



European  
Commission

# RAPID-N

## Rapid Natech Risk Assessment and Mapping Framework

**Serkan Girgin**

**Joint Research Centre**

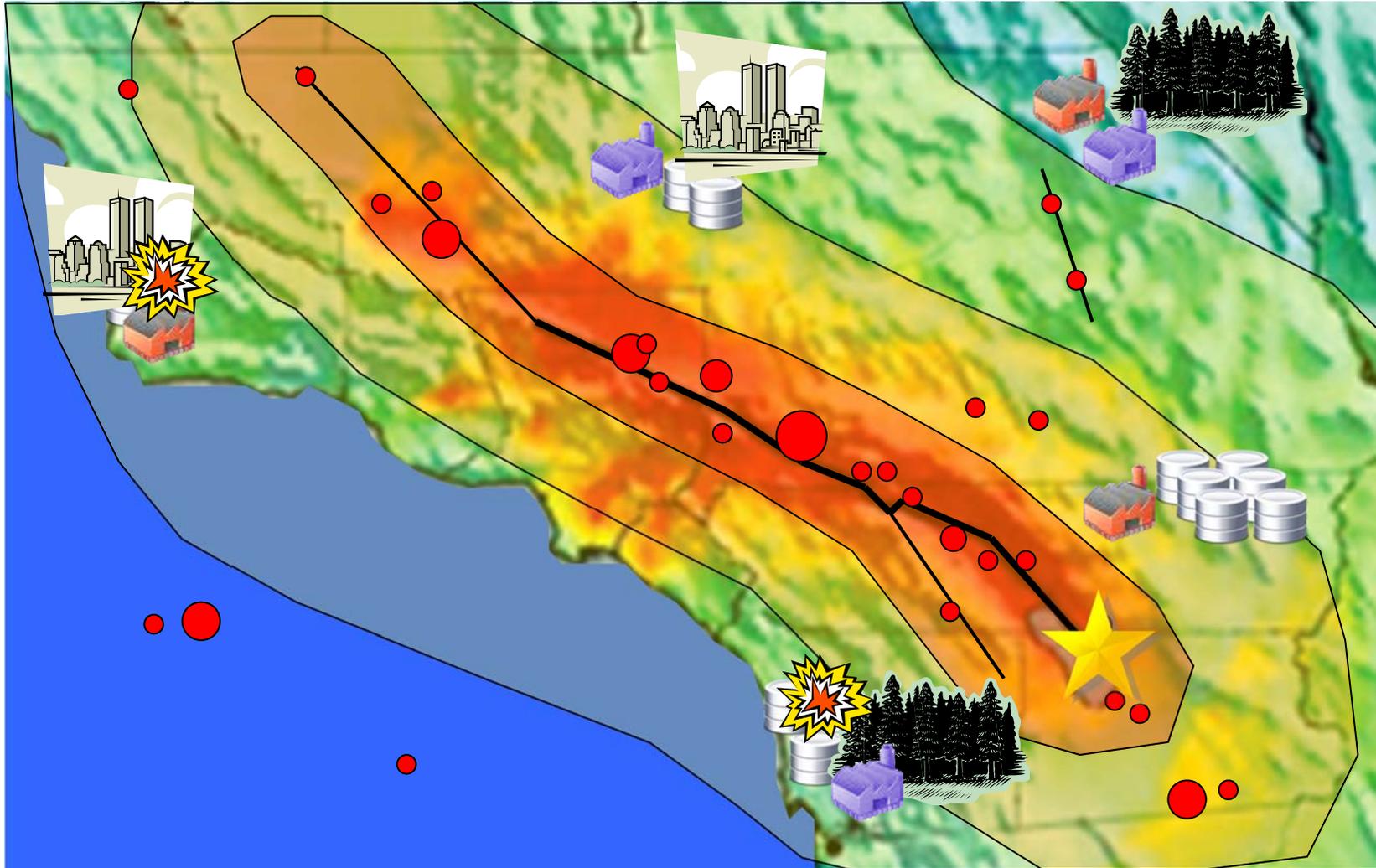
the European Commission's  
in-house science service

JRC Science Hub: [ec.europa.eu/jrc](https://ec.europa.eu/jrc)

