

RAPID-N

Rapid Natech Risk Assessment and Mapping Framework

Serkan Girgin

Joint Research Centre

the European Commission's
in-house science service

JRC Science Hub: ec.europa.eu/jrc

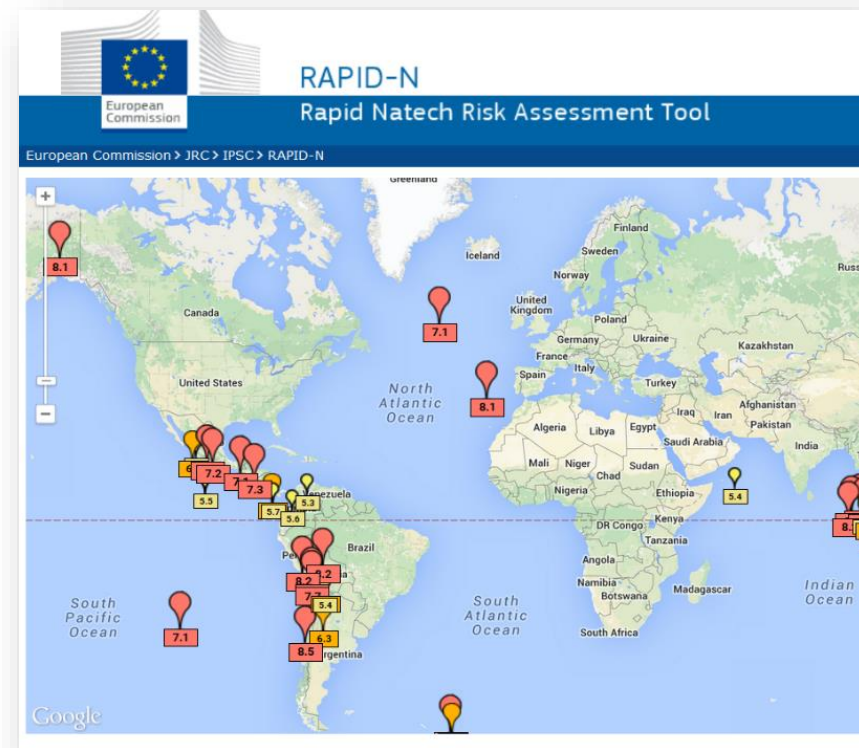
JRC Natech Activities

- **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**

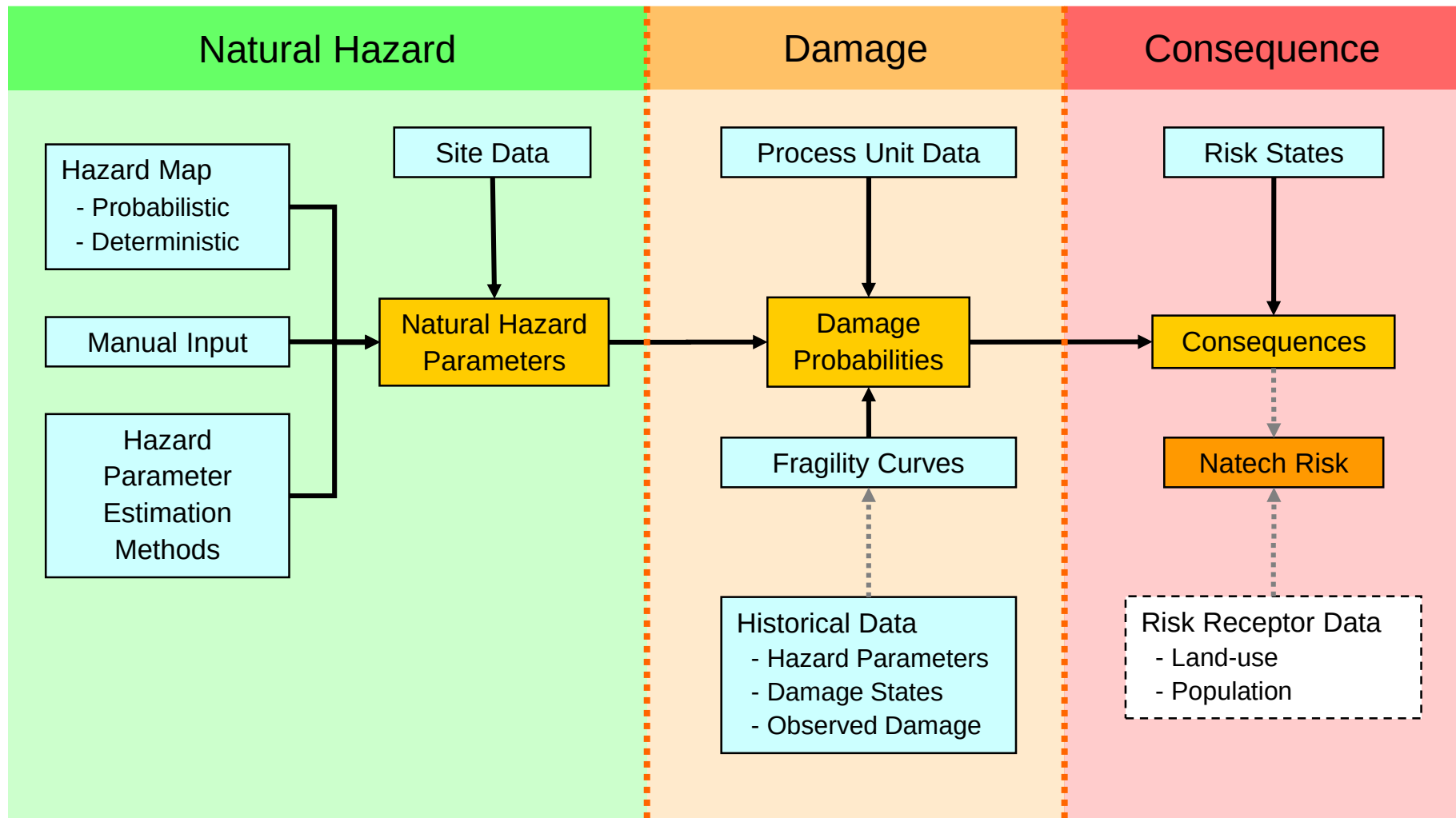
The screenshot displays the RAPID-N (Rapid Natech) web interface. At the top, it features the European Commission logo and the text 'JOINT RESEARCH CENTRE eNATECH - Natural hazard-t'. Below this, the 'RAPID-N Rapid Natech' header is visible. The main content area is divided into two panels. The left panel contains a form for data entry with fields for 'Type:', 'Date:', 'Natural hazard:', 'Industrial site:', 'Units Involved:', and 'Event Sequence:'. The right panel shows a map with a red circular hazard zone centered on a green building icon. Below the map, there are fields for 'Name:', 'Date:', 'Hazard:', and 'Hazard Map:'. The 'Date' field is populated with '2014/06/03 08:27:59'. The 'Hazard Map' field is populated with 'ShakeMap (XML, Gzipped)'.

