Physics Driven Geometrical Model Reduction (GMM)

Vincent Vadez, François Brunetti, Pierre Alliez

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(GMM)

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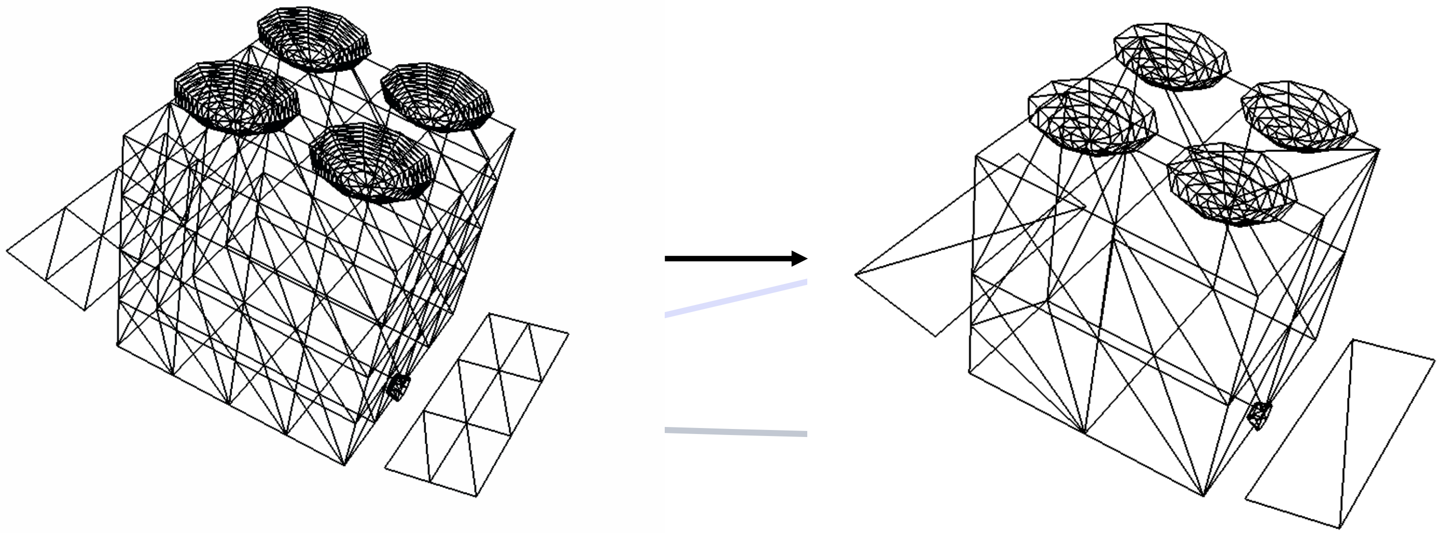
Outline

- **Previous results on new view factor computation methods**

- **Physics driven geometrical model reduction**
  - Problem statement
  - Reduction process coupled to an oracle for the physical component (here thermal)
  - Limits