Joint  
Research  
Centre

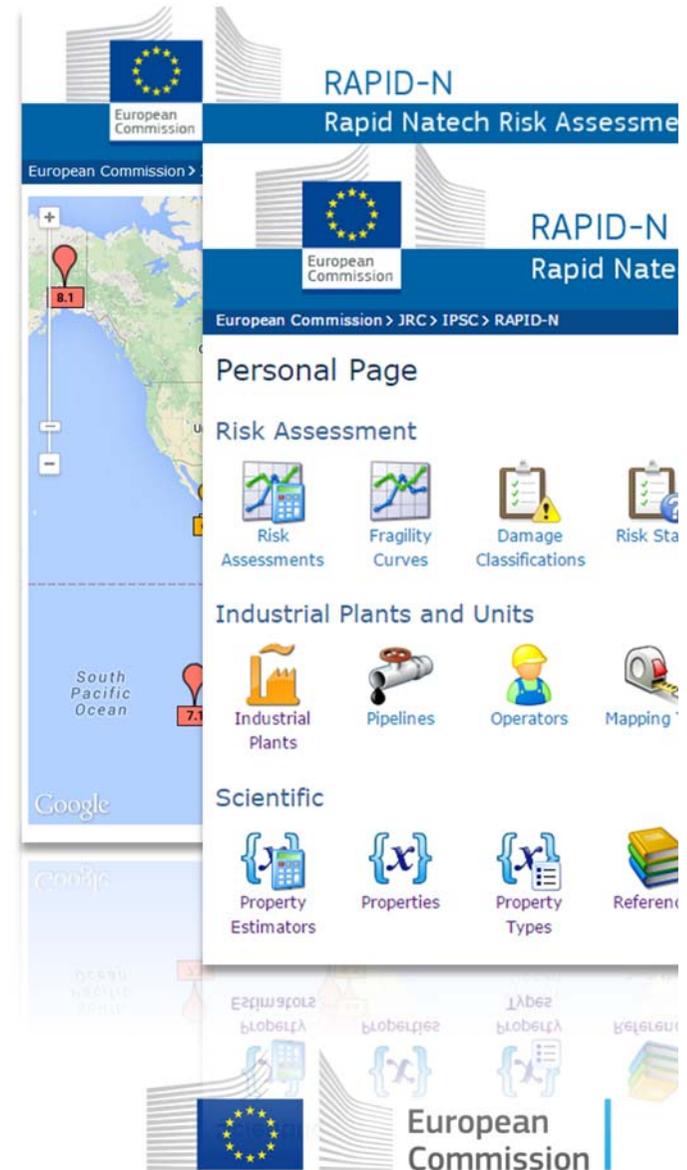


# Natech Risk

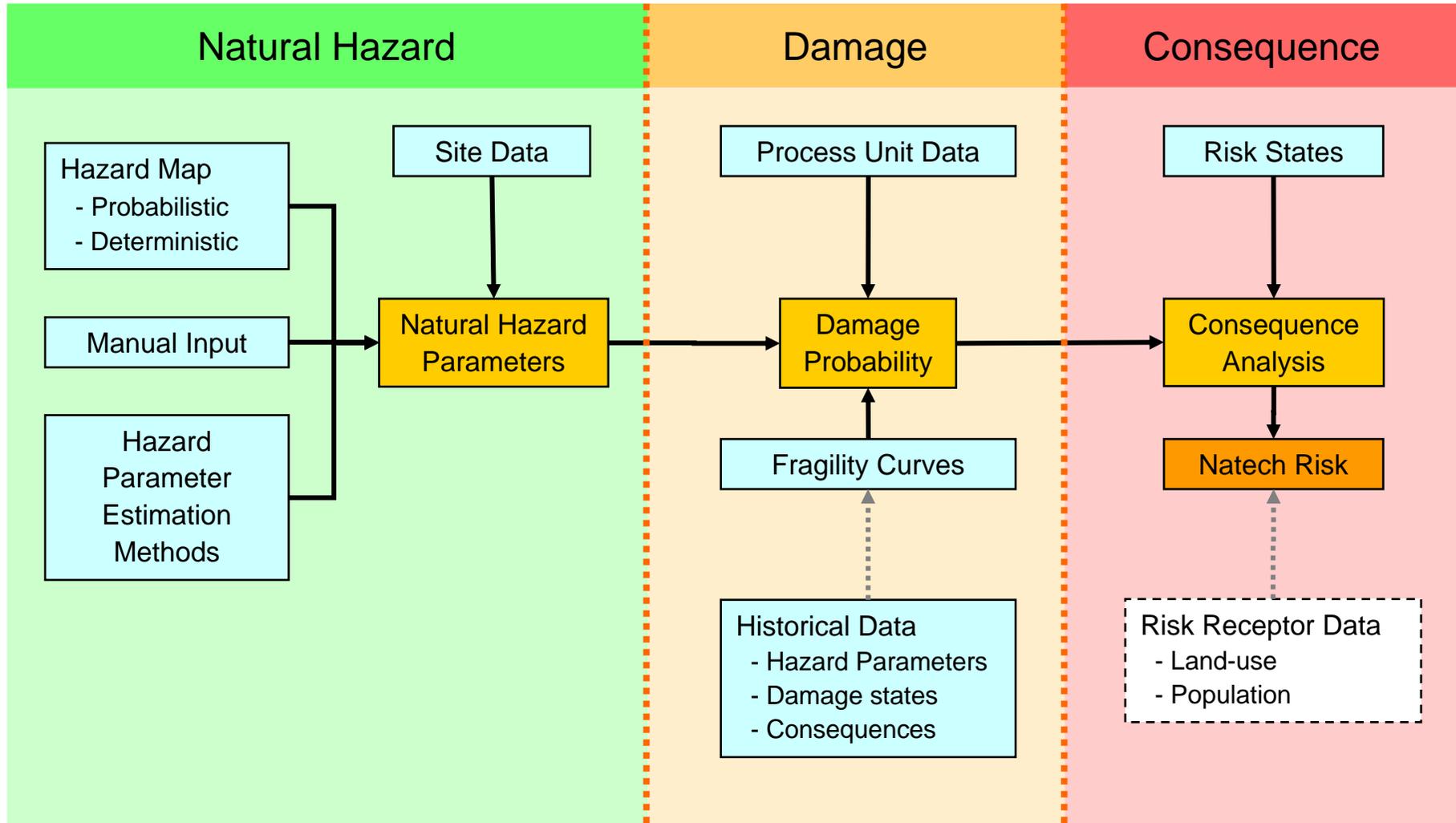


# Rapid Natech Risk Mapping Framework

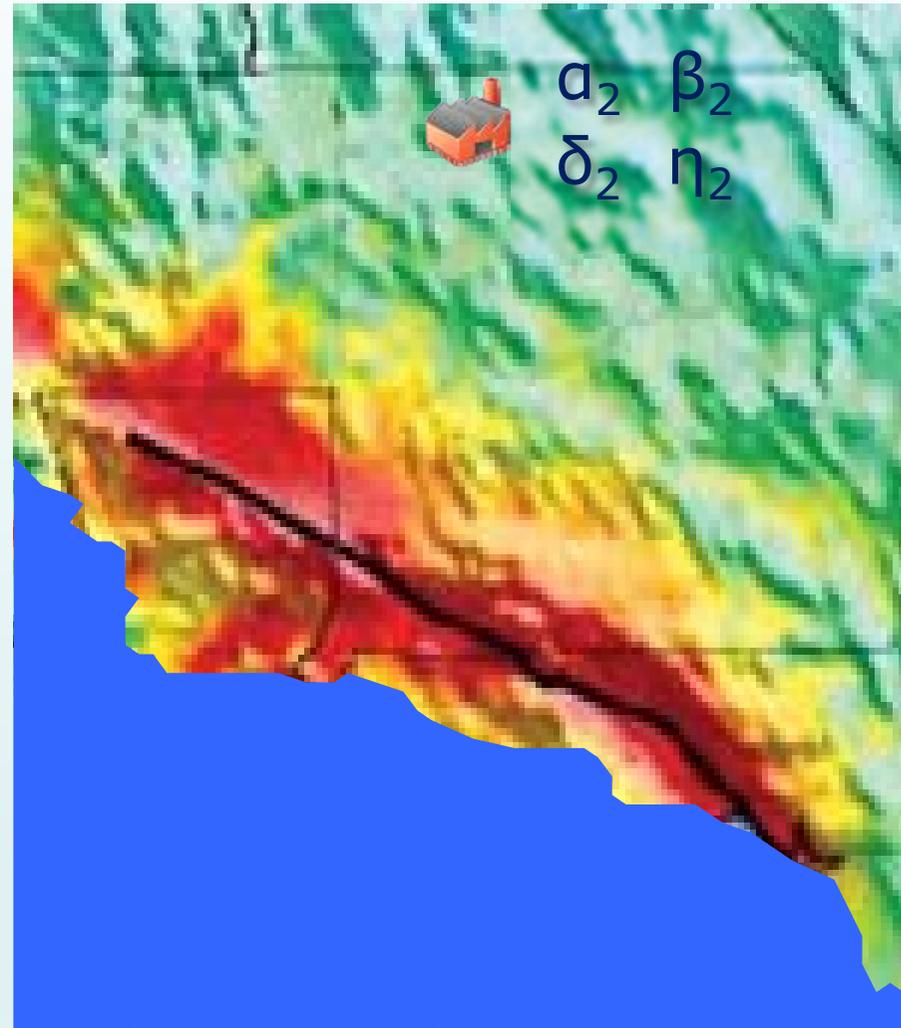
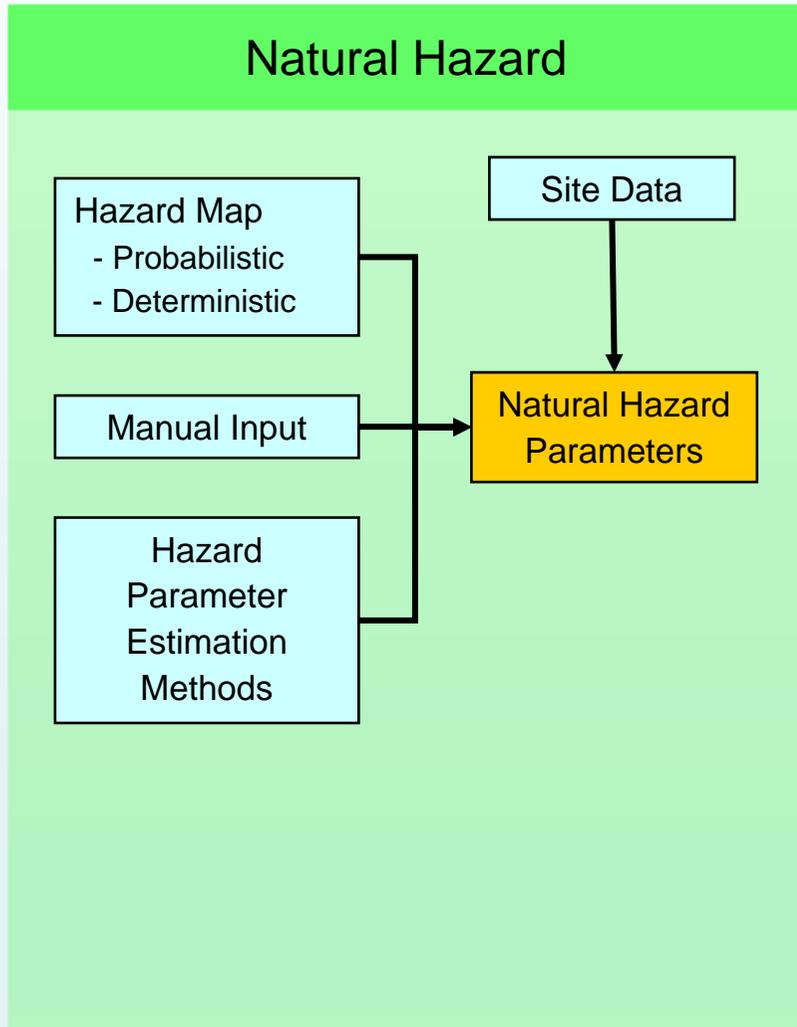
- Integrated methodology
  - **Natural Hazard + Accident**
- Rapid assessment
  - **Local and regional analysis**
- Publicly available
  - **Multilingual cloud service**
- User friendly application
  - **Easy and quick data entry**
  - **Visualization**
- Collaborative environment



