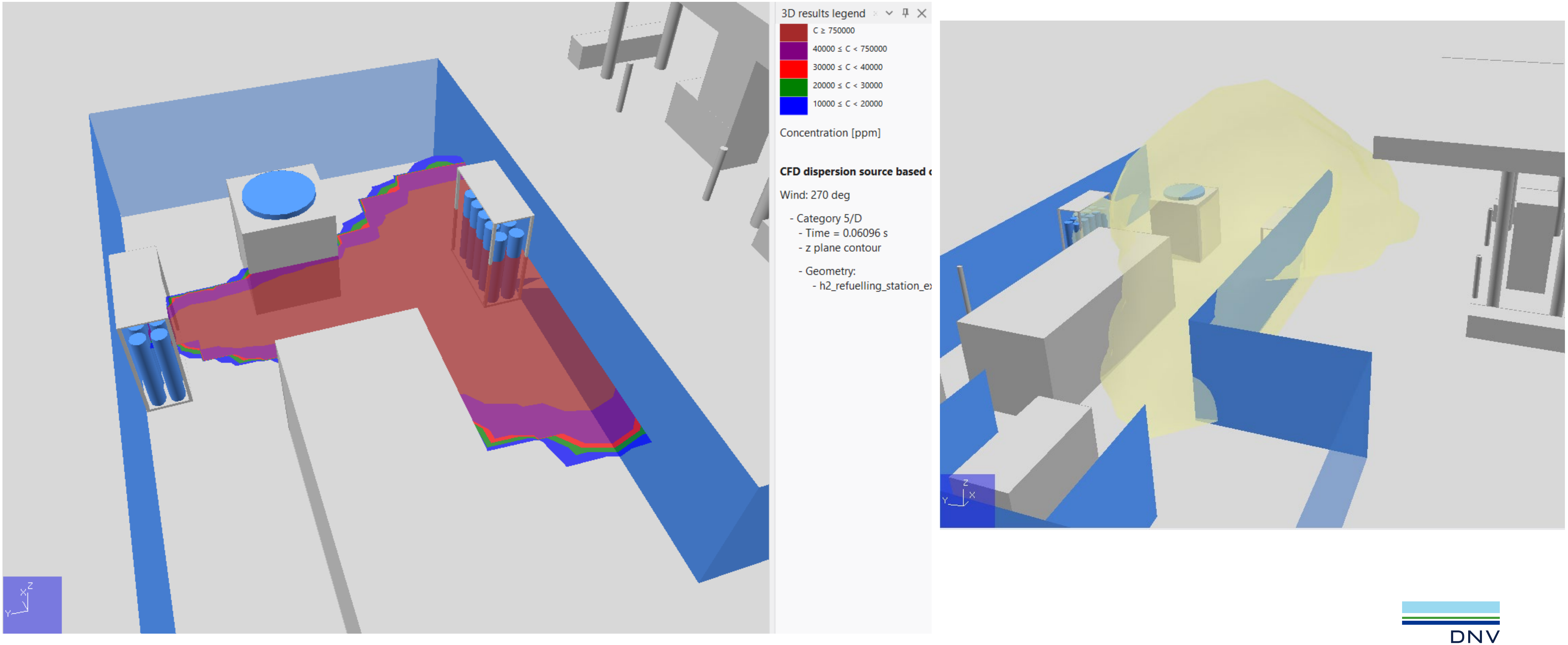
Phast CFD – Dispersion
Vent dispersion





Phast CFD – Dispersion
Hydrogen dispersion in refuelling station



