CENTRE NATIONAL D'ÉTUDES SPATIALES

ELECTRA©

LAUNCH AND RE-ENTRY SAFETY ANALYSIS TOOL

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- **Conclusions and prospects**

Introduction (1/2)

CNES Safety concerns

Risk management for launches from Guiana Space Center

Random or controlled re entry of LEO spacecraft

State advisor for space safety (French space act June 2008)

Introduction (2/2)

ELECTRA Objectives

To develop a unique Method and a Software to estimate the risks of fragment fall back (launch and reentry)

CNES Know-How

- Ariane launchers Hazards analysis
- Space Mechanic
- Satellites operation
- Risks Analysis

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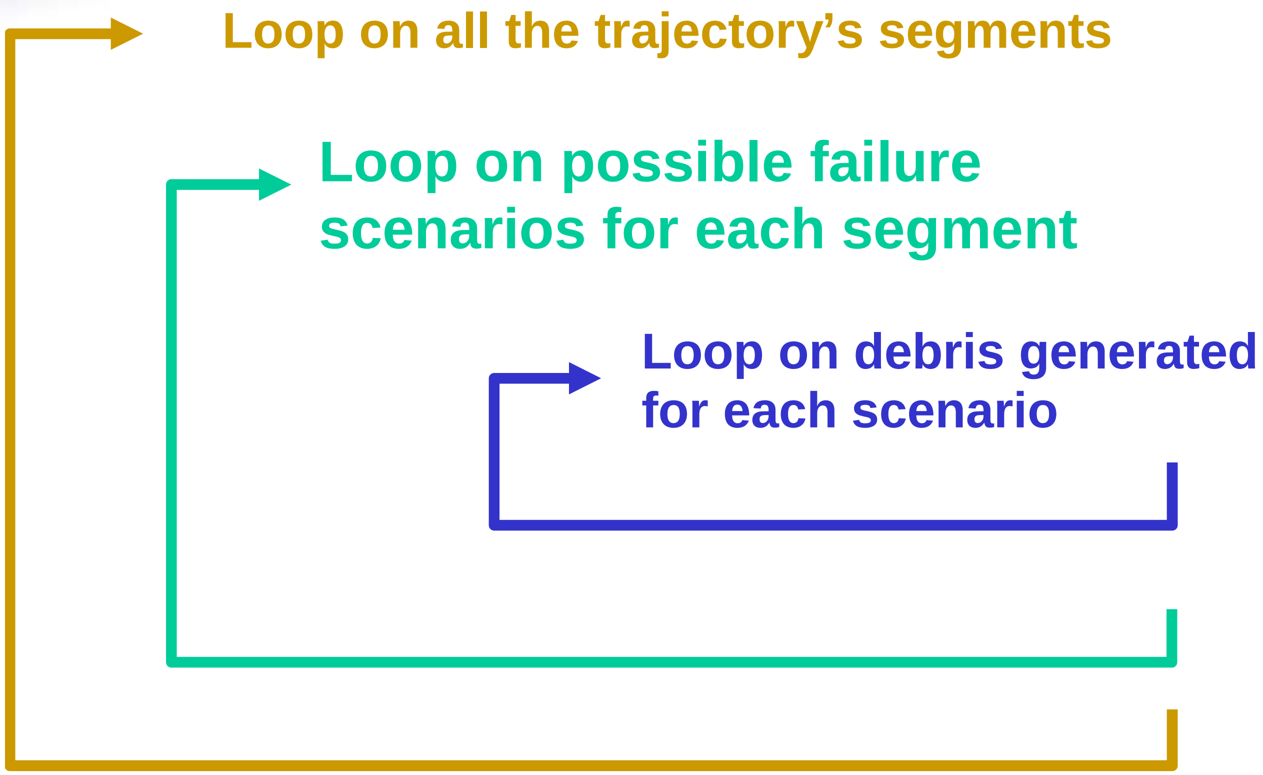
Method (1/2)