- **Conclusion & future works**

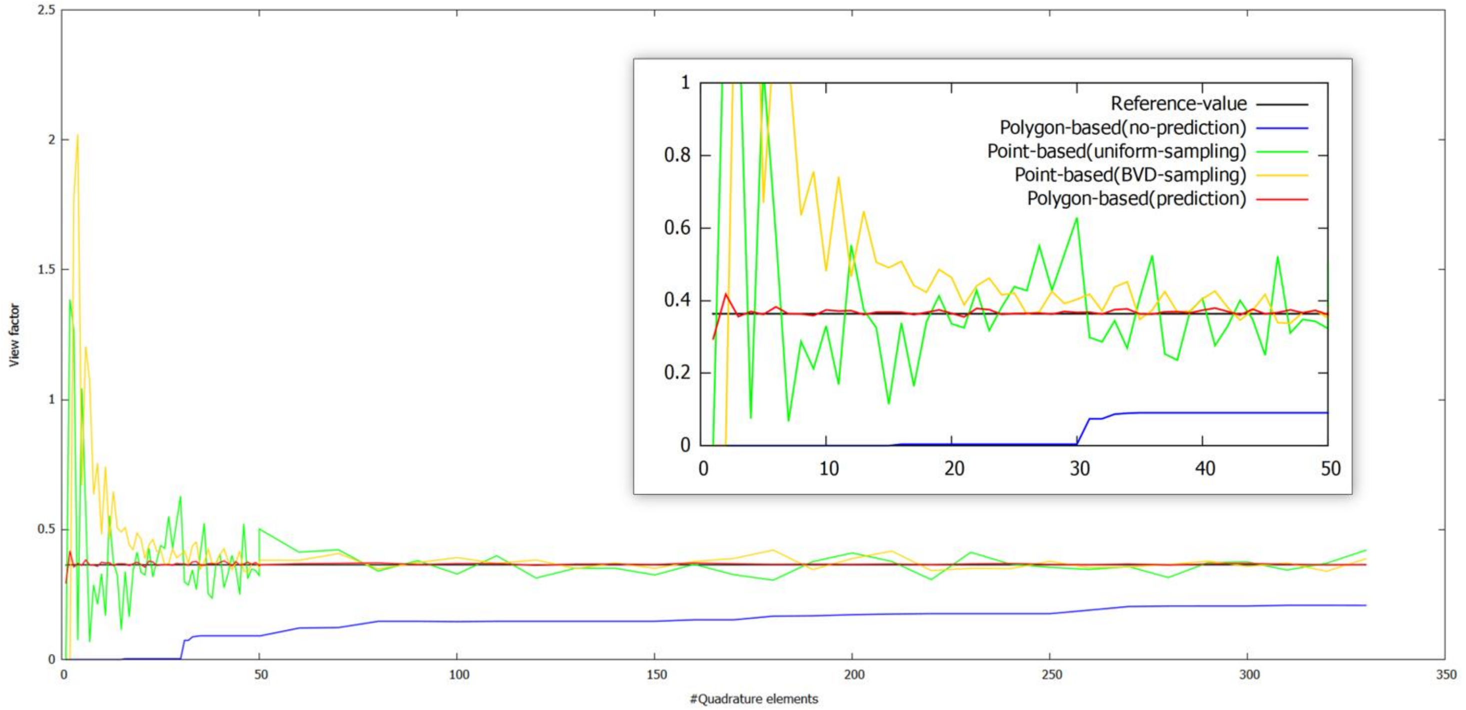


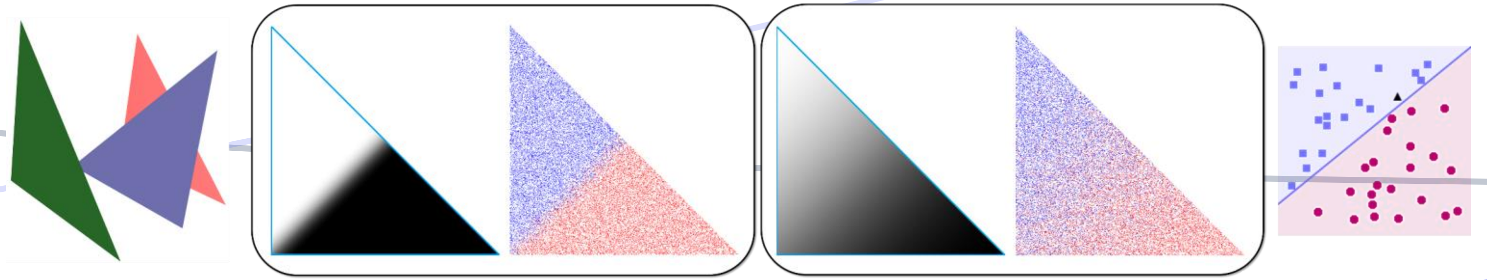
Progressive geometric view factors

- **Polygon-based quadrature**
- **Adaptive splitting**
- **Predictions**

More details here:

V. Vadez, F. Brunetti, P. Alliez. Progressive Geometric View Factors for Radiative Thermal Simulation. *International Conference on Environmental Systems (ICES2020)*