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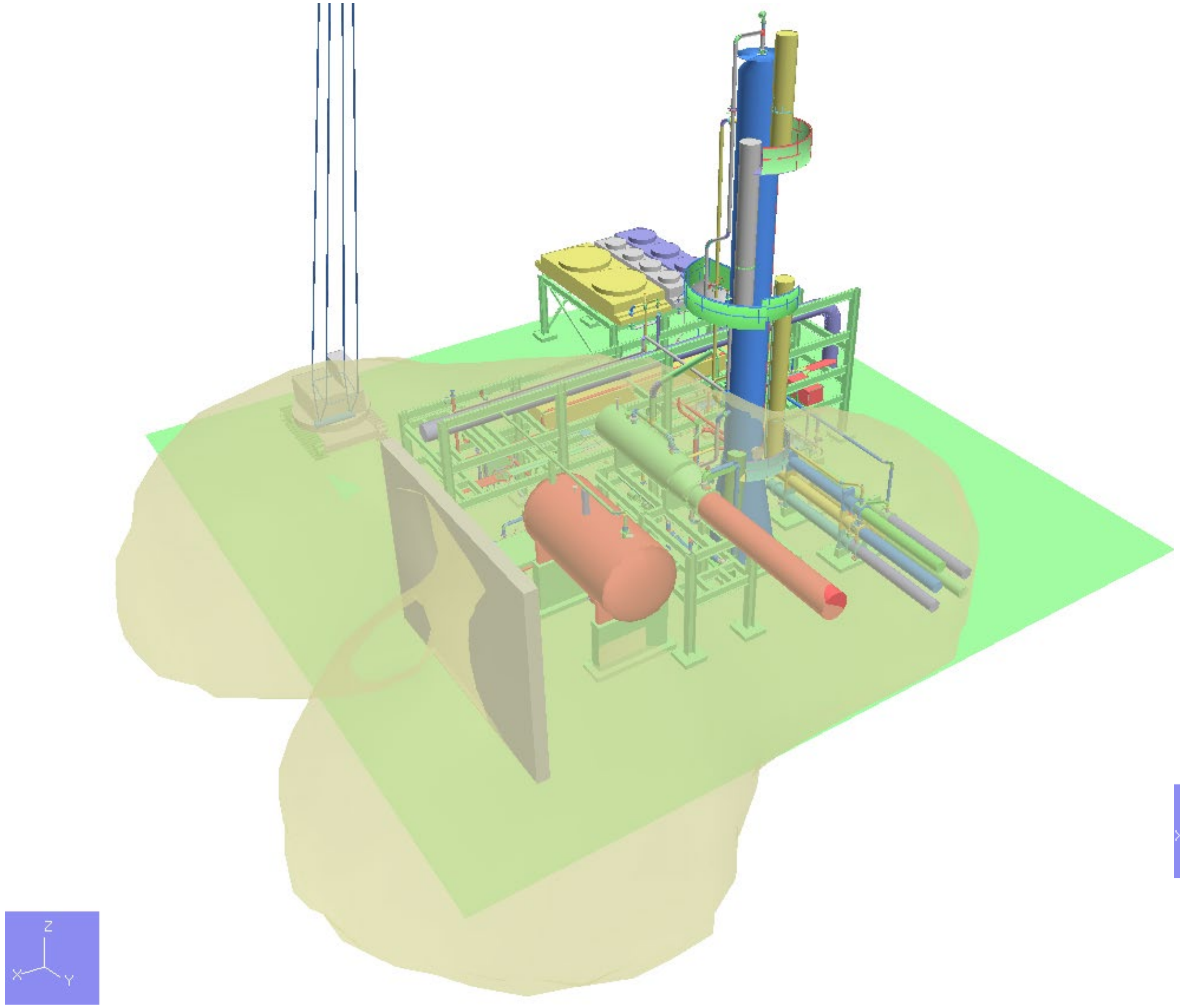
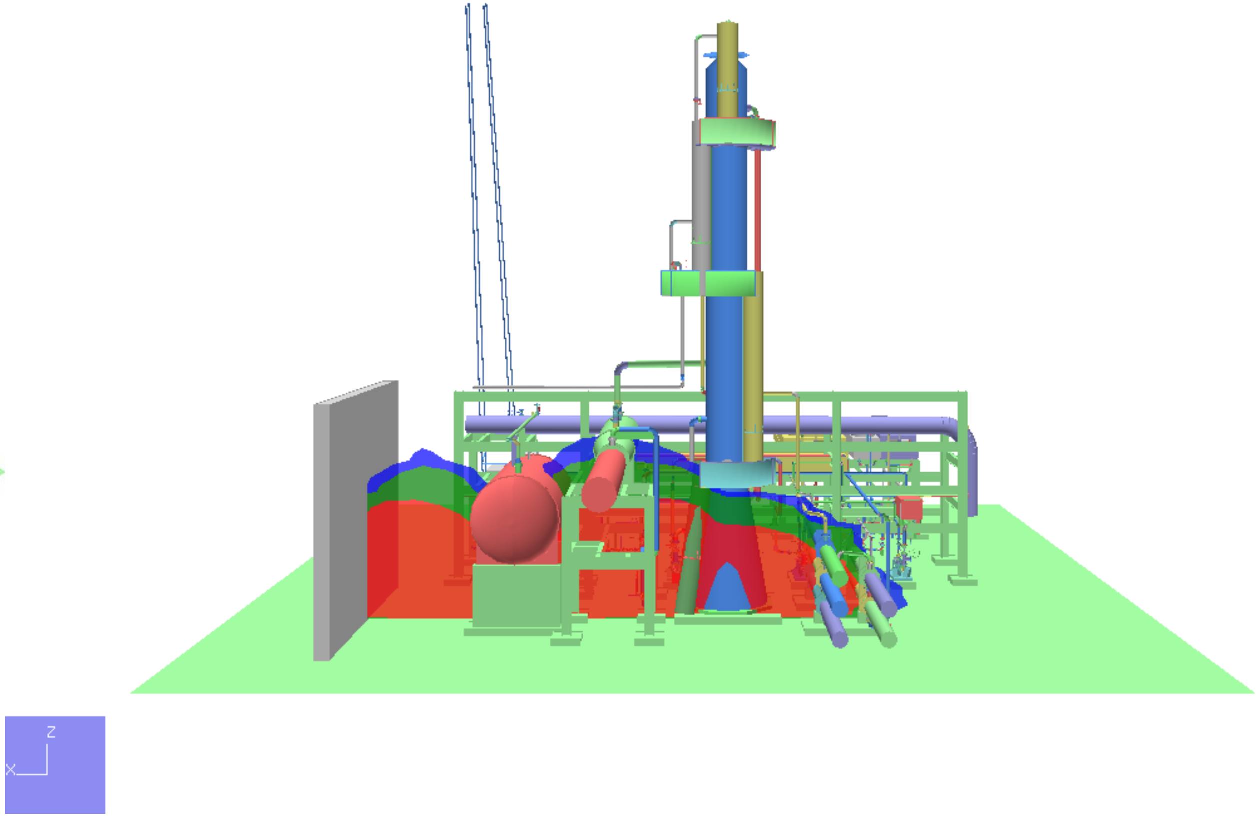
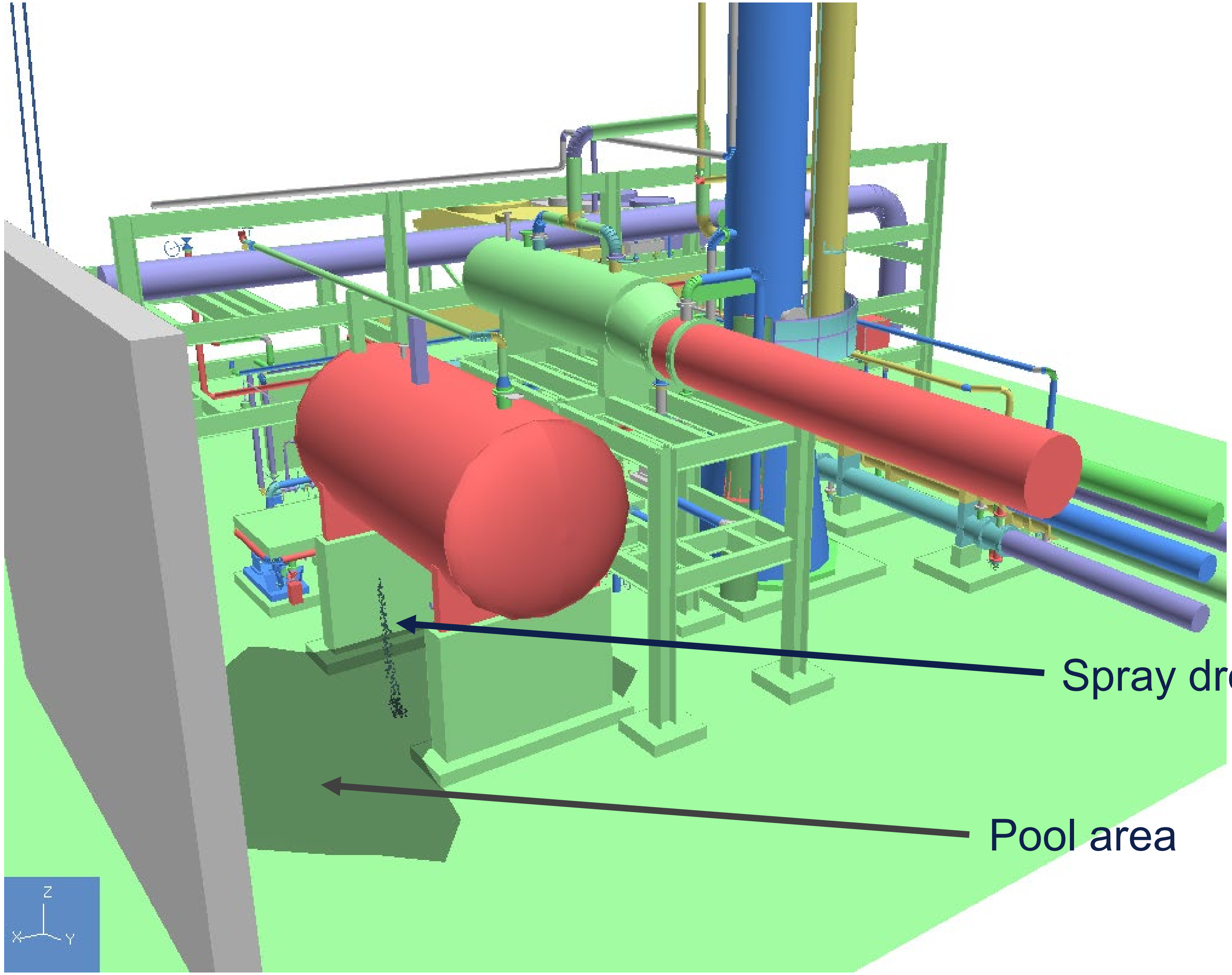
Phast CFD - Dispersion