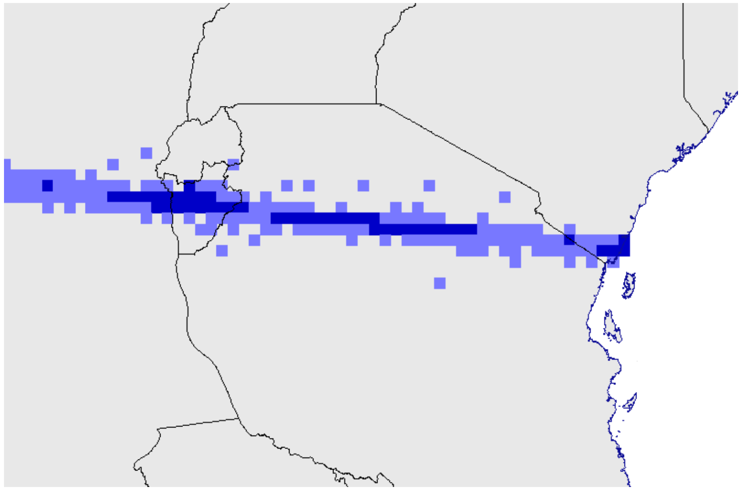

Loop on all the trajectory's segments
Loop on possible failure scenarios for each segment
Loop on debris generated for each scenario

Method (2/2)

ELECTRA© : 2 complementary estimations

⇨ Probability Pc of incurring at least one victim

⇨ Expected value Ec



$$Ec(i, j) = P(i, j) \times N_j \times \frac{A_{ci}}{S_j}$$

where:

$P(i, j)$ Probability that fragment i will fall inside cell j,

N_j Number of inhabitants in cell j,considered as being uniformly distributed,

A_{ci} Impacted surface area assigned to fragment i (casualty area)

S_j Surface area of cell j.

The pair {Pc(≥1), Ec} enables better characterisation of the risk incurred, particularly for heavily populated zones.

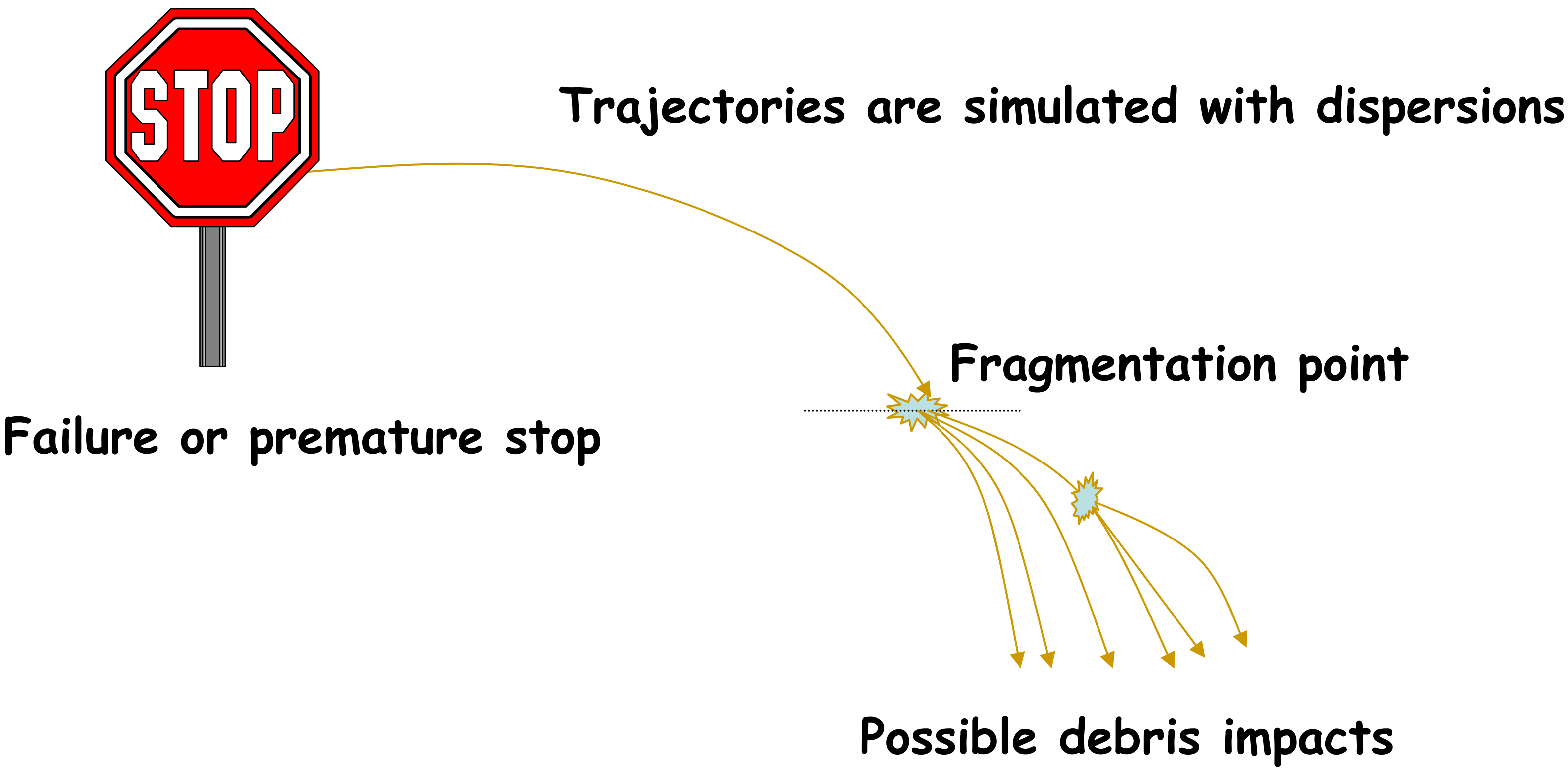
Models (1/6)

