



CENTRE NATIONAL D'ÉTUDES SPATIALES

ELECTRA©

LAUNCH AND RE-ENTRY SAFETY ANALYSIS TOOL

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Third IAASS Conference - Rome - 2008

- Introduction
- Method
- Models
 - Probabilities of failure
 - 'Impact Risk'
 - 'Casualty Risk'
- Methodology for use
- Software's highlights
 - Trajectory extrapolator
 - Oreste© (Electra©'s viewer)
- Conclusions and prospects



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)

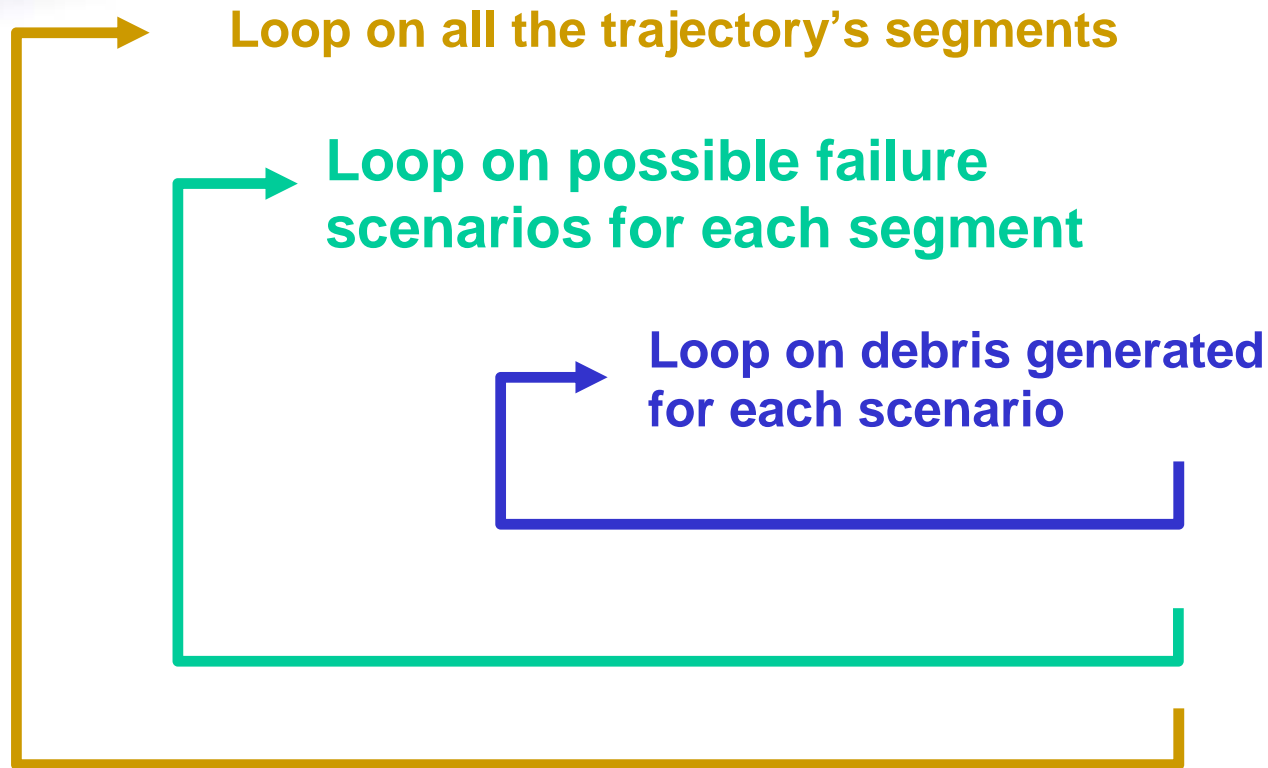
ELECTRA Objectives

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

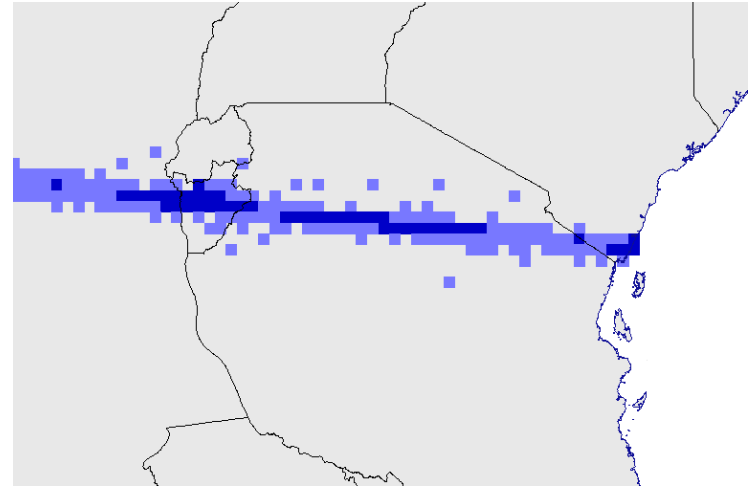