Phast CFD – Dispersion



Spray droplets

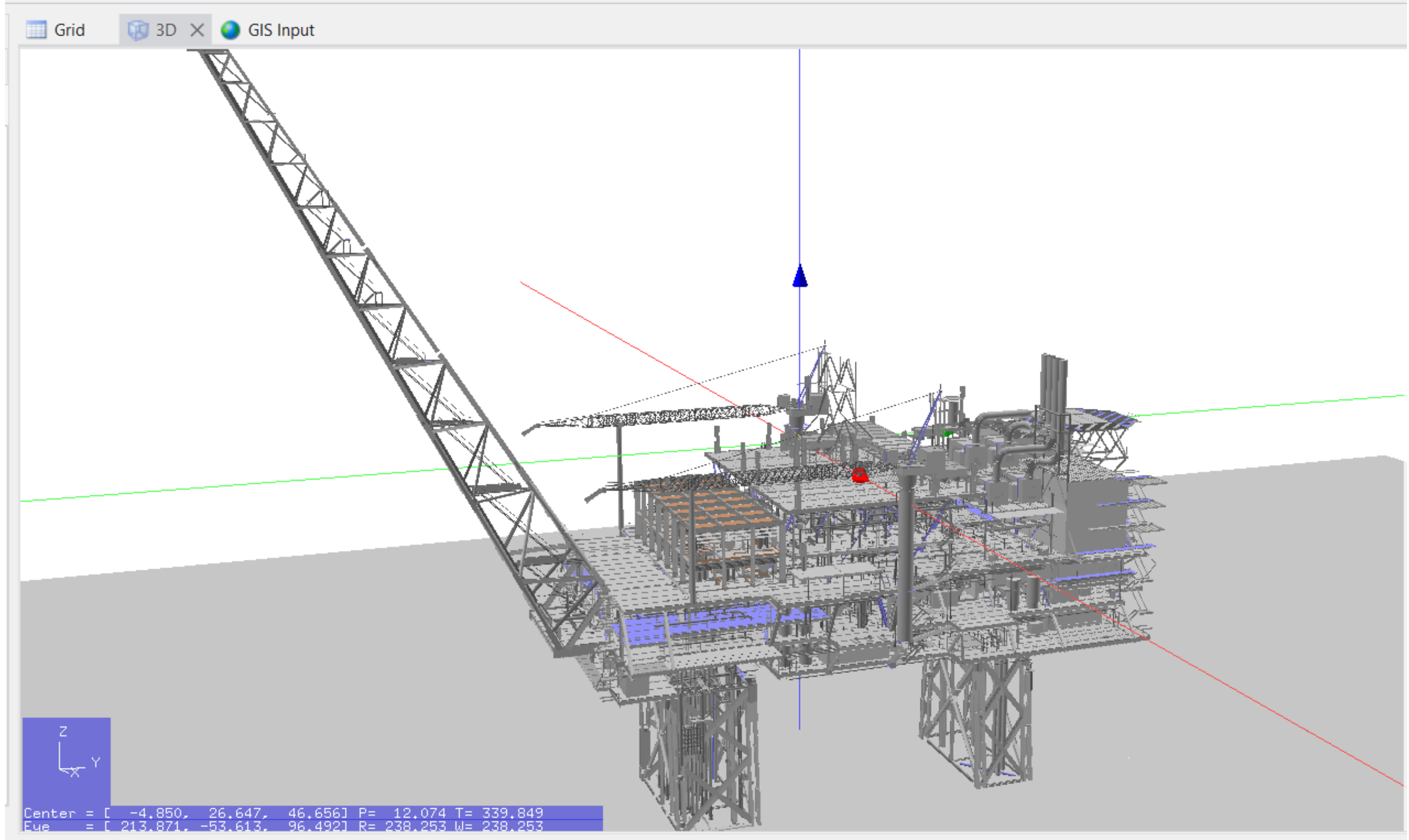
Pool area

Phast CFD and KFX

- Phast CFD is designed for users to run CFD without barriers
- KFX will continue to be developed, especially for safe energy transition
- Phast CFD is not created to replace KFX. More advanced scenarios require KFX, such as:
  - Delayed ignition or specific ignition sources
  - Fires from time varying leak rates
  - Simultaneous fires and vents
  - Flame detection
  - Deluge model
  - Wind field generated by helicopters
  - Export of fire heat loads to USFOS for structural response and PFP
- It is possible to export Phast scenarios into KFX to continue to run more advanced simulations

Use of external geometry files

- For complex geometry, external geometry files are required
- Typical 3D formats are supported, such as *.kfx, *.dgn, *.rvm, *.obj, *.mcr, *.cge, *.cgeo and *.stl
- If 3D file format is not in the above list, you may convert them into the supported formats, e.g. convert Navisworks .nwd file into obj file by using OBJ Converter



Summary

We are committed to provide 'state of the art' software for prediction of the consequence of flammable and/or toxic releases through cutting edge innovation

The conventional empirical models have been validated continuously and extensively which can generate results quickly and be used for safety design

The CFD modelling powered by KFX provides unique value for modelling dispersion, fire and explosions which take into account the geometry and generate additional results

The Phast CFD - Pool fires, Jet fires & Dispersion are available.

Phast CFD - Explosion is planned and will be available in 2024.

Phast CFD will be improved continuously, and we welcome any feedback

Features	Standard Phast	Phast CFD – pool fire extension licence	Phast CFD – jet fire extension licence	Phast CFD – dispersion extension licence
General features				
Insert 3D geometries and custom 3D objects for visualization	☑			
Independent release and wind directions in the CFD calculations	☑			
CFD batch running capability	☑			
CFD Pool fire features				
Pool fire modelling using CFD	☑			
3D geometries used in pool fire calculations	☒	☑	☒	☒
Radiation (CFD profiles)	☑			
Temperature (CFD profiles)	☑			
CFD Jet fire features				
Jet fire modelling using CFD	☑			
3D geometries used in jet fire calculations	☒	☒	☑	☒
Radiation (CFD profiles)	☑			
Temperature (CFD profiles)	☑			
CFD Dispersion features				
Dispersion modelling of unignited flammable material using CFD	☑			
3D geometries used in dispersion calculations	☒	☒	☒	☑
Animation of dispersion CFD results	☑			
Dispersion profiles	☑			
Temperature (CFD profiles)	☑			
Display of spray droplets and pool area for two-phase and liquid releases	☑			