Three types of space activities for which the ELECTRA© method characterises risks :

- ⇨ Launch :**'Risk during Launch'** module
- ⇨ Controlled Re-entry : **'Controll****-entry'** module
- ⇨ Random R **'Random Re****y'** module

Models (2/6)

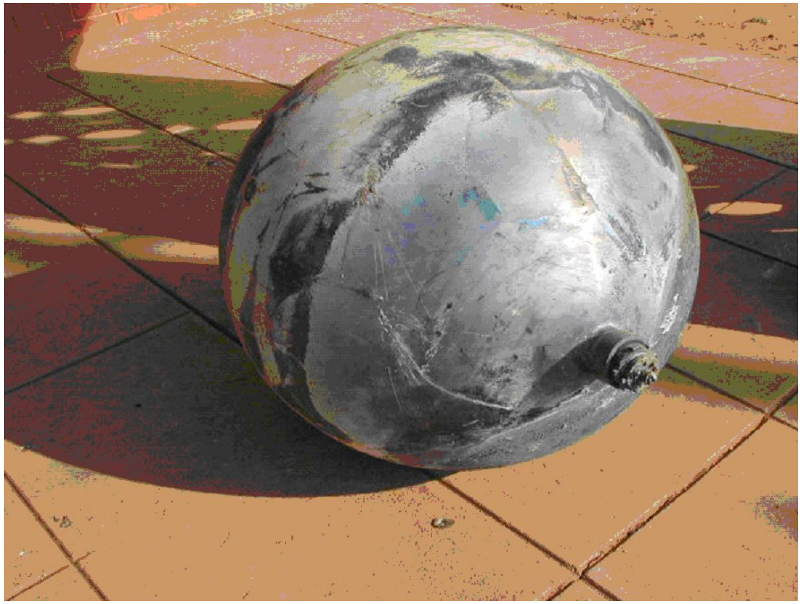
Factors taken into account in the COLLECTIVE RISK inherent in a spacecraft flying over a populated area (launch phase, controlled re-entry, random re-entry) .



Models (3/6)

"Impact risk"

