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HAPPIE

THE DUTCH BALLISTIC MISSILE INTERCEPT CONSEQUENCE SIMULATOR

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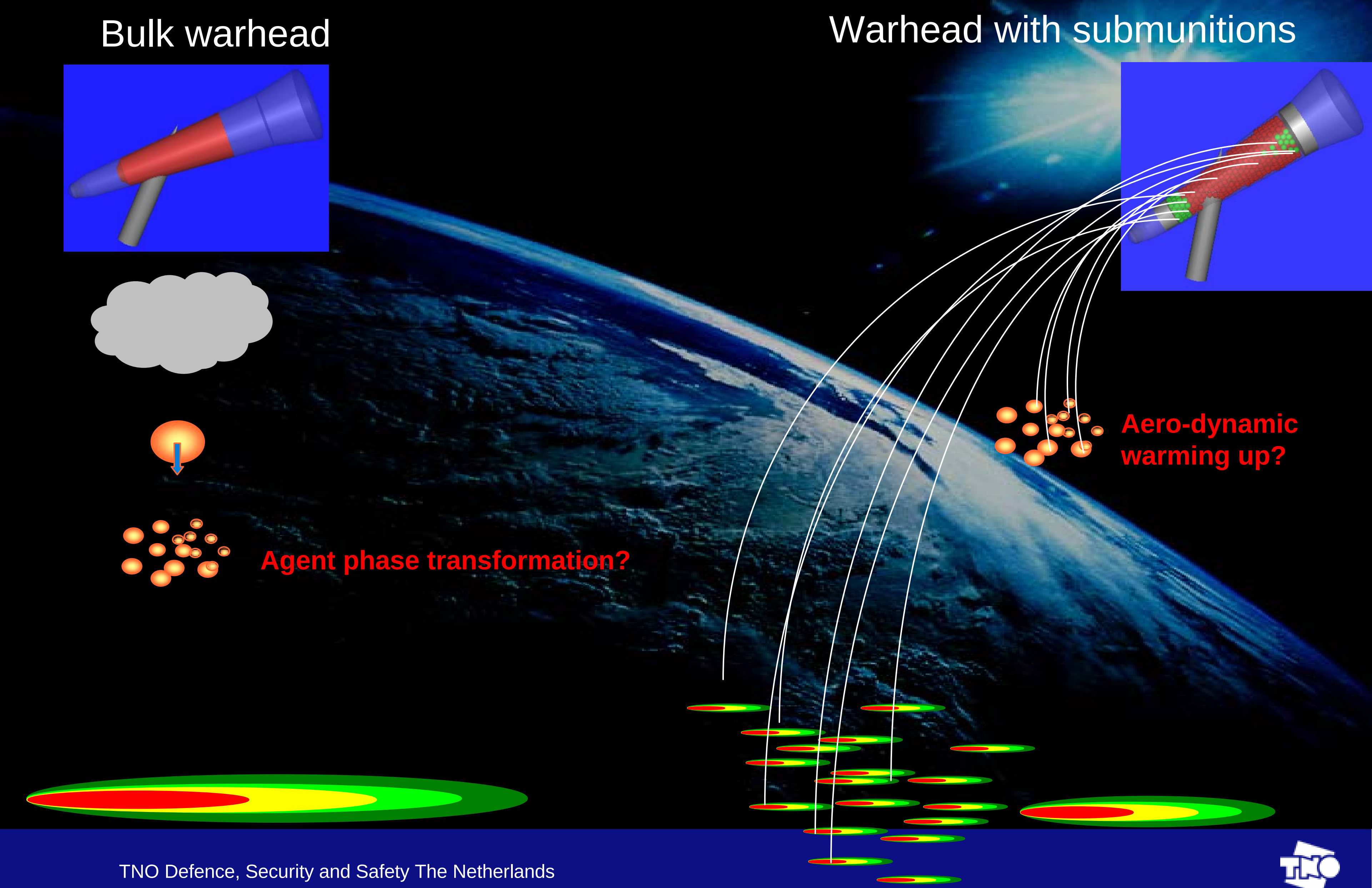