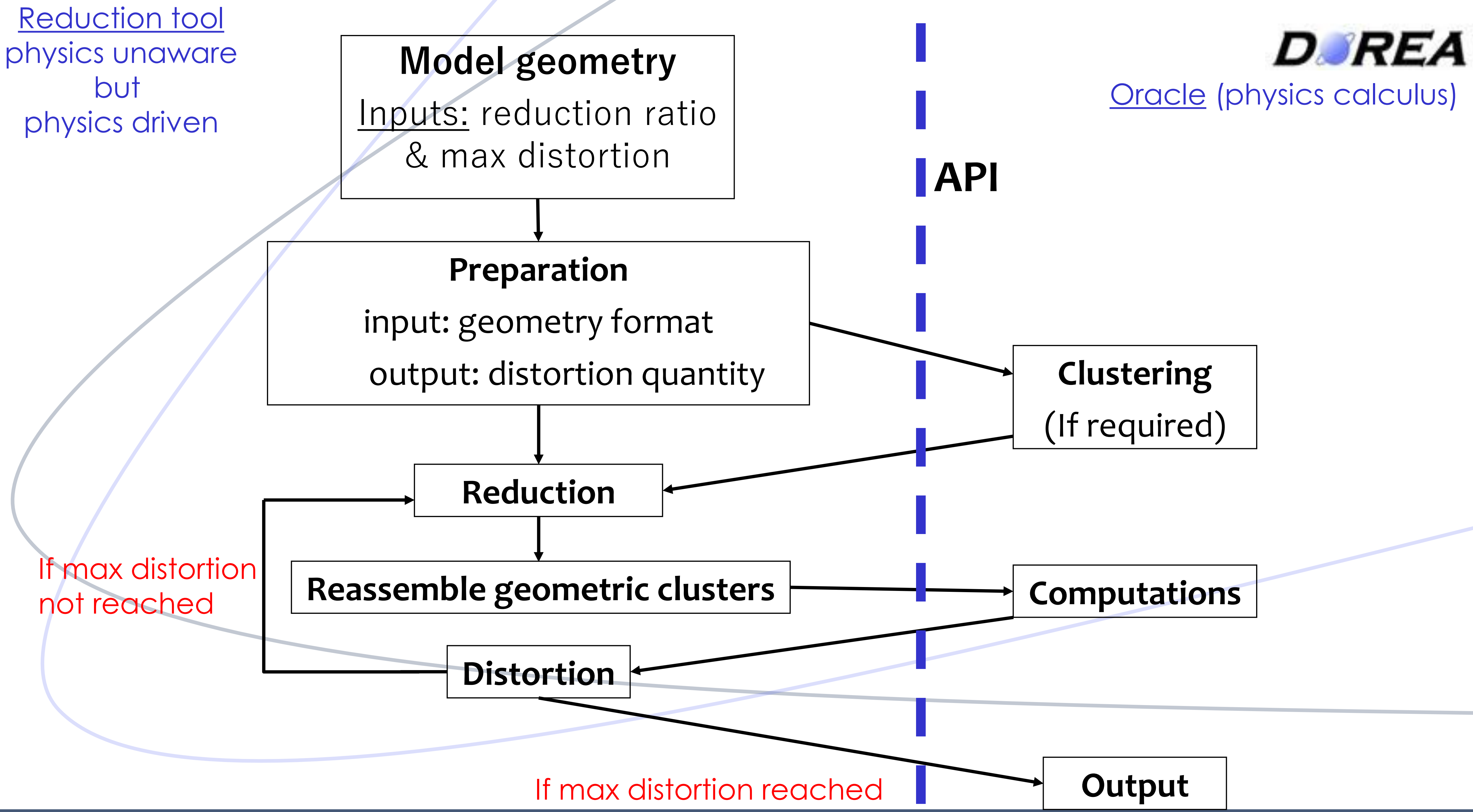


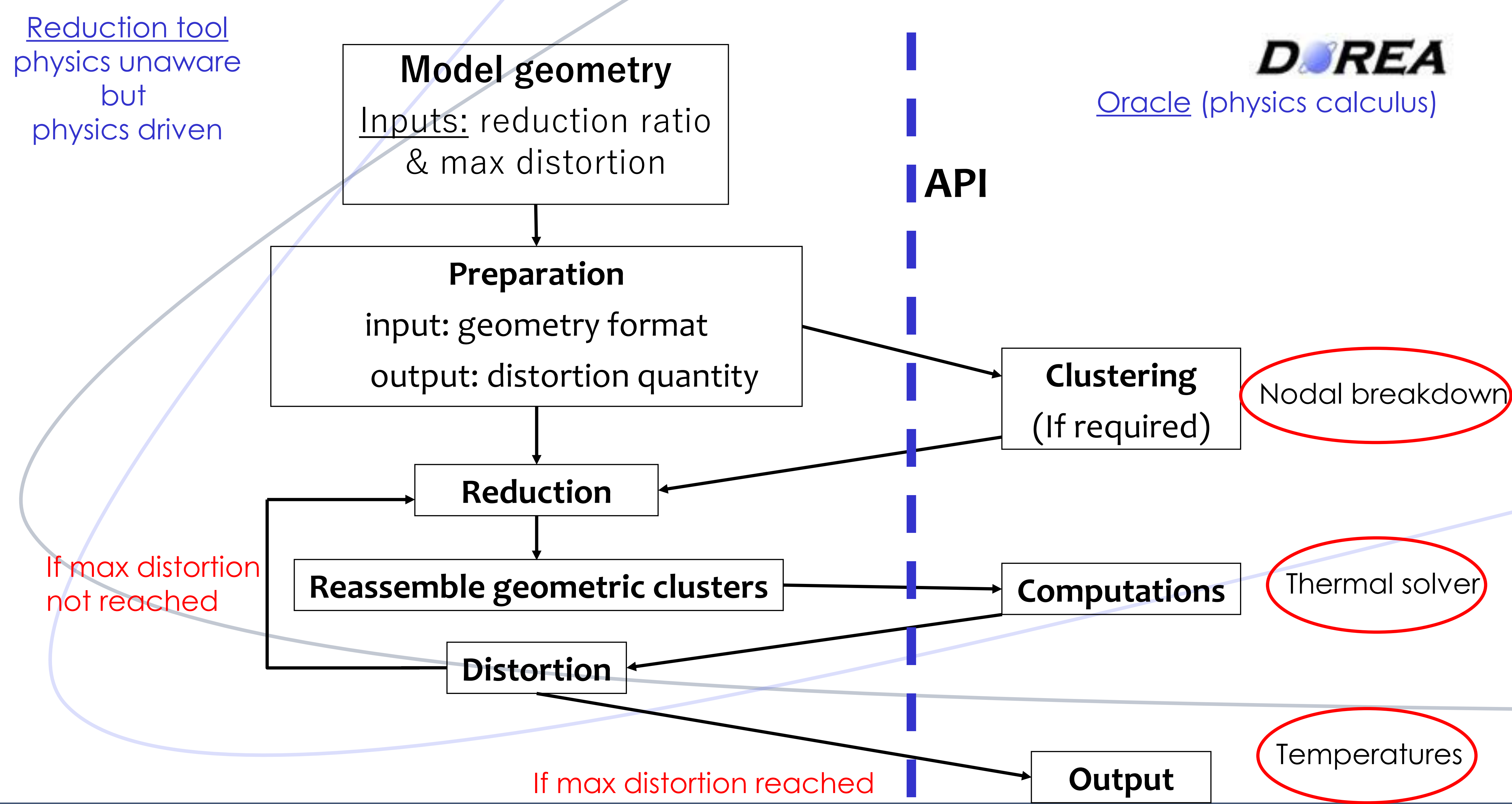


Physics driven geometrical model reduction

- **Problem statement:**
  - Radiative thermal computations are time consuming
  - Goal: Geometric reduction consulting **physics unaware** but **physics driven** thanks to an oracle
    User inputs: Geometric file & decimation step
    Output: Distortion