DEMO of Phast CFD dispersion

Provide the best, most validated modelling

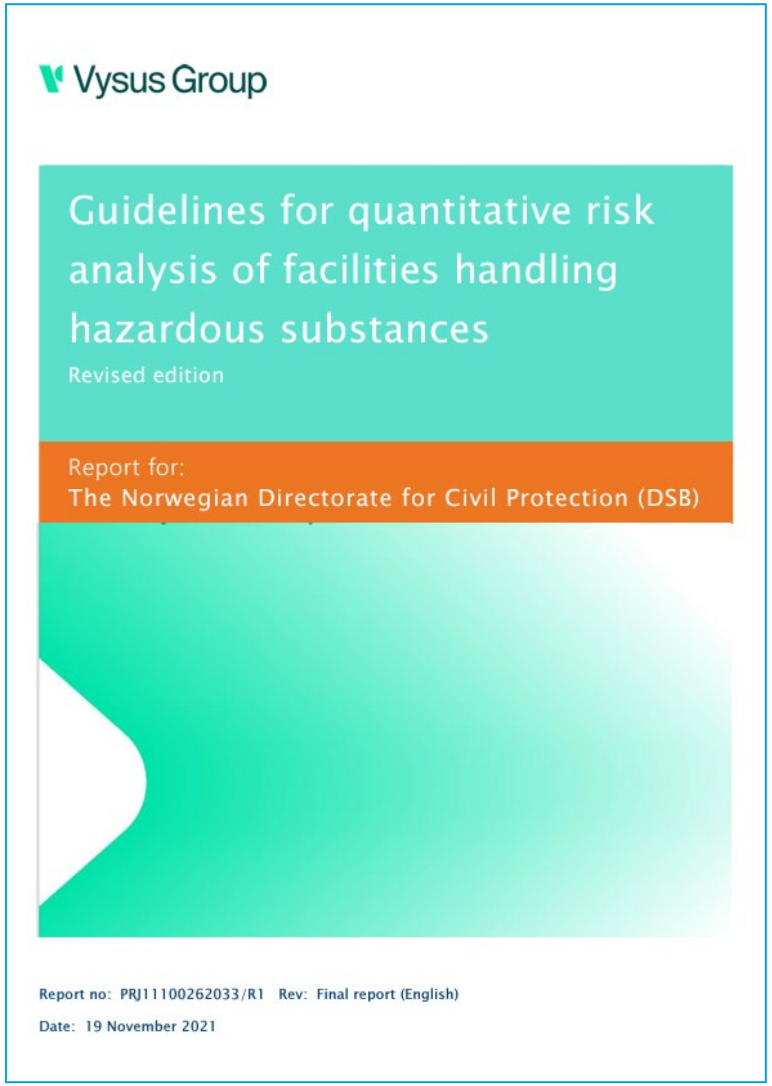
Lower the barriers to entry

Live in the customer environment

New ignition model

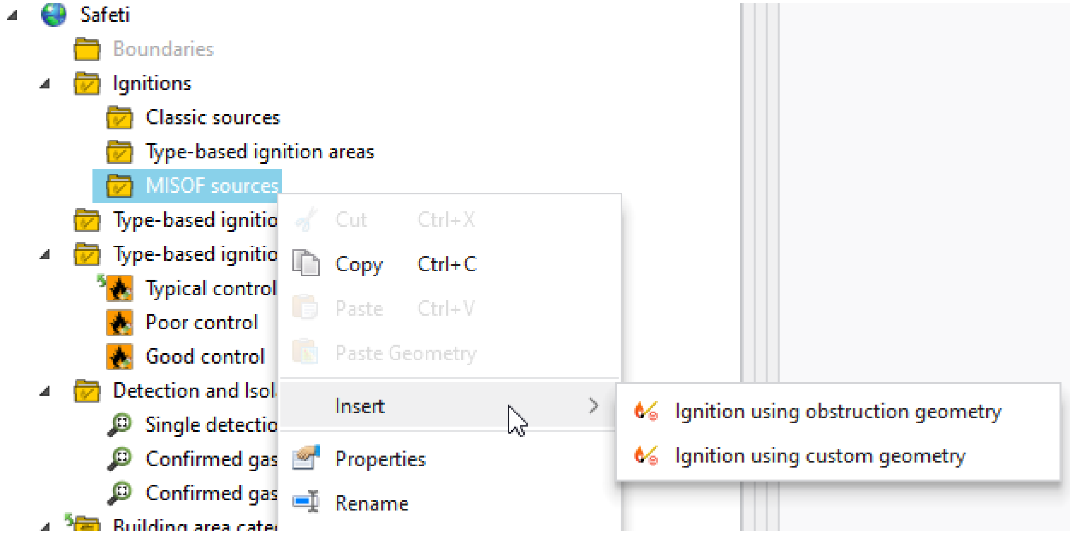
New ignition model in Safeti

- Based on the Norwegian Directorate for Civil Protection (DSB) ***Guidelines for quantitative risk analysis of facilities handling hazardous substances***
- The three methodologies described include:
  - MISOF
  - HYEX
  - Outside Plant Boundary



MISOF method

- Modelling of Ignition Sources on Offshore oil and gas Facilities (MISOF)
- Originally developed by Lloyd's Register and was adapted by Safetec for the DSB for the *modelling of ignition probability for use in quantitative risk assessments for land-based oil and gas facilities*
- It is recommended for defining the ignition probability given exposure to flammable fluid for the most important potential sources of ignition
- Requires an Explosions extension license



HYEX method

- Recommended method to calculate overall probability of ignition for hydrogen leaks
- The equations are currently not available in the software but can be entered manually using the immediate and delayed ignition probabilities fields

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THEORY

MPACT MODEL

DATE: September 2023

The MPACT model calculates the impact of the release of a toxic or flammable chemical on the population. It takes the results of the consequence calculations of the toxic and flammable effects, together with additional data on wind direction, ignition sources, levels of overpressure-generating obstructions, event location and frequency and superimposes them on the population to calculate the fatality risk in the surrounding area. The results are presented in a variety of forms including F-N data for societal risk, individual risk presented as grid over the calculation area, ranking tables for the contribution of each event, overall rate of death and other summary societal risk measures as defined by regulators in the Netherlands and UK. In addition to people risks the model can also be used to integrate financial consequences and risks.

Reference to part of this report which may lead to misinterpretation is not permissible.

5.22.9 The HYEX Ignition Model for Hydrogen

This model is referenced in the DSB Guidelines for quantitative risk analysis document[xxxi]. The overall ignition probability is specified as a function of mass release rate.

$$P_{HYEX} = min\left(1.0, 0.5\dot{m}^{0.87}, 0.267\dot{m}^{0.52}\right) \quad (119)$$

This probability is split between immediate and delayed in the ratio 1:2

$$P_{HYEX,immediate} = \frac{1}{3} P_{HYEX} \quad (120)$$

$$P_{HYEX,delayed} = \frac{2}{3} P_{HYEX} \quad (121)$$

As of the time of writing it is necessary to calculate these probabilities manually according to release rate. Then the immediate probability of ignition must be entered manually. The prescribed probability of delayed ignition then needs to be entered as

$$P_{i,du} = \frac{\frac{2}{3} P_{HYEX}}{1 - \frac{1}{3} P_{HYEX}} \quad (122)$$

The delayed ignition probability is distributed between time steps according to equation 81.

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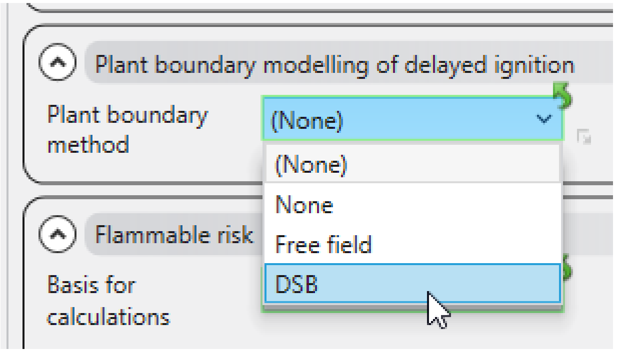
Outside plant boundary approach

- Designed to ensure delayed ignition outside of the plant boundary is considered
- Recommended to have a cumulative ignition probability (across all timesteps) equal to 1 outside the plant boundary
- This is suitable for all leaks resulting in a flammable cloud outside the plant boundary