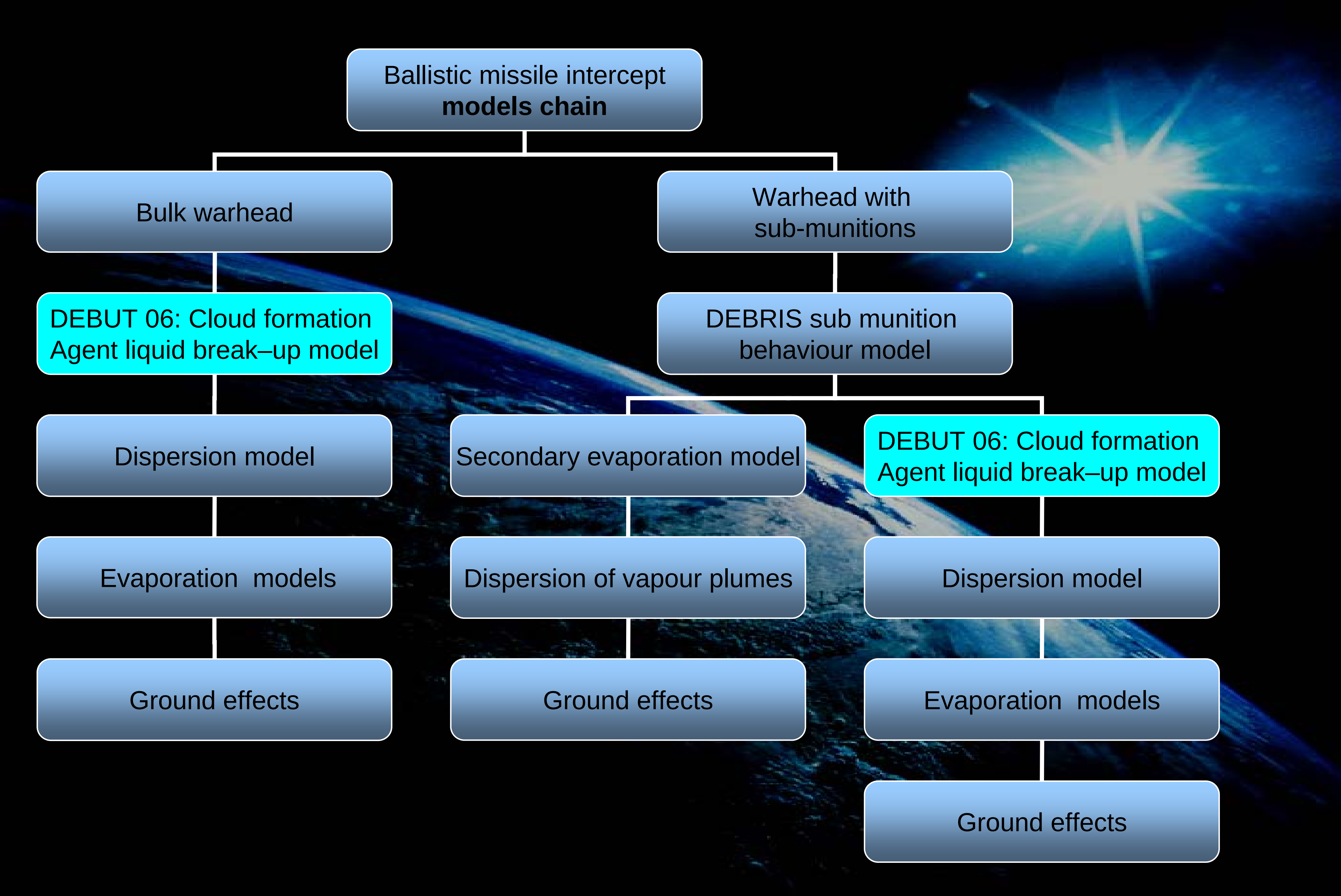
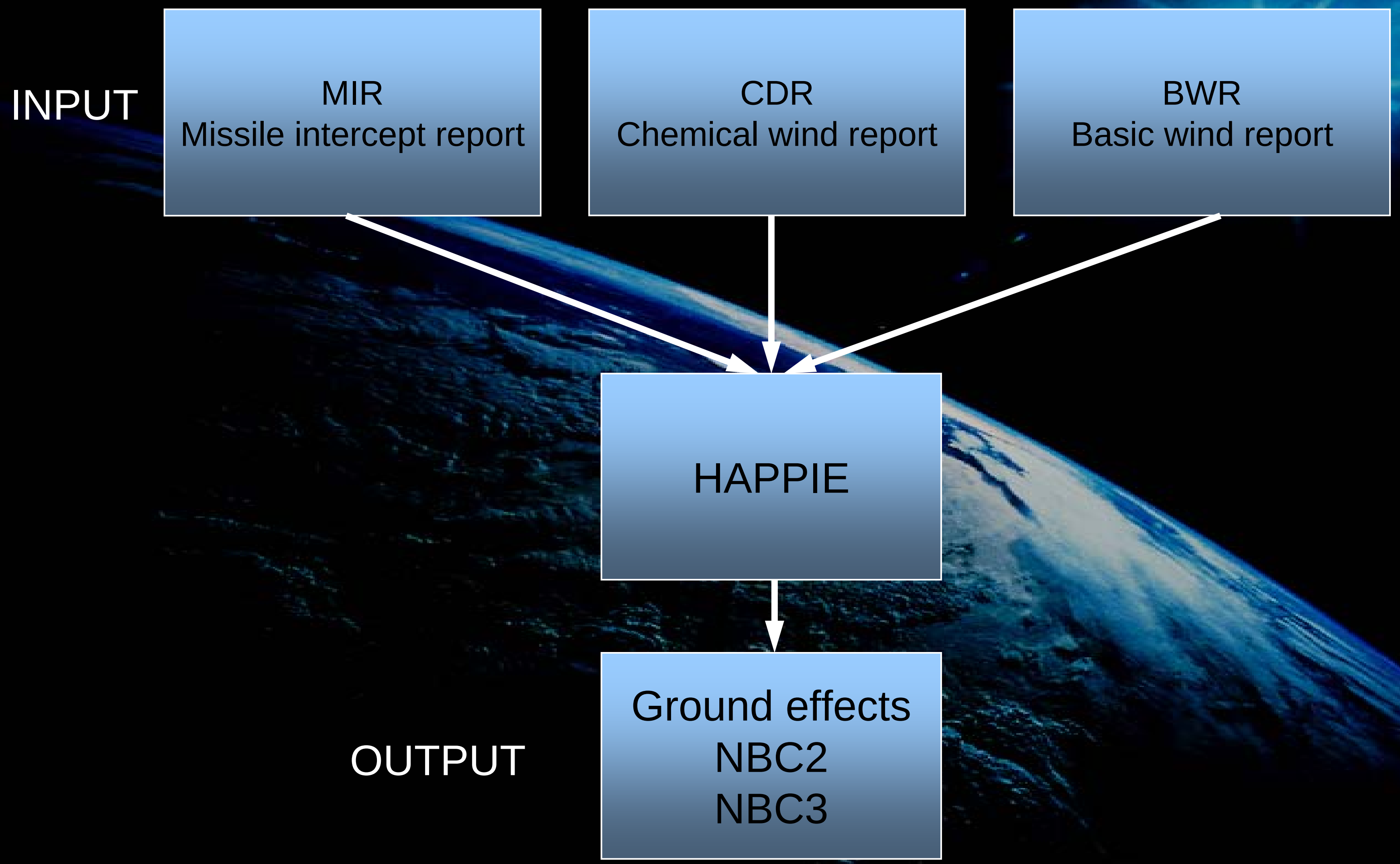
OUTLINE

