RAPID-N

Rapid Natech Risk Assessment and Mapping Framework

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Joint Research Centre
the European Commission's in-house science service

JRC Science Hub: ec.europa.eu/jrc
JRC Natech Activities

- **Identification** of vulnerable equipment, scenarios and consequences
- Site **surveys** for Natech damage assessment (e.g. Japan, China)
- Statistical **analysis** of accident data
- **Lessons learned** and **recommendations**
- Natech **trainings** (e.g. Natech Workshops)
- **Natech database**: eNatech
- **Natech risk assessment and mapping framework**: RAPID-N
RAPID-N

- Web-based, publicly available **decision-support** tool for Natech risk assessment and mapping


- **Unites** natural-hazard damage estimation and consequence analysis **in one tool!**

- Features
  - **Easy** and **quick** data entry
  - Automated **data estimation**
  - **Rapid** and **scalable** analysis
  - **Visualization**
Methodology

Natural Hazard

- Hazard Map
  - Probabilistic
  - Deterministic
- Manual Input
- Hazard Parameter Estimation Methods

Site Data

Natural Hazard Parameters

Damage

- Process Unit Data
- Damage Probabilities
- Fragility Curves

Consequence

- Risk States
- Consequences
- Natech Risk

Historical Data
- Hazard Parameters
- Damage States
- Observed Damage
- Risk Receptor Data
  - Land-use
  - Population
Modular Structure
Scientific Module
**Scientific Module**

### Properties

<table>
<thead>
<tr>
<th>No</th>
<th>Type</th>
<th>Code</th>
<th>Symbol</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Magnitude</td>
<td>E</td>
<td>ε₀</td>
<td>Radiated Str</td>
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<tr>
<td>2</td>
<td>Magnitude</td>
<td>M₀</td>
<td>M₀</td>
<td>Seismic Mo</td>
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<tr>
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<td>FM</td>
<td>FM</td>
<td>Faulting Me</td>
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<tr>
<td>4</td>
<td>Storage</td>
<td>SC</td>
<td></td>
<td>Storage Cor</td>
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<tr>
<td>5</td>
<td>Chemical</td>
<td>TC</td>
<td></td>
<td>Type of Ch</td>
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<td>6</td>
<td>Distance</td>
<td>FD</td>
<td></td>
<td>Focal Depth</td>
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<tr>
<td>7</td>
<td>Construction</td>
<td>CVF</td>
<td></td>
<td>Year of Con</td>
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<tr>
<td>8</td>
<td>Dimension</td>
<td>S</td>
<td></td>
<td>Shape</td>
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<tr>
<td>9</td>
<td>Distance</td>
<td>dₑ</td>
<td></td>
<td>Epicentral D</td>
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<tr>
<td>10</td>
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<td>SM</td>
<td></td>
<td>State of Mat</td>
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<tr>
<td>11</td>
<td>Construction</td>
<td>UYF</td>
<td></td>
<td>Year of Upg</td>
</tr>
<tr>
<td>12</td>
<td>Structural</td>
<td>RT</td>
<td></td>
<td>Roof Type</td>
</tr>
<tr>
<td>13</td>
<td>Distance</td>
<td>dₜ</td>
<td></td>
<td>Hypocentral D</td>
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<td>MW</td>
<td>MW</td>
<td>Molecular W</td>
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<tr>
<td>15</td>
<td>Distance</td>
<td>dₚ</td>
<td></td>
<td>Equivalent H</td>
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<td>16</td>
<td>Chemical</td>
<td>dₚ</td>
<td></td>
<td>Density</td>
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<td>17</td>
<td>Structural</td>
<td>RST</td>
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<td>Roof Support</td>
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<td>18</td>
<td>Distance</td>
<td>dₑ</td>
<td></td>
<td>Distance to</td>
</tr>
<tr>
<td>19</td>
<td>Chemical</td>
<td>Tb</td>
<td>Tb</td>
<td>Boiling Point</td>
</tr>
<tr>
<td>20</td>
<td>Structural</td>
<td>BT</td>
<td></td>
<td>Base Type</td>
</tr>
</tbody>
</table>

