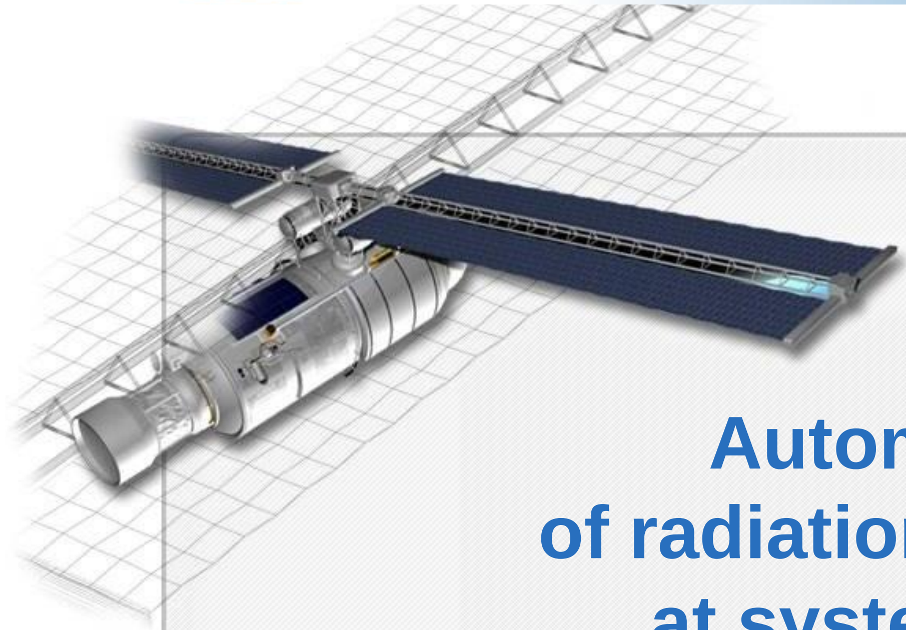

Automation of radiation shielding at system level

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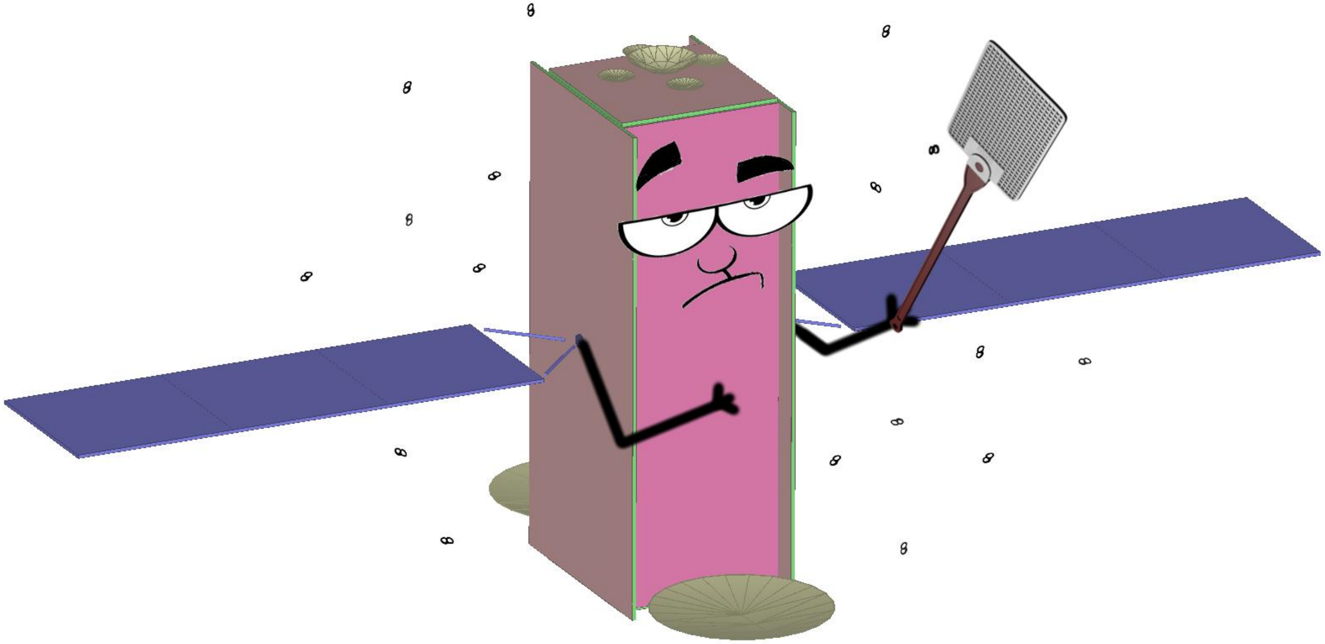
Current shielding method