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ELECTRA© : 2 complementary estimations

- ⇒ Probability P_c of incurring at least one victim
- ⇒ Expected value E_c

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



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 $\{P_c(\geq 1), E_c\}$ enables better characterisation of the risk incurred, particularly for heavily populated zones.

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

⇒ Launch : **'Risk during Launch'** module



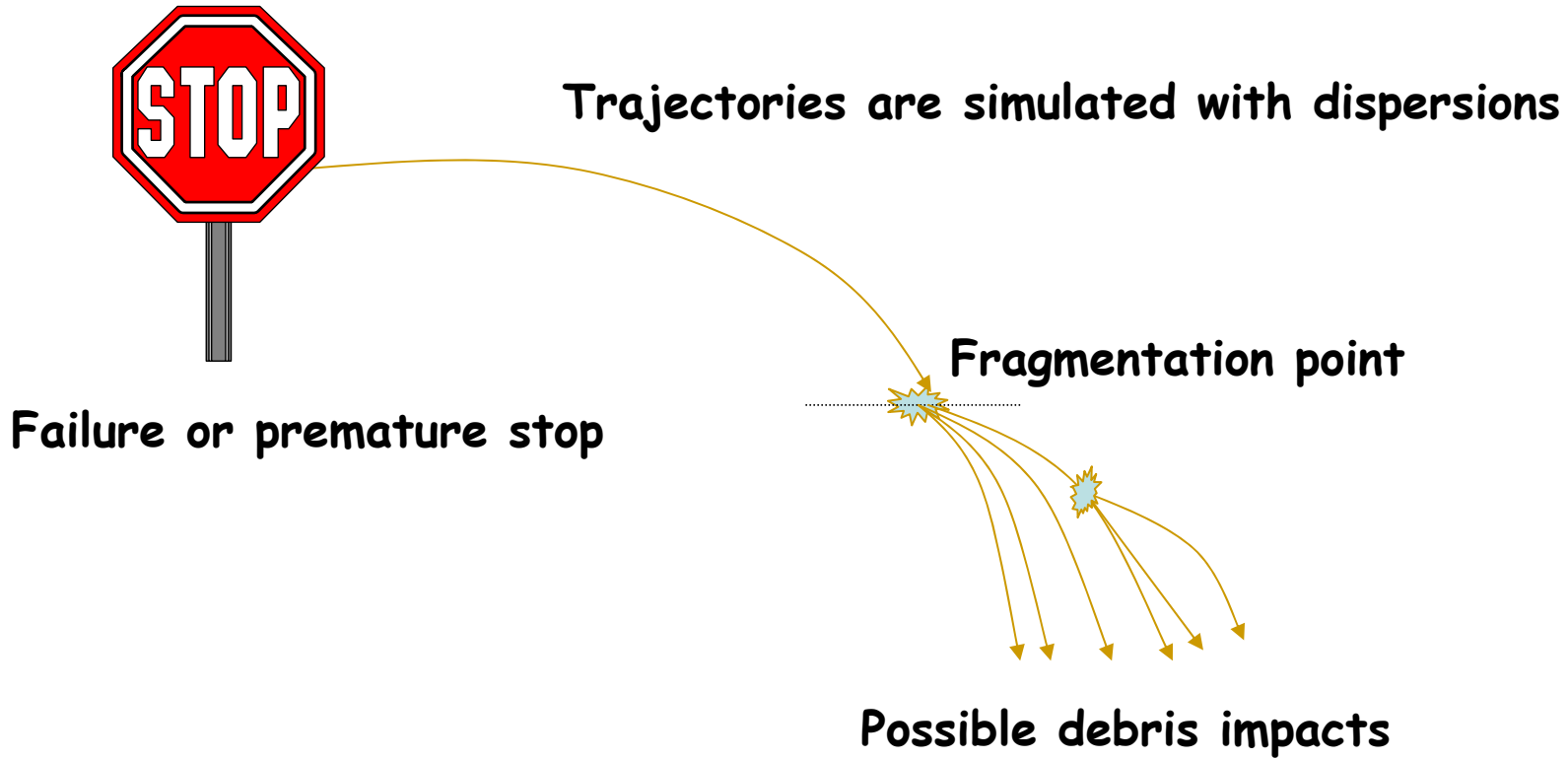
⇒ Controlled Re-entry : **'Controlled Re-entry'** module



