HNS-MS stakeholders meeting

Session 5 : Modelling HNS behaviour in the marine environment

The near-field model CHEMSPELL

DG-ECHO civil protection funding mechanism
2014 Call for Prevention and Preparedness

museum Cedre ARMINES ALYOTECH

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The near-field model CHEMSPELL

In some specific cases, HNS can be **released from the water column** with different configurations:

- Leak from a sunken vessel, from a broken pipeline/well
- Pollutant with various behaviours (floaters, dissolvers, etc.)

Goals:

- **Cover these specific underwater release scenarios**
- Model the different physical/chemical involved processes
- Validate with experimental data and/or use results
- Provide **relevant information of the water column**

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The near-field model CHEMSPELL

- CHEMSPELL : **CHEM**ical **S**ubsea **P**lume mod**EL** for **L**eakage
- Simulation of **HNS behaviours and fate** in the water column, from the breach to the surface
- Integration in the decision support system prototype as **near-field** model to provide a **source term** to the HNS-MS far-field model
- 4 Scenarios includes the near-field model:
  - **Spill from a sunk vessel** (discharge estimated / breach characteristics known)
  - **Spill from a broken pipeline** (discharge estimated / breach characteristics known)

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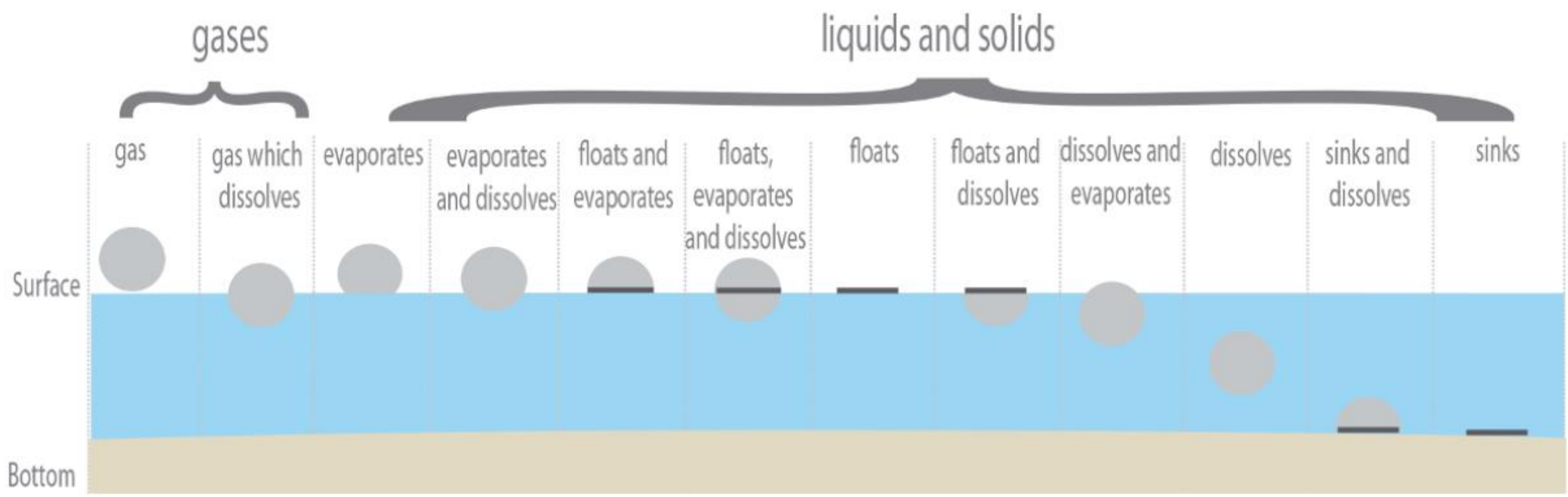
- Simulation for both **gas** and **liquid** entities
- It covers products with **behaviours G, D, E, F, S** (and combinations) in the water column



HNS types by Standard European Behaviour Classification

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- Scenario **key parameters** for CHEMSPELL:
  - Type of scenario
  - Simulation time
  - Location, depth
  - HNS description (SEBC, physical-chemical constants)
  - Environmental conditions for the water column
    - Temperature, salinity, currents
  - Options