Provide the best, most validated modelling

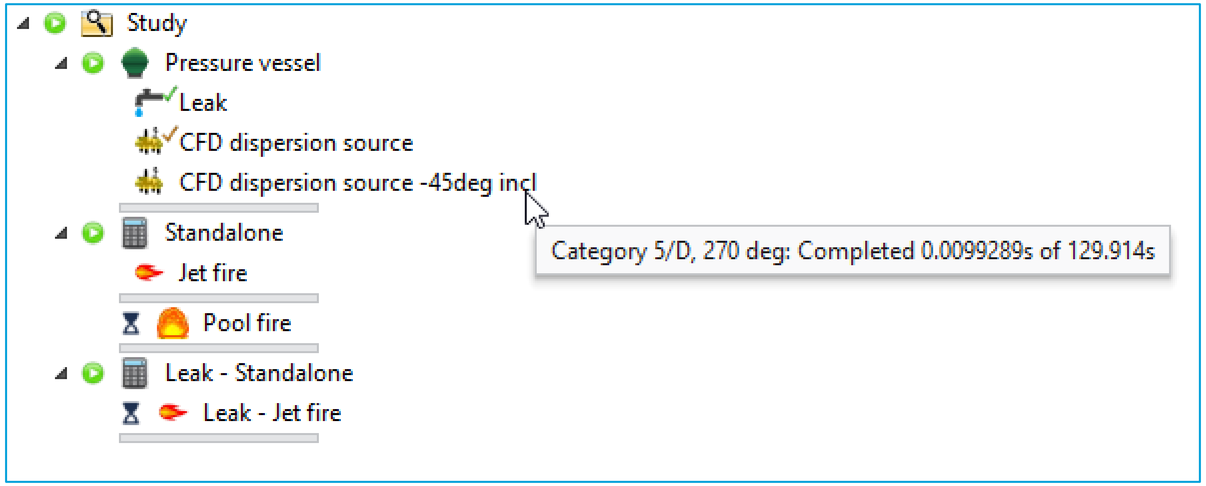
Lower the barriers to entry

Live in the customer environment

Batch runner

Batch-running capabilities

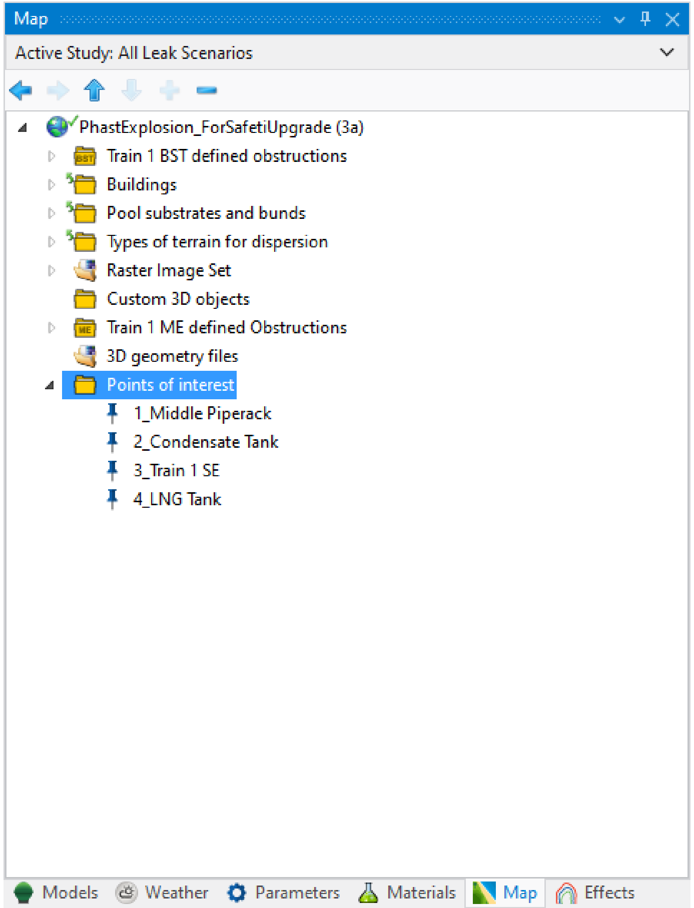
- Add scenarios to the queue
- Decide the number of CFD scenarios to run in parallel
- View the time steps for each CFD scenario in the queue



Points of interest

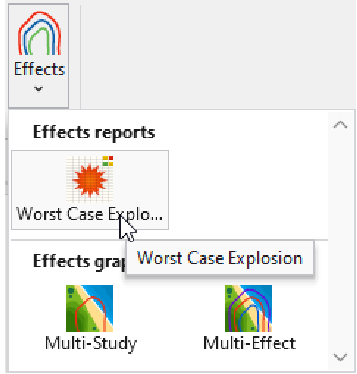
Points of interest

- Highly requested feature by users over the years
- Similar to Risk Ranking Points (RRPs) in Safeti
- Available for Explosions extension license holders
- The type of results presented depends on the Obstruction Sets selected in the study.



Points of interest

- Display the worst-case explosion results at various locations of interest within the Phast user interface
- Export worst-case explosion results in Excel for further data processing
- View all explosion results through the diagnostics feature



All Leak Scenarios w...explosion data

Drag a column header here to group by that column.

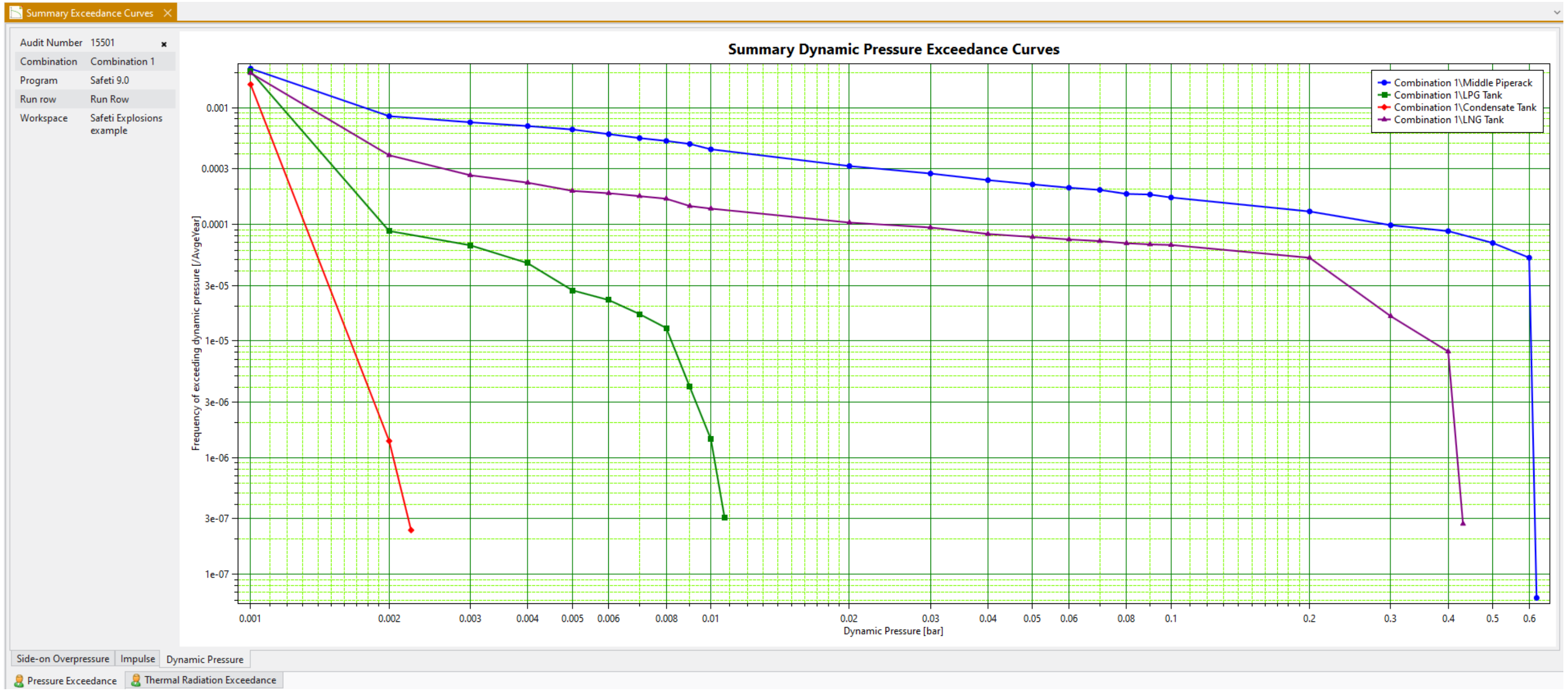
Path	Scenario	Point of interest	Worst case value (bar)	Weather	Wind direction (deg)	Ignition time (s)	Flammable mass (kg)	Explosion centre east (m)	Explosion centre north (m)	Dominant obstructed region
All Leak Scenarios\1_...	1_100mm	1_Middle Piperack	0.0541745	1_1.5/F	90	34.6683	65.4708	1068.96	322.794	C1 Main Piperack
All Leak Scenarios\1_...	1_100mm	2_Condensate Tank	0.00954125	1_1.5/F	108	34.6683	65.4708	1070.92	335.175	C1 Main Piperack
All Leak Scenarios\1_...	1_100mm	3_Train 1 SE	0.0483007	1_1.5/F	81	34.6683	63.9875	1069.98	316.667	C1 Main Piperack
All Leak Scenarios\1_...	1_100mm	4_LNG Tank	0.0122994	1_1.5/F	108	34.6683	65.4708	1070.92	335.175	C1 Main Piperack
All Leak Scenarios\2_...	2_100mm	1_Middle Piperack	1.01773	1_1.5/F	270	375.032	641.93	890.049	331.217	C1 Main Piperack
All Leak Scenarios\2_...	2_100mm	2_Condensate Tank	0.0177447	1_1.5/F	261	474.912	680.647	888.147	331.855	C1 Main Piperack
All Leak Scenarios\2_...	2_100mm	3_Train 1 SE	0.0537121	1_1.5/F	270	474.912	675.086	890.636	331.32	C1 Main Piperack
All Leak Scenarios\2_...	2_100mm	4_LNG Tank	0.0485078	1_1.5/F	99	474.912	402.051	751.375	331.792	C1 Main Piperack
All Leak Scenarios\3_...	3_100mm	1_Middle Piperack	0.0287873	1_1.5/F	270	10.9252	11.5285	767.297	338.866	C1 Main Piperack
All Leak Scenarios\3_...	3_100mm	2_Condensate Tank	0.00349315	1_1.5/F	261	10.9252	11.5285	767.041	342.114	C1 Main Piperack
All Leak Scenarios\3_...	3_100mm	3_Train 1 SE	0.00855387	1_1.5/F	288	10.9252	11.5285	766.281	332.45	C1 Main Piperack
All Leak Scenarios\3_...	3_100mm	4_LNG Tank	0.0145167	1_1.5/F	108	10.9252	11.5285	726.787	345.282	C1 Main Piperack
All Leak Scenarios\4_...	4_100mm	1_Middle Piperack	0.0517087	1_1.5/F	72	16.7505	62.516	1060.8	390.96	C10 Gas Dehydratio..
All Leak Scenarios\4_...	4_100mm	2_Condensate Tank	0.00949454	1_1.5/F	45	16.7505	62.0323	1070.53	375.37	C10 Gas Dehydratio..
All Leak Scenarios\4_...	4_100mm	3_Train 1 SE	0.0374991	1_1.5/F	45	16.7505	62.0323	1070.53	375.37	C10 Gas Dehydratio..
All Leak Scenarios\4_...	4_100mm	4_LNG Tank	0.0128876	1_1.5/F	90	16.7505	62.5152	1058.87	403.151	C10 Gas Dehydratio..
All Leak Scenarios\5_...	5_100mm	1_Middle Piperack	1.01744	1_1.5/F	207	0.925903	32.332	927.256	332.039	C1 Main Piperack
All Leak Scenarios\5_...	5_100mm	2_Condensate Tank	0.0116437	1_1.5/F	252	50.0278	165.116	969.898	327.751	C1 Main Piperack
All Leak Scenarios\5_...	5_100mm	3_Train 1 SE	0.0430855	1_1.5/F	261	50.0278	163.191	972.65	319.289	C1 Main Piperack