⇒ Random Re-entry : **'Random Re-entry'** module

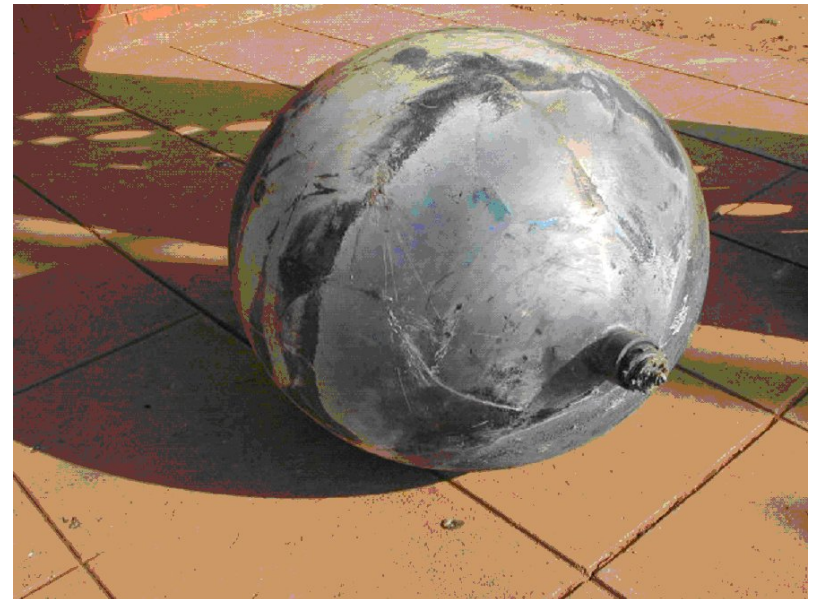


Factors taken into account in the COLLECTIVE RISK inherent in a spacecraft flying over a populated area (launch phase, controlled re-entry, random re-entry).