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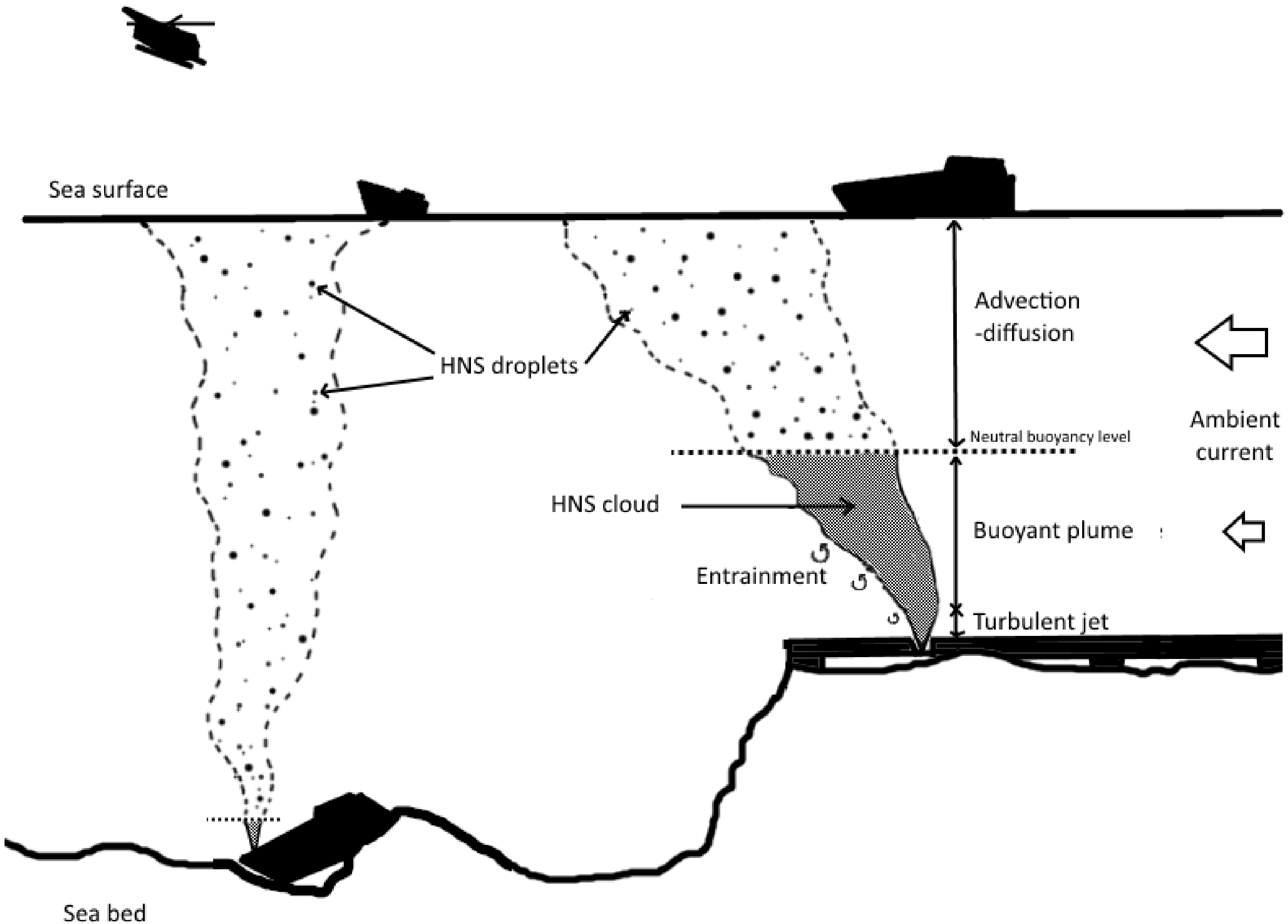

Illustration of HNS leaks in the water column
(Alyotech, 2016)

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Hydrodynamic modules
- Advection-Diffusion stage
- Plume Dynamic stage