Side On | Dynamic | Duration | Impulse | Stagnation | Reflected

Exceedance curve – dynamic pressure

Exceedance curve – dynamic pressure

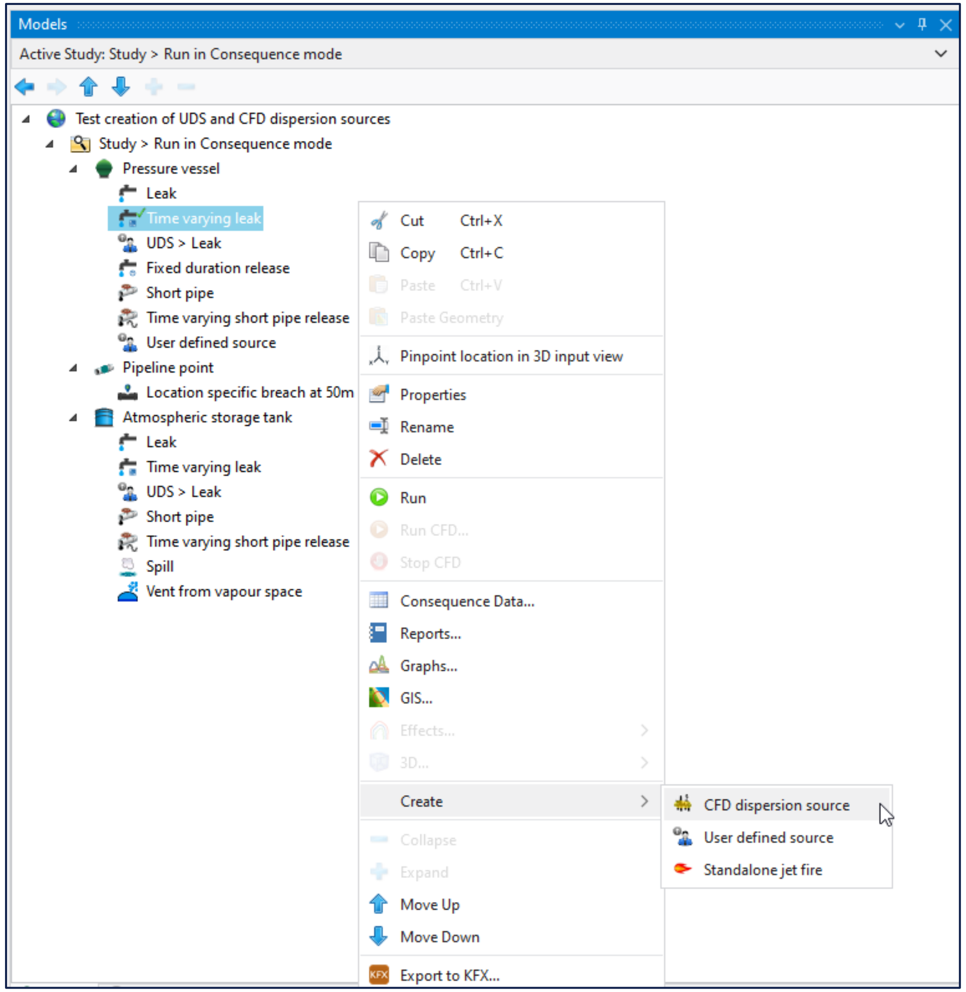
- Highly requested feature by users
- Users can view dynamic overpressure exceedance curves, in addition to the side-on overpressure and impulse results, at various risk ranking points



Further improvements

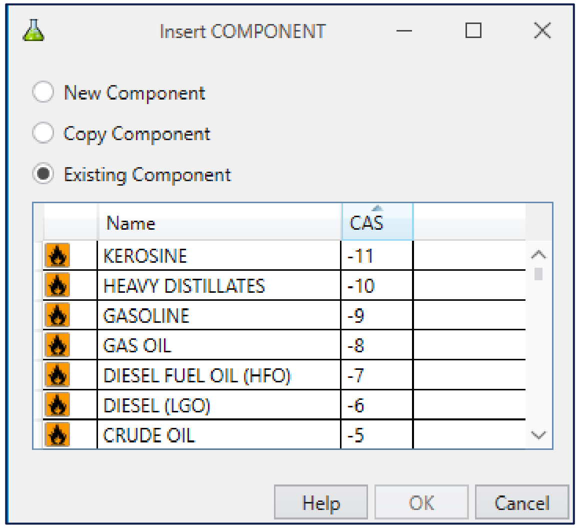
Further improvements

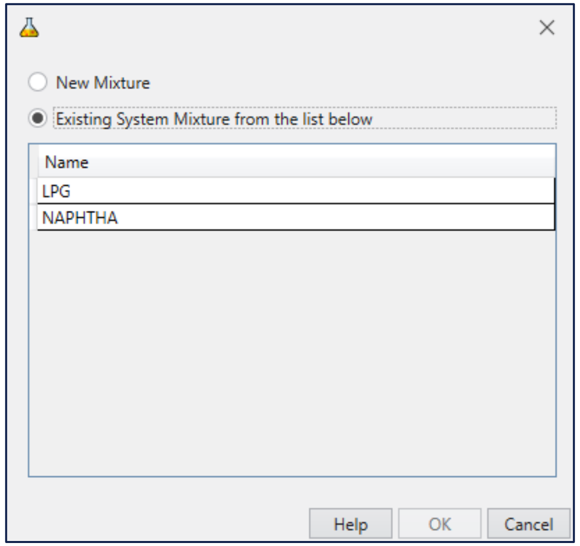
- Simplification of the user-defined source scenario
- New representative materials
- New diagnostics functionality
- Technical documentation
- Hydrogen and Carbon Dioxide guidance documentation updates