Radiation analysis

- Space is unfriendly for electronic systems aboard spacecraft that shall be well suitable for resisting to such an hostile environment



Current shielding method

Radiation analysis

<u>Goal</u>: Assessment of radiation level on the sensitive parts of equipment in order to insure reliability of spacecraft during space mission

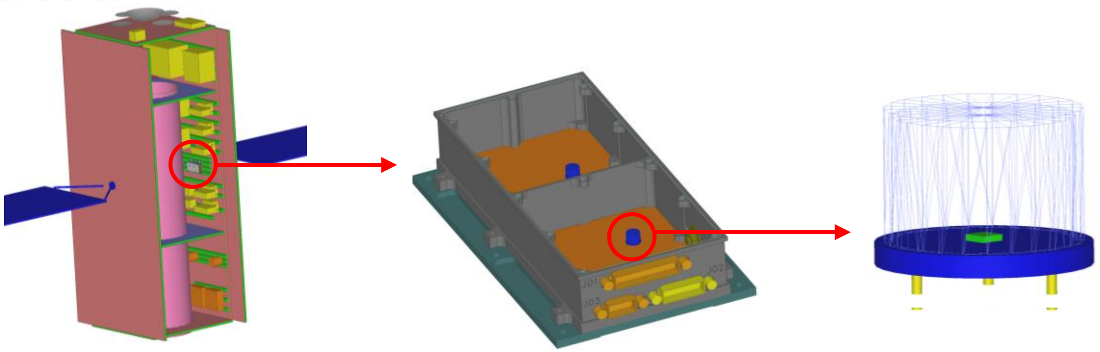
Thanks to calculation tools like FASTRAD:

- **3D model compatible with radiation calculation**
- **Two methods to estimate the radiation level**
  - **Sector analysis for a geometrical resolution of the radiation constraint**
    - $\Rightarrow$ **Dose estimation only, fast and hot spot highlighting**
  - **Monte Carlo with a physical resolution of the constraint**
    - $\Rightarrow$ **Accurate for the dose and transmitted flux calculation**

Current shielding method

Shielding process (1/3)