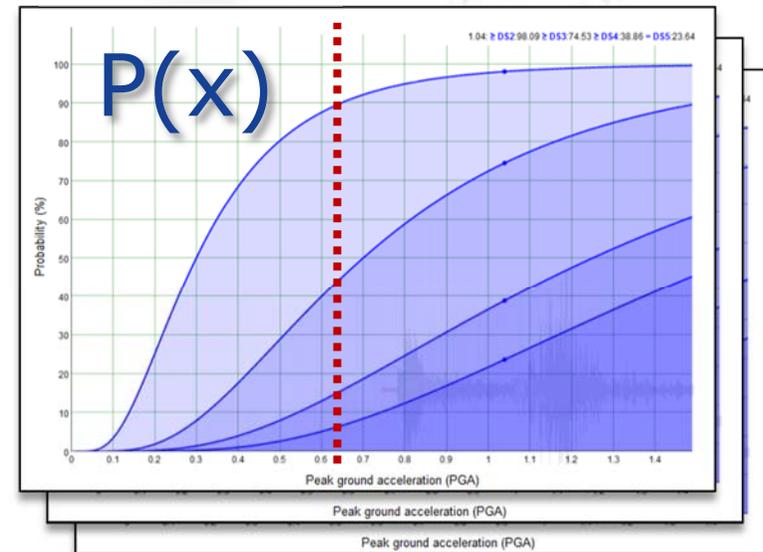
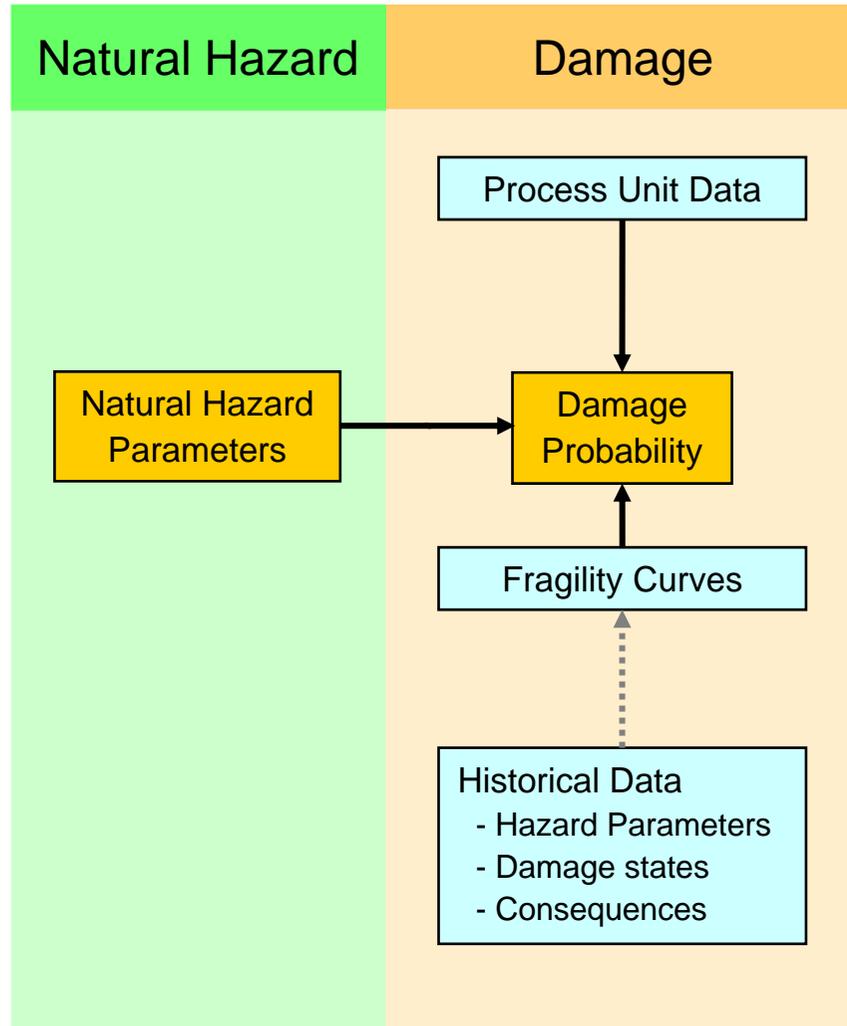
# Methodology



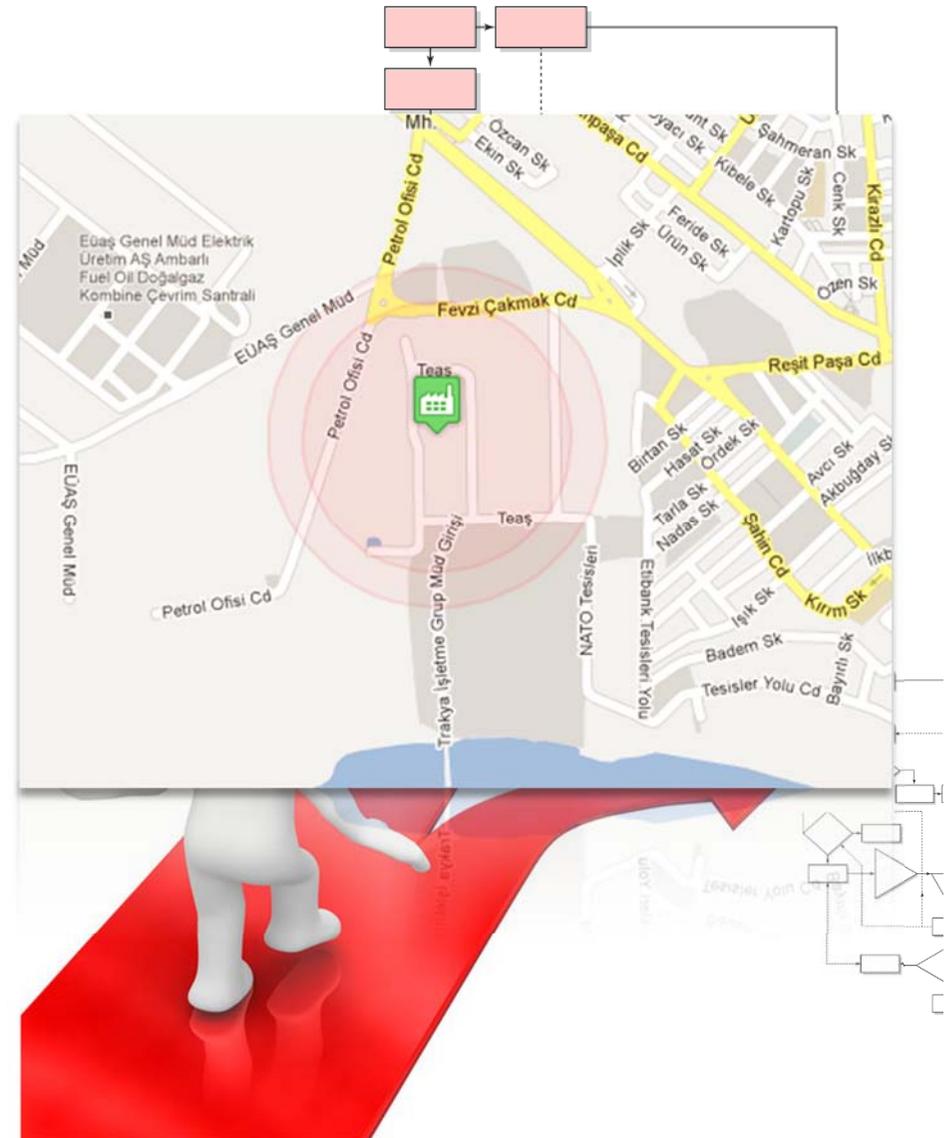
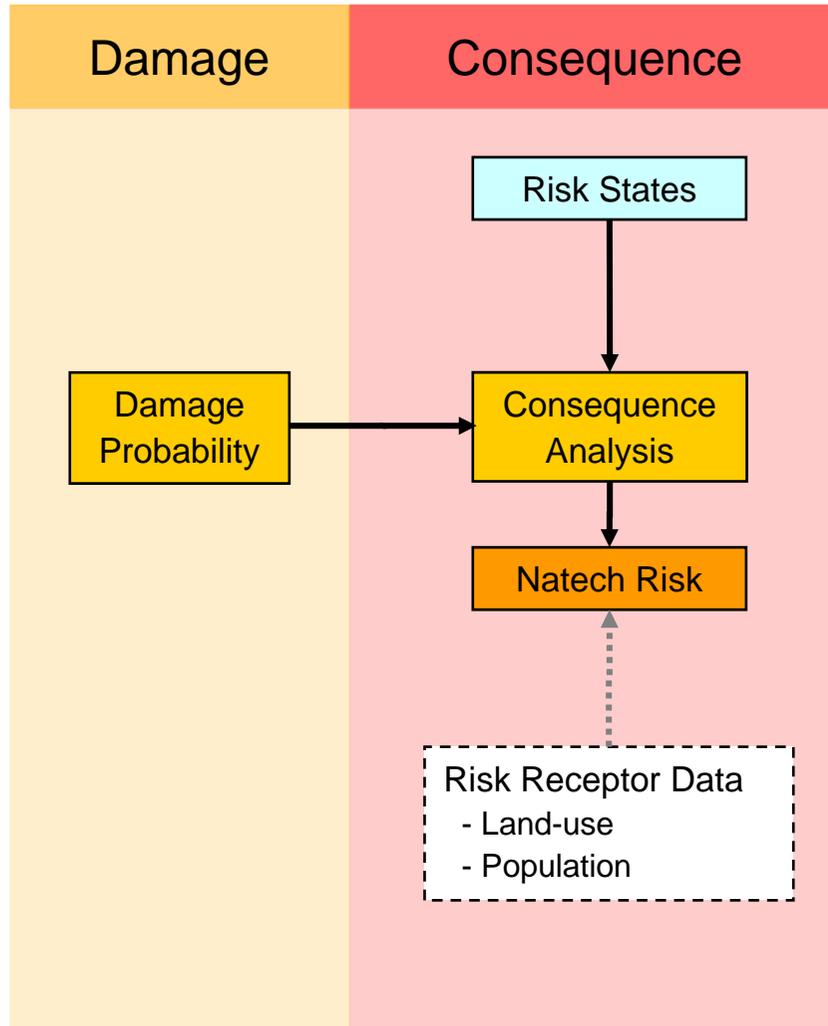
# Methodology