"Impact risk"

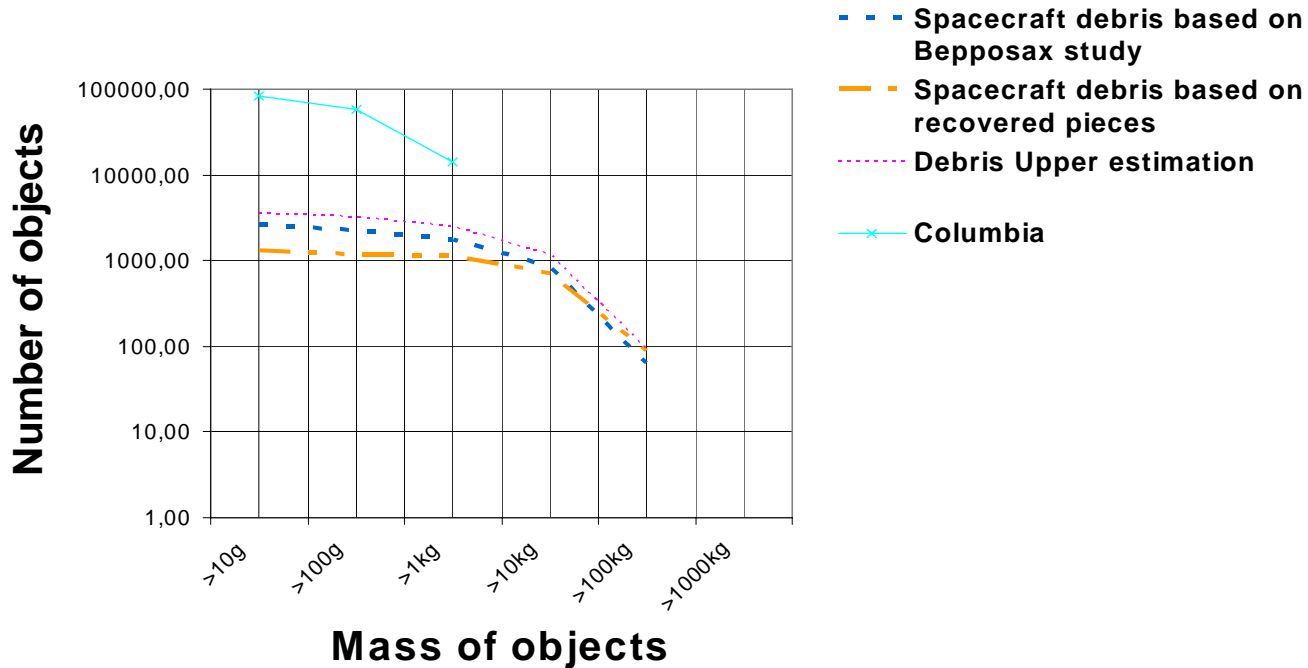
⇒ 1 - FRAGMENTATION (1/2)



“Impact risk”

⇒ 1 - FRAGMENTATION (2/2)

- Input data
- Great impact on risk results

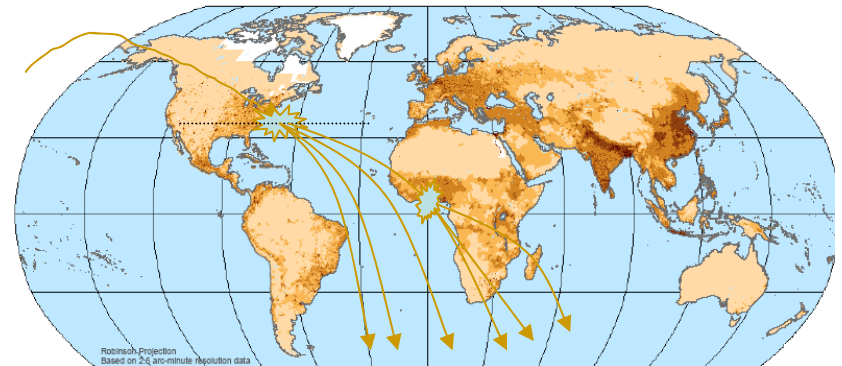
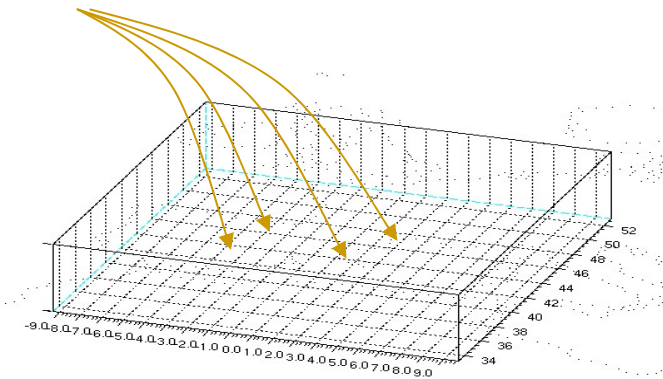