- First step is to model in 3D the system to be simulated



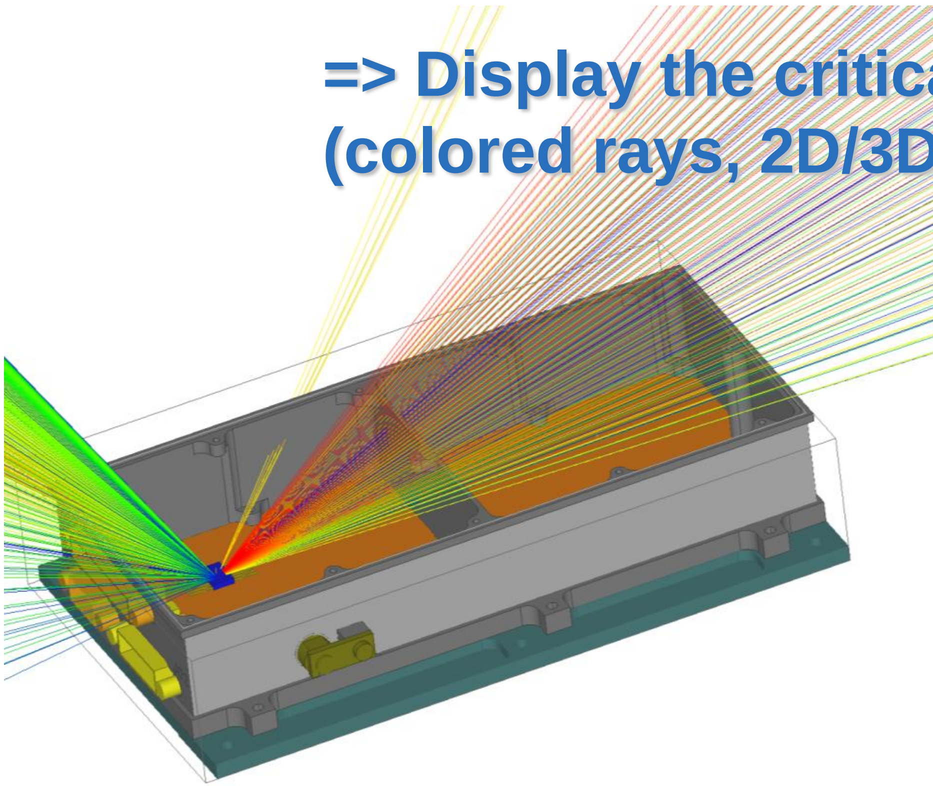
- Then calculation has to be performed on all the sensitive targets
  - Sector analysis to know the thicknesses distribution
  - Reverse MC to calculated accurate doses
- Received doses are compared to the design doses

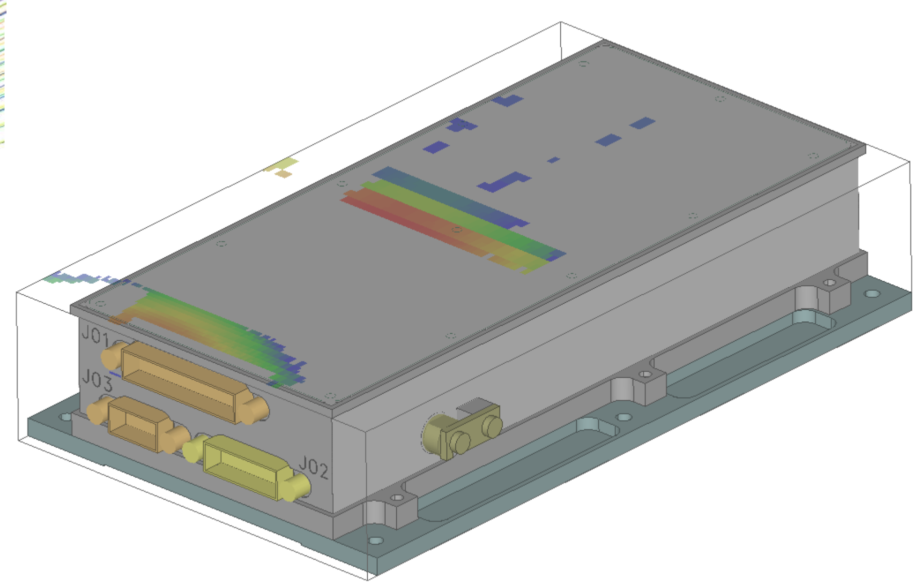
Current shielding method

Shielding process (2/3)

- **Radiation tools allow post-processing results**

  => Display the critical crossed thicknesses (colored rays, 2D/3D mapping) for each target

