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DOPEX project: Toward Fast-Computing Tools for weapon effects evaluation on Nuclear Facilities

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

EUROSAFE 2016

Role of IRSN in the French Nuclear Security Field to support the competent authority

- Carry out evaluation and expertise on
  - physical protection of facilities
  - accounting system and control
  - physical inventories
  - physical protection of transports
- Carry out inspections
- Monitoring of nuclear material transports
- Centralization of nuclear material accountancy
- Research & Development

Technical Need of Fast-computing tool

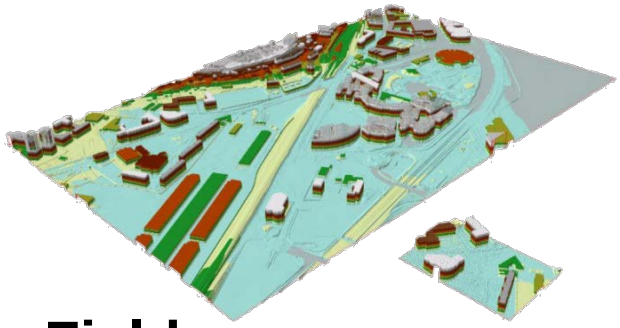
- **First Evaluation for technical assessments**
  - Identifying the potential vulnerabilities
  - Estimating a first order of magnitude of the damage

For aggression means employed
(e. g. Fire weapons, rocket launchers, explosive devices…)

- **First Evaluation for crisis situations**
  - Estimating the state of nuclear facilities after an attack
  - Identifying the potential aggravating factors by an aggression means in progress (revision of the projected “source term” for possible radiological consequences)
- **Advantage Global Overview of the Damage ($t_{computing}$ << 10 min)**

Model of a nuclear facility with GIS*

*Geographic Information System



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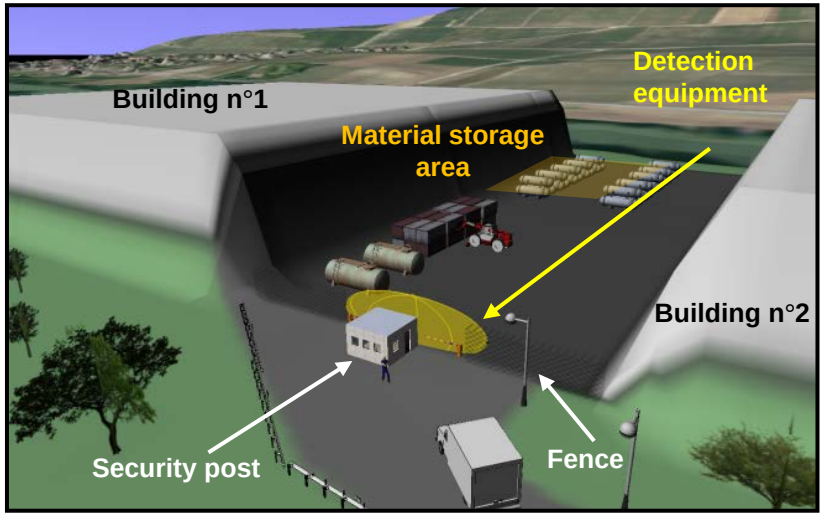
- **Data compilation for the Nuclear Security Field**
  - Geographic data base
    - Topography and building (elevation, identification of building's number…)
    - Physical barrier (localization, type and delimitation of physical protection areas)
    - Detection and mitigation equipments (localization and type for nuclear safety and security)
    - Points of response forces (localization inside or outside the plant area)
  - Different information sources
    - Data collected by the French National Institute of Geographic and Forestry information (IGN)
    - Information and description in the security plan or study
- **Input of the DOPEX tools → Geographic security data base**