⇨ **1 – FRAGMENTATION (1/2)**

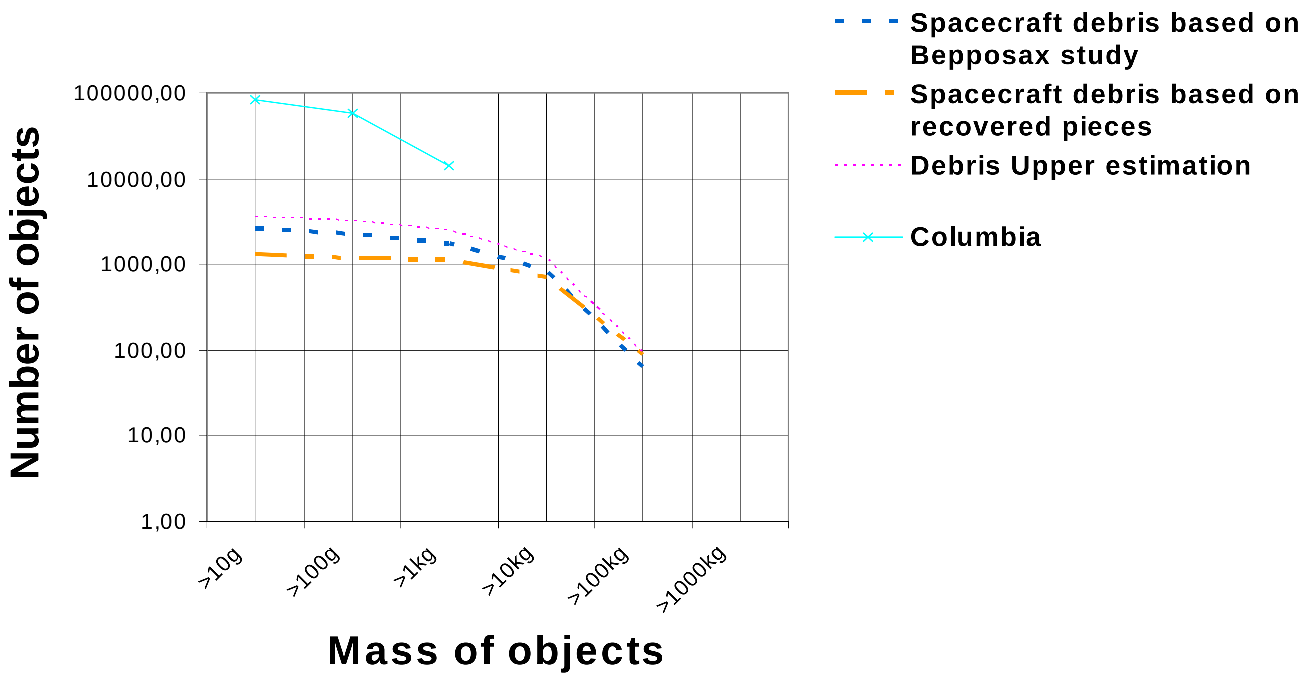


Models (4/6)

"Impact risk"

⇨ **1 – FRAGMENTATION (2/2)**

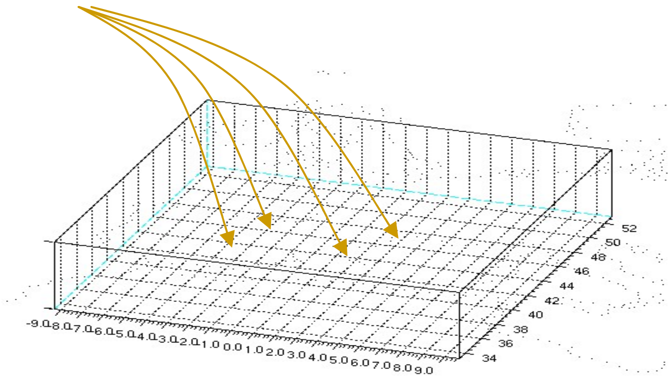
- Input data
- Great impact on risk results



Models (5/6)

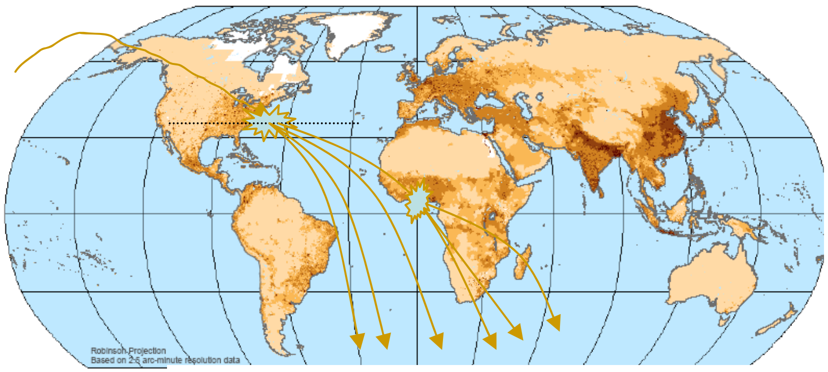
"Impact risk"

⇨ **2 - Calculating the re-entry trajectory**



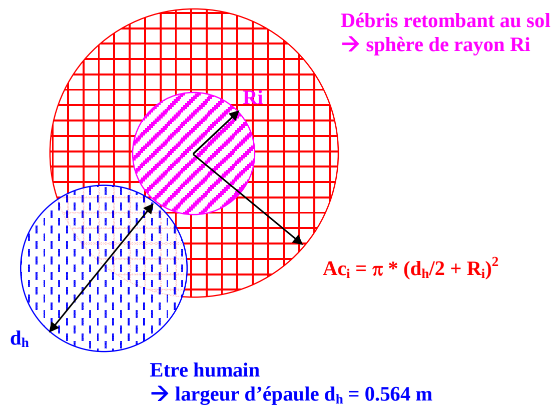
⇨ **3 - Consideration of population density**