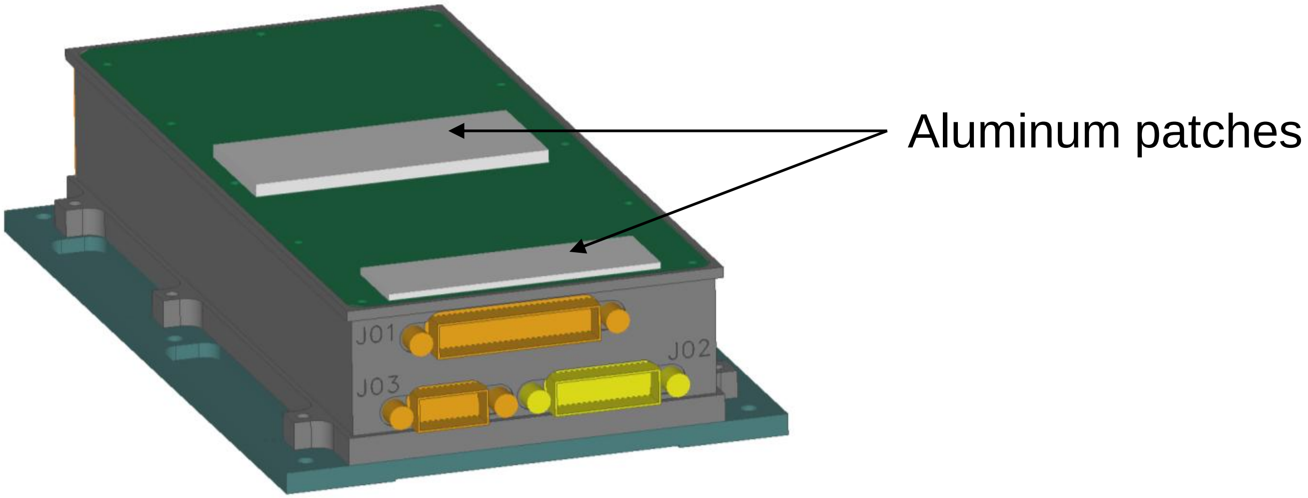




Current shielding method

Shielding process (3/3)

- **Radiation engineer can handle the results to know where are the hot directions bringing the most part of the dose**
- **In this way he/she is able to add shielding patches to reduce the dose received by the selected device**



Current shielding method

Limitations

- The shielding process is performed for each electronic device one at a time
- Process asks for iterative computation to check the dose that takes a lot of time (may be boring…)
- Impossible to be sure that the shielding solution is the best in term of response and mass

⇒ Interesting to think about a strategy to automatically design the shielding patches

Automated strategy

Shielding optimization

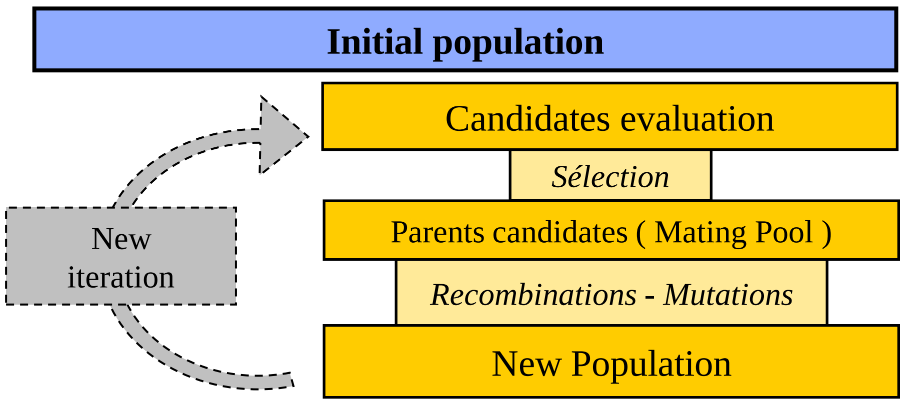
<u>Purpose</u>: To find the best shielding solution able to minimize effects of the radiation constraint and the additional mass on an electronic equipment

- **The possible solutions are numerous, composed of many shielding patch configurations (different positions, dimensions and thicknesses)**
- **Global optimization problem adapted to a non-determinist algorithm**