Further improvements

- Simplification of the user-defined source scenario
- New representative materials
  - Crude Oil [based on the physical properties of n-Octane]
  - Diesel (LGO) [based on the physical properties of n-Undecane]
  - Diesel Fuel Oil (HFO) [based on the physical properties of n-tetradecane]
  - Gas Oil [based on the physical properties of n-dodecane]
  - Gasoline [based on the physical properties of n-octane]
  - Heavy Distillates [based on the physical properties of n-tetradecane]
  - Kerosine [based on the physical properties of n-nonane]
  - LPG [based on the physical properties of 70 mol% propane and 30 mol% of n-butane]
  - Naphtha [based on the physical properties of 33.3 mol% n-pentane, 33.3 mol% n-hexane, and 33.3 mol% n-heptane]
- New diagnostics functionality
- Technical documentation
- Hydrogen and Carbon Dioxide guidance documentation updates





Further improvements

- Simplification of the user-defined source scenario
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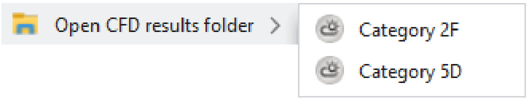
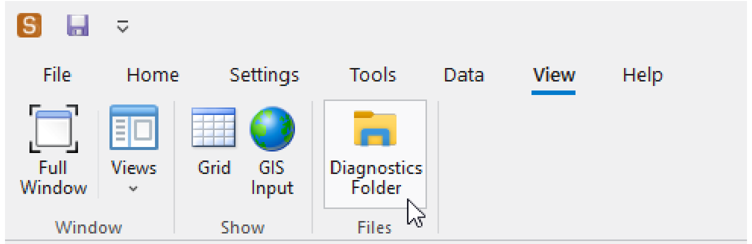
1

Viewing full details of behaviour of CFD calculations



2

Viewing diagnostics results files easily



Further improvements

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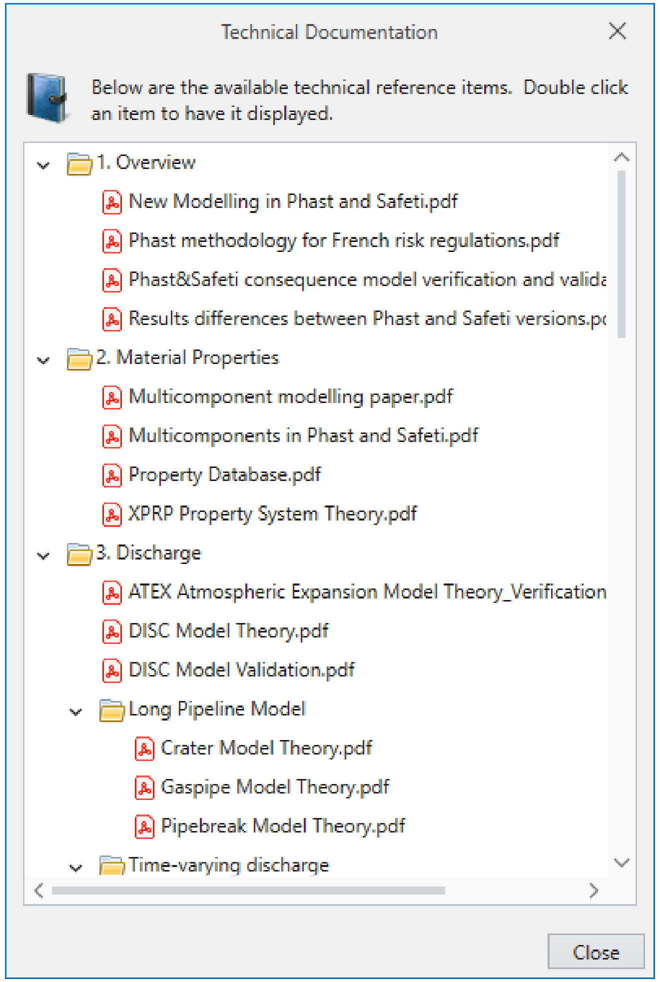

Further improvements

- Simplification of the user-defined source scenario
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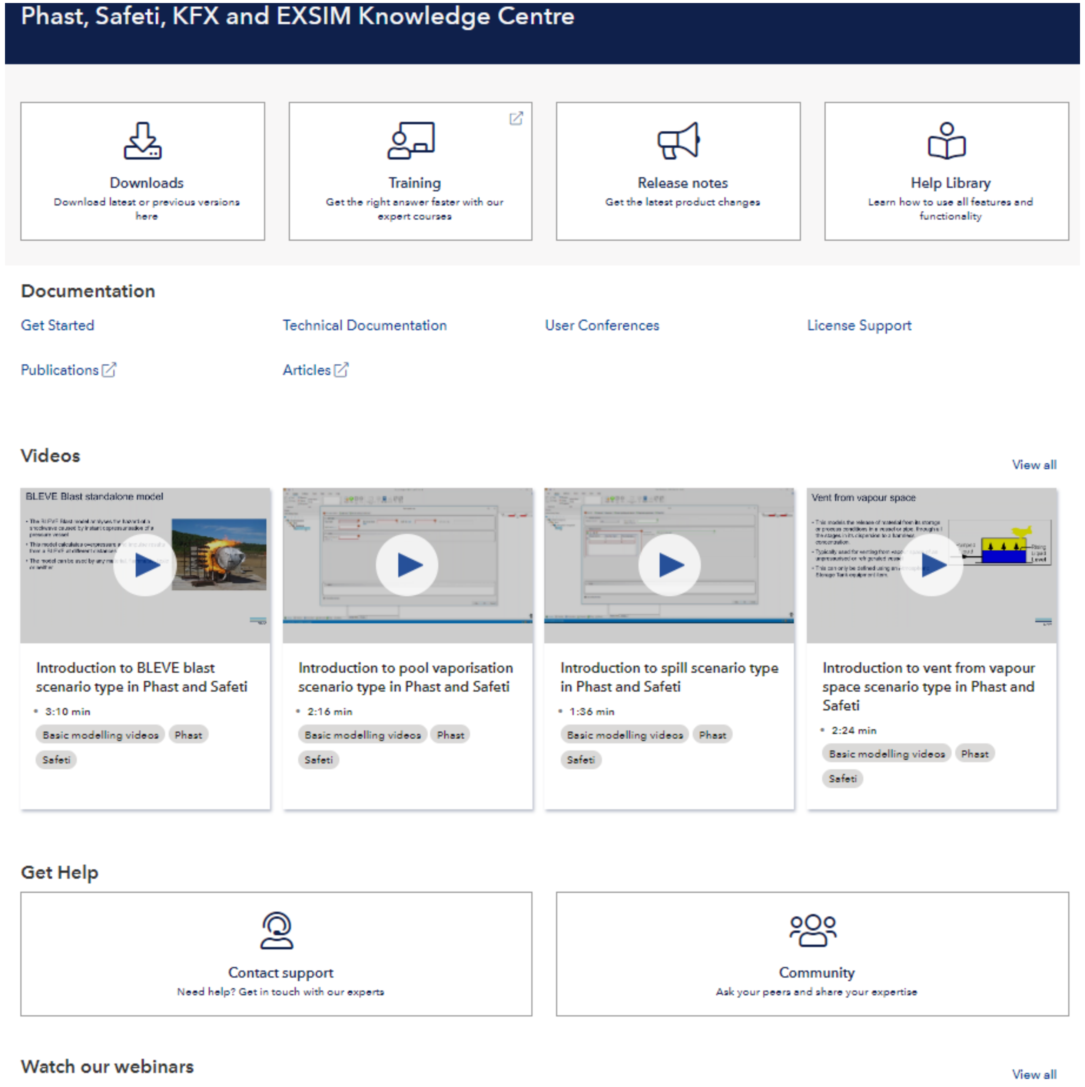
Knowledge Centre