Model of a Nuclear Facility with GIS

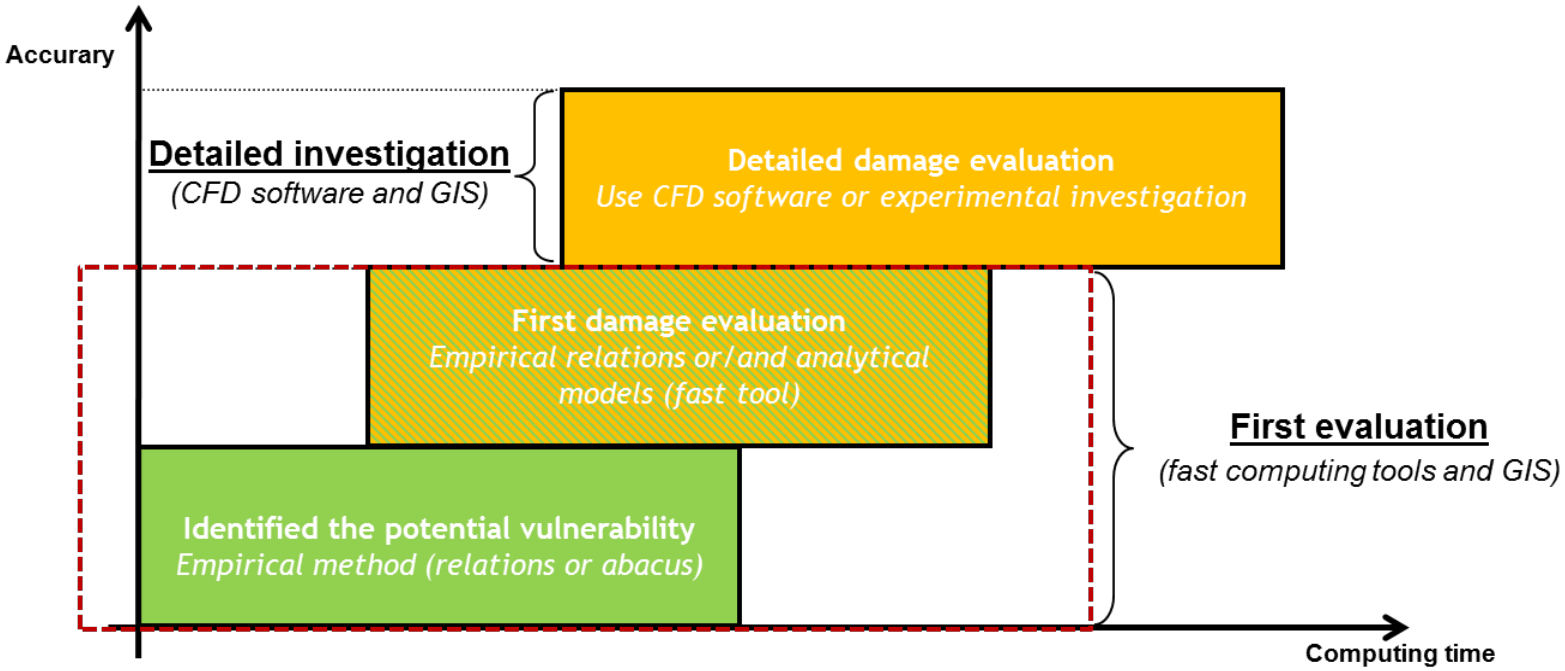
- **Modeling of a nuclear plant's topography**
  - Development of 3D model with geographic data
    - With simple geometric shapes (prismatic or cylinder structure)
  - This 3D model input for others security softwares
    - Evaluation of progress outside facilities (distance and time)
    - Meshing for the Computational Fluid Dynamics (CFD)



View progress with SICAP software used a 3D model (fictive factory)

Fast-computing tools developed in the DOPEX project

- **Perimeter of the DOPEX tools**



  - **Main advantages**
    - The accuracy compared to the computing time ratio
    - Connection between geographic data and weapon effects models

Principle of the DOPEX tools

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- **Operation Principle**
  - Input data of the DOPEX tools
    - Aggression means
    - Geographic coordinates action