- **Global generic architecture:**
  - Preparation: reference calculation case request and clustering
  - Reduction: decimation iterations for each cluster
  - Reassembling: reduced geometry reconstitution and calculations request
  - Distortion: stop criteria according to user input and calculations results (max distortion)


Reduction tool
physics unaware
but
physics driven
DOREA
Oracle (physics calculus)
Model geometry
Inputs: reduction ratio
& max distortion
API
Preparation
input: geometry format
output: distortion quantity
Clustering
(If required)
Reduction
If max distortion
not reached
Reassemble geometric clusters
Computations
Distortion
Output
If max distortion reached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API
DOREA
Oracle (physics calculus)
Clustering
(If required)
Nodal breakdown
Computations
Thermal solver
Output
Temperatures

Physics driven geometrical model reduction

- **Current prototype thermal limitations**
  - View surfaces face to face only (no solar or albedo fluxes computed)
  - Node-to-node radiative couplings
  - Thermal equation solved: steady state
  - No conductive part in considered model (so only radiative couplings influence final temperatures aka radiative component totally drives temperatures)
  - Same thermo-optical properties everywhere

Note: if solar and albedo computations are performed, if conductive couplings are added, if thermo-optical properties are different for each node -> final reduced output would be different **BUT reduction algorithm does not change**

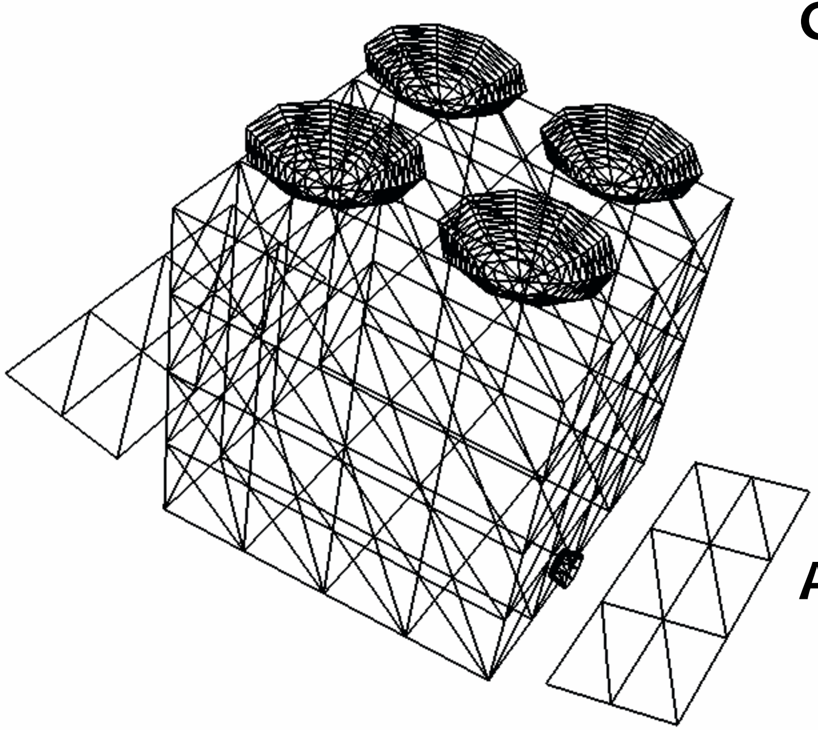
Physics driven geometrical model reduction

- **State of the art on geometric model reduction**
  - Edge-collapse or halfedge-collapse
  - Cost function & placement function
    - Lindstrom-Turk [1]: optimizes shape, volume & boundaries
    - Garland-Heckbert [2]: encodes approximate distance to the original mesh by using quadric matrices that it assigns to each vertex
    - Volume preserving memory-aware
    - Normal preserving

[1] Peter Lindstrom and Greg Turk. Fast and memory efficient polygonal simplification. In *IEEE Visualization*, pages 279–286, 1998.

[2] M. Garland and P. S. Heckbert. Surface simplification using quadric error metrics. In *Proc. SIGGRAPH '97*, pages 209–216, 1997.

Physics driven geometrical model reduction



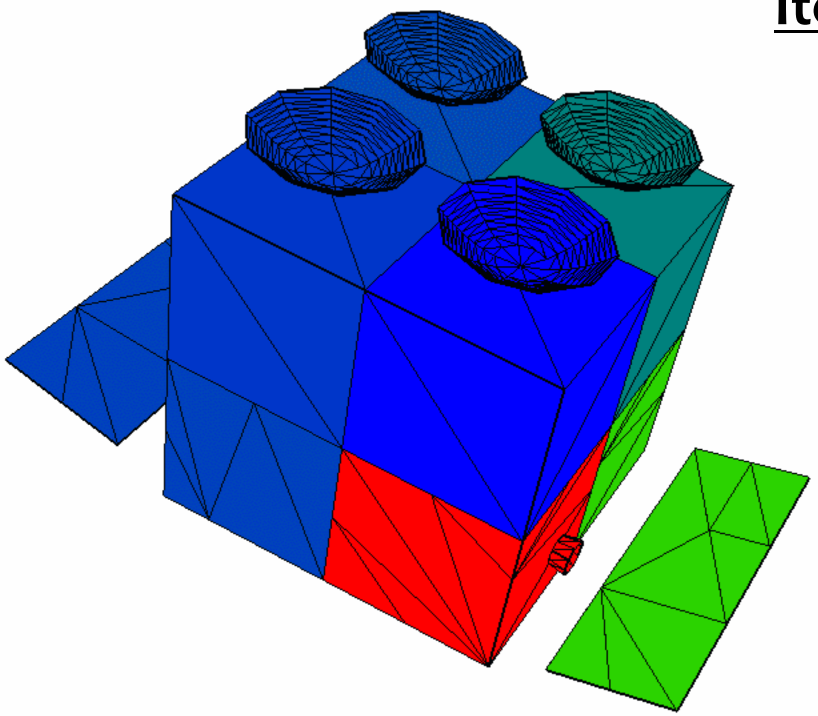
Considered model:

- 10 thermal nodes
- 1006 triangle faces
- 4 antennas oriented towards Earth and 2 reflectors
- 0,1W injected at the nozzle
- 1 boundary node

Algorithm inputs:

- reduction step ratio: **10%** of faces
- desired max distortion: **0.5° C**
- Lindstrom-Turk edge collapse (appropriate since boundaries are preserved and view factors depend on area, squared distance and orientations of the faces)

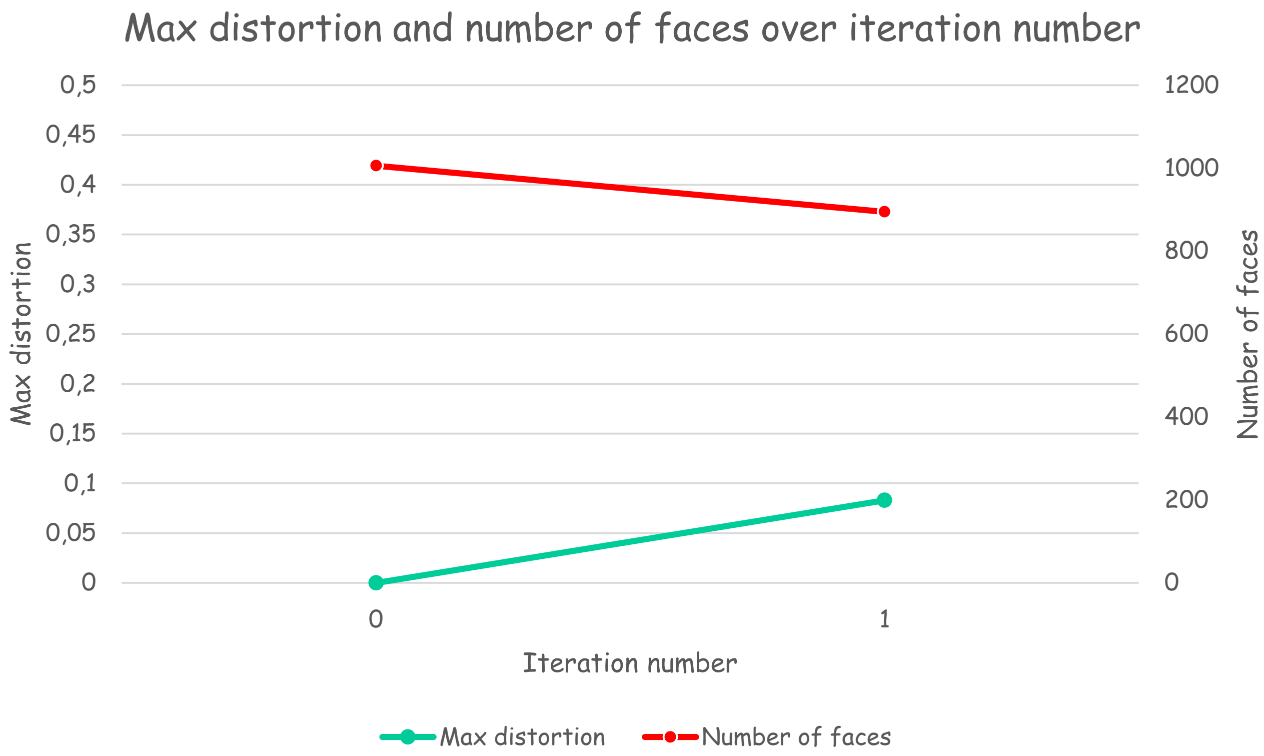
Physics driven geometrical model reduction



Iteration 1:

895 faces over 1006 original faces (89%)