- Introduction
- Description of the models chain – present status
- Development of new sub-models – project in progress
- Applications

Ballistic missile intercept consequence simulation




Ballistic missile intercept
models chain
Bulk warhead
Warhead with sub-munitions
DEBUT 06: Cloud formation Agent liquid break–up model
DEBRIS sub munition behaviour model
Dispersion model
Secondary evaporation model
DEBUT 06: Cloud formation Agent liquid break–up model
Evaporation models
Dispersion of vapour plumes
Dispersion model
Ground effects
Ground effects
Evaporation models
Ground effects


INPUT
MIR
Missile intercept report
CDR
Chemical wind report
BWR
Basic wind report
HAPPIE
OUTPUT
Ground effects
NBC2
NBC3

- Ground effects
  - Liquid and vapour deposition patterns

    (probability contour levels)
  - Dose ground patterns
  - Agent mass recovery on the ground
  - Casualty model (available but not included)

Meteo Model

- Monte Carlo procedures simulate the wind direction, the wind speed and the Pasquill class (generate a systematic frequency distribution of the three meteo parameters)
- Sigma=-a*ln(u)+b, gaussian distribution of the wind direction, u is the predicted wind speed
- To generate Meteo conditions we randomly combine: wind speed, wind direction and Pasquill class
- All combinations of Meteo conditions form an ensemble with a representative frequency distribution
- Experimentally validated based on 20 months hourly observations and predictions at 30 meteorological stations

Dispersion model

Puff definition

$$C(x,y,z,t) = m(t) \cdot E_x \cdot E_y \cdot E_z$$

$$E_x = \frac{1}{\sqrt{2\pi} \cdot \sigma_x} \cdot \exp\left(- \frac{(x - x_c)^2}{2\sigma_x^2} \right)$$

C(x, y, z) : mass concentration at location *(x, y, z)*
x_c y_c z_c : co-ordinates of the centre of the puff
m(t) : mass contained in the puff
σ_x σ_y σ_z : standard deviations of the mass distribution

Puff expansion

$$\sigma_{xy} = f(x, a, b, u(z_i))$$

$$\sigma_z = f(x, z_0, c, d)$$

x - travel distance
a,b,c,d – Pasquill stability class dependent constants
u – wind speed at height z_i
z_0 – terrain roughness length

Concentration

$$C(x,y,z,t) = \sum_i C_{puff,i}(x,y,z,t) + \sum_j C_{plume,j}(x,y,z,t)$$

Deposition

$$G(x,y,t) = \int_{-\infty}^{\infty} C(x,y,z,t)\,\mathrm{d}z$$

Dosage

$$D(x,y,z,t) = \int_0^t C(x,y,z,\tau)\,d\tau$$

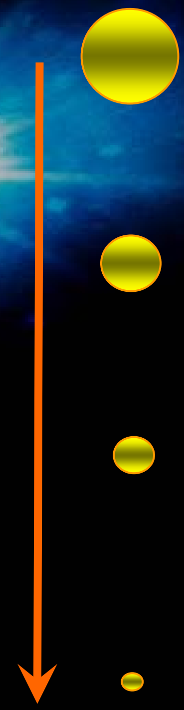
Evaporation models

Evaporation of falling drops

$$\frac{dm}{dt} = -2\pi RDShC_S$$

R – drop radius
D – diffusion coefficient
Cs – saturation concentration at Ts
Ts – drop surface temperature

$$Sh, Sc, Nu, \Pr, \mathrm{Re} = f(\eta, k^{air}, c_P^{air}, T^{air}, D, \rho^{air})$$



Secondary evaporation from the surface - the old Monaghan model

$$q_1 = m_i \cdot \frac{1 - f_{ss}}{t_{ss} - t_{imp}}$$

$$q_2 = m_i \cdot \frac{f_{ss} - f_{te}}{t_{te} - t_{ss}}$$

$$q_3 = 0$$

q_1, q_2 , q_3 - evaporation rates in the three phases

f_{imp} - remaining liquid fraction at drop's impact time
f_{ss} - at drop's steady state time
f_{te} - at the total evaporation time

DEBRIS submunition behaviour model

- Trajectory analysis

- Aerodynamic heating of the submunitions:

  - Shape and material of the submunition
  - Available thermal protection coating
  - Type of the agent
  - Ejection velocity
  - Height of release