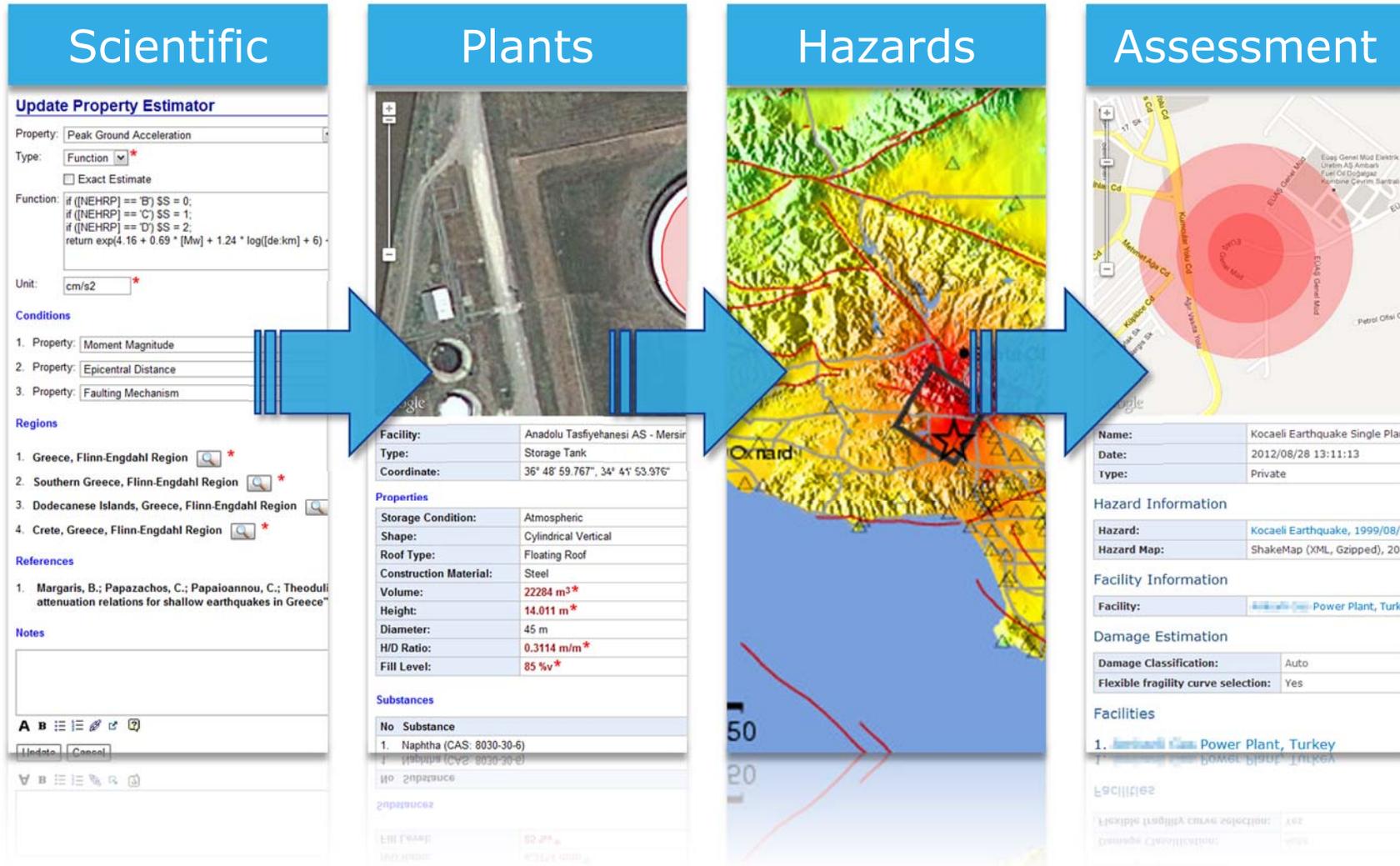
# Methodology



# Methodology



# Modular Structure



# Scientific Module

- Units
  - Flexible input
  - Automated conversion
- Fuzzy data
  - Fuzzy arithmetic
  - Fuzzy statistics
- Geoprocessing
  - GIS analysis
  - Mapping
- References

Reference Information

Locked

Type:	Article
Title:	Peak horizontal acceleration and velocity from strong-motion records in California, earthquake
Authors:	William B. Joyner; David M. Boore
Journal:	Bulletin of the Seismological Society of America
Year:	1981
Volume:	71
Number:	6
Pages:	2011-2038
Abstract:	<p>We have taken advantage of the recent increase in strong-motion data for peak horizontal acceleration and velocity. This new analysis uses a <math>r</math> spreading and anelastic attenuation, for the attenuation curve. An independent determination of the distance dependence of the data from the magnitude</p> $\log A = -1.02 + 0.249 \log r - 0.00255r + 0.26 P$ $r = (d^2 + 7.3^2)^{1/2}, 5.0 \leq M \leq 7.7$ $\log V = -0.67 + 0.489 M - \log r - 0.00256 r + 0.17 S + 0.22 P$ $r = (d^2 + 4.0^2)^{1/2}, 5.3 \leq M \leq 7.4$ <p>where <math>A</math> is peak horizontal acceleration in <math>g</math>, <math>V</math> is peak horizontal velocity in <math>\text{cm/s}</math>, <math>d</math> is distance to the surface projection of the fault rupture in <math>\text{km}</math>, <math>S</math> takes on <math>P</math> is zero for 50 percentile values and one for 84 percentile values.</p> <p>We considered a magnitude-dependent shape, but we find no basis for independent shape because it requires fewer parameters.</p>

Files

No	File	URL
1.	PDF Document (1.62 MB)	<a href="http://daveboore.com/pubs_online/1981bssa_jb81.pdf">http://daveboore.com/pubs_online/1981bssa_jb81.pdf</a>



# Plants Module

- Plants
  - Industrial activity
  - Site properties
- Plant Units
  - Unit characteristics
  - Stored substances
- Typical Plant Units
- Substances
  - Identifiers
  - Physicochemical properties

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/ft <sup>3</sup> * (0.7958 g/cm <sup>3</sup> )
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 ft <sup>2</sup> /lb
RMP Liquid Factor Ambient:	0.018
RMP Liquid Factor Boiling:	0.11
RMP Liquid Leak Factor:	39

# Hazards Module

- Natural Hazards
  - Hazard parameters
- Earthquake Catalog Data
  - Continuous monitoring
  - Automated update
- Hazard Maps
  - Shakemaps
- On-site Hazard Data
- Natechs
  - Damage parameters

Natech Information														
Hazard:	Kocaeli Earthquake, Turkey, 1999/08/17													
Facility:	Turkish Petroleum Refineries Corp. (TUPRAS) Izmit Refinery, Turkey													
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: aftermath and less													
2.	Durukal, E.; Erdik, M., "Physical and economic losses sustained by the industry in the 1999 Koc													
3.	Steinberg, L. J. and Cruz, A. M., "When natural and technological disasters collide: lessons from i													
4.	Danış, H.; Görgün, M., "Marmara earthquake and TÜPRAŞ fire", 2005													
5.	Suzuki, K., "Report on damage to industrial facilities in the 1999 Kocaeli earthquake, Turkey", 200													
Created: Serkan Girgin, 2011/10/18 15:48:13														
Natech Damages														
No	Process Unit Type	Process Unit Properties	Damage Classification											
1.	Storage Tank	Storage Condition: Atmospheric Roof Type: Floating Roof Construction Material: Steel Base Support Type: Unanchored	Seligson et al. (1996)											
<table border="1"> <thead> <tr> <th>No</th> <th>Process Unit Type</th> <th>Process Unit Properties</th> <th>Damage Classification</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Storage Tank</td> <td>Storage Condition: Atmospheric</td> <td>Seligson et al. (1996)</td> </tr> <tr> <td>2</td> <td>Storage Tank</td> <td>Storage Condition: Atmospheric</td> <td>Seligson et al. (1996)</td> </tr> </tbody> </table>			No	Process Unit Type	Process Unit Properties	Damage Classification	1	Storage Tank	Storage Condition: Atmospheric	Seligson et al. (1996)	2	Storage Tank	Storage Condition: Atmospheric	Seligson et al. (1996)
No	Process Unit Type	Process Unit Properties	Damage Classification											
1	Storage Tank	Storage Condition: Atmospheric	Seligson et al. (1996)											
2	Storage Tank	Storage Condition: Atmospheric	Seligson et al. (1996)											