RAPID-N

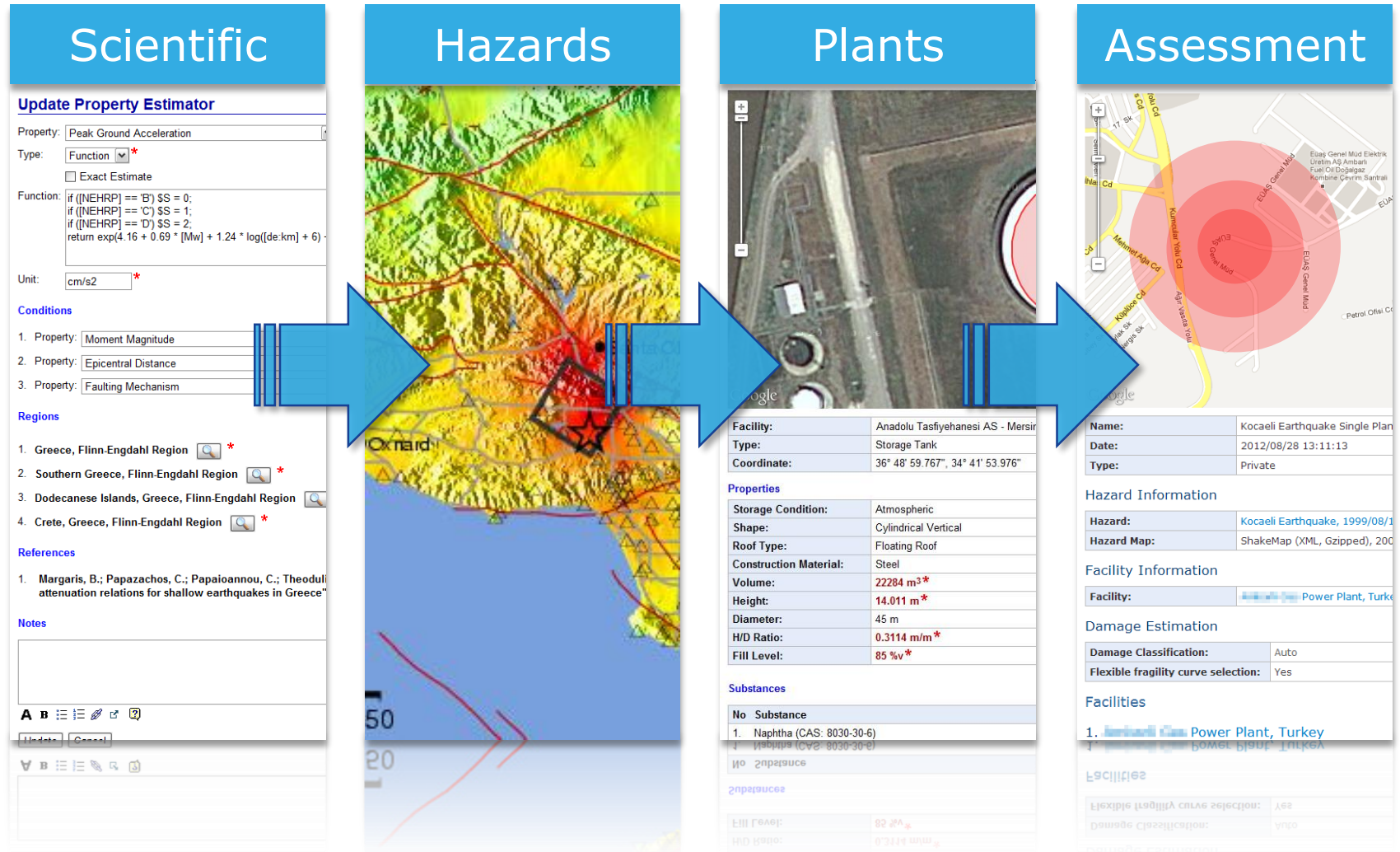
- Web-based, publicly available **decision-support** tool for Natech risk assessment and mapping
<http://rapidn.jrc.ec.europa.eu>
- **Unites** natural-hazard damage estimation and consequence analysis **in one tool!**
- Features
 - **Easy** and **quick** data entry
 - Automated **data estimation**
 - **Rapid** and **scalable** analysis
 - **Visualization**



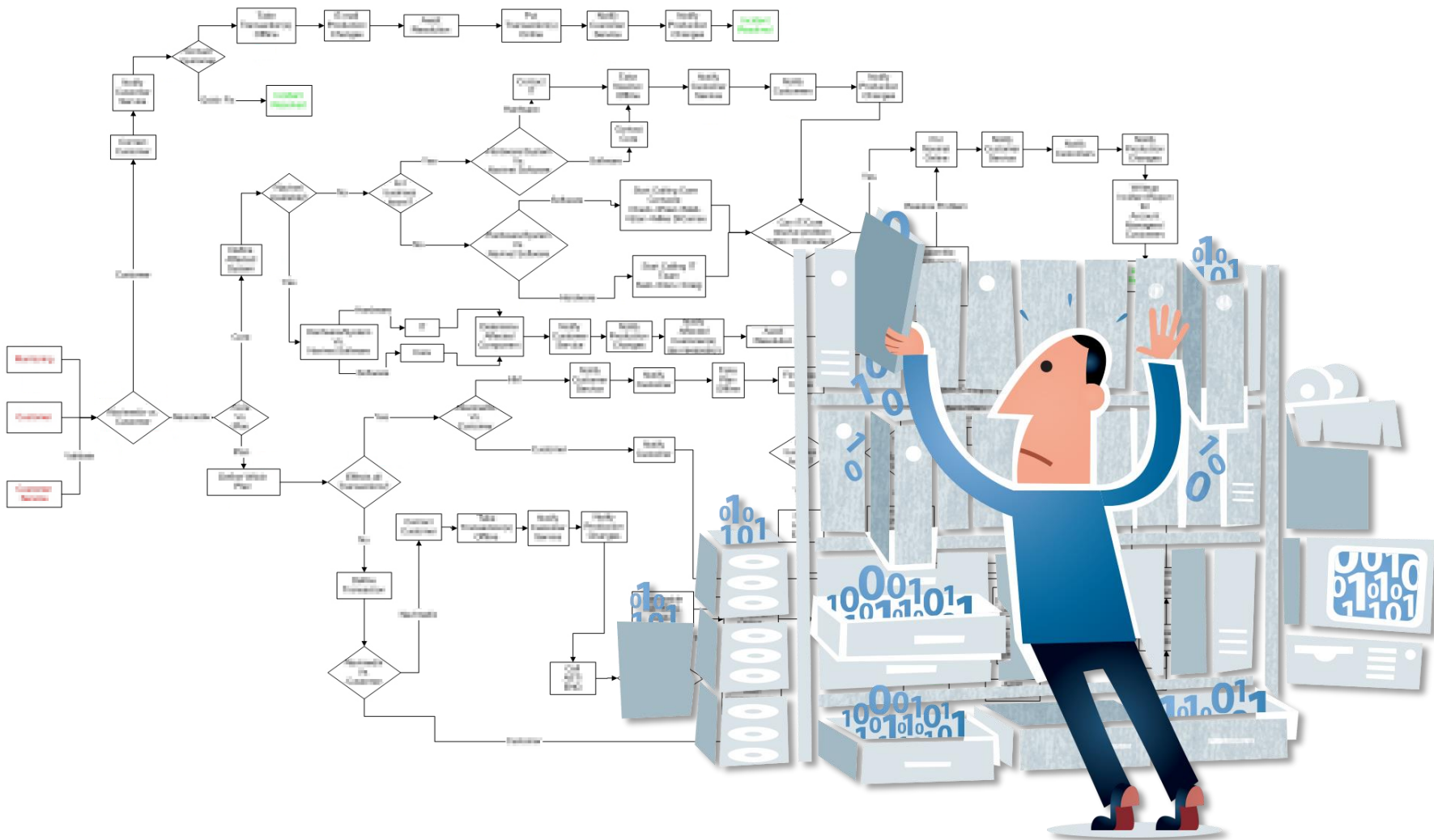
Methodology



Modular Structure



Scientific Module



Scientific Module

Properties

Type: Code: Name:

85 records found

No	Type	Code	Symbol	Name
1.	Magnitude	Es	E _s	Radiated Se
2.	Magnitude	M0	M ₀	Seismic Mo
3.	Mechanism	FM	FM	Faulting Mec
4.	Storage	SC	-	Storage Con
5.	Chemical	TC	-	Type of Chei
6.	Distance	FD	-	Focal Depth
7.	Construction	CYF	-	Year of Cons
8.	Dimensional	S	-	Shape
9.	Distance	de	d _e	Epicentral D
10.	Chemical	SM	-	State of Mat
11.	Construction	UYF	-	Year of Upgr
12.	Structural	RT	-	Roof Type
13.	Distance	dh	d _h	Hypocentral
14.	Chemical	MW	MW	Molecular W
15.	Distance	dq	d _q	Equivalent H
16.	Chemical	d	ρ	Density
17.	Structural	RST	-	Roof Suppor
18.	Distance	dE	d _E	Distance to
19.	Chemical	Tb	T _b	Boiling Point
20.	Structural	BT	-	Base Type

Property Information

Type:	Dimensional (Process Unit)
Code:	D
Name:	Diameter
Description:	Diameter of the
Data Type:	Numeric
Unit:	m
Unit Type:	Common Units Only
View Order:	35

Parameter: Value:

Parameter: Value: Unit:

Parameter: Value: Unit:

Validation

Empty:	Please enter a
	Çapı giriniz.
Invalid:	Invalid diameter
	Geçersiz çap.
Active:	[S] != 'R'
Validate:	[x] > 0

Created: Serkan Girgin, 2011/10/04 09:32:14 - Updated:

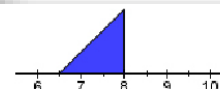
Aliases

diameter

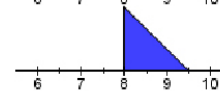
cap

European Macroseismic:	Destructive
Horizontal peak ground acceleration:	0.25 g
Vertical peak ground acceleration:	0.2 g
Peak Ground Displacement:	40-60 cm