- Heating and thermal demise of agent contained in the submunition

  - Convection model
  - Agent properties studies

Break-up model – in progress

DEBUT 06: Drop Evaporation and Break-Up Tool

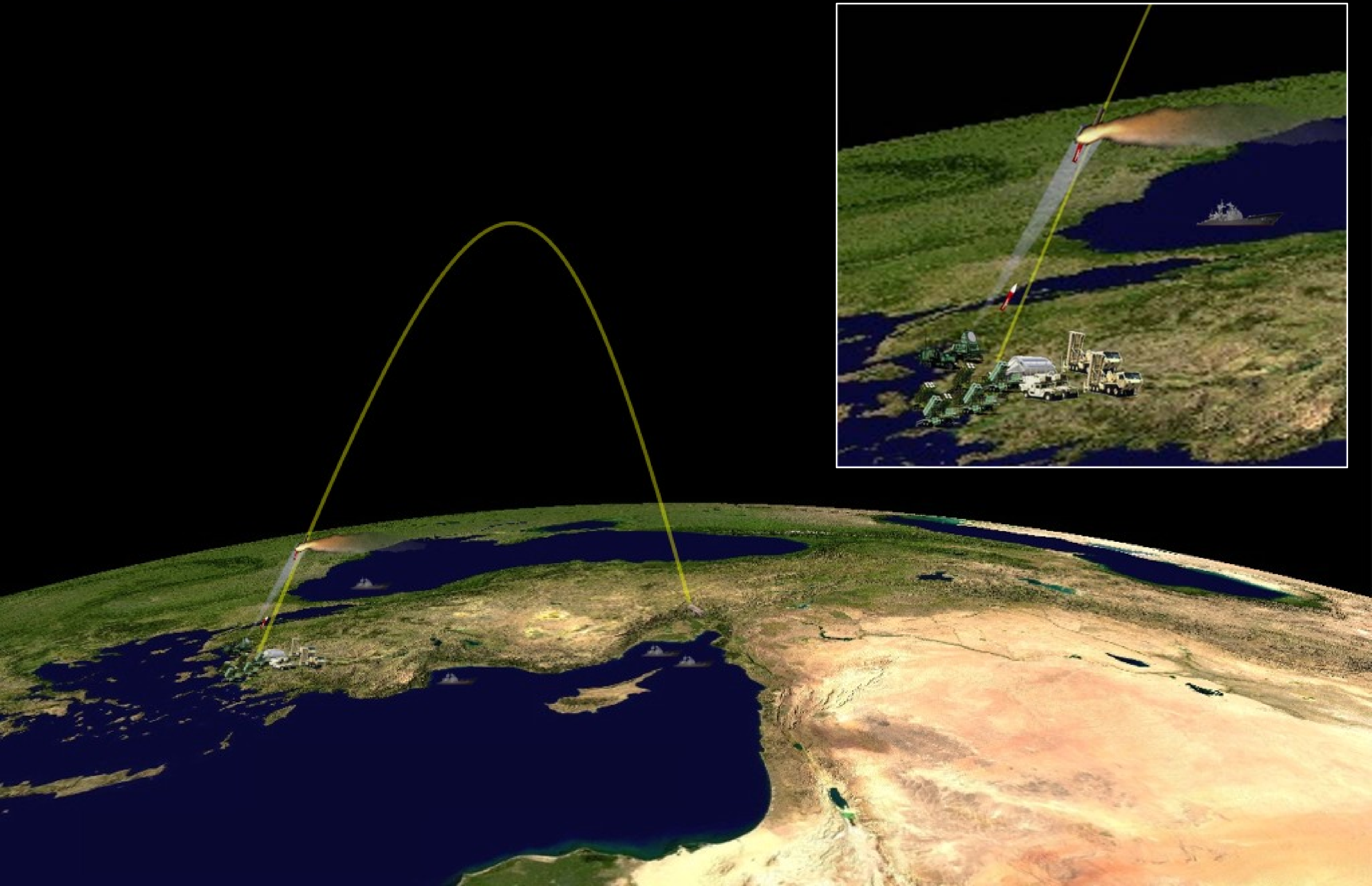
It calculates:

- Agent cloud dimensions
- Drop size distributions
- Initial mass loss due to evaporation
- Validation on-going (experiments due in 2007 / 2008)

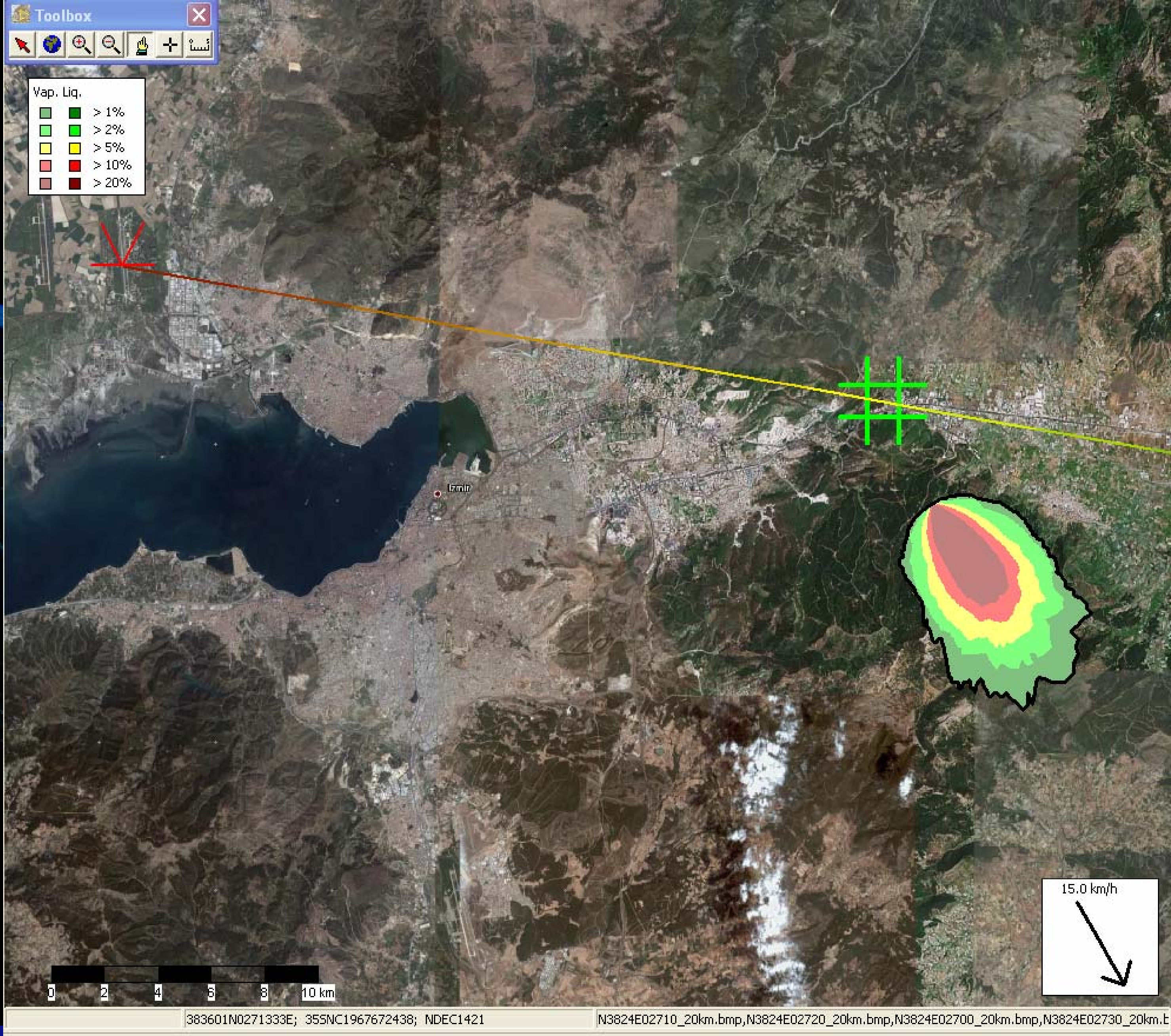
To be developed also for non-Newtonian liquids