# Assessment Module

- Damage Classifications
- Fragility Curves
- Risk States
  - **Non-linear DS-RS relations**
  - **Damage parameters, e.g.:**
    - Natech event (e.g. BLEVE)
    - Conditional probability (e.g. 50%)
    - Volume involved (e.g. 10 %v)
  - **Validity conditions**



# Risk Assessment

### 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 Cost of Honshu, Japan Earthquake occurred on 2012/01/28.

**B** **x** **x'** **≡** **≡** **↶** **↷** **?**

#### Data Protection

Access:

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

#### Hazard Information

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

#### Facility Information

<b>Facility:</b>	Power Plant, Turkey
------------------	---------------------

#### Damage Estimation

<b>Damage Classification:</b>	Auto
<b>Flexible fragility curve selection:</b>	Yes

#### Facilities

1. **Kocaeli Earthquake Single 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 <sub>e</sub> : 101.38 km; d <sub>h</sub> : 102.79 km; PGA <sub>h</sub> : 74.415 cm/s <sup>2</sup> ; PGV: 15.573 cm/s <<<	OS00-F50-G	≥ DS2: 4.0546%	Fire/Explosion Event: Vapor Cloud Explosion; Q <sub>involved</sub> : 4250 kg; f <sub>m, passive</sub> : 1; P <sub>c, fire</sub> : 100%; f <sub>v, involved</sub> : 10 %; V <sub>involved</sub> : 5.7432 m <sup>3</sup> ; P <sub>c, release</sub> : 30%; f <sub>yield</sub> : 0.1; RMP Scenario: Worst-case; t <sub>release</sub> : 10 min; Q <sub>release</sub> : 425 kg/min; Q <sub>released</sub> : 4250 kg; A <sub>pool</sub> : 6146.1 ft <sup>2</sup> ; h <sub>pool</sub> : 1 cm; Q <sub>release, r</sub> : 425 kg/min; T <sub>a</sub> : 1; R: 0.4; Q <sub>R</sub> : 5000 W/m <sup>2</sup> ; t <sub>exp</sub> : 40 s; D <sub>T</sub> : 342 TDU; d <sub>e</sub> : 270.58 m; Q <sub>fuel</sub> : 4250 kg; P <sub>damage</sub> : 4.0546%; P <sub>natech</sub> : 4.0546% <<<	271 m: 4.0546%
				≥ DS3: 0.004631%	Fire/Explosion Event: Vapor Cloud Explosion; Q <sub>involved</sub> : 8500 kg >>>	341 m: 0.004631%
				≥ DS4: Very low	-	-

# Modelling

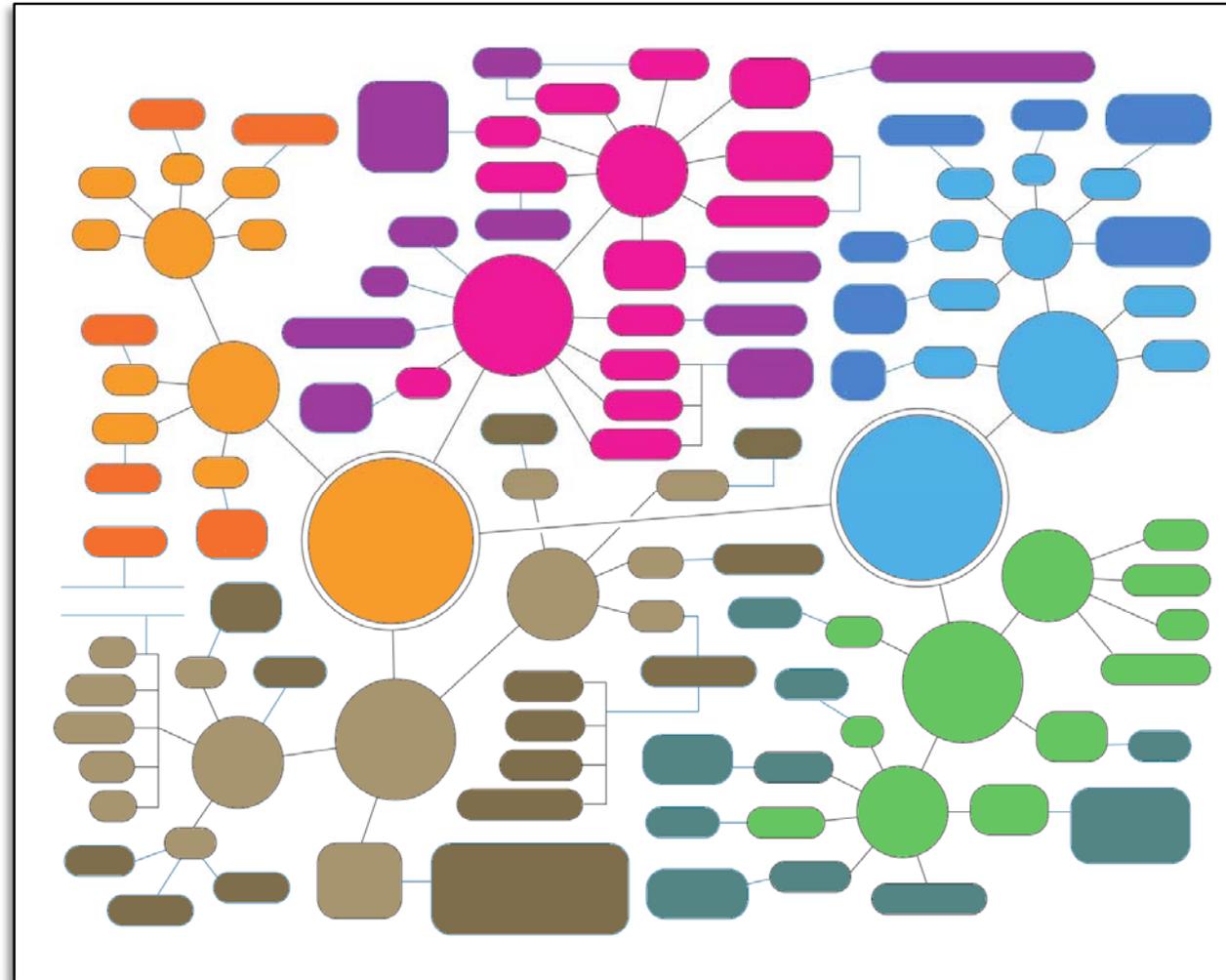
## Consequence

## Hazard

Plant Unit

Plant

Damage



# Modelling: RAPID-N



Building Blocks



Tool Set



Model

# Property Estimation Framework

- Properties
  - Natural hazard: e.g. PGA
  - Site: e.g. Soil class
  - Facility: e.g. Capacity
  - Process unit: e.g. Volume
  - Substance: e.g. Density
- Data
  - Numerical (with unit)  
e.g. 10 m<sup>3</sup>, 1.5 m/s
  - Tabular  
e.g. Atmospheric, Pressurized

### Property Information

Type:	Dimensional (Process Unit)		
Code:	D		
Name:	Diameter		
Description:	Diameter of the process unit.		
Data Type:	Numeric		

Parameter:	European Macroseismic	Value:	Damaging
Parameter:	Peak Ground Acceleration	Value:	0.5 f Unit: %G
Parameter:	Peak Ground Displacement	Value:	40-60 f Unit: cm

Empty: Please enter a diameter.