### Property Information

**Type:** European Macroseismic  
**Value:** Destructive

**Parameter:** Horizontal peak ground acceleration  
**Value:** 0.25 g

**Parameter:** Vertical peak ground acceleration  
**Value:** 0.2 g

**Parameter:** Peak Ground Displacement  
**Value:** 40–60 cm

<table>
<thead>
<tr>
<th>Validation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty:</td>
<td>Please enter a value.</td>
</tr>
<tr>
<td>Invalid:</td>
<td>Invalid diameter or Gaçaralç gap.</td>
</tr>
</tbody>
</table>

**Aliases**

- diameter
- Cap

**Created:** 2011/10/04 08:32:14 – Updated: 2011/10/04 08:32:14

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< 8  Less than 10  
> 8  Greater than 8  
7 – 9  Between 8 and 10  
≈ 8  About eight  
8  Exactly eight
### Scientific Module

#### Update Property Estimator

<table>
<thead>
<tr>
<th>Property</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Ground Acceleration</td>
<td>Function</td>
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</tbody>
</table>

#### Description

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimator</th>
<th>Unit</th>
<th>Validity conditions</th>
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</thead>
<tbody>
<tr>
<td>Default ambient temperature</td>
<td>25</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Wind speed</td>
<td></td>
<td>m/s</td>
<td>RMP Scenario = Worst-case</td>
</tr>
<tr>
<td>H/D ratio from diameter</td>
<td></td>
<td>m/m</td>
<td>Shape = Spherical</td>
</tr>
<tr>
<td>Storage condition from roof type</td>
<td></td>
<td>m/m</td>
<td>Roof Type = Floating Roof</td>
</tr>
<tr>
<td>Storage condition from roof type</td>
<td></td>
<td>m/m</td>
<td>Roof Type = Internal Floating Roof</td>
</tr>
<tr>
<td>Diameter from volume</td>
<td></td>
<td>m</td>
<td>Region = Western U.S.A.</td>
</tr>
<tr>
<td>Energy magnitude from radiated seismicity</td>
<td></td>
<td>m/m</td>
<td>Fire/Explosion Event = BLEVE</td>
</tr>
<tr>
<td>Peak ground acceleration</td>
<td></td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>U.S. EPA RMP Liquid Factor Boiling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of fireball</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Properties

- **Storage Condition:** Atmospheric
- **Shape:** Cylindrical Vertical
- **Roof Type:** Floating Roof
- **Construction Material:** Steel
- **Volume:** 22285 m³
- **Height:** 14.00 m
- **Diameter:** 147.64 ft (45.00 m)
- **H/D Ratio:** 0.3114 m/m
- **Fill Level:** 85 %

#### References

1. Margaris, B.; Papazachos, C.; Papaioannou, C.; Theodoulidis, N.; Kalogeris, I.; Skarlatoudis, Attenuation relations for shallow earthquakes in Greece*”, 2002
Property Estimation Framework

Estimated property
Property Estimation Framework

Building Blocks + Tool Kit = Model
Property Estimation Framework

- Minimizes data input
  - Estimates missing data
- Provides extensibility
  - Custom properties
  - Custom estimators
- Increases flexibility
  - Dynamic model building
    - Uses most suitable estimators
    - Recursively
    - Exhaustively
### Facility Information

<table>
<thead>
<tr>
<th>Name:</th>
<th>Turquoise Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity:</td>
<td>Petrochemical Plant</td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Country:</td>
<td>Turkey</td>
</tr>
<tr>
<td>Province:</td>
<td>Izmir</td>
</tr>
<tr>
<td>City:</td>
<td>Aliaga</td>
</tr>
<tr>
<td>Coordinate:</td>
<td>38° 40'N, 26° 30'E</td>
</tr>
</tbody>
</table>

### Substance Information

**Name:** Acrylonitrile  
**CAS No:** 107-13-1  
**EC No:** 203-465-5  
**EC Index No:** 608-003-90-4

#### Identifiers

- **Formula:** C₃H₃N  
- **SMILES:** N\#C=C  
- **InChI:** inChI=1/C3H3N/c1-2-3-4/h2H1H2