HAPPIE in JPOW IX 2006

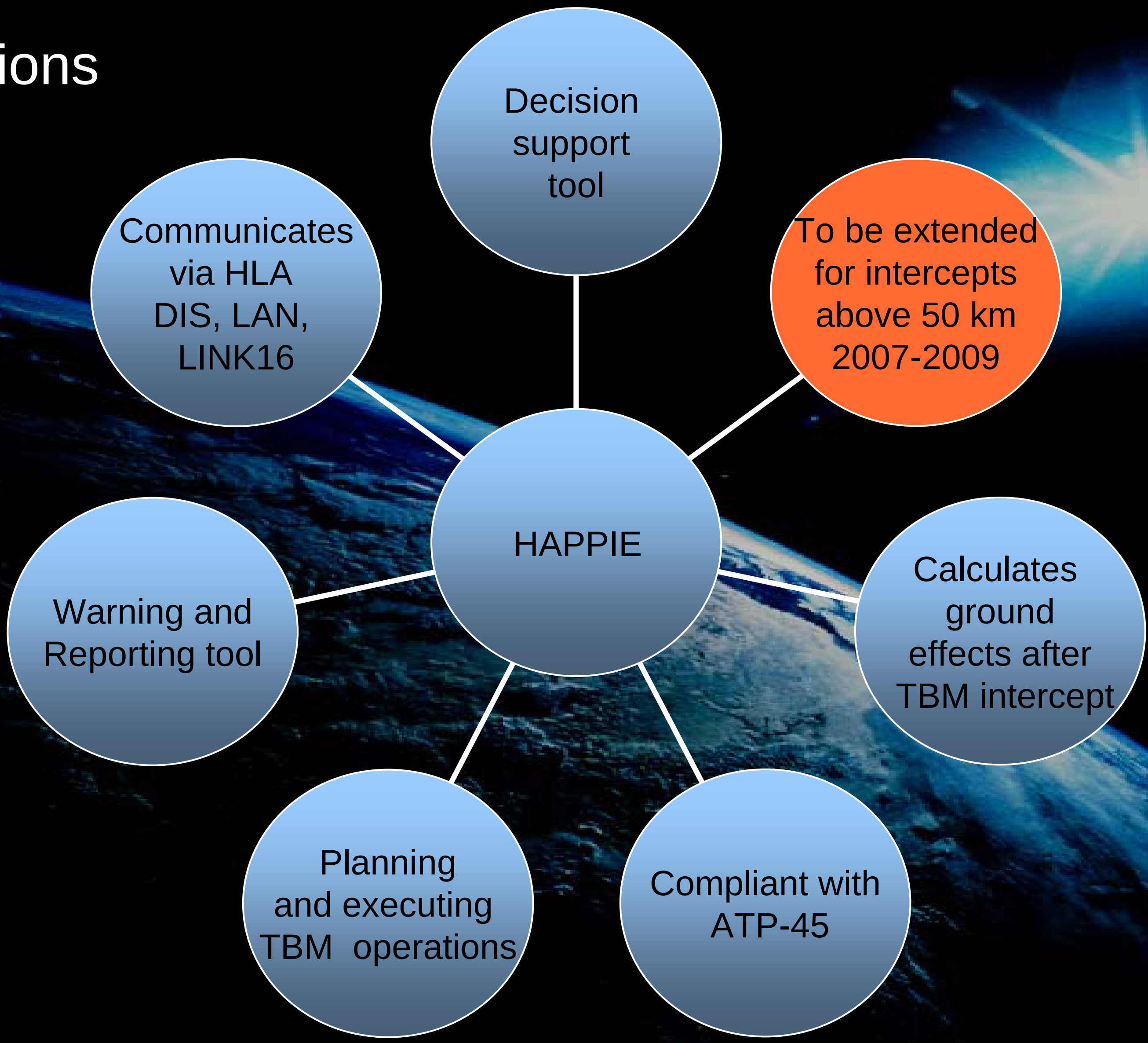
An missile intercept exercise performed within JPOW IX



Ground effect calculation after an missile intercept performed within JPOW IX



Applications



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