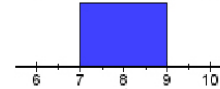
< 8 Less than 10



> 8 Greater than 8



7 - 9 Between 8 and 10



~ 8 About eight



8 Exactly eight



Scientific Module



Update Property Estimator

Property: *

Type: *

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

Properties

Storage Condition:	Atmospheric
Shape:	Cylindrical Vertical
Roof Type:	Floating Roof
Construction Material:	Steel
Volume:	22285 m ³ *
Height:	14.00 m *
Diameter:	147.64 ft (45.00 m)
H/D Ratio:	0.3114 m/m *
Fill Level:	85 %v *

```

} else {
    return 2.6*pow([QFL:kg],1/6);
}

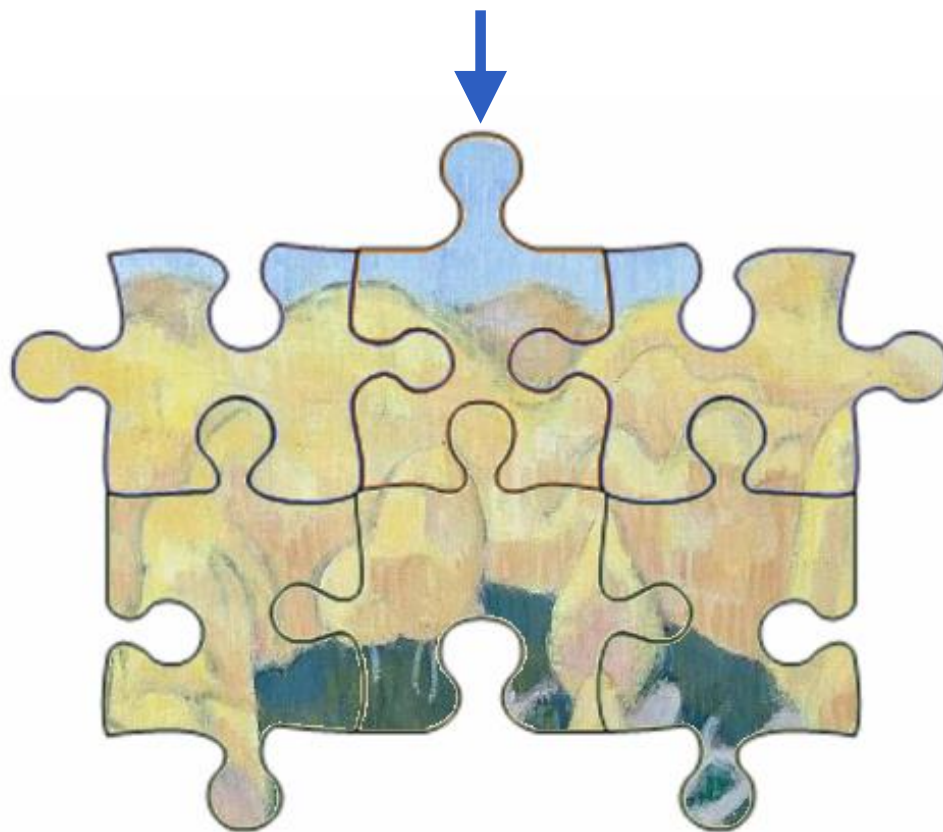
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References

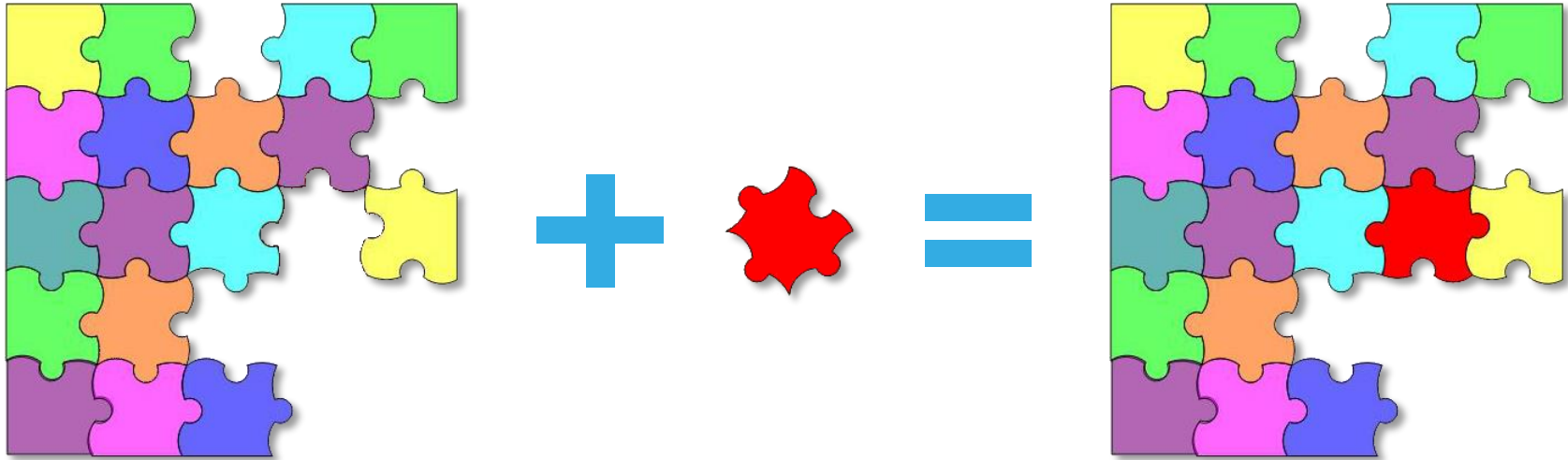
1. Margaris, B.; Papazachos, C.; Papaioannou, C.; Theodulidis, N.; Kalogeras, I.; Skarlatoudou, A.; et al. "Attenuation relations for shallow earthquakes in Greece", 2002 *

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



Plants Module

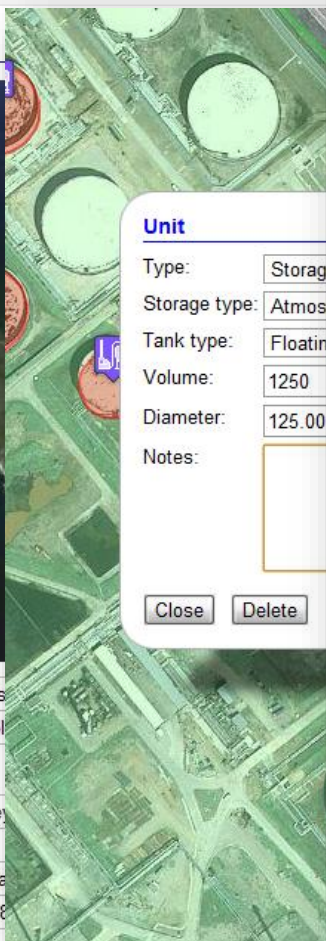
Facility Information



Name: Turkey
Activity: Petrol

Location

Country: Turkey
Province: Izmir
City: Aliaga
Coordinate: 38° 48'



Unit

Type: Storage
Storage type: Atmos
Tank type: Floating
Volume: 1250
Diameter: 125.00
Notes:

Close Delete



Facility: Anadolu Tasfiyehanesi AS - Mer
Type: Storage Tank
Coordinate: 36° 48' 59.767", 34° 41' 53.976"

Properties

Storage Condition: Atmospheric
Shape: Cylindrical Vertical
Roof Type: Floating Roof
Construction Material: Steel
Volume: 22284 m³*
Height: 14.011 m*
Diameter: 45 m
H/D Ratio: 0.3114 m/m*
Fill Level: 85 %v*

Substances

No Substance
1. Naphtha (CAS: 8030-30-6)

Substance Information

Name: Acrylonitrile
CAS No: 107-13-1
EC No: 203-466-5
EC Index No: 608-003-00-4

Identifiers

Formula: C₃H₃N
SMILES: N#CC=C
InChI: InChI=1/C₃H₃N/c1-2-3-4/h2H,1H2

Properties

Type of Chemical: Toxic
State of Matter: Liquid
Molecular Weight: 53.06 g/mol
Density: 49.677 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: 0.61 ft²/lb
RMP Liquid Factor Ambient: 0.018
RMP Liquid Factor Boiling: 0.11
RMP Liquid Leak Factor: 39

Created: System

Aliases

acrylonitrile EN
akrilonitril TR

Hazards Module

Update Hazard

Type: Earthquake *

Status: Historical *

Name: New Britain Region, Papua New Guinea

Date: 2012/03/14 *

Time: 21:13:11 HH:mm

☐ Locked

Location

Country: Papua New Guinea

Province:

Origin: -5 36' 00.000"

Countries Affected

No counties affected. +

Hazard Parameters

1. Parameter: Moment Magnitude

2. Parameter: Focal Depth

Catalog Data

Catalog: - All - Country: - All -

List Create

122615 records found

No	Date	Earthquake
581.	2011/11/01	Minahasa, Sulawesi
582.	2011/11/01	Minahasa, Sulawesi
583.	2011/11/01	Northern Xinjiang, China
584.	2011/11/01	Northern Xinjiang, China
585.	2011/10/31	Sichuan-Gansu Border
586.	2011/10/31	Sichuan-Gansu Border
587.	2011/10/31	Rat Islands, Aleutian
588.	2011/10/31	Rat Islands, Aleutian
589.	2011/10/31	Rat Islands, Aleutian
590.	2011/10/31	Rat Islands, Aleutian
591.	2011/10/31	Rat Islands, Aleutian
592.	2011/10/31	Rat Islands, Aleutian
593.	2011/10/31	Southern East Pacific
594.	2011/10/31	Southern East Pacific
595.	2011/10/31	Southern East Pacific
596.	2011/10/31	Gulf of Aden
597.	2011/10/31	Gulf of Aden
598.	2011/10/30	Antofagasta, Chile
599.	2011/10/30	Southern Sumatra, Indonesia

Natech Information

Hazard:	Kocaeli Earthquake, Turkey, 1999/08/17
Facility:	Turkish Petroleum Refineries Corp. (TUPRAS)

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

No	Reference
1.	Girgin, S., "The natech events during the August 17, 1999 Kocaeli Earthquake"