$\Rightarrow$ **Implementation of a genetic algorithm**

Genetic algorithms

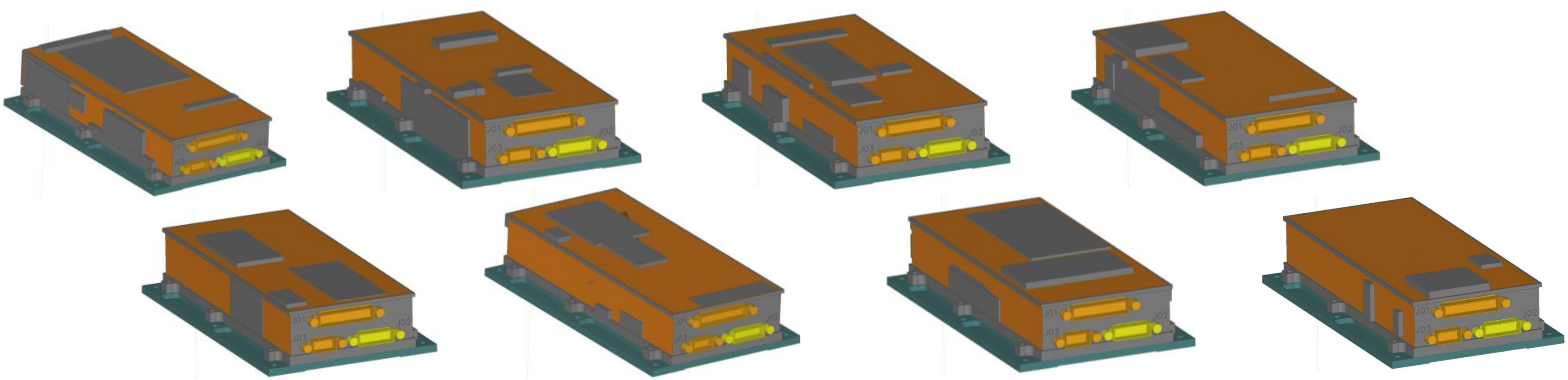
- **Mimic the process of natural selection that tends toward favoring the most adapted subjects**
- **The GA methodology requires:**
  - **An initial population of candidate solutions**
  - **Rules to perform genetic operations**
  - **A fitness function to evaluate the solutions**



Automated strategy

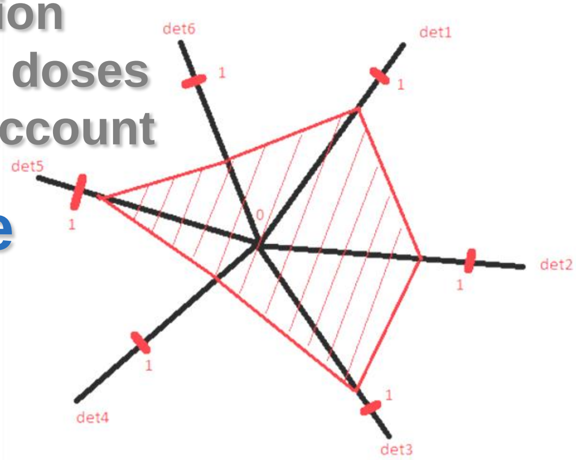
Genetic algorithms for shielding (1/3)

- **The initial population is automatically generated**
- **Need rules for the generation of a shielding solution**
  - Selection of the surfaces to be patched
  - Positions limited by the dimensions of these surfaces
  - User defined maximum sizes of the patch
  - No overlapping between two patches



Genetic algorithms for shielding (2/3)

- **Initialization of the radiation constraint**
  - Selection of the sensitive components
  - Sector analysis is performed on these targets
  - Comparison of the calculated doses with the design doses
  - Save the problematical components
- **Per generation, each candidate solution is evaluated**
  - Sector analysis is performed on each selected component by taking into account the shielding configuration
  - Received doses are compared to the design doses
  - Mass of the added patch is also taken into account
- **Fitness is deduced to the ratio of the received dose on the design dose weighted by the mass**