“Impact risk”

⇒ 3 - Consideration of population density

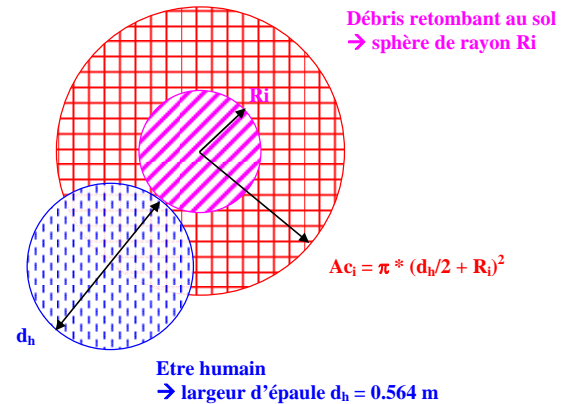
⇒ 2 - Calculating the re-entry trajectory

GPW - V3 - 0.25°



⇒ 4 - Integration of the “Casualty Area”

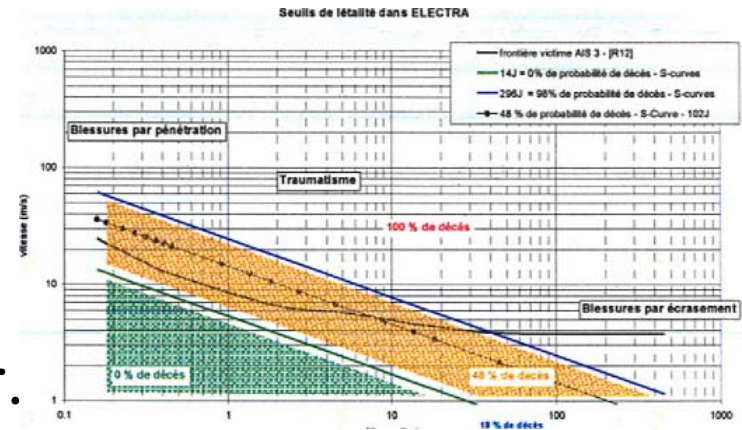
$$Ac = \sum_{i=\text{tous les fragments}} (0,6 + \sqrt{S_i})^2 = \sum_{i=\text{tous les fragments}} \pi \left(\frac{d}{2} + \sqrt{\frac{S_i}{\pi}} \right)^2$$



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

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

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

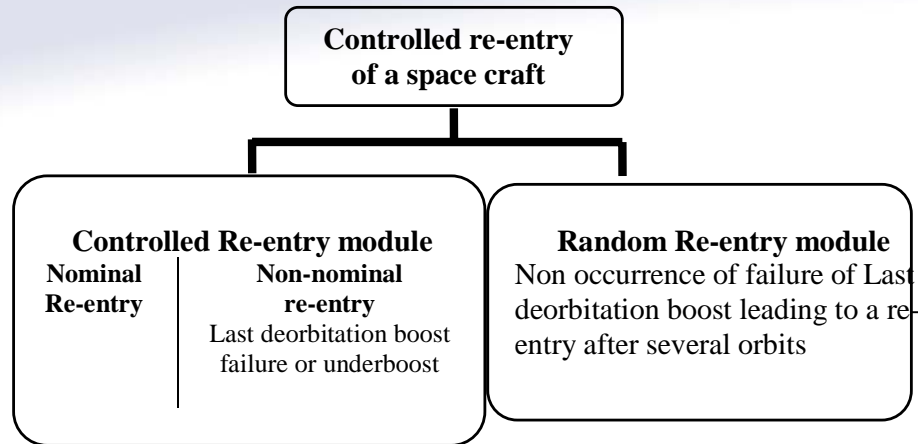
$$C = R \text{ 'Random Fallback Risk ' module}$$