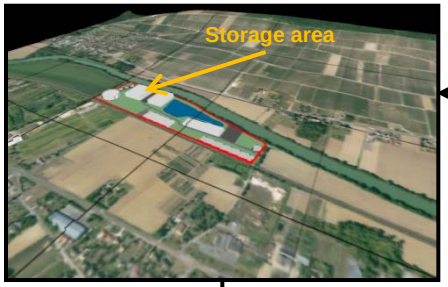
    } ***Defined by users***

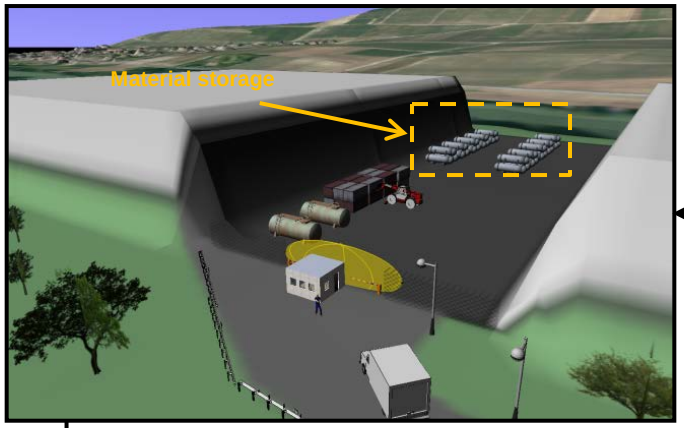
    - Structure dimensions and constitution

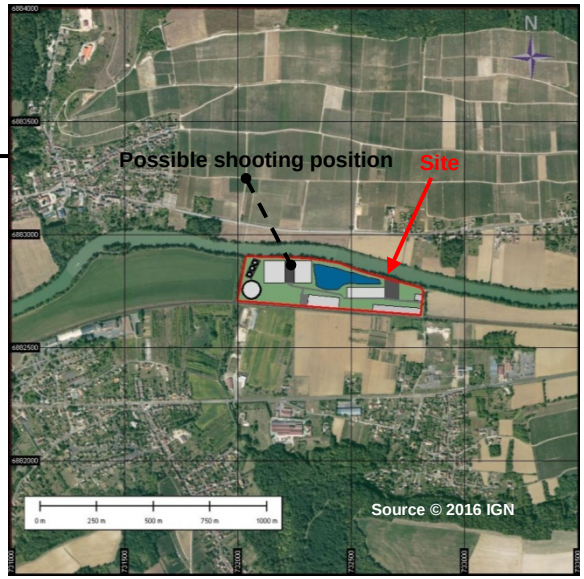
    } ***Loading of the geographic security data base***
  - First part of the DOPEX tools -> Geometric Modules
    - Estimation of different geometrical parameters (angle / distance)
    - Geometrical parameters necessary for weapon effects evaluation
  - Second part of the DOPEX tools -> Physical Modules
    - Ballistic impact, Blast Wave effects…
  - Final results: Global Overview of the Damages on a map or a meshing

First part of the DOPEX tools: Geometric Modules

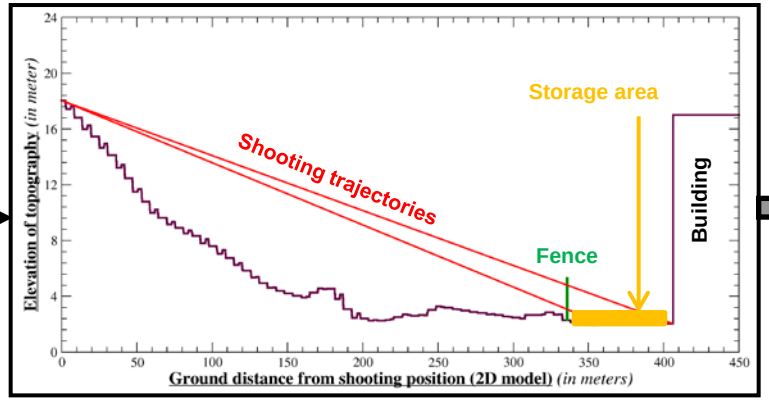
- Example of an aggression scenario with rocket launchers







1rst stage: load geographic data base
Topography and physical protection equipment (for example, fence…)