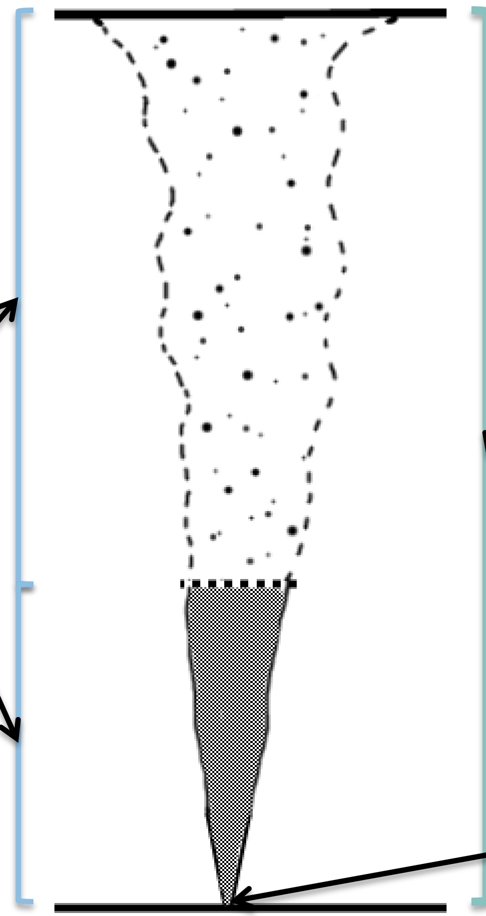

Illustration of a HNS plume
(Alyotech, 2016)

HNS behaviours modules
- DSD
- Dissolution
- Slip velocity

Initialization modules
- Sunken vessel
- Broken pipeline

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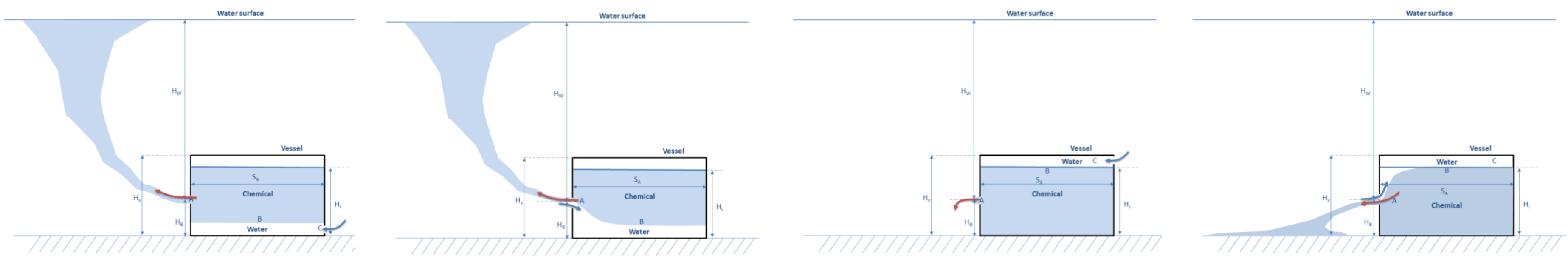
- Sunken vessel initialization
  - Model implemented from the work done by L. Aprin (EMA)
  - 4 configurations are considered : **simple or double breach, for floating or sinking pollutant**



Discharge model configurations (L. Aprin 2016)

  - Evaluation of the flow rate at the breach based on **Bernouilli's principle**
  - Evaluation of the **draining time**

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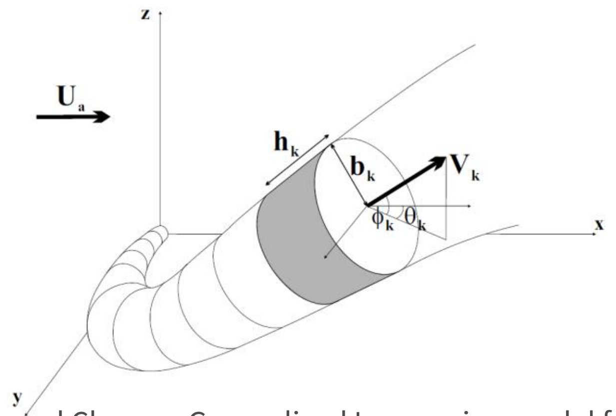
- Plume Dynamic stage (PDS)
  - For the **jet/buoyant** plume stage
  - A Lagrangian integral model based on a **control volume**
  - **Shear and forced entrainment** of ambient water are evaluated
  - **Conservation of mass, and state variables**
  - **Conservation of momentum**