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

$$C = (1 - \mu) \times R(\lambda) \text{ 'Controlled Fallback Risk ' Module}$$

$$+ \mu \times R \text{ 'Random Fallback Risk ' module}$$

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



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

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

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

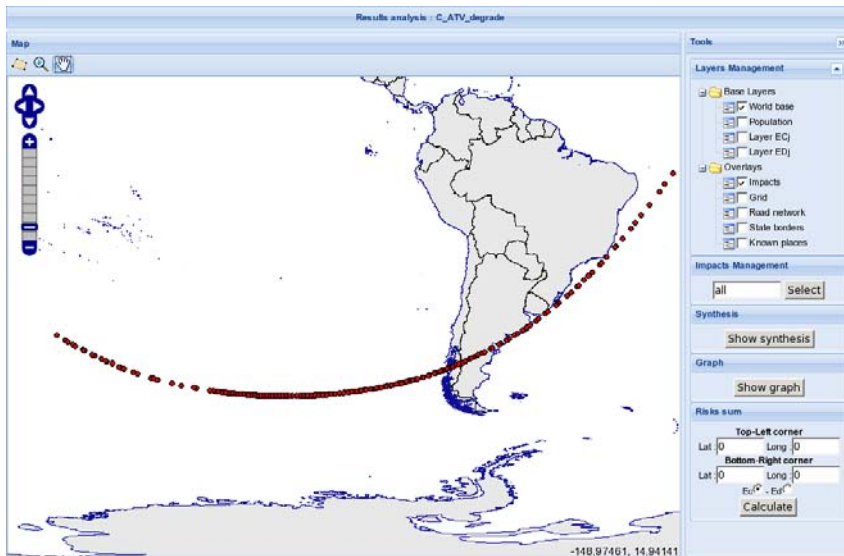
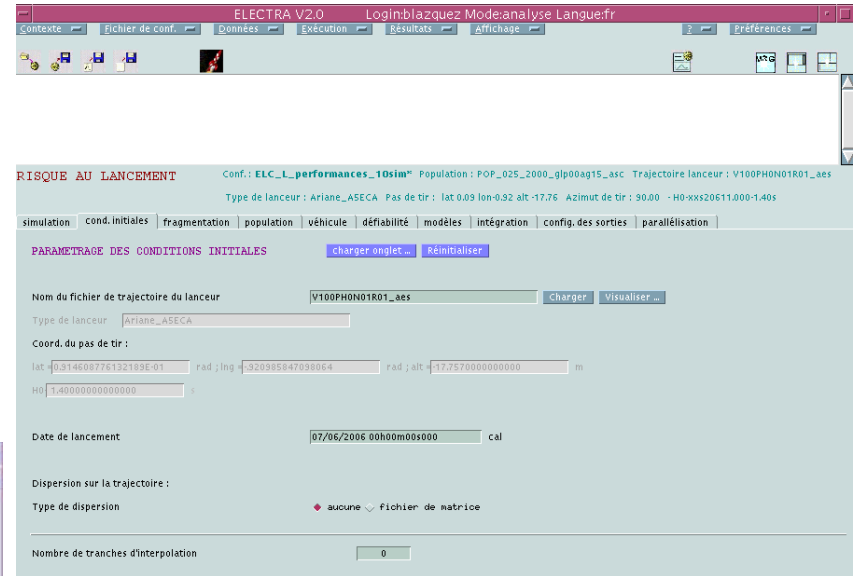
$$A' = (1 - \mu) R_{\text{'Controlled Re-entry Risk' module}} (\lambda)$$