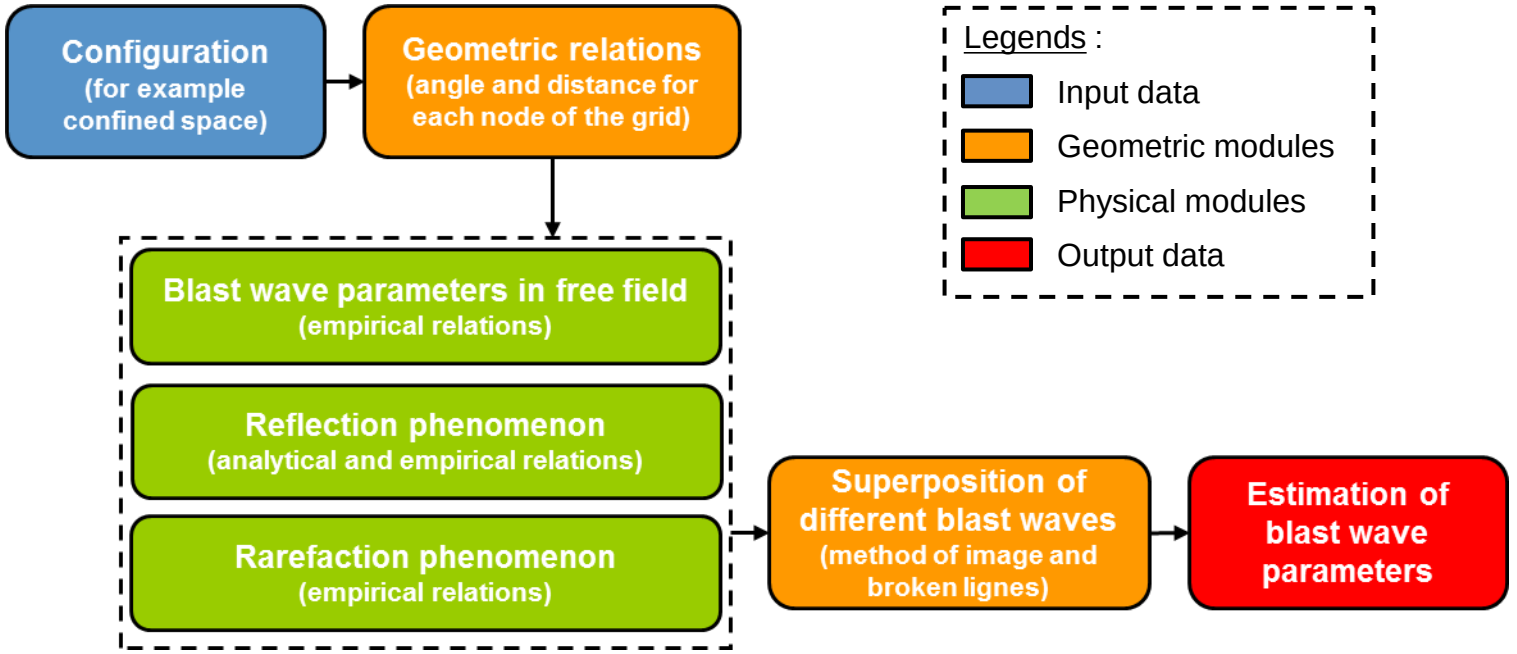


2th stage: geometric module
Analyze of different shooting trajectories

3th stage: physical part
Analyze of jet propagation and jet penetration in tank

Second part of the DOPEX tools: Physical Modules

- **Evaluation of blast wave parameters**



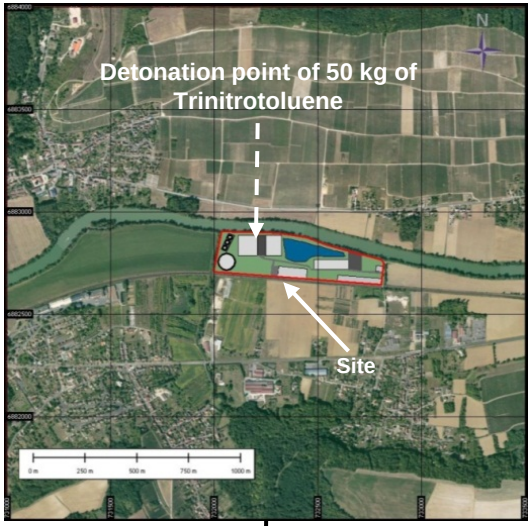
- Estimation of the pressure profile for each point of a meshing
- Blast wave parameters evaluated with this profile (overpressure and impulse)