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

Created: Serkan Girgin, 2011/10/04 09:32:14 – Updated: Serkan Girgin, 2011/10/05 07:00:57

#### Aliases

diameter	EN [ a-z, 0-9, _ ]	<input checked="" type="checkbox"/> Locked
cap	TR [ a-z, 0-9, _ ]	

20	Structural	BT	-	Base Type					
<input type="button" value="Add"/> <input type="button" value="Delete"/>									
cap	Structural	BT	-	Base Type					
cap	Structural	TP	TP	Bojiug Point					
18	Distance	qE	qE	Distance to Euclid Center					
11	Structural	R21	-	Koof zibbou Type					
18	Structural	q	b	Distance					

# Property Estimation Framework

- Property Estimators

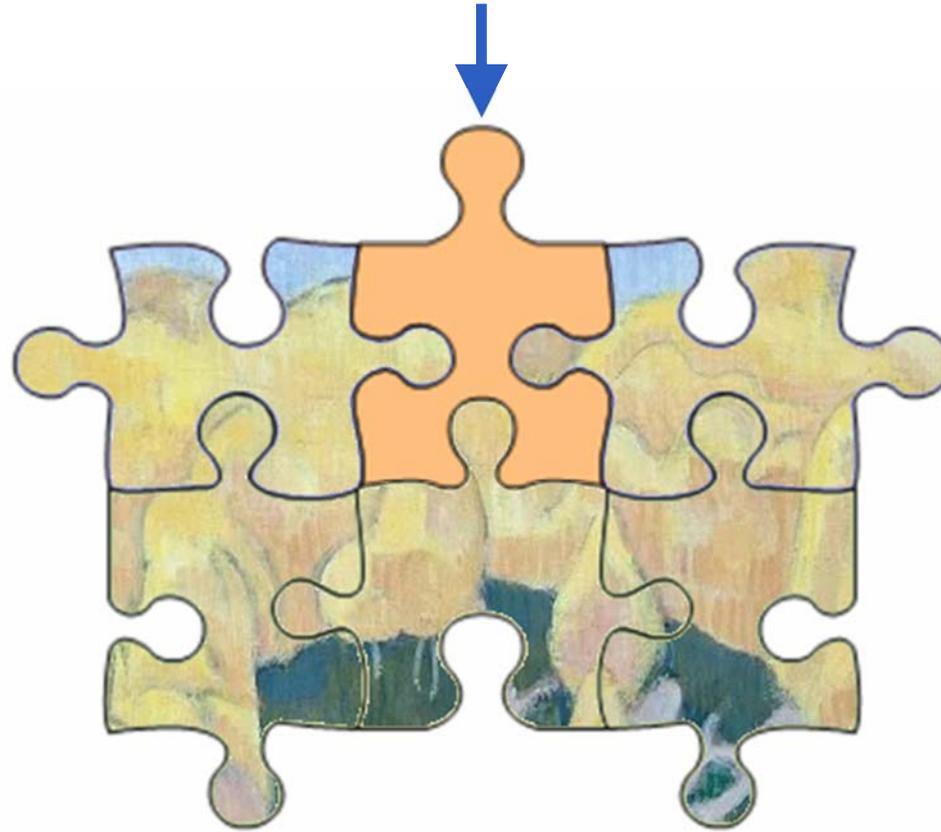
Description	Estimator	Unit	Validity conditions
Default ambient temperature	25	°C	–
Wind speed	1.5	m/s	RMP Scenario = <i>Worst-case</i>
H/D ratio from diameter	1	m/m	Shape = <i>Spherical</i>
Storage condition from roof type	Atmospheric	–	Roof Type = <i>Floating Roof</i> Roof Type = <i>Internal Floating Roof</i> Roof Type = <i>Open Roof</i>
Diameter from volume		m	Shape = <i>Spherical</i>
Energy magnitude from radiated seismic energy		–	
Peak ground acceleration		%g	Region = <i>Western U.S.A.</i>
U.S. EPA RMP Liquid Factor Boiling			
Duration of fireball		s	Fire/Explosion Event = <i>BLEVE</i>

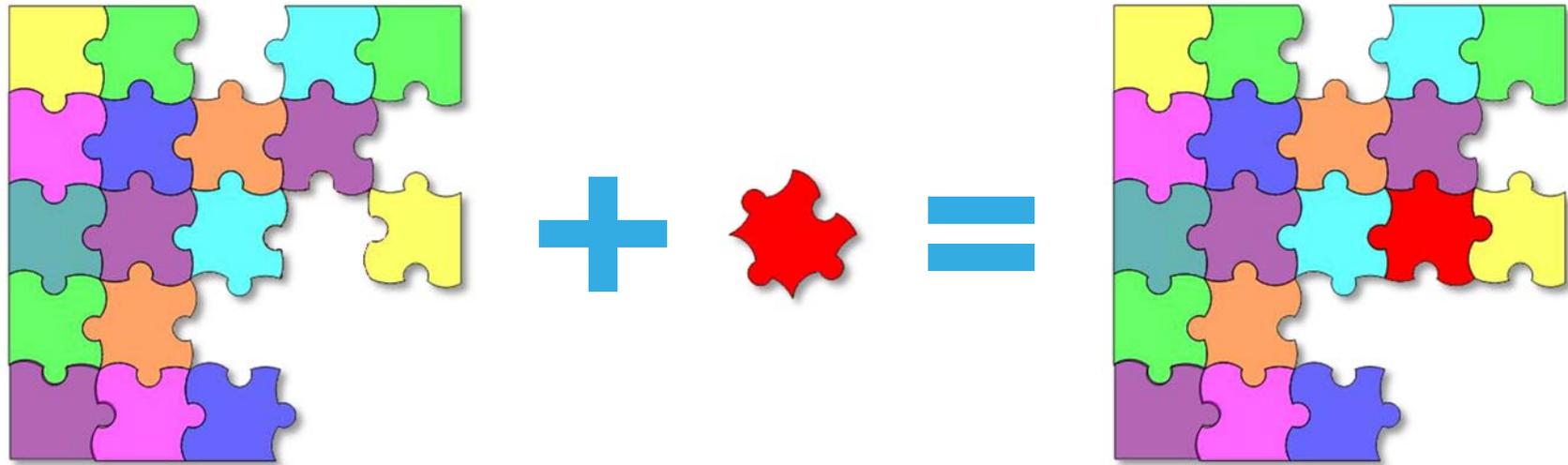
Properties	
Storage Condition:	Atmospheric
Shape:	Cylindrical Vertical
Roof Type:	Floating Roof
Construction Material:	Steel
Volume:	22285 m <sup>3</sup> *
Height:	14.00 m*
Diameter:	147.64 ft (45.00 m)
H/D Ratio:	0.3114 m/m*
Fill Level:	85 %v*

# Property Estimation Framework

Estimated property



# Property Estimation Framework



Building Blocks



Tool Kit



Model

# Property Estimation Framework

- Minimizes data input
  - Estimates missing data
- Increases flexibility
  - Dynamic model building
- Provides extensibility
  - Custom properties
  - Custom estimators
- Selects most suitable
  - Recursive
  - Exhaustive



# Data Availability

- Global coverage
- > 21,000 earthquakes (> M 5.5)
- > 56,400 earthquake catalog data
- > 11,800 ShakeMaps
- > 5,500 industrial facilities
  - **Refineries**
  - **Power plants**
- > 64,500 plant units
  - **Storage tanks**

# Data Availability

- > 330 properties
- > 500 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)

# Application Areas

- Rapid local and regional natech risk assessment
- Land-use and emergency planning
- Identification of neighboring infrastructures at risk
- Early warning
- Preliminary damage assessment

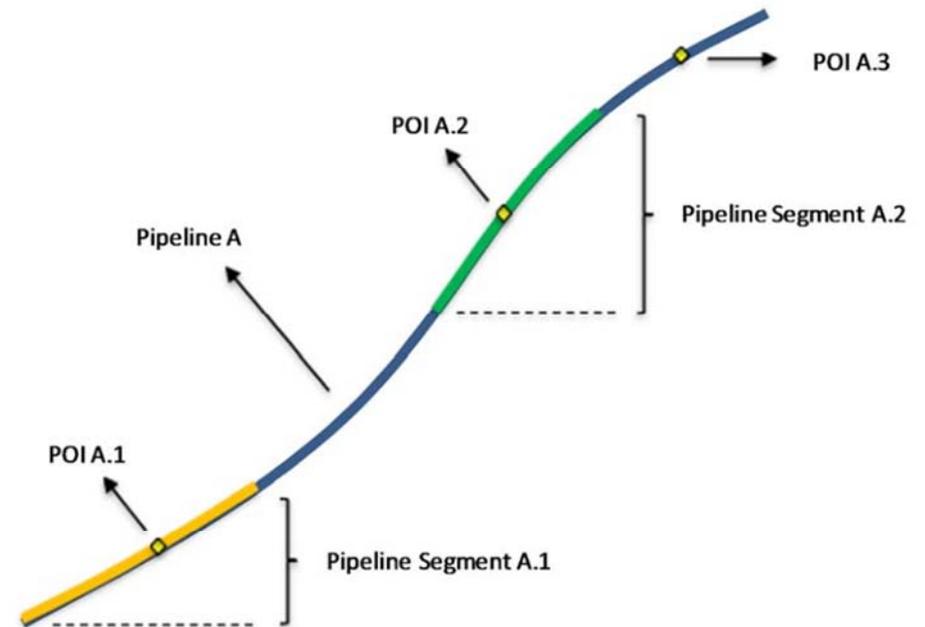
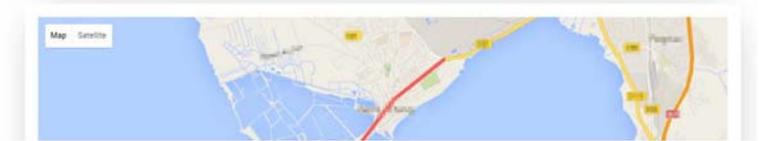