2.	Durukal, E.; Erdik, M., "Physical and economic losses sustained by the 1999 Kocaeli Earthquake"
3.	Steinberg, L. J. and Cruz, A. M., "When natural and technological disaster meet"
4.	Daniş, H.; Görgün, M., "Marmara earthquake and TUPRAŞ fire", 2005
5.	Suzuki, K., "Report on damage to industrial facilities in the 1999 Kocaeli Earthquake"

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Natech Damages

No	Process Unit Type	Process Unit Properties	Damage
1.	Storage Tank	Storage Condition: Atmospheric Roof Type: Floating Roof Construction Material: Steel Base Support Type: Unanchored	Seismic

Risk Assessment Module

Fragility Curve Information

Name:	HAZUS (2010) - Unanchored Tank
Abbreviation:	HAZUS-UA
Plant Unit Type:	Storage Tank
Damage Classification:	HAZUS (2010) - Storage Tank
Hazard Parameter:	
Unit:	
Functional Type:	
Precedence:	

Damage Classification Information

Name:	HAZUS (2010) - Storage Tank
Damage Classification:	HAZUS (2010) - Storage Tank
Damage State:	DS3 (Moderate)
Precedence:	Auto

Risk State Information

Damage Classification:	HAZUS (2010) - Storage Tank
Damage State:	DS3 (Moderate)
Precedence:	Auto

Scenario Parameters

Involved Volume Percent:	2 %v
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Validity Conditions

Hole Area:	0
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[Update](#) [Delete](#) [Go Back](#)

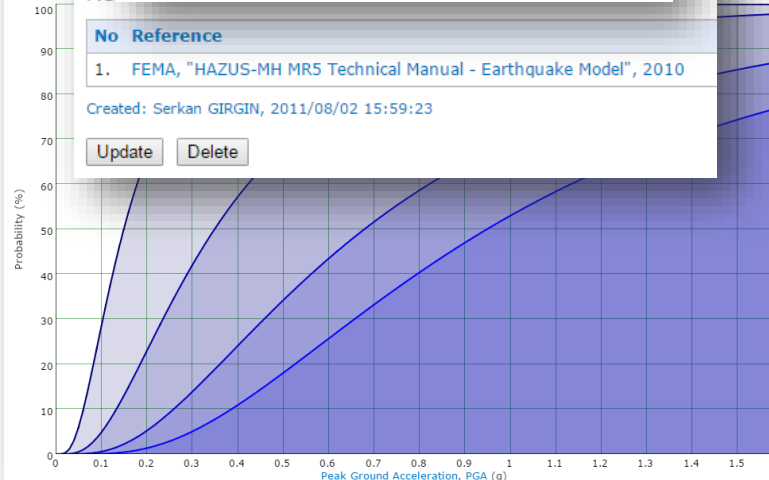
References

No Reference

1. FEMA, "HAZUS-MH MRS Technical Manual - Earthquake Model", 2010

Created: Serkan GIRGIN, 2011/08/02 15:59:23

[Update](#) [Delete](#)



Create Risk Assessment

Name: *

Hazard Information

Hazard: *

Hazard Map: ▼

Industrial Plant Information

Industrial Plant: *

Cutoff Distance: km *

☐ Exclude plants without units

Risk Assessment

Damage Classification: ▼

☒ Flexible fragility curve selection

☐ Use private property estimators

Risk Assessment Parameters

1. Parameter: * Value: * Unit: * [-](#) [+](#)

2. Parameter: * Value: * [-](#) [+](#)

3. Parameter: * Value: * [-](#) [+](#)

Notes

Automated natech risk assessment for Near the East Coast of Honshu, Japan Earthquake occurred on 2012/01/28.

B **x** **x'** **≡** **≡** **≡** **≡** **≡** **?**

Data Protection

Access: ▼

[Create](#) [Cancel](#)

Risk Assessment



Name:	Kocaeli Earthquake Single Plant
Date:	2012/08/28 13:11:13
Type:	Private

Hazard Information

Hazard:	Kocaeli Earthquake, 1999/08/17
Hazard Map:	ShakeMap (XML, Gzipped), 2008/11/09 03:19:14

Facility Information

Facility:	Power Plant, Turkey
-----------	---------------------

Damage Estimation

Damage Classification:	Auto
Flexible fragility curve selection:	Yes

Facilities

1. Power Plant, Turkey

No	Process Unit	Hazard Parameters	Fragility Curve	Damage Estimate	Damage Parameters	End-point Distance
1.	Storage Tank (T-STR) [Gasoline]	PGA: 18.777 %g; EMS: Slightly damaging; MM: Strong; MSK: Strong; MMI: 6.4866; d _e : 101.38 km; d _h : 102.79 km; PGA _h : 74.415 cm/s ² ; PGV: 15.573 cm/s	OS00-F50-G	≥ DS2: 4.0546%	Fire/Explosion Event: Vapor Cloud Explosion; Qinvolved: 4250 kg; f _m , passive: 1; P _c , fire: 100%; f _v , involved: 10 %V; Vinvolved: 5.7432 m ³ ; P _c , release: 30%; f _{yield} : 0.1; RMP Scenario: Worst-case; t _{release} : 10 min; Q _{release} : 425 kg/min; Q _{released} : 4250 kg; A _{pool} : 6146.1 ft ² ; h _{pool} : 1 cm; Q _{release} , r: 425 kg/min; T _a : 1; R: 0.4; q _R : 5000 W/m ² ; t _{exp} : 40 s; D _r : 342 TDU; d _e : 270.58 m; Q _{fuel} : 4250 kg; P _{damage} : 4.0546%; P _{natech} : 4.0546% <<	271 m: 4.0546%
				≥ DS3: 0.004631%	Fire/Explosion Event: Vapor Cloud Explosion; Qinvolved: 8500 kg >>	341 m: 0.004631%