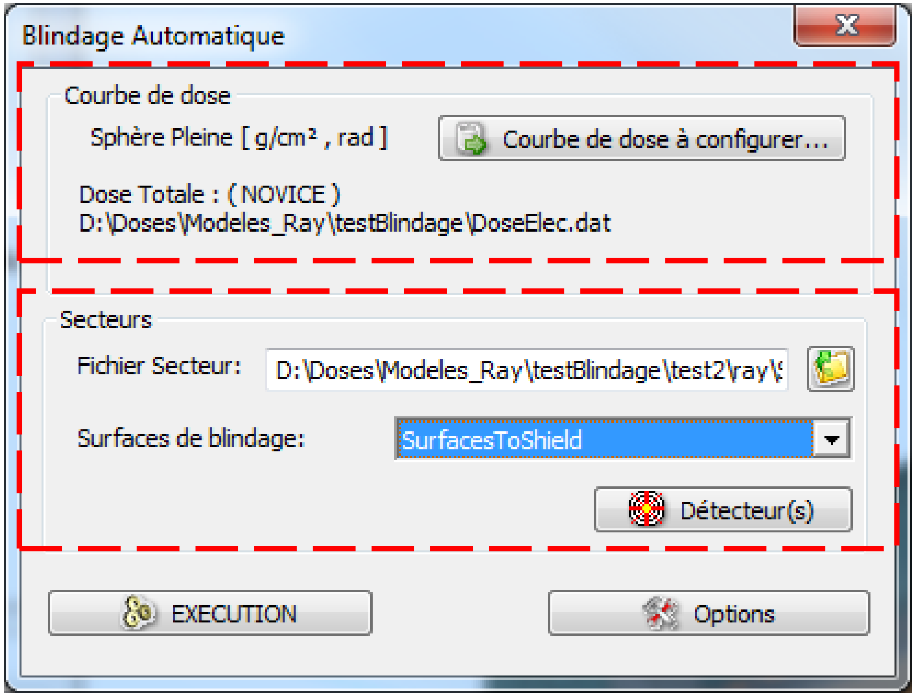


Genetic algorithms for shielding (3/3)

- **Tournament strategy to select solutions with the best fitness**
  - 2 solutions randomly selected (uniform distribution)
  - Keep the solution with the best fitness
  - Give a chance to few bad solutions to be selected
- **Crossover between randomly chosen solutions**
  - To mix the shielding patches of the solution A with the patches of the solution B (barycentric recombination)
- **Mutation on a few solutions to bring diversity in the new generation**
  - Slight modifications of some patches (thickness, position, dimensions)