# Further Research

- Automated Natech damage and consequence estimation (**Natech Alert**)
- Extension to other natural hazards (**Floods, Lightning**)
- Extension to other industrial facilities (**Pipelines**)
- Consideration of risk receptors
- Domino effects
- Statistical analysis of natech damage data

# 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



Pipe Specification:	API 5L
Pipe Location:	Underground*
Number of valve sites:	1
Average distance between valve sites:	2.2902 km*
Maximum Allowable Operating Pressure:	1351.5 psi*
Maximum Operating Pressure:	1351.5 psi*
Safe Operating Pressure:	1486.7 psi*
Nominal Capacity:	7000 barrels/d* (1112.9 m <sup>3</sup> /d)

# Pipeline Natech Risk Assessment

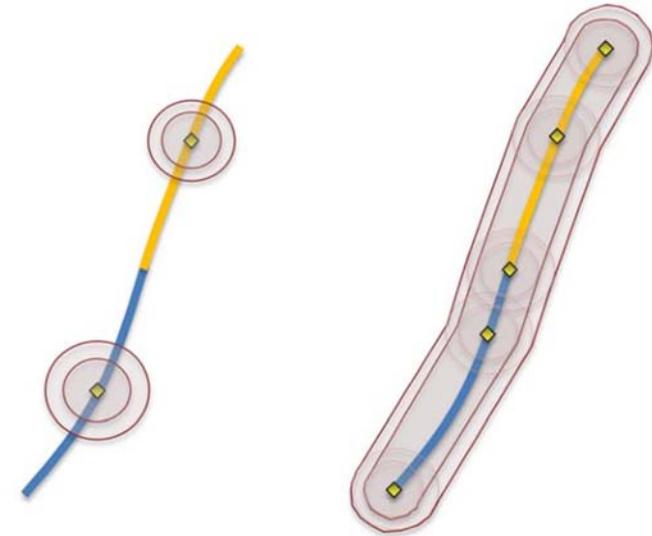
- Pipeline-specific features
  - Overlapping segments
  - Auto-segmentation
  - Automated POI generation
  - Impact zone consolidation

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

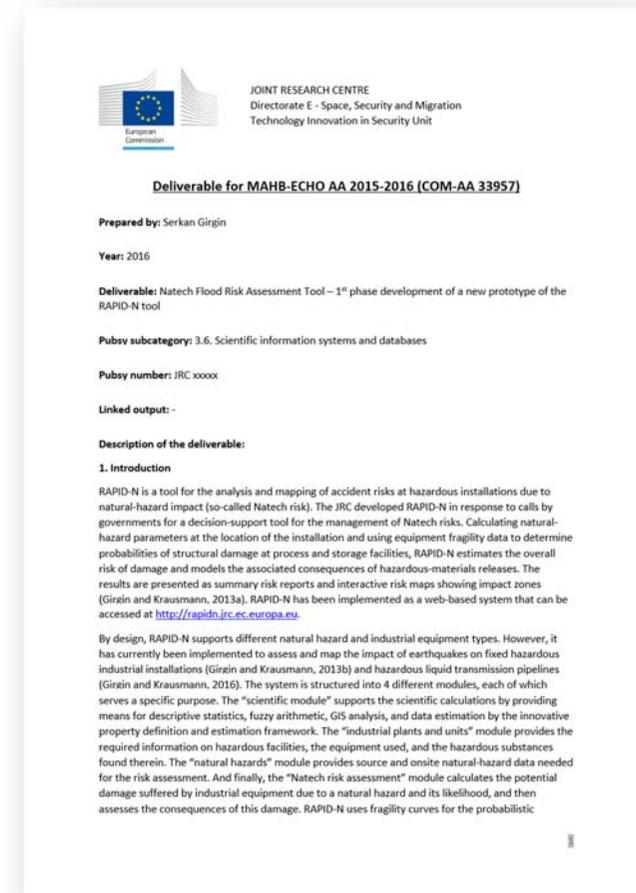
  

Damage and Consequence Parameter	POI 1	POI 2
Damage probability, = RS1 (limited loss)	$1.7 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$
Damage probability, = RS2 (significant loss)	$8.1 \cdot 10^{-11}$	$2.1 \cdot 10^{-11}$
Release rate	5.3 kg/s	5.3 kg/s
Maximum pool diameter	11 m	11 m
End-point distance (5 kW/m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



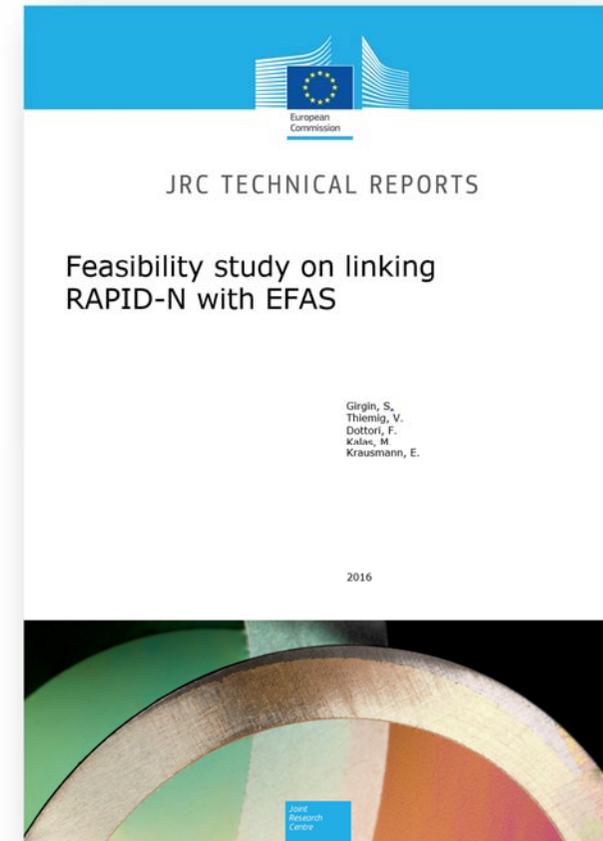
# Flood Natech Risk Assessment

- 1<sup>st</sup> Phase of the prototype is completed (MAHB-ECHO AA 2015-2016)
- Collection of scientific and technical knowledge
  - Methodologies
  - Hazard data sources
  - Equipment vulnerability
  - Consequence analysis
- Gap analysis
  - Modifications
  - Further development