				≥ DS4: Very low	-	-

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)

Resources

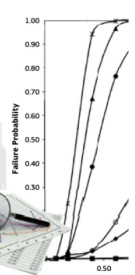


JRC SCIENTIFIC AND POLICY REPORTS

RAPID-N Rapid Natech Risk Assessment Tool

User Manual
Version 1.0

Serkan Girgin
2012



Report EUR 25164 EN



Journal of Loss Prevention in the Process Industries

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/jlp

RAPID-N: Rapid natech risk assessment and mapping framework

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Natech
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Risk assessment
Software framework

ABSTRACT

Natech accidents at industrial plants are an emerging risk with possibly serious consequences. For the mitigation of natech risk, authorities need to identify natech prone areas in a systematic manner. In order to facilitate probabilistic natech risk mapping, a unified methodology was developed that is based on the estimation of on-site natural hazard parameters, determination of damage probabilities of plant units, and assessment of probability and severity of possibly triggered natech events. The methodology was implemented as an on-line, extensible risk assessment and mapping software framework called RAPID-N that allows rapid local and regional natech risk assessment and mapping with minimal data input. RAPID-N features an innovative data estimation framework to complete missing input data, such as on-site natural hazard parameters and plant unit characteristics. The framework is also used for damage assessment and natech consequence analysis, and allows easy modification of input parameters, dynamic generation of consequence models according to data availability, and extension of models by adding new equations or substituting existing ones with alternatives. Results are presented as summary reports and interactive risk maps, which can be used for land-use and emergency planning purposes by using scenario hazards, or for rapid natech consequence assessment following actual disasters. As proof of concept, the framework provides a custom implementation of the US EPA's RMP Guidance for Office Consequence Analysis methodology to perform natech consequence analysis and includes comprehensive data for earthquakes. It is readily extensible to other natural hazards and more comprehensive risk assessment methods.

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1. Introduction

Major accidents at industrial plants, which are triggered by natural hazards and result in the release of hazardous materials, can have serious consequences on the population, the environment, and the economy (Girgin, 2011; Krausmann, Cozzani, Salzano, & Berni, 2013; Krausmann, Berni, Campedel, & Cozzani, 2011; Shewalter & Myers, 1994; Stenberg & Cruz, 2004; Young, Rathuz, & Mallay, 2004). Termed natechs, the risk of such accidents is expected to increase in the future due to growing industrialization, the predicted change of natural hazard occurrence patterns by climate change, and the increasing vulnerability of the society that is becoming more and more interconnected. Adequate preparedness and proper emergency planning are needed to prevent natechs and mitigate their consequences. For this reason, natech-prone areas should be identified and natech risks must be assessed in a methodical way by the competent authorities.