Max distortion: 0.083° C

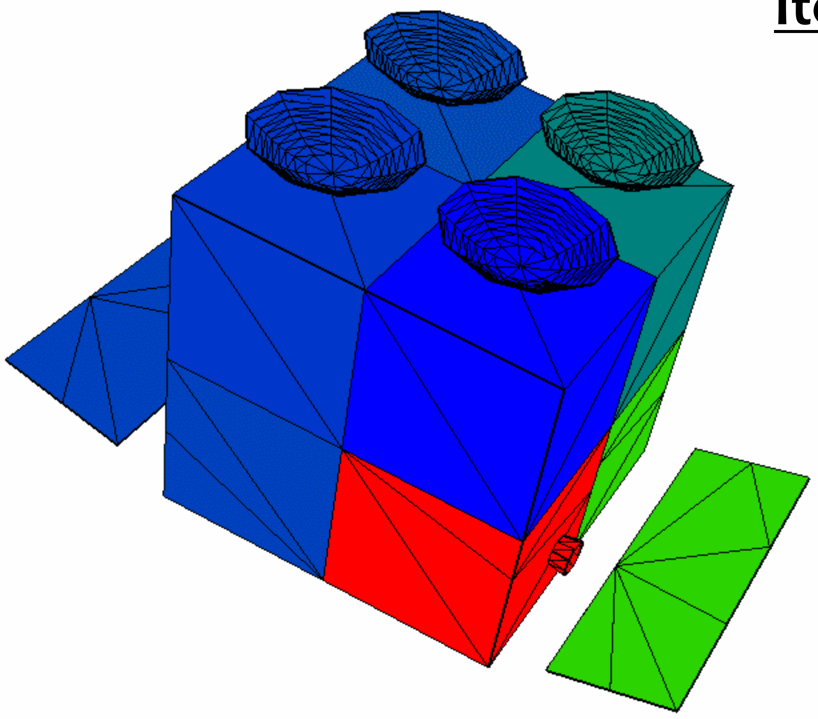


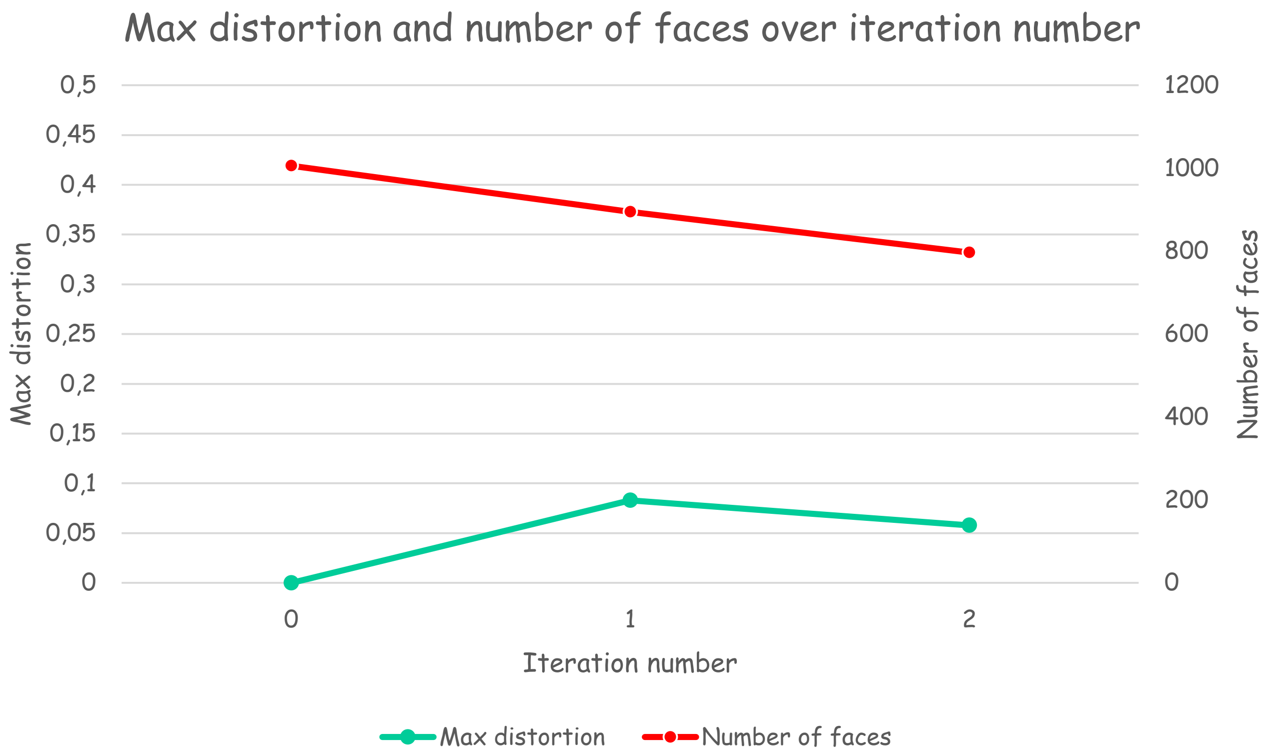
Physics driven geometrical model reduction

Iteration 2:

797 faces over 1006 original faces (79%)