GPW - V3 - 0.25°



⇨ **4 - Integration of the "Casualty Area"**

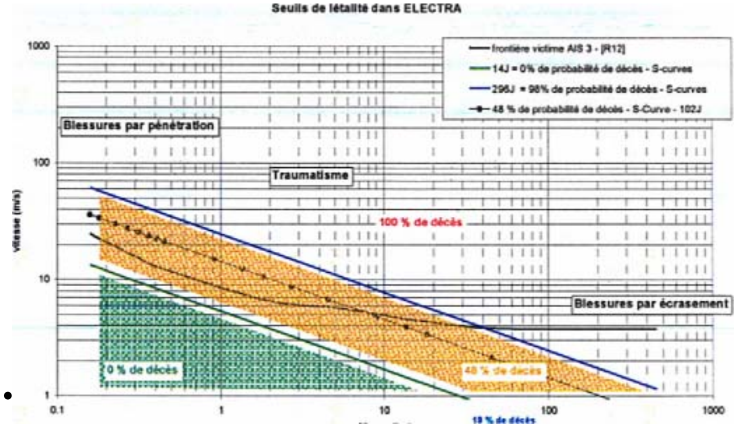
$$Ac = \sum_{i=tous\ les\ fragments} \left(0{,}6 + \sqrt{S_i}\right)^2 = \sum_{i=tous\ les\ fragments} \pi \left(\frac{d}{2} + \sqrt{\frac{S_i}{\pi}}\right)^2$$



Models (6/6)

"Casualty risk"

For this, the following points must be defined:



1. The intrinsic danger rating of the fragment upon impact.
2. The protection afforded by dwelling structures.
3. The percentage of protected and unprotected people according to their location in the world.

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Methodology for use (1/2)

$$R_{ELECTRA\ LAUNCHER} = A + B + C$$

$$A = R(\lambda)_{'Risk\ during\ Launch\ 'Module}$$

$$B = R_{Fallback\ of\ Stages}$$

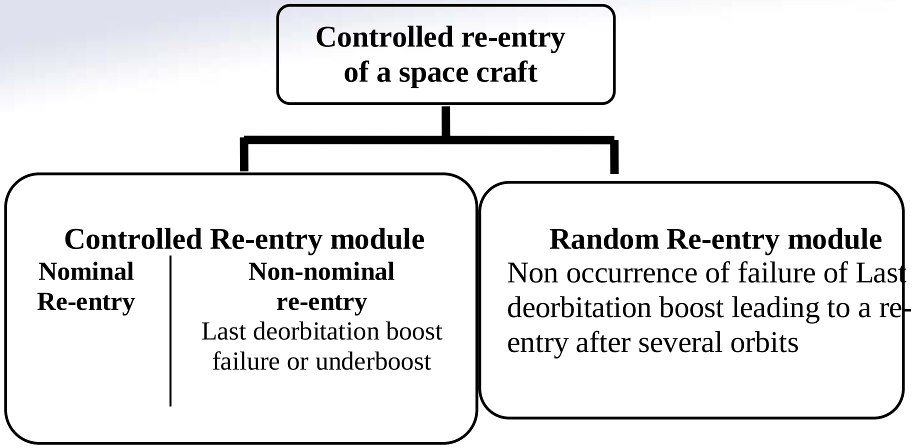
$$C = R_{'Random\ Fallback\ Risk\ 'module}$$

in the event that deorbiting the upper stage is not part of the mission.

$$C = (1-\mu) \times R(\lambda)_{'Controlled\ Fallback\ Risk\ 'Module} + \mu \times R_{'Random\ Fallback\ Risk\ 'module}$$

in the event that deorbiting the upper stage is part of the mission.

Methodology for use (2/2)



To evaluate the risk of the controlled re-entry of a satellite, we used:

$$R_{ELECTRA\ SAT} = A' + C$$

where

$$C = \mu \, R_{\text{'Random Fallback Risk' module}}$$

$$A' = (1-\mu) R_{\text{'Controlled Re-entry Risk' module}}(\lambda)$$

With:

- μ as probability of a random re-entry
- λ as unreliability of the last deorbitation boost