In the past, several authors developed natech risk assessment methodologies of varying levels of resolution. Cruz and Uchida (2008) proposed a qualitative natech risk screening methodology at the district level while Salzano et al. (2009) developed an index method aimed mainly at ranking natech hazards at the regional or national level. Rustin, Marzocchi, Colliani, and Rota (2011) proposed a qualitative screening tool using a multi-criteria decision model. Antonioni, Spadoni, and Cozzani (2007) and Campedel, Cozzani, Garcia-Agenda, and Salzano (2008) described the development and application of a procedure for the quantitative assessment of natech risk due to earthquake impact. Antonioni, Berni, Spadoni, and Cozzani (2009) generalized this procedure to other types of natural hazard impact. These studies also provided case-study natech risk maps displaying individual and societal risk around an industrial facility, which were obtained using an extended version of the RAPID software. However, a consolidated methodology for natech risk assessment and mapping is currently not available. Recent studies also showed that hardly any natech risk maps exist for the EU and OECD member states. Where available, natech risk maps are simple overlays of natural and technological hazards without considering site-specific features or the interaction of hazards (Krausmann & Salzano, 2009, 2012). The

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doi:10.1016/j.jlp.2013.10.004

CHAPTER

10

Case-Study Application I: RAPID-N

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European Commission, Joint Research Centre, Ispra, Italy

In this chapter, the rapid Natech risk analysis and mapping framework RAPID-N introduced in Chapter 8 is used to carry out a simplified Natech risk analysis for an industrial facility in İmit Bay in Turkey that was subjected to a predicted Istanbul earthquake scenario. The results demonstrate RAPID-N's capability to assess the earthquake impact on an industrial plant, including the simultaneous analysis of the Natech risk at several plant units.

10.1 EARTHQUAKE SCENARIO

The Marmara region is one of the most tectonically active regions in Eurasia. Over the last century, seismic activity with nine earthquakes with $M_w \geq 7$ was registered. The Kocaeli and Düzce earthquakes in 1999 were two extremely destructive events that occurred in the eastern part of the region along the North Anatolian Fault (NAF). The NAF is a strike-slip fault system that crosses the north of Turkey for over 1200 km and accommodates about 25 mm right lateral slip per year between the Anatolian and the Eurasian plate (McClusky et al., 2000; Straub et al., 1997).

The large earthquakes generated by the NAF are in a sequence that appears to propagate westward (Stein et al., 1997; Barka, 1992; Ambraseys, 1970). The 1999 Kocaeli earthquake occurred in the southern part of the eastern border of Istanbul province. The westward motion of the earthquakes suggests that Istanbul is at high risk of being hit by strong future seismic activity. Studies estimate that the occurrence probability of $M_w \geq 7$ earthquakes in the Marmara region which could impact the Istanbul Metropolitan area is 41 ± 14% for the time period of 2004–34 (Parsons, 2004). The Yalova fault segment in the south of Istanbul and the Northern Boundary fault in the southeast have the potential to rupture and are therefore of the biggest concern in this context (Parsons et al., 2003; Huber-Ferrari et al., 2003).

The high level of seismic risk warrants an in-depth assessment of the regional earthquake hazard to understand potential impacts to the urban area and the hazardous industry it includes. The Istanbul disaster prevention and mitigation plan completed in 2002 considers four different scenario earthquakes for the assessment of potential seismic damage (JICA, 2002). These four scenarios differ in the assumed location and length of NAF rupture. For this RAPID-N case study we have selected