#### Properties

- **Type of Chemical:** Toxic  
- **State of Matter:** Liquid  
- **Molecular Weight:** 53.06 g/mol  
- **Density:** 49.577 lb/ft³ (0.7958 g/cm³)  
- **Boiling Point:** 77.35°C  
- **Vapour Pressure:** 108 mmHg (14399 Pa)  
- **RMP Reference Table:** Dense  
- **RMP Toxic Endpoint:** 0.076 mg/L  
- **RMP Density Factor:** 0.51 ft³/ft  
- **RMP Liquid Factor Ambient:** 0.018  
- **RMP Liquid Factor Boiling:** 0.11  
- **RMP Liquid Leak Factor:** 39

#### Substances

<table>
<thead>
<tr>
<th>No</th>
<th>Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Naphtha (CAS: 8030-30-6)</td>
</tr>
</tbody>
</table>

#### Aliases

- Acrylonitrile
- akrylonitril

**Created:** System
Hazards Module

Update Hazard
- Type: Earthquake
- Status: Historical
- Name: New Britain Region, Papua New Guinea
- Date: 2012/03/14
- Time: 21:13
- Location: Papua New Guinea
- Countries Affected: No countries affected.
- Hazard Parameters:
  1. Parameter: Moment Magnitude
  2. Parameter: Focal Depth

Catalog Data
- Catalog: All
- Country: All

12,261,156 records found

Natech Information
- Hazard: Kocaeli Earthquake, Turkey, 1999/08/17
- Facility: Turkish Petroleum Refineries Corp. (TÜPRAS)
- On-site Hazard Parameters:
  - European Macroseismic: Destructive
  - Horizontal peak ground acceleration: 0.25 g
  - Vertical peak ground acceleration: 0.2 g
  - Peak Ground Displacement: 40-60 cm

References
1. Girgin, S., "The natech events during the August 17, 1999 Kocaeli Earthquake, Turkey."
2. Durukal, E., Erdik, M., "Physical and economic losses sustained by the Kocaeli earthquake in 1999, Turkey."
3. Steinberg, L. J. and Cruz, A. M., "When natural and technological disasters meet: The Kocaeli Earthquake, Turkey."
5. Suzuki, K., "Report on damage to industrial facilities in the 1999 Kocaeli Earthquake, Turkey."

Created: Serkan Girgin, 2011/10/13 15:48:13

Natech Damages
- No: 1
  - Process Unit Type: Storage Tank
  - Process Unit Properties: Storage Condition: Atmospheric, Roof Type: Floating Roof, Construction Material: Steel, Base Support Type: Unanchored
  - Damage: Significant
Risk Assessment Module

Create Risk Assessment

Name: Near the East Coast of Honshu, Japan, 2012/01/28

Hazard Information
Hazard: Near the East Coast of Honshu, Japan, 2012/01/28

Hazard Map: [ShakeMap XML (Gzipped)], 2012/01/28 03:42:19

Industrial Plant Information
Industrial Plant: Plants within the cutoff distance
Cutoff Distance: 2.0 km

Exclude plants without units

Risk Assessment
Damage Classification: - Auto -

Flexible fragility curve selection
Use private property estimators

Risk Assessment Parameters
1. Parameter: Ambient Temperature
   Value: 20
   Unit: °C

2. Parameter: Topography
   Value: Urban

3. Parameter: RMP Scenario
   Value: Worst-case

Notes
Automated motech risk assessment for Near the East Coast of Honshu, Japan Earthquake occurred on 2012/01/11.

Data Protection
Access: Private

Create Cancel
Data Availability

• Global coverage
• > 21,000 earthquakes (> M 5.5)
• > 56,700 earthquake catalog data
• > 12,000 ShakeMaps
• > 5,500 industrial facilities*
  • Refineries
  • Power plants
• > 64,500 plant units*
  • Storage tanks

* Not publicly available
Data Availability

• > 375 properties
• > 590 property estimators

• Implemented methodologies
  • **U.S. EPA RMP Offsite Consequence Analysis**
    (U.S. EPA, 1999)
  • **Preliminary Natech Risk Assessment in Urban Areas**
    (Cruz and Okada, 2008)
Consequence models

• **Source term**
  • Instantaneous release
  • Release from a hole
  • Pool Evaporation

• **Atmospheric dispersion**
  • Based on U.S. EPA ALOHA model
  • Bouyant / Dense
  • Rural / Urban
  • D stability, 3.0 m/s wind / F stability, 1.5 m/s wind
  • Chemical-specific: Ammonia, Chlorine, Sulfur Dioxide