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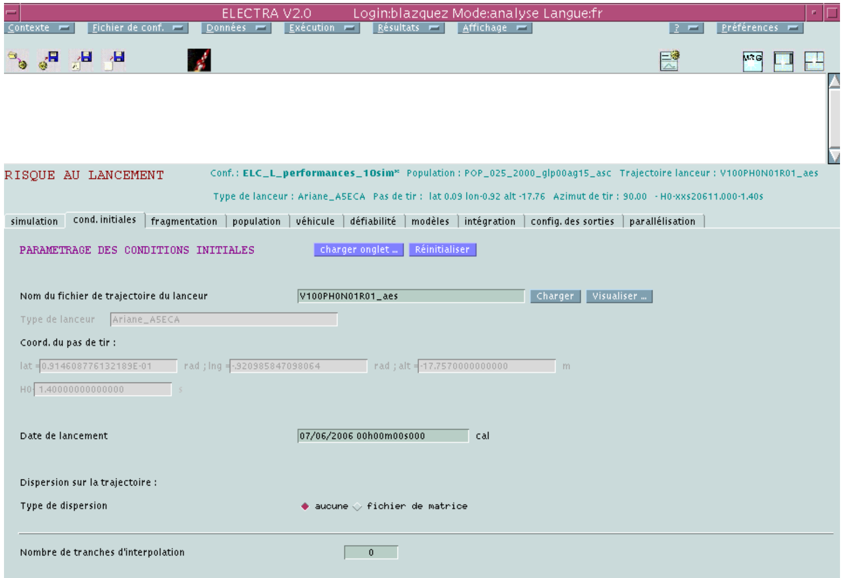
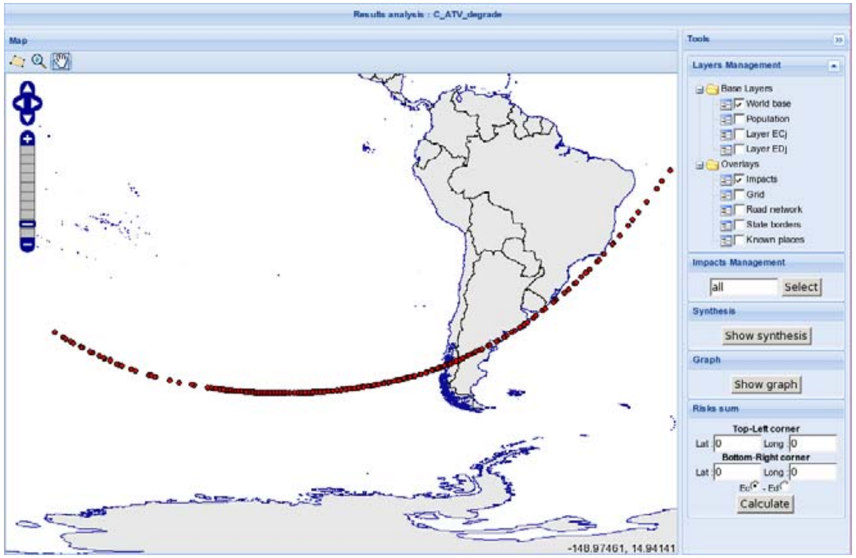
Software's Conception (1/4)