doi:10.1016/B978-0-12-803807-9.00010-3

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

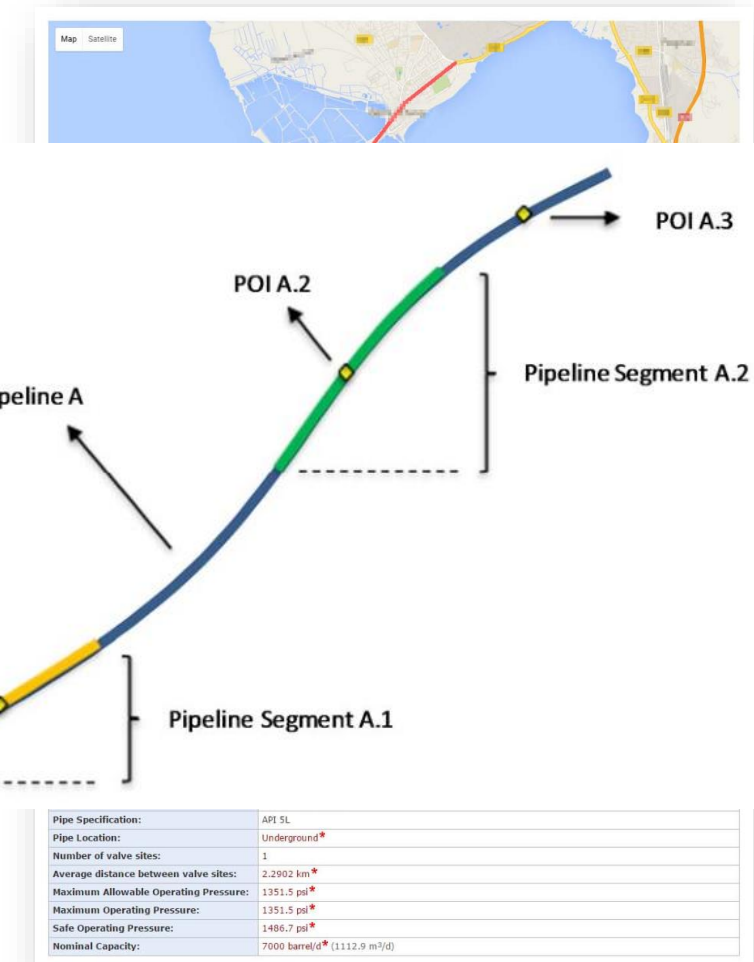


Ongoing and Future Research

- 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**



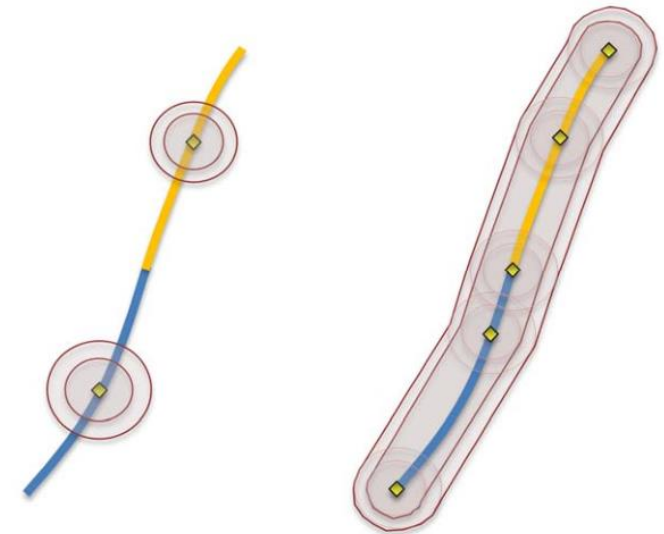
Pipeline Natech Risk Assessment

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

Pipeline A	Segment A.1	Segment A.2	Final Pipeline Segmentation
Diameter: 14" Cover depth: 2 m Topography: Rural NEHRP Site Class: C	Topography: Urban NEHRP Site Class: D		14", 2 m cover, Rural, NEHRP Class C
			14", 2 m cover, Urban, NEHRP Class D
		Cover depth: 3 m	14", 3 m cover, Urban, NEHRP Class D
			14", 3 m cover, Rural, NEHRP Class C
			14", 2 m cover, Rural, NEHRP Class C

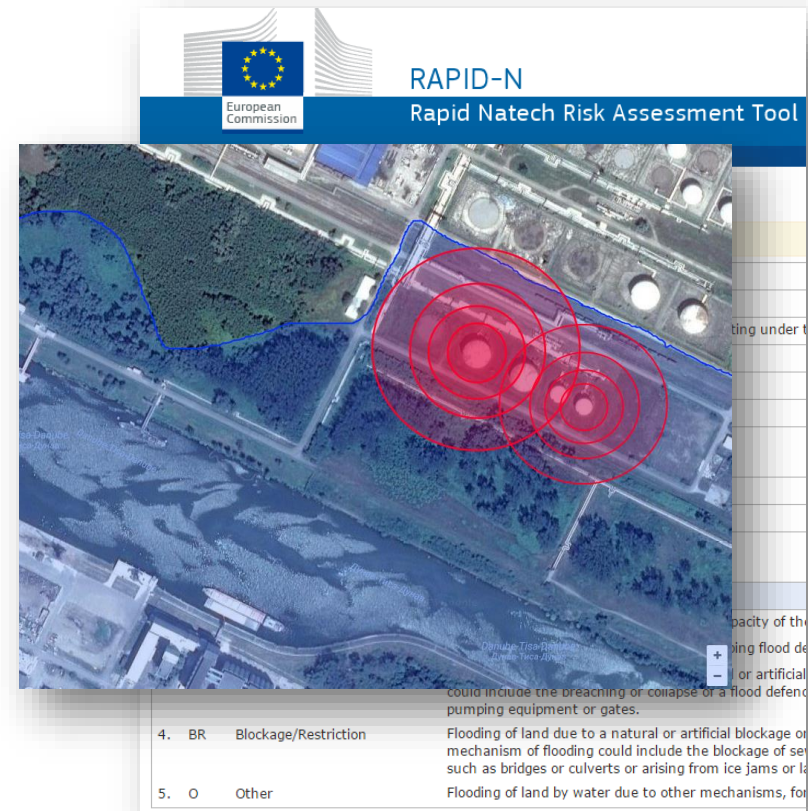
Hazard Parameter	POI 1	POI 2
Epicentral distance	33.7 km	42.8 km
Hypocentral distance	95.2 km	98.8 km

Damage and Consequence Parameter	POI 1	POI 2
Damage probability, = RS1 (limited loss)	$1.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$
Damage probability, = RS2 (significant loss)	$8.1 \cdot 10^{-11}$	$2.1 \cdot 10^{-11}$
Release rate	5.3 kg/s	5.3 kg/s
Maximum pool diameter	11 m	11 m
End-point distance (5 kW/m ²)	27 m	27 m



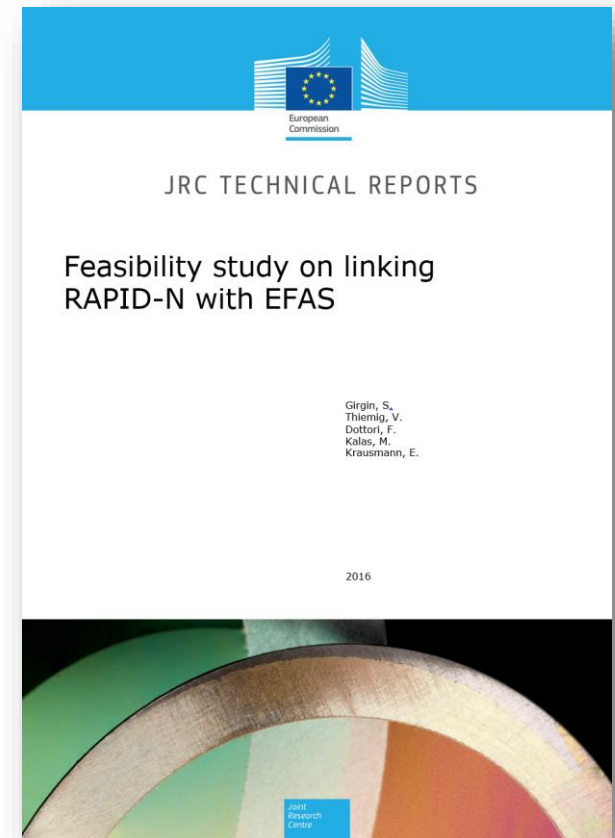
Flood Natech Risk Assessment

- 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**

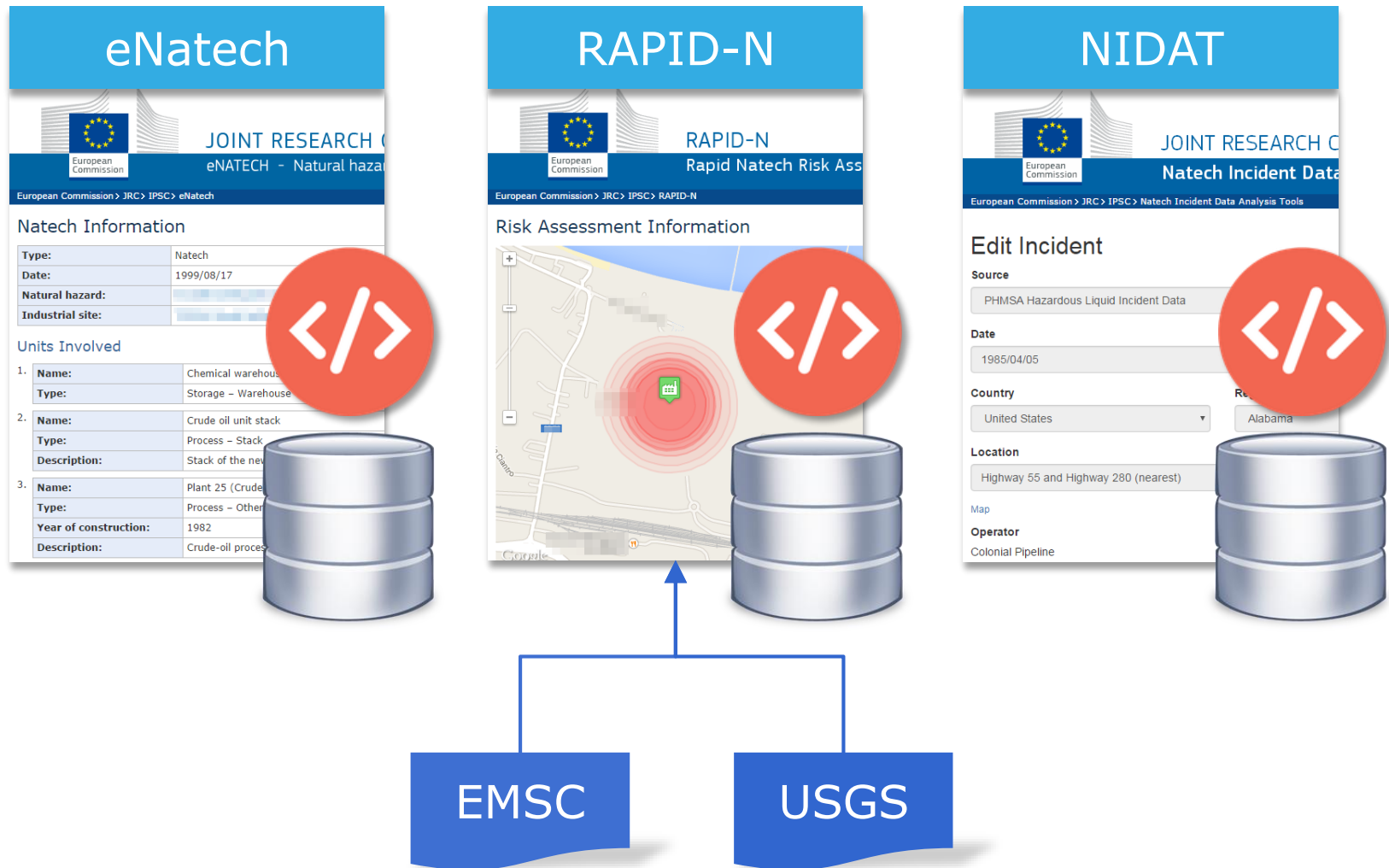


Flood Natech Risk Assessment

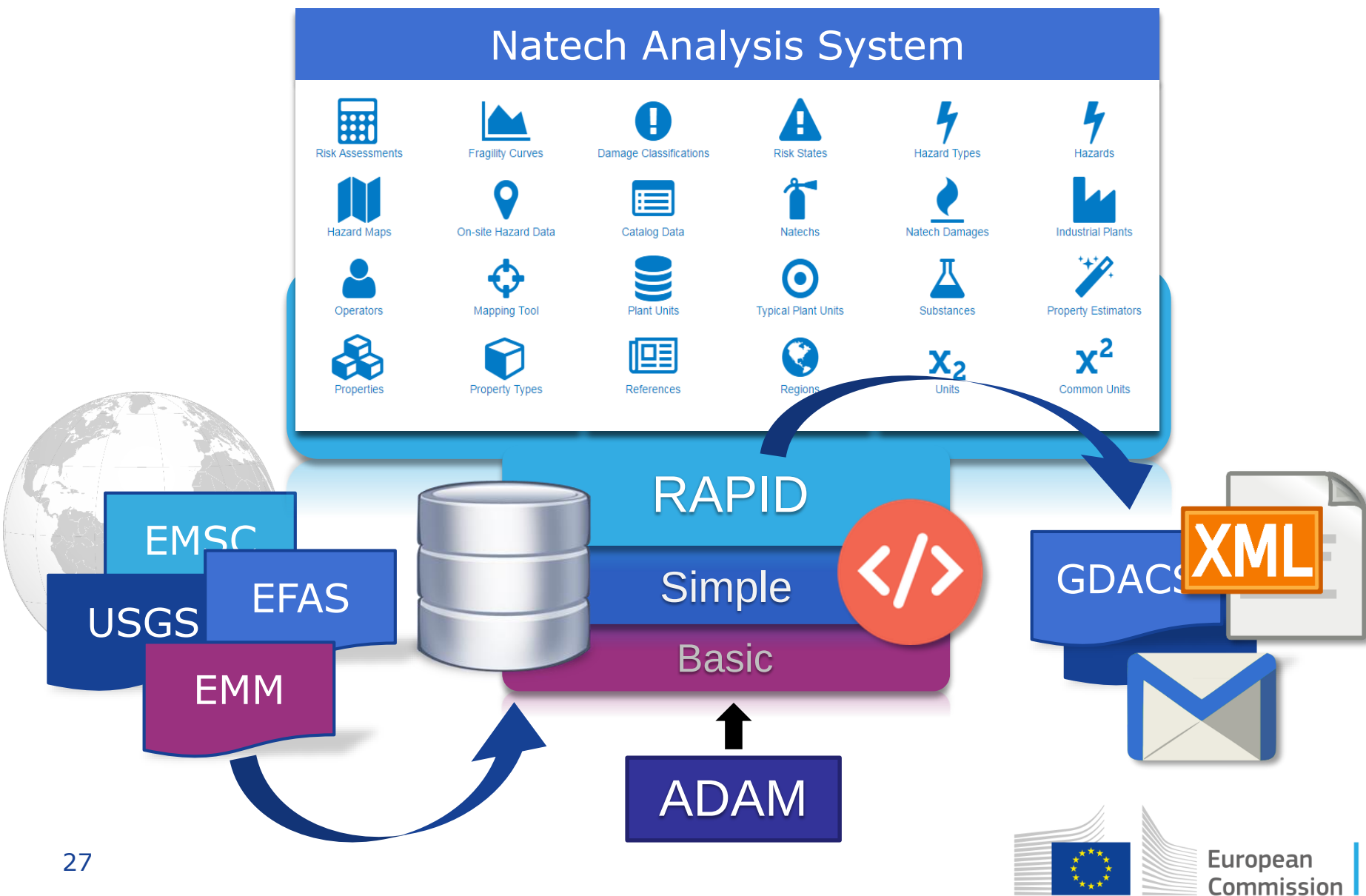
- EFAS/RAPID-N interoperability
(JRC Technical Report JRC105055)
- Benefits
 - **Flood hazard data for natech risk assessment**
 - **Natech risk data for emergency management**
 - **Flood forecasts → Natech Alert**
 - **Data sharing between JRC systems**



Today



Outlook



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**

Name: Skarlatoudis et al.

Property: Peak Ground Accel

Type: Function

Function:

$$\begin{aligned} & \text{if } \text{M} \leq 5.0 \\ & \quad \text{if } \text{NEHRP} = 15, \text{FN} = \text{km} : \text{PGA} = 4.647 \\ & \quad \text{if } \text{M} > 5.0 \\ & \quad \quad \text{if } \text{NEHRP} = 15, \text{FN} = \text{km} : \text{PGA} = 4.647 \\ & \quad \quad \text{if } \text{M} > 5.0 \\ & \quad \quad \quad \text{if } \text{NEHRP} = 15, \text{FN} = \text{km} : \text{PGA} = 4.647 \\ & \quad \quad \quad \text{if } \text{M} > 5.0 \\ & \quad \quad \quad \quad \text{if } \text{NEHRP} = 15, \text{FN} = \text{km} : \text{PGA} = 4.647 \end{aligned}$$

Unit: cm/s²

Exact Estimate: No

Precedence: Auto

Disabled: No

Notes: See Douglas (2011)
Validation: M = 5.0
NEHRP = 15, FN = km : PGA = 4.647

Validity Conditions

Moment Magnitude: 4.5–7

Focal Depth: 0–30.1 km

Faulting Mechanism: Normal, Thrust, St

Epicentral Distance: 1.5–150 km

Validity Regions

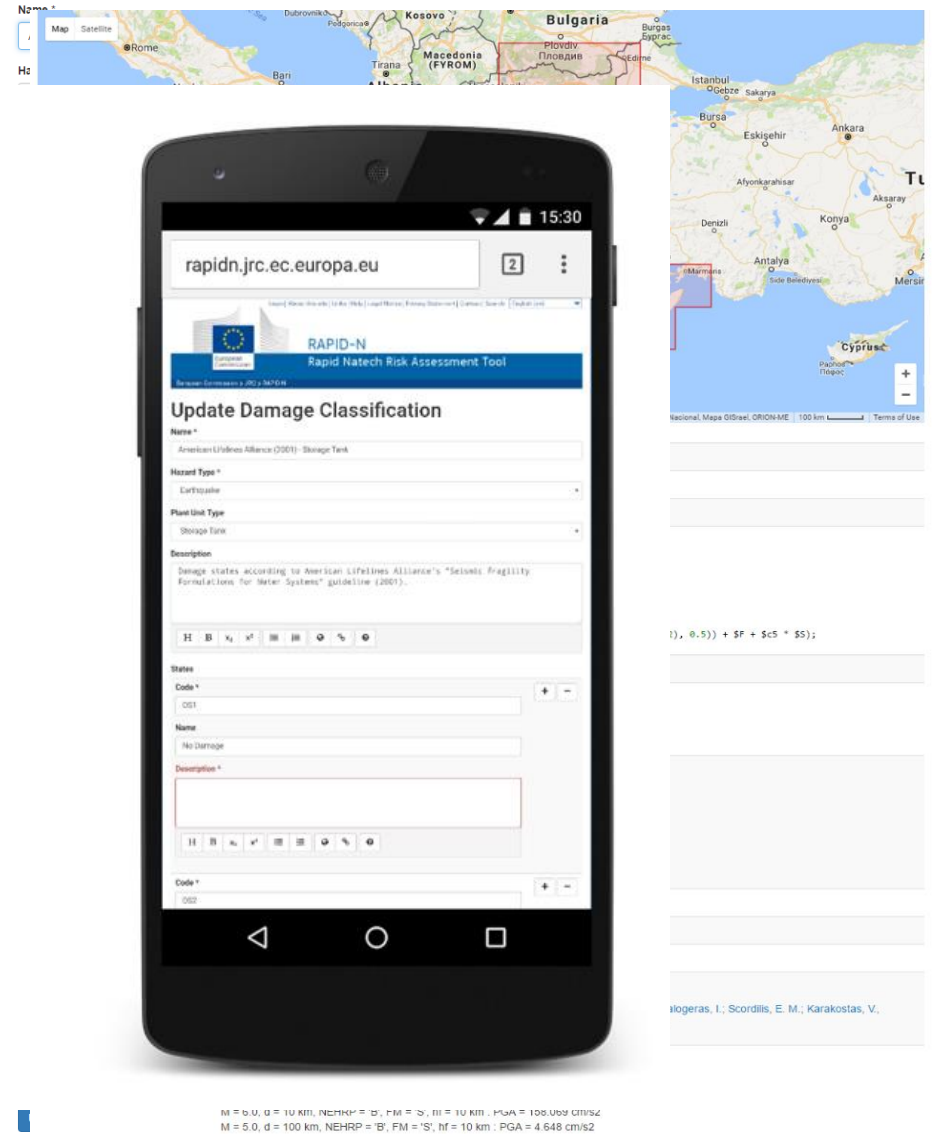
No Region

1. Greece-Bulgaria Border Region (363)
2. Greece (364)
3. Aegean Sea (365)
4. Southern Greece (368)
5. Dodecanese Islands, Greece (369)
6. Crete, Greece (370)
7. Greece-Albania Border Region (392)
8. Ionian Sea (399)

References

No Reference

1. Douglas, J., "Ground-motion prediction equation
2. Skarlatoudis, A. A.; Papazachos, C. B.; Margaris, B. N.; Theodulidis, N.; Papaioannou, C.; Kalogeras, I.; Scordilis, E. M.; Karakostas, V., "Empirical peak ground-motion predictive relations for shallow earthquakes in Greece", 2003



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



RAPID-N

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