(Lee and Cheung, Generalized Lagrangian model for buoyant Jets in current, 1990)

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- Advection Diffusion stage (ADS)
  - When buoyant plume reaches a **neutral buoyancy level**
  - HNS cloud from the CV is divided into numerous parcels
  - Droplets are **advected** by ambient current
  - Droplets are **diffused** by ambient turbulence (use of a random walk)
  - HNS dissolved volume is also represented by parcels

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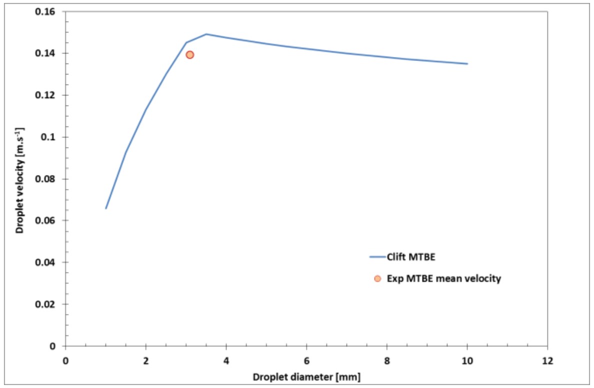
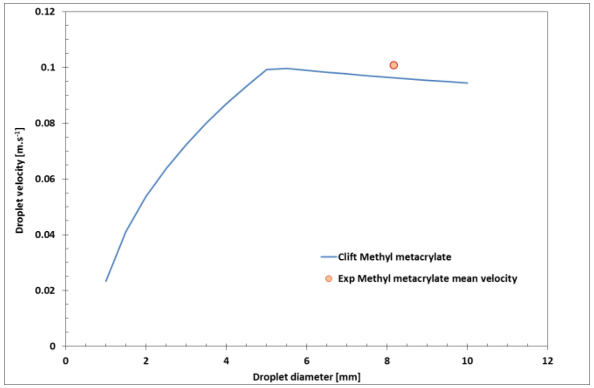
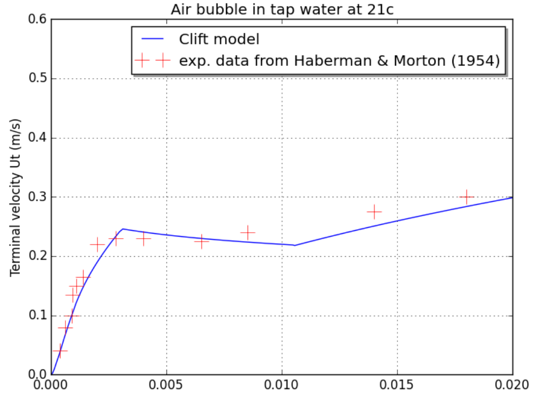
- Slip velocity
  - Crucial to know the time spent in the water column
    - Impact on **dissolution**
    - Impact on **surfacing time**
  - Use of the Clift correlations for 3 regimes: Spherical, ellipsoidal and spherical-cap
  - Experimental data shows good agreements







Experiments comparisons of methyl ter butyl ether (on the left) and methyl methacrylate (in the middle) with Clift model (L. Aprin 2016). Comparisons of air bubble in tap water on the right.

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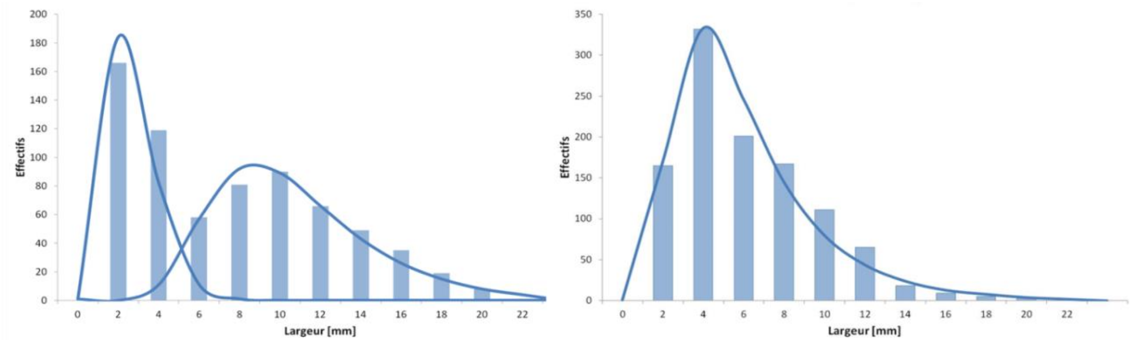
- Droplet size distribution (DSD)
  - At initialization, a DSD is evaluated based on experimental data and depends on flow rate:



Drop size distributions. On the left , flow rate < 10^{-4} $m^3.s^{-1}$, on the right < 10^{-4} $m^3.s^{-1}$. (L. Aprin 2016)

  - Evolution with droplet dissolution
  - During the PDS, the whole DSD is represented **in each control volumes**
  - At the beginning of the ADS, each parcel corresponds to **one class** of the DSD

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- Dissolution
  - **Common module** between CHEMSPELL and HNS-MS
  - Dissolution rate is **calculated at bubble/droplet/spillet scale** as :

$$\frac{dn}{dt} = KA(C_s - C_0)$$

K the mass transfer coefficient (*m.s*$^{-1}$), *A* the contact area (*m*^{2}), C_s the concentration at saturation (i.e. solubility *mol.m*$^{-3}$), C_0 the ambient concentration (*mol.m*$^{-3}$)

  - Use of the **HNS solubility value from data base**
  - Evaluation of the mass transfer coefficient *K* based on Sherwood Number formulations
  - Next step : **Validation with CEDRE/EMA experiments**

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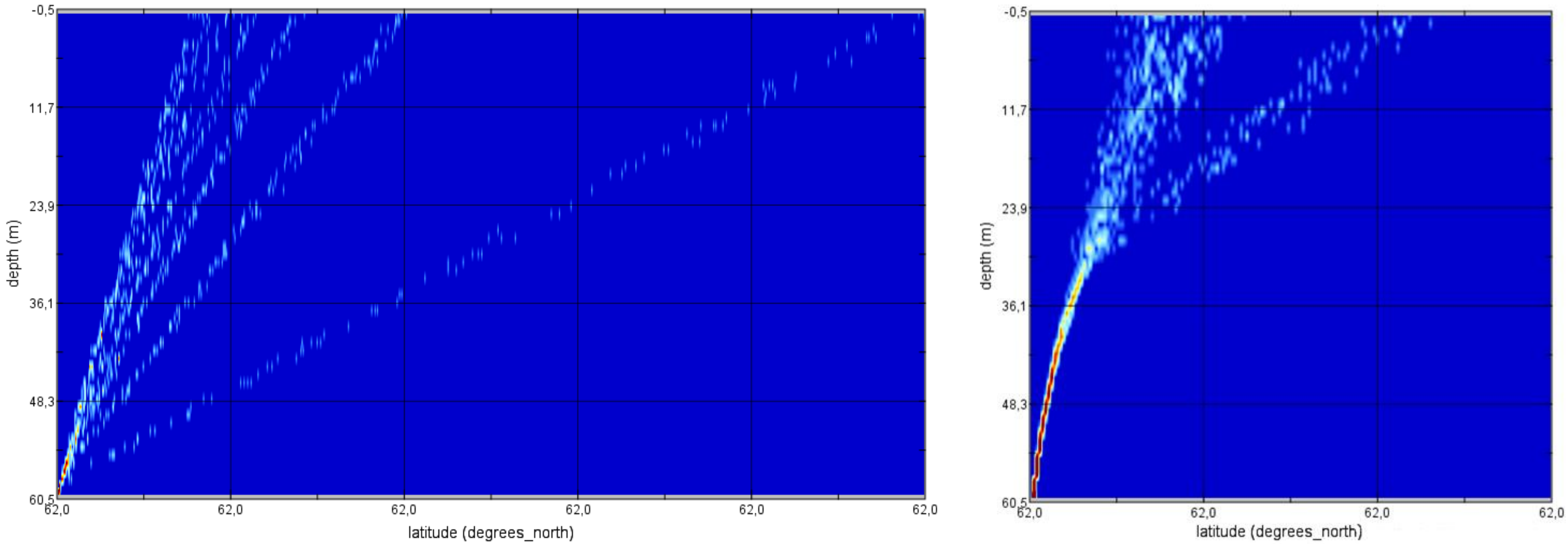
- Output data
  - Generation of netCDF file that contains : Concentration, velocity, droplet size distribution per depth, number of parcel, ..
  - A dedicated post treatment in the case of gas release