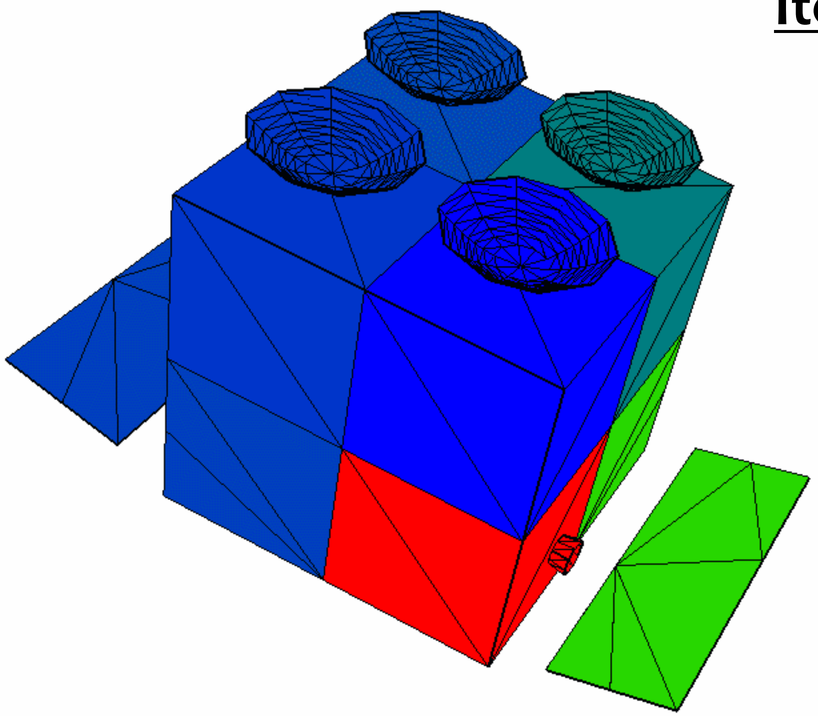
Max distortion: 0.058° C





Physics driven geometrical model reduction

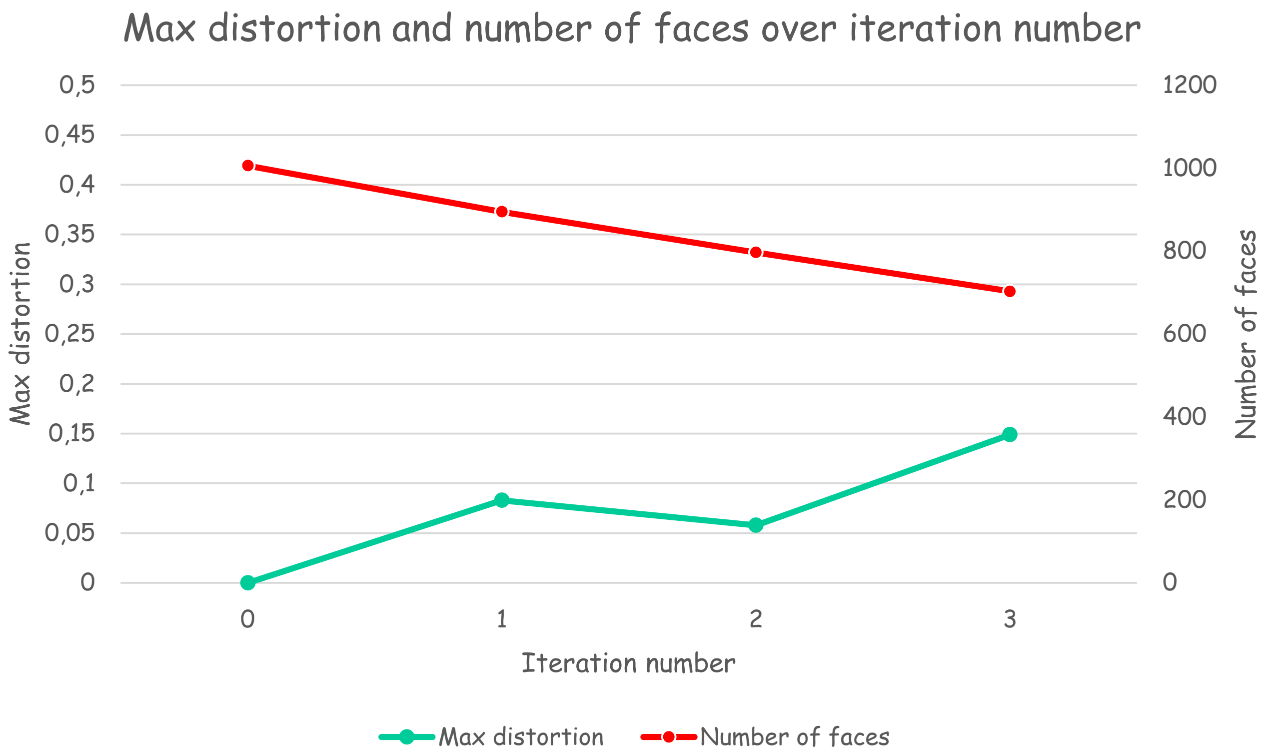
DOREA



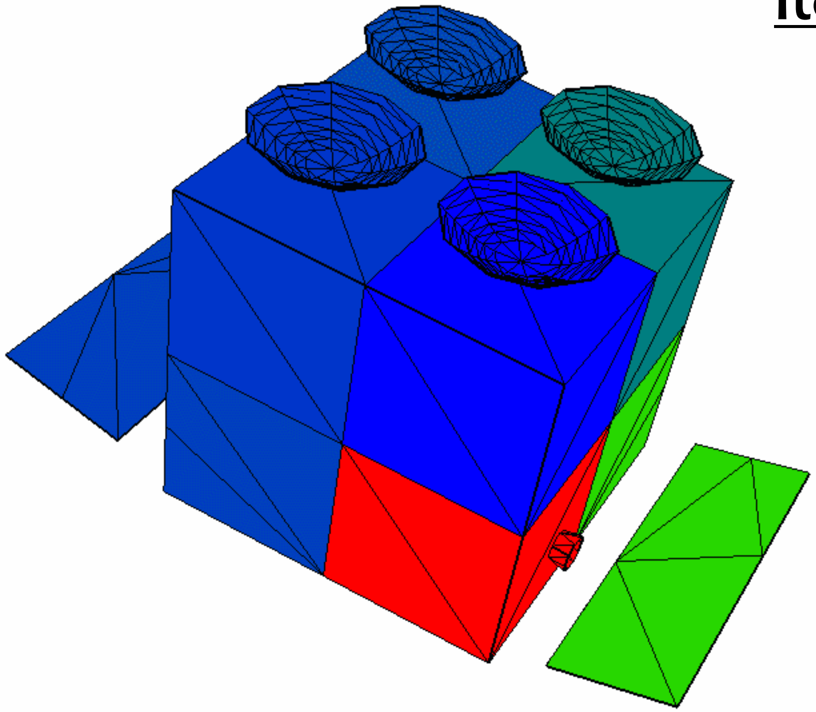
Iteration 3:

703 faces over 1006 original faces (70%)

Max distortion: 0.149° C



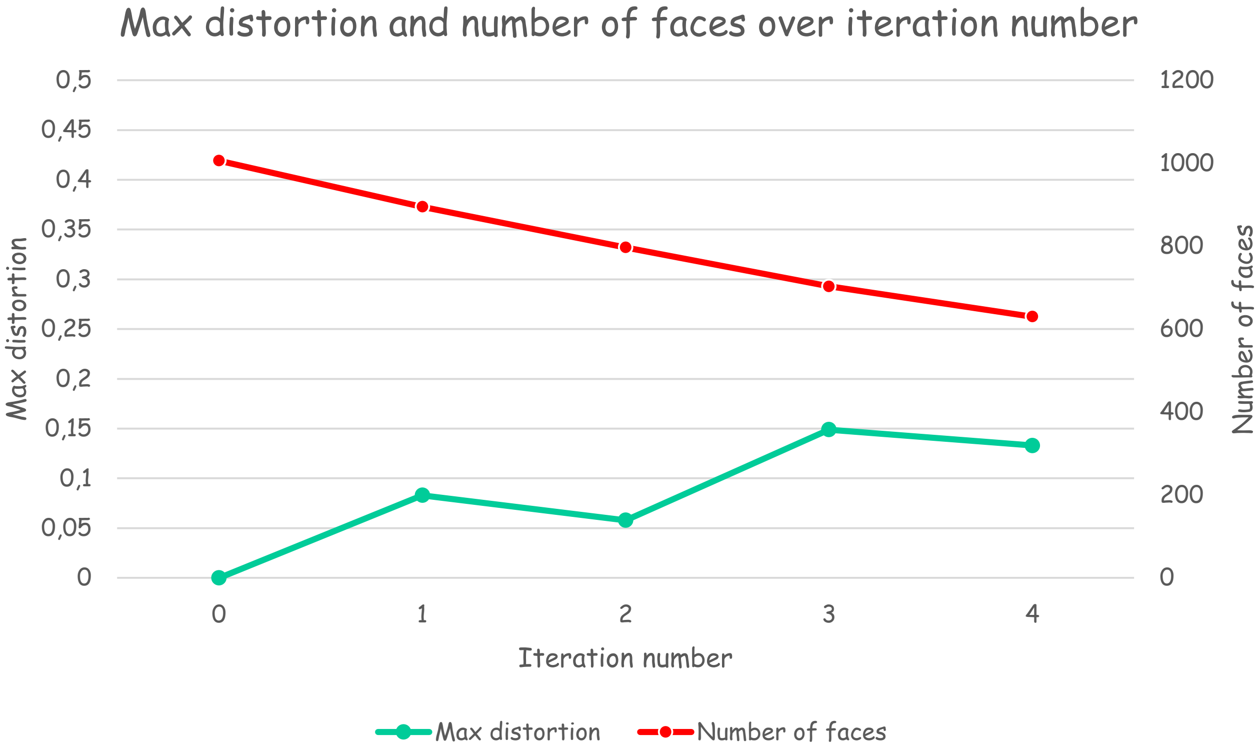
Physics driven geometrical model reduction



Iteration 4:

630 faces over 1006 original faces (63%)

Max distortion: 0.133° C

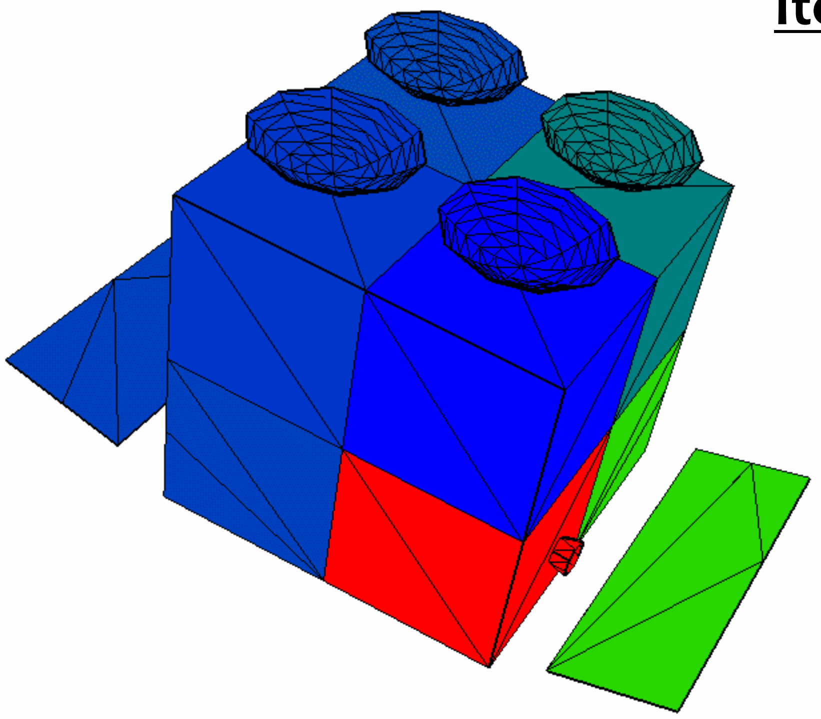