• **Fire/Explosion**
  • Vapor Cloud Fire
  • Pool Fire (Point source, Solid-surface)
  • BLEVE
  • Vapor Cloud Explosion (TNT-equivalent, Multi-energy)
Application Areas

- Rapid local and regional natech risk analysis
- Land-use and emergency planning
- Identification of infrastructures at risk
- Preliminary damage and consequence assessment
- Early warning
Ongoing and Future Research

• Extension to other natural hazards (Floods, Lightning)
• Extension to other industrial facilities (Pipelines)
• Automated Natech damage and consequence assessment (Natech Alert)
• Multiple-scenario analysis
• Integration with ADAM
• Domino effects
• Consideration of risk receptors
• Statistical analysis of natech data (Fragility Functions)
Pipeline Natech Risk Assessment

- Prototype completed in 2016 (JRC Technical Report JRC101463)

- Pipeline-specific entities
  - Pipeline
  - Pipeline Segment
  - Point of interest (POI)

- Pipeline-specific data
  - Damage states
  - Fragility functions
  - Properties
  - Property estimators
Pipeline Natech Risk Assessment

- Pipeline-specific features
  - Overlapping segments
  - Auto-segmentation
  - Automated POI generation
  - Impact zone consolidation

<table>
<thead>
<tr>
<th>Hazard Parameter</th>
<th>POI 1</th>
<th>POI 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epicentral distance</td>
<td>33.7 km</td>
<td>42.8 km</td>
</tr>
<tr>
<td>Hypocentral distance</td>
<td>95.2 km</td>
<td>98.8 km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damage and Consequence Parameter</th>
<th>POI 1</th>
<th>POI 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage probability, = RS1 (limited loss)</td>
<td>1.7 \times 10^{-4}</td>
<td>1.3 \times 10^{-4}</td>
</tr>
<tr>
<td>Damage probability, = RS2 (significant loss)</td>
<td>8.1 \times 10^{-11}</td>
<td>2.1 \times 10^{-11}</td>
</tr>
<tr>
<td>Release rate</td>
<td>5.3 kg/s</td>
<td>5.3 kg/s</td>
</tr>
<tr>
<td>Maximum pool diameter</td>
<td>11 m</td>
<td>11 m</td>
</tr>
<tr>
<td>End-point distance (5 kW/m²)</td>
<td>27 m</td>
<td>27 m</td>
</tr>
</tbody>
</table>
Flood Natech Risk Assessment

• 1st phase completed in 2016 (MAHB-ECHO AA 2015-2016)

• Collection of scientific and technical knowledge
  • Methodologies
  • Hazard data sources
  • Equipment vulnerability
  • Consequence analysis

• Gap analysis
  • Modifications
  • Further development
Flood Natech Risk Assessment

- EFAS/RAPID-N interoperability (JRC Technical Report JRC105055)

- Benefits
  - Flood hazard data for natech risk assessment
  - Natech risk data for emergency management
  - Flood forecasts → Natech Alert
  - Data sharing between JRC systems
Outlook

Natech Analysis System

Risk Assessments
Fragility Curves
Damage Classifications
Risk States
Hazard Types
Hazard Maps
On-site Hazard Data
Catalog Data
Natechs
Industrial Plants
Operators
Mapping Tool
Plant Units
Typical Plant Units
Substances
Properties
Property Types
References
Natech Damages
Property Estimators
Regions
Units
Common Units
X²

RAPID
Simple
Basic
ADAM

EMSC
USGS
EFAS
EMM

GDACS
XML

European Commission
New Version

• Prototype is completed *(NATECH WPK 984)*

• Features
  
  • **Object-oriented code base**
    • Fully documented
  
  • **Modern architecture**
    • Stand-alone data definition/estimation framework
    • Data abstraction layer (advance query, DB-independent)
    • Simplified record definition syntax
  
  • **Improved user interface**
    • Responsive
    • Mobile friendly
  
  • **Advance data estimation/analysis**
New Version
RAPID-N

- Integrated natech risk assessment framework
- User-friendly interface
- Publicly available (web application)
- Rapid regional and local analysis
- Ready-to-use data
- Data estimation (minimum data input)
- Extensible structure (easily customizable)
- Dynamic model building
- Regularly updated