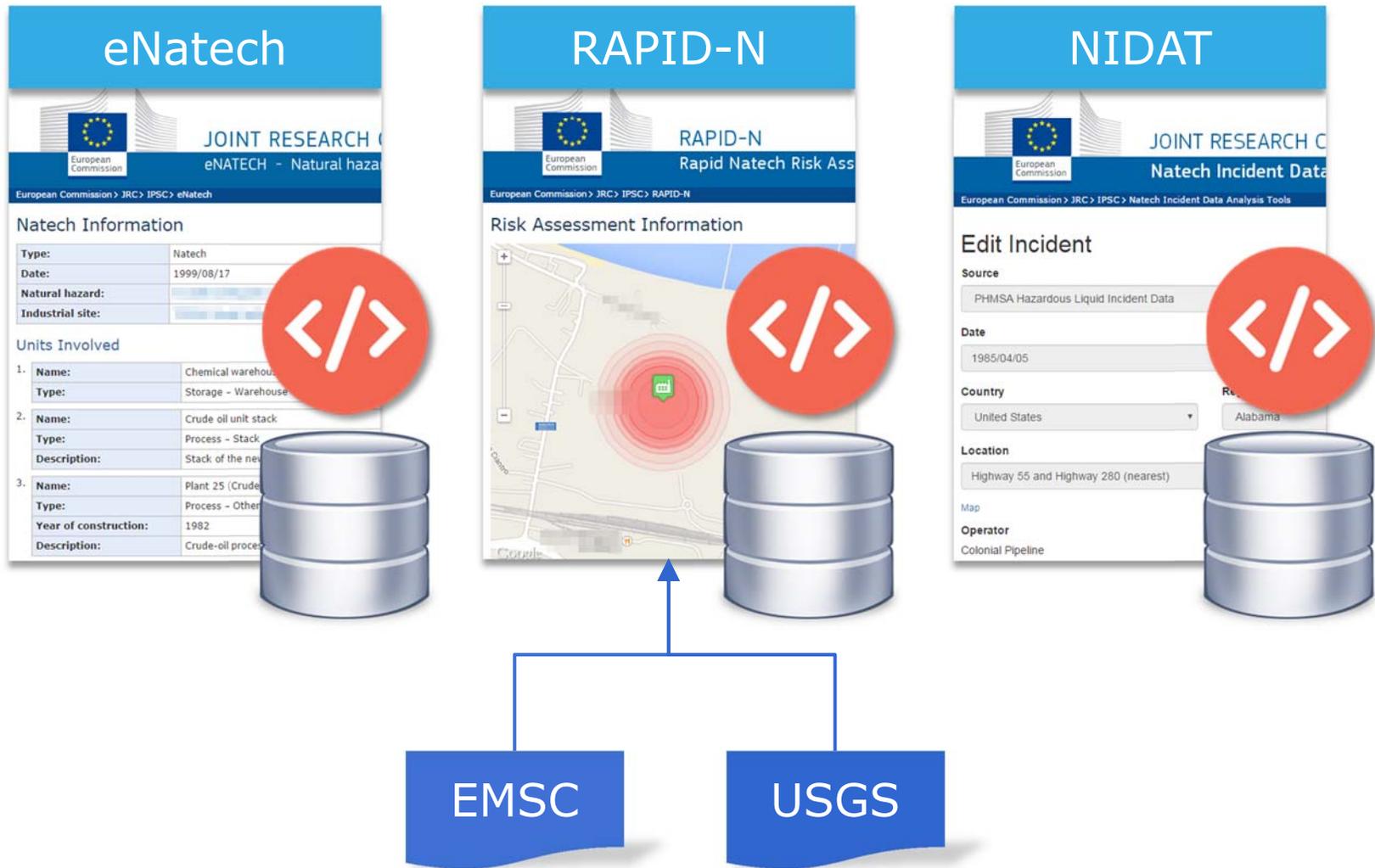


# Flood Natech Risk Assessment

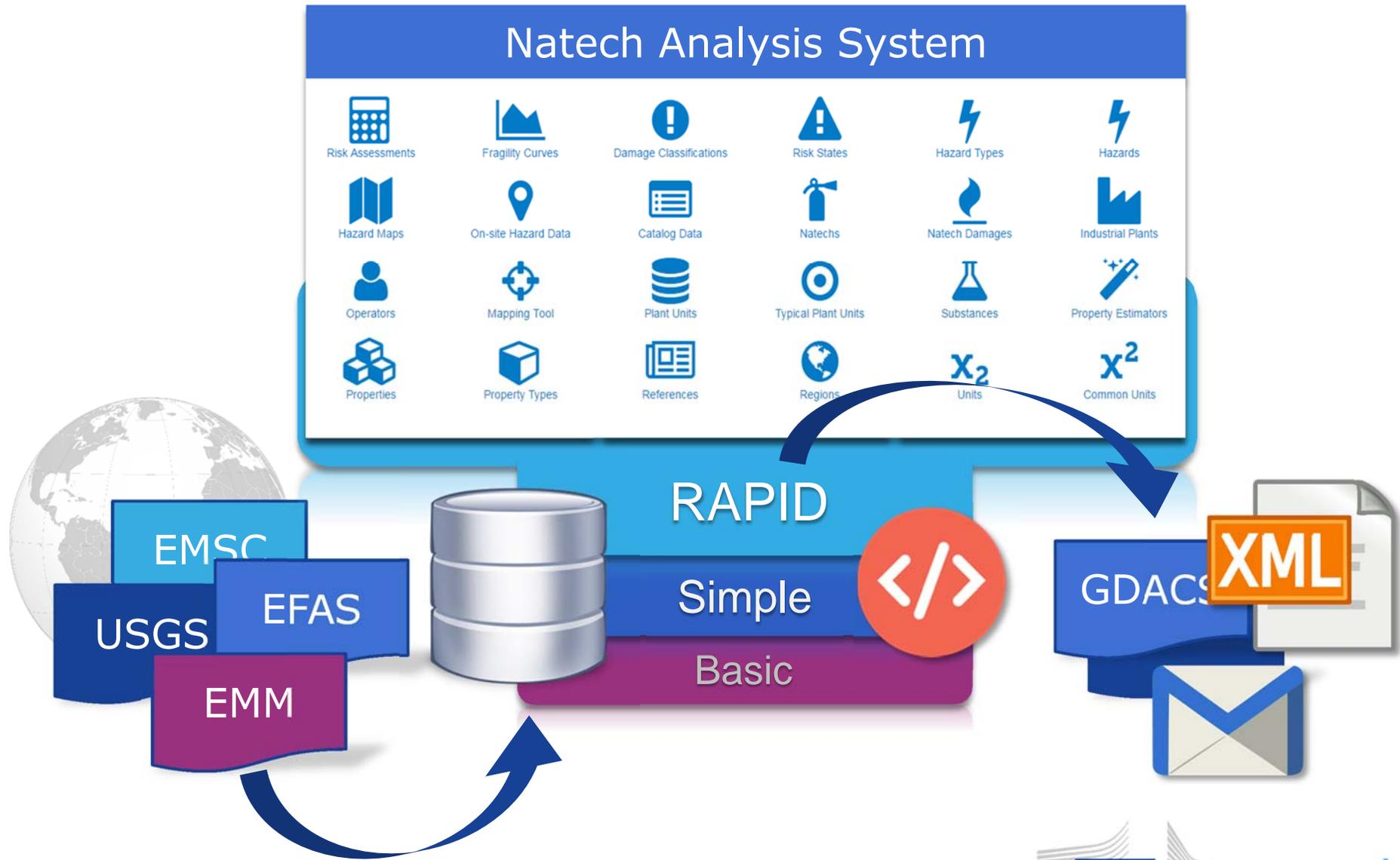
- EFAS/RAPID-N interoperability  
(JRC Technical Report JRC105055)
- Benefits
  - **Flood hazard data for natech risk assessment**
  - **Natech risk data for emergency management**
  - **Flood forecasts → Natech Alert**
  - **Data sharing/cooperation between JRC systems**



# 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**

# New Version

**Name:** Skarlatoudis et al.  
**Property:** Peak Ground Accel  
**Type:** Function  
**Function:**  
 $acc=0.02$   
 $acc1=0.45$   
 $acc2=1.275$   
 $fF=[70] \cdot [1]^{0.1010}$   
 $acc3=0.02$   
 $fS=[1]^{0.002} \cdot [2]$   
 return pow(10, fS  
 cm/s<sup>2</sup>  
**Unit:**  
**Exact Estimate:** No  
**Precedence:** Auto  
**Disabled:** No  
**Notes:** See Douglas (2011  
 Validation: M = 5.0  
 NEHRP = 'B', FM =  
 km : PGA = 4.647)

**Validity Conditions**

<b>Moment Magnitude:</b>	4.5-7
<b>Focal Depth:</b>	0-30.1 km
<b>Faulting Mechanism:</b>	Normal, Thrust, St
<b>Epicentral Distance:</b>	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

- Douglas, J., "Ground-motion prediction equati
- Skarlatoudis, A. A.; Papazachos, C. B.; Margaris, B. N.; Theodoulis, N.; Papaioannou, C.; Kalogeras, I.; Scordilis, E. M.; Karakostas, V., "Empirical peak ground-motion predictive relations for shallow earthquake in Greece", 2002

Created: Vincenzo ARCIDACONO, 2014/01/27 11:49:22 - Updated: Vincenzo ARCIDACONO, 2014/03/10 17:49:37

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**Name:** American/Polish Mine (2011) Storage Tank  
**Historic Type:** Earthquake  
**Plant Unit Type:** Storage Tank  
**Description:**  
 Damage states according to American Lifelines Alliance's "Seismic Fragility Formulations for Water Systems" guideline (2001).  
 $f(0.05) + SF + SCS * S5$   
**States**  
**Code:** 001  
**Name:** No Damage  
**Description:**  
**Code:** 002

**Validity Conditions**

<b>Moment Magnitude:</b>	4.5-7
<b>Focal Depth:</b>	0-30.1 km
<b>Faulting Mechanism:</b>	Normal, Thrust, St
<b>Epicentral Distance:</b>	1.5-150 km

**Validity Regions**

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# Key Messages

- Integrated natech risk assessment framework
- Rapid regional and local analysis
- Dynamic model building
- Missing data estimation (minimum data input)
- Extensible structure (easily customizable)
- User-friendly interface
- Cloud service (publicly available)



## **RAPID-N**

*[rapidn.jrc.ec.europa.eu](mailto:rapidn.jrc.ec.europa.eu)*

## **eNatech**

*[enatech.jrc.ec.europa.eu](mailto:enatech.jrc.ec.europa.eu)*

## **TecRisk**

[elisabeth.krausmann@jrc.ec.europa.eu](mailto:elisabeth.krausmann@jrc.ec.europa.eu)

[serkan.girgin@jrc.ec.europa.eu](mailto:serkan.girgin@jrc.ec.europa.eu)