- Customer Portal has now been retired
- Access downloads, FAQs, how-to videos, webinars, etc. in the Knowledge Centre

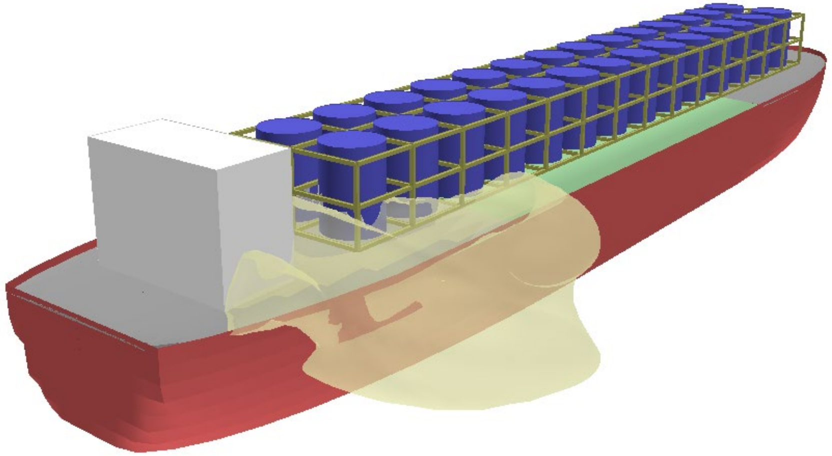
- Link: https://myworkspace.dnv.com/knowledge-centre/phast-and-safeti/

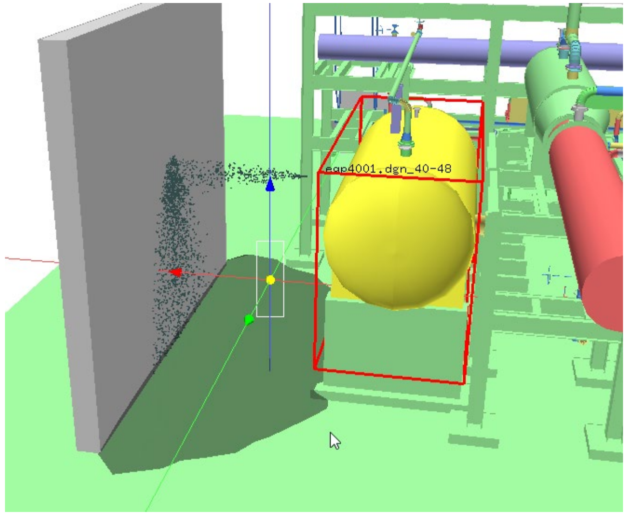


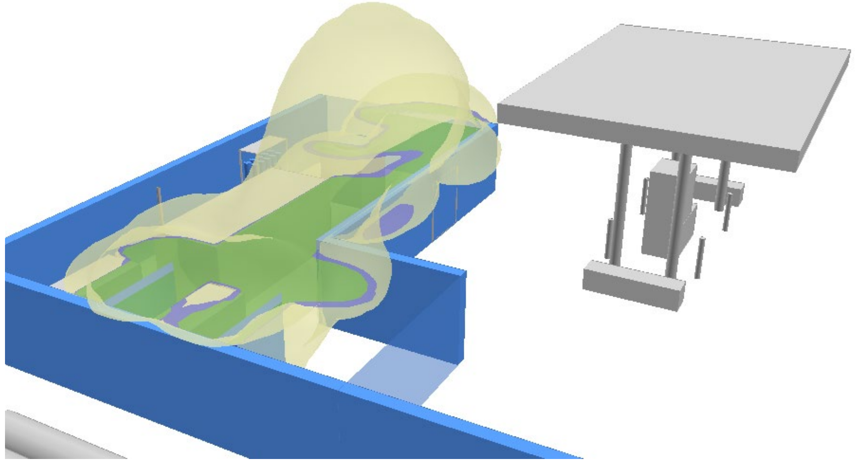
Main highlights

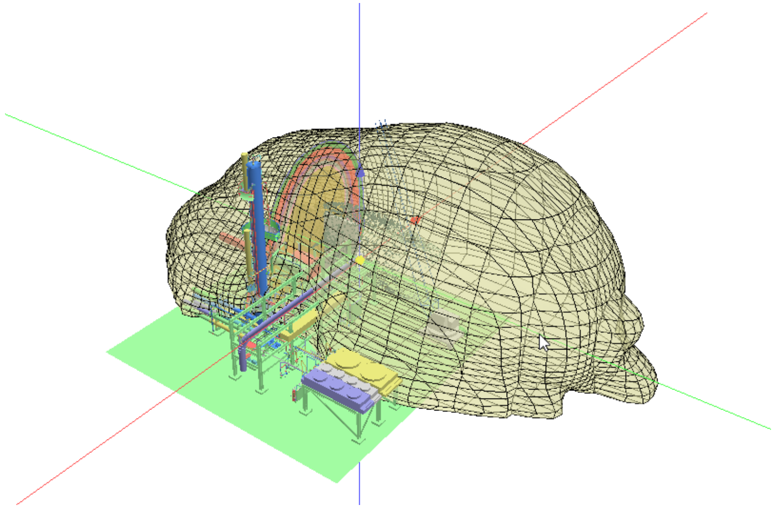
- Version 9.0 will include:
  - Phast CFD dispersion
  - Batch runner
  - Points of interest
  - New ignition model
  - Exceedance curve – dynamic pressure
  - And other new features
- An active Phast CFD extension license is required in order run CFD calculations accounting for 3D geometries
- Version 9.0 is expected to be released in December 2023

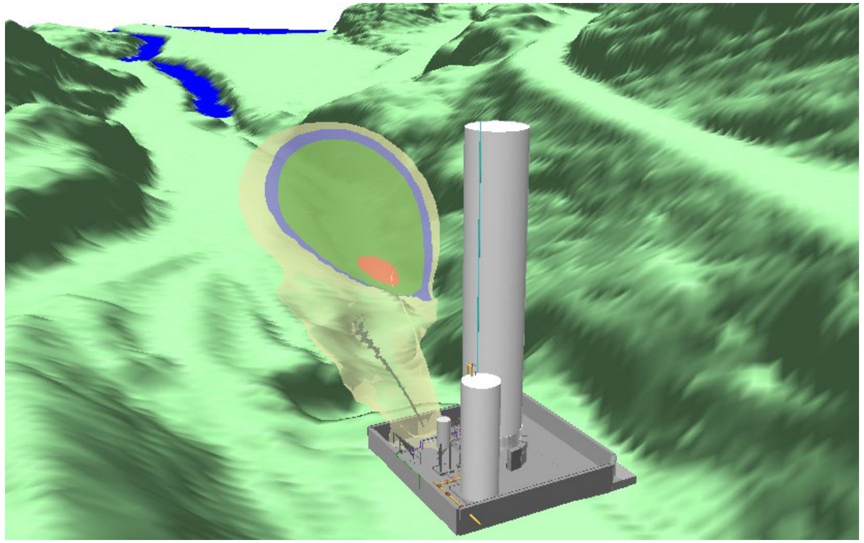
Questions











Contact us

For further **inquiry, free trial, demo or quote**, please contact us at **digital@dnv.com**

For **technical support** or questions, please contact **software.support@dnv.com**

Phast and Safeti are available for purchase on our **Veracity Marketplace:**
https://store.veracity.com/

DNV

Our vision

A trusted voice to tackle global transformations

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