Illustrations of HNS concentration in the water column. Sunken vessel scenario on the left, pipeline scenario on the right (captures from NASA/GISS Panoply)

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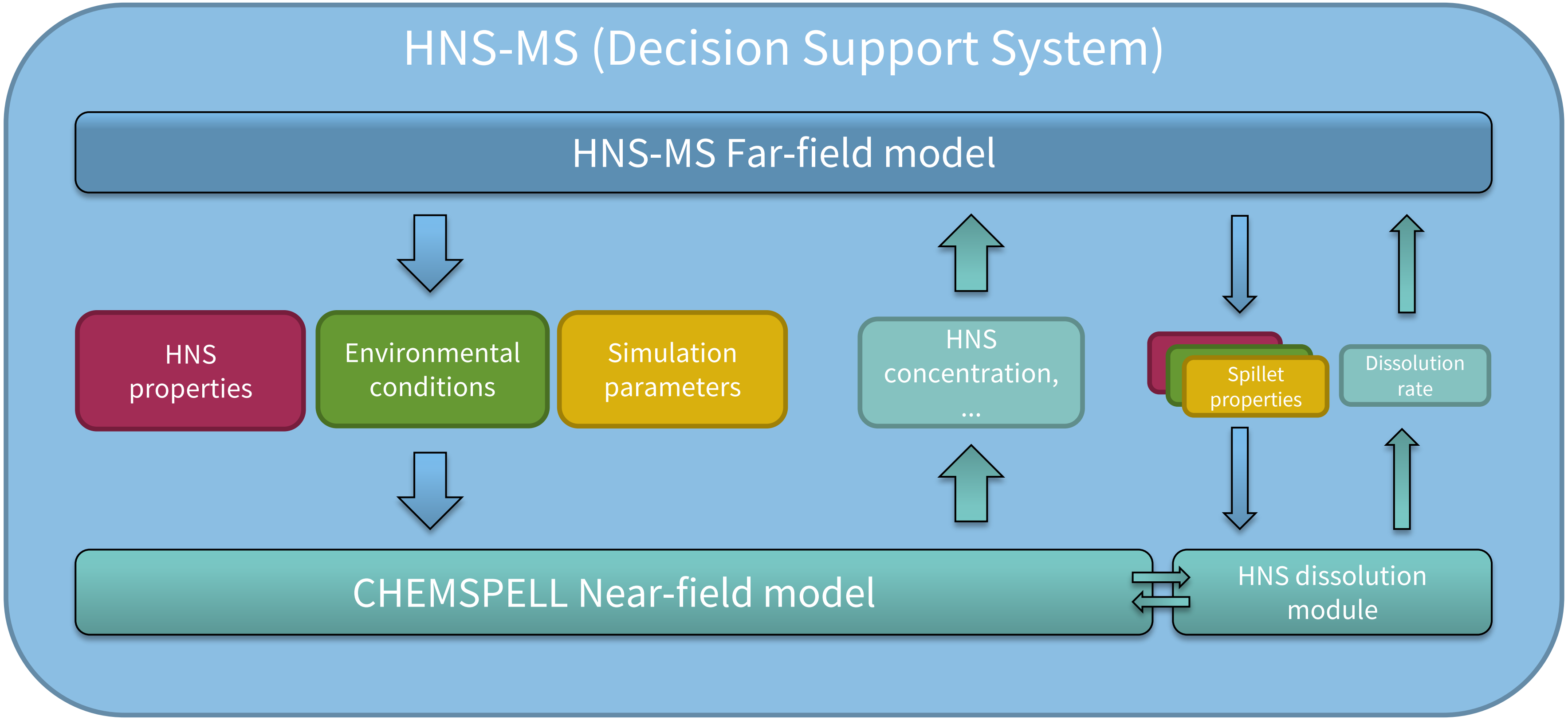
- HNS-MS / CHEMSPELL models interface



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- CHEMSPELL technical description:
  - Programming languages : C++, Qt Framework
  - 64 bits executable binaries
  - OS : Debian 8 64 bits, Windows 7 64 bits

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Thank you for your attention

Any questions ?