With:

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

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The computation module: ELECTRA©



The viewer module: ORESTE©

⇒ ELECTRA©

ELECTRA V2.0 Login:blazquez Mode:analyse Language:en

Context Layout file Data Run results Display Preferences

CONTROLLED ENTRY Layout: ELC_C_ATV_nominal* Population: POP_025_2005_glp05ag15_asc

simulation initial conditions fragmentation population vehicle behavior manoeuvres patterns integration output layout parallelization

FRAGMENTATION PARAMETERS Load tab ... Reset Edit a fragments list ...

1st fragmentation altitude

Dispersion Uniform Gaussian

Maximal fragmentation altitude km

Minimal fragmentation altitude km

Lists number

Current list number 1

List 1

Probability

List file name Load ... Visualize ...

Fragments number

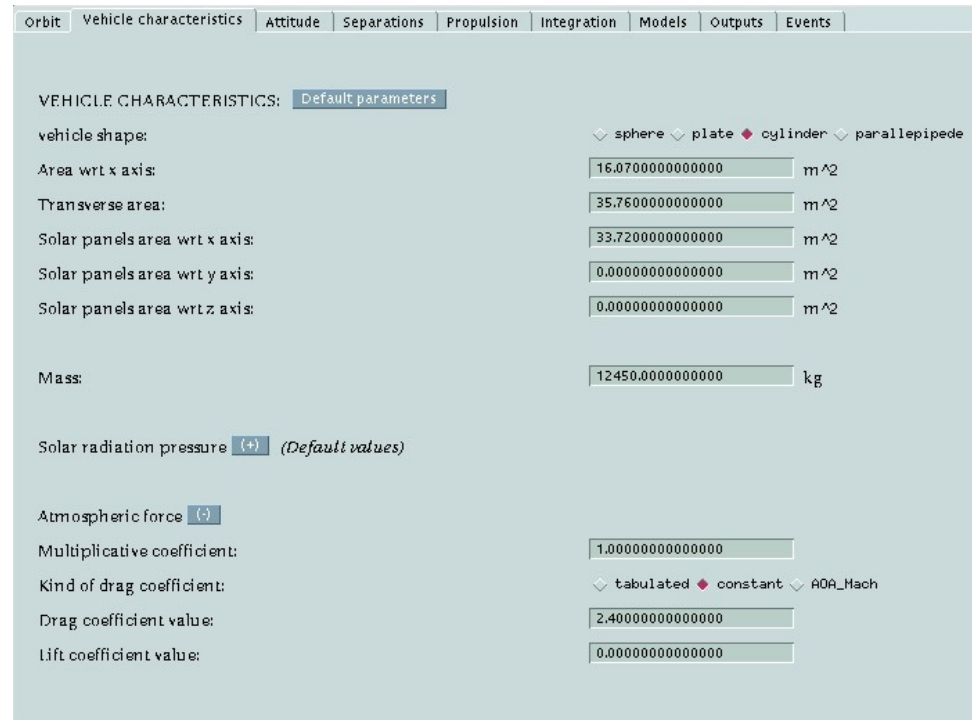
Nombre de sous-fragments

⇒ 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.