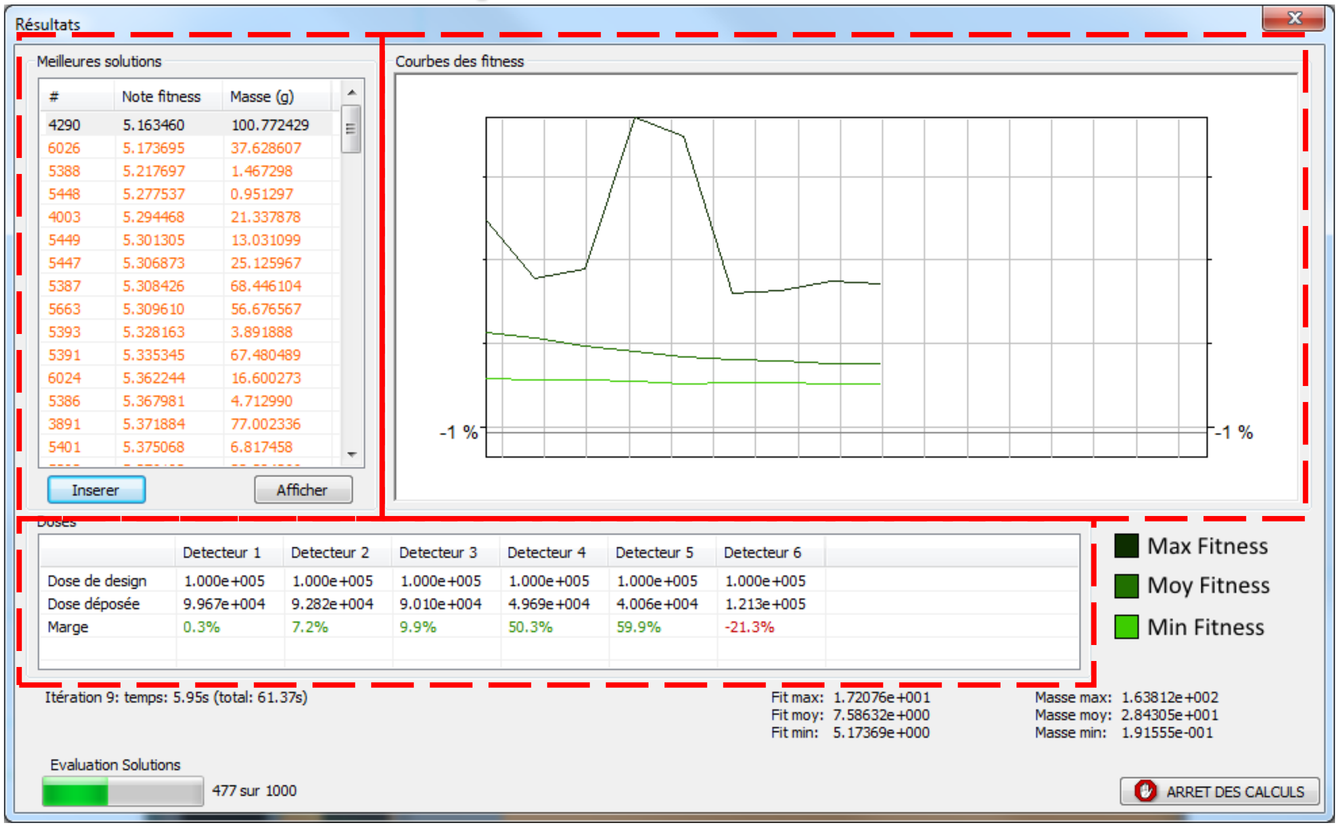
Prototype interfaces (1/2)

- **A first dialog box has been designed to initialize the shielding optimization**



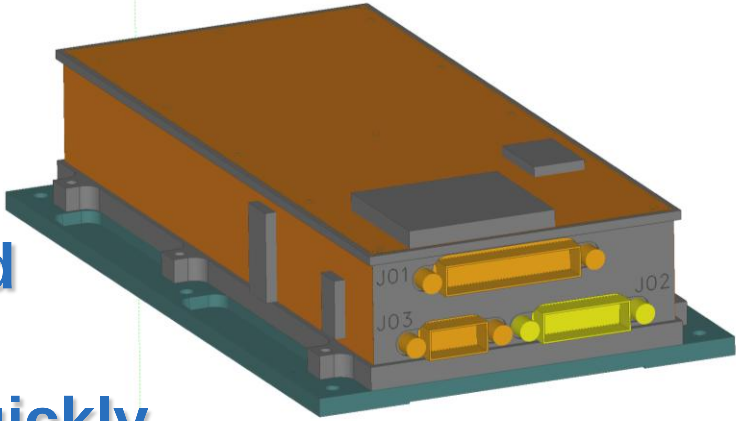
Prototype interfaces (2/2)

- **A second interface allows displaying the progression of the automatic process**



Automated strategy

Results



- A realistic case has been tested
- Implemented algorithm runs quickly (multi-treaded, data structure optimization)
- But the evaluation of the solutions depends overly on the mass
- Algorithm seems to find local minima regarding the criterion to optimize

Conclusion & Perspectives

- **Developed prototype shows the interest for going further in the development of an engineering tool**

- **This prototype allowed us identifying two main areas for improvement**
  - **The way to code the recombination between two solutions has to be modified**
  - **Algorithm to calculate the fitness needs to be improved in order to decrease the mass influence**

- **Many other test cases should be processed and results compared to hand-made shielding solutions**

THANK YOU FOR YOUR ATTENTION