The computation module: ELECTRA©

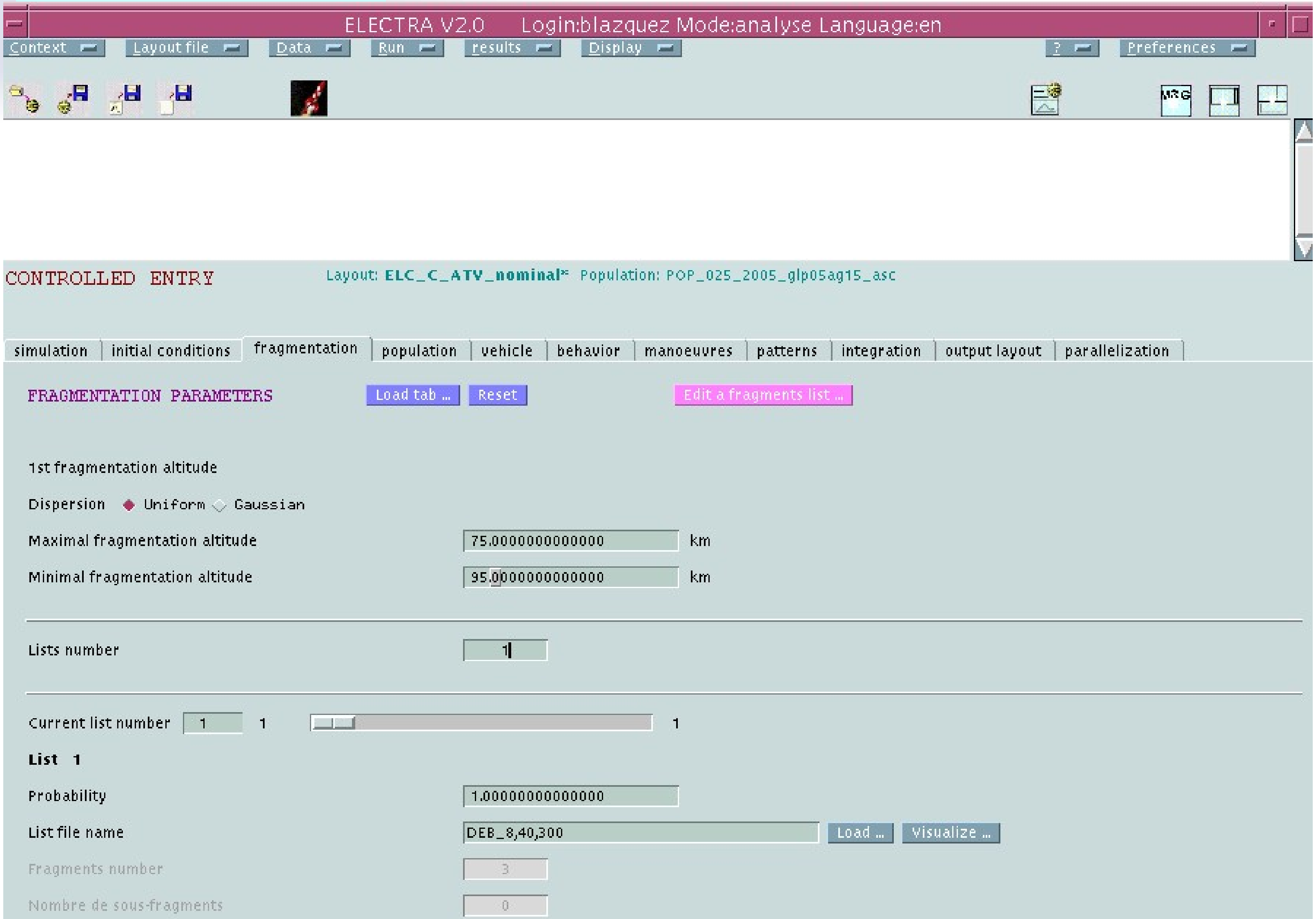




The viewer module: ORESTE©

Software's Conception (2/4)

➪ELECTRA©



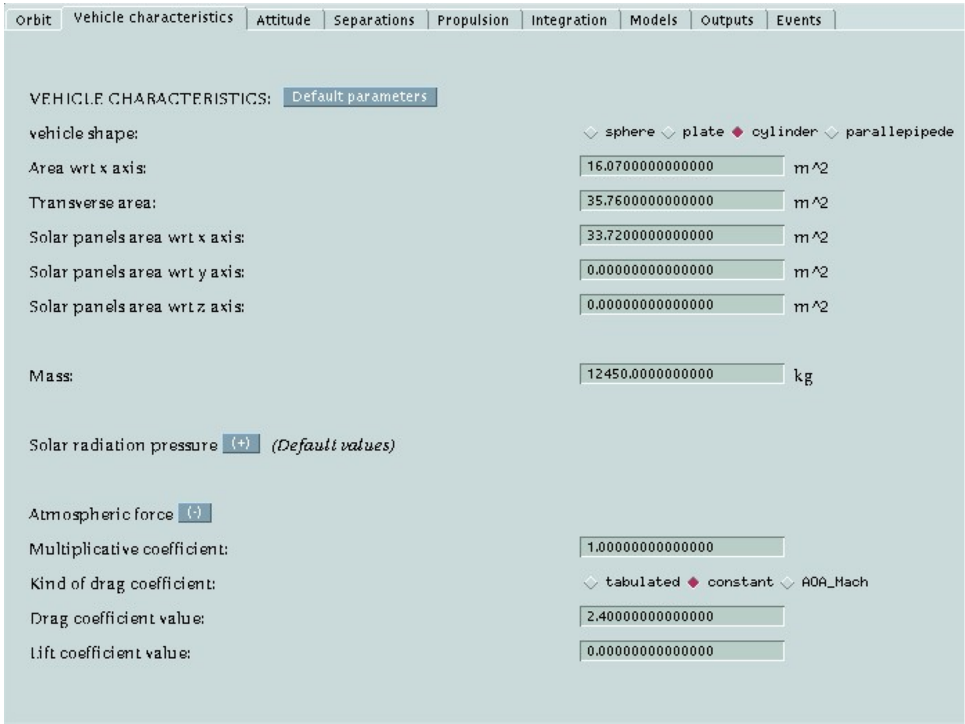
Software's Conception (3/4)

➩ PSIMU© : Trajectory extrapolator

PSIMU© is one of the basic tools used for Flight Dynamics studies and operations in CNES.