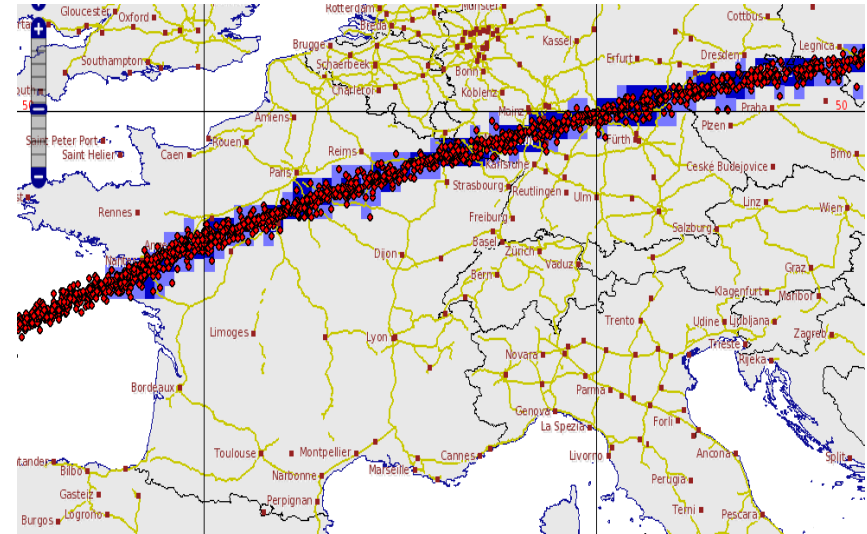
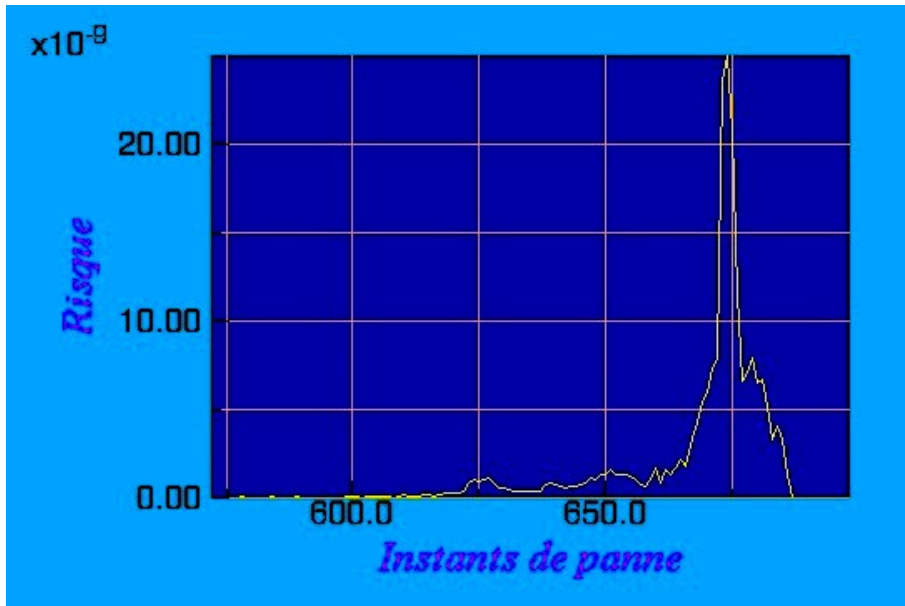


The screenshot shows the 'Vehicle characteristics' configuration window in PSIMU. The window has a tabbed interface with 'Vehicle characteristics' selected. Below the tabs, there is a 'Default parameters' button. The configuration is organized into several sections:

- VEHICLE CHARACTERISTICS:** A dropdown menu for 'vehicle shape' is set to 'cylinder'. Other options include 'sphere', 'plate', and 'parallepipede'.
- Area parameters:**
 - Area wrt x axis: 16.0700000000000 m²
 - Transverse area: 35.7600000000000 m²
 - Solar panels area wrt x axis: 33.7200000000000 m²
 - Solar panels area wrt y axis: 0.0000000000000 m²
 - Solar panels area wrt z axis: 0.0000000000000 m²
- Mass:** 12450.00000000000 kg
- Solar radiation pressure:** (+) (Default values)
- Atmospheric force:** (-)
- Multiplicative coefficient:** 1.0000000000000
- Kind of drag coefficient:** tabulated (selected), constant, AOA_Mach
- Drag coefficient value:** 2.4000000000000
- Lift coefficient value:** 0.0000000000000

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



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