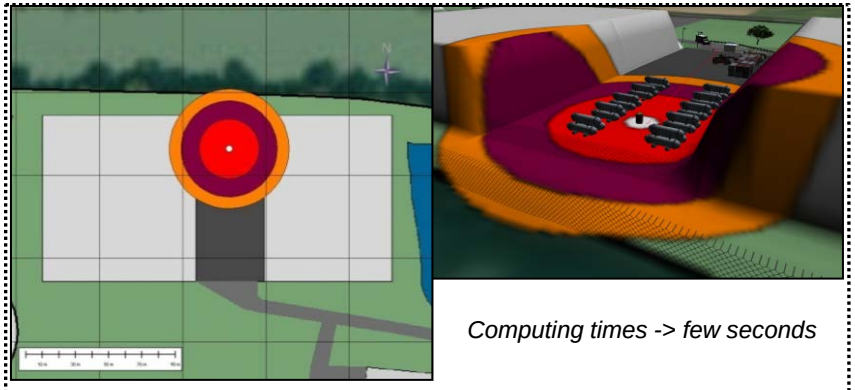
Second part of the DOPEX tools: Physical Modules

- **Evaluation of blast wave effects**
  - The damages are estimated by the blast wave parameters
    - Positive overpressure and impulse
    - Standard effect values from the literature (TNO (1992), Baker (1973)…)
- **Evaluation of weapons effects on a Nuclear Facility**
  - Shaped charge (PER method, Bernoulli theory…)
    - Depth and diameter of penetration for shaped charges recorded
  - Ballistic impact
    - Depth and diameter of penetration for projectiles recorded
- **All fast-computing tools constitute a first version catalog of tools for the Nuclear Security Field**

Second part of the DOPEX tools: Physical Modules

- **Stakes evaluation on industrial plant area**





Computing times -> few seconds

Evaluation of the effected areas with the blast wave parameters in free field (without taking account the presence of buildings)

Damages Areas – First order

Area Z_1 , $\Delta P^+ > 0{,}43$ bar

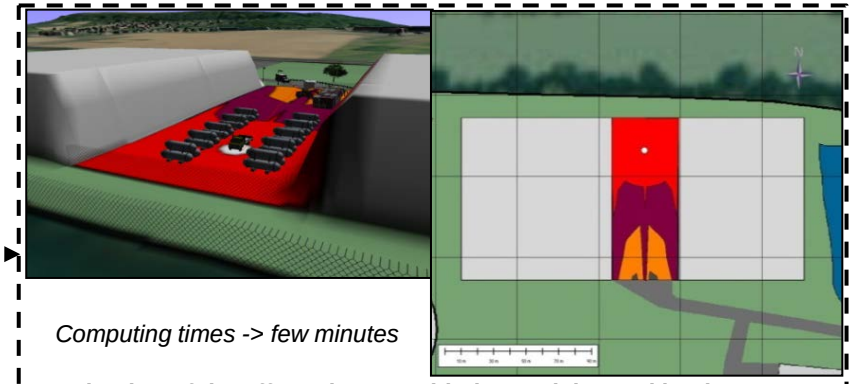
Standard value for destruction of house or reversal of wagon

Area Z_2 , $\Delta P^+ > 0{,}20$ bar

Standard value for damage on industrial equipment in building

Area Z_3 , $\Delta P^+ > 0{,}14$ bar

Standard value for small damage on concrete wall



Computing times -> few minutes

Evaluation of the effected areas with the models used by the DOPEX tools (with the presence of buildings)

Fast-computing tools developed in the DOPEX project

- **Limits of the simple tools**
  - Limited simple geometric configurations
  - All physical phenomena not simulated
  - Results with a certain degree of uncertainty (about 20-30%)

  → **A global overview of damages expected or caused**
- **Actions after fast evaluations**
  - Great indication to initiate the first measures / assessments
  - Whether a further in depth study is necessary -> CFD deployed

Conclusion and perspective

- Fast-computing tools give a Global Overview of the Damage in order to initiate the first adapted measures
- Easy to use by any engineer, even without specific knowledge in weapon effects evaluation
- The physical method employed can be improved to reducing uncertainty
- Increase the number of tools according to aggression means
- Extend the data base with the overpressure effect values and the material suspension factors