Simulate any kind of trajectories around a planet (considering attitude and manoeuvres)

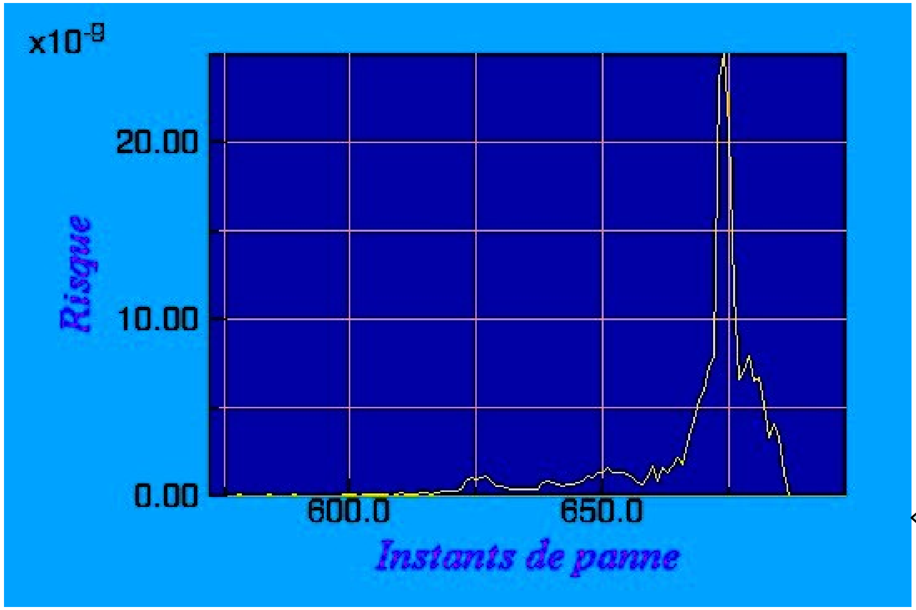
From very high altitudes (even in case of eccentricity greater than one) as well as for re-entry trajectories up to zero meter of altitude.

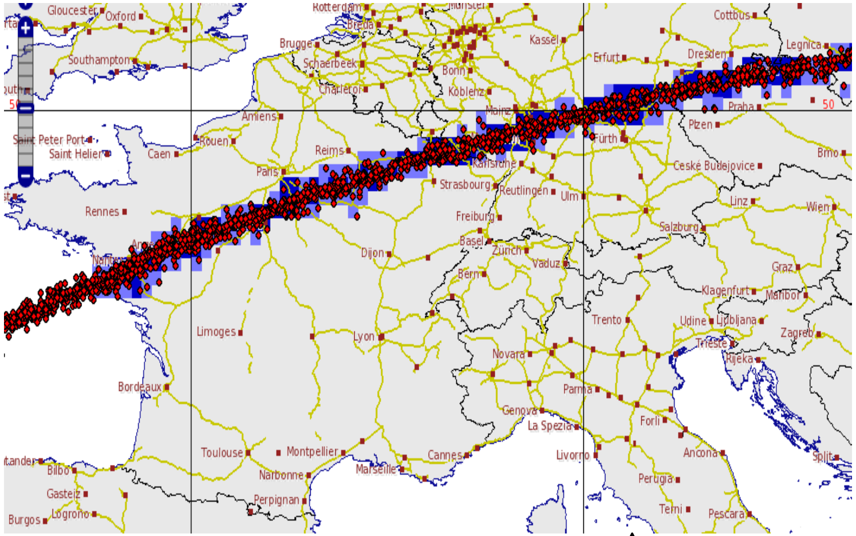


Software's Conception (4/4)

⇨ ORESTE© : ELECTRA©'s viewer

To help at the decision and to provide the elements needed to minimise risks.





Avoiding big cities

Special focus on the possible stops that high the risk

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Conclusions and Prospects

- Calibration of Risk estimations
- Objectives and method Unification between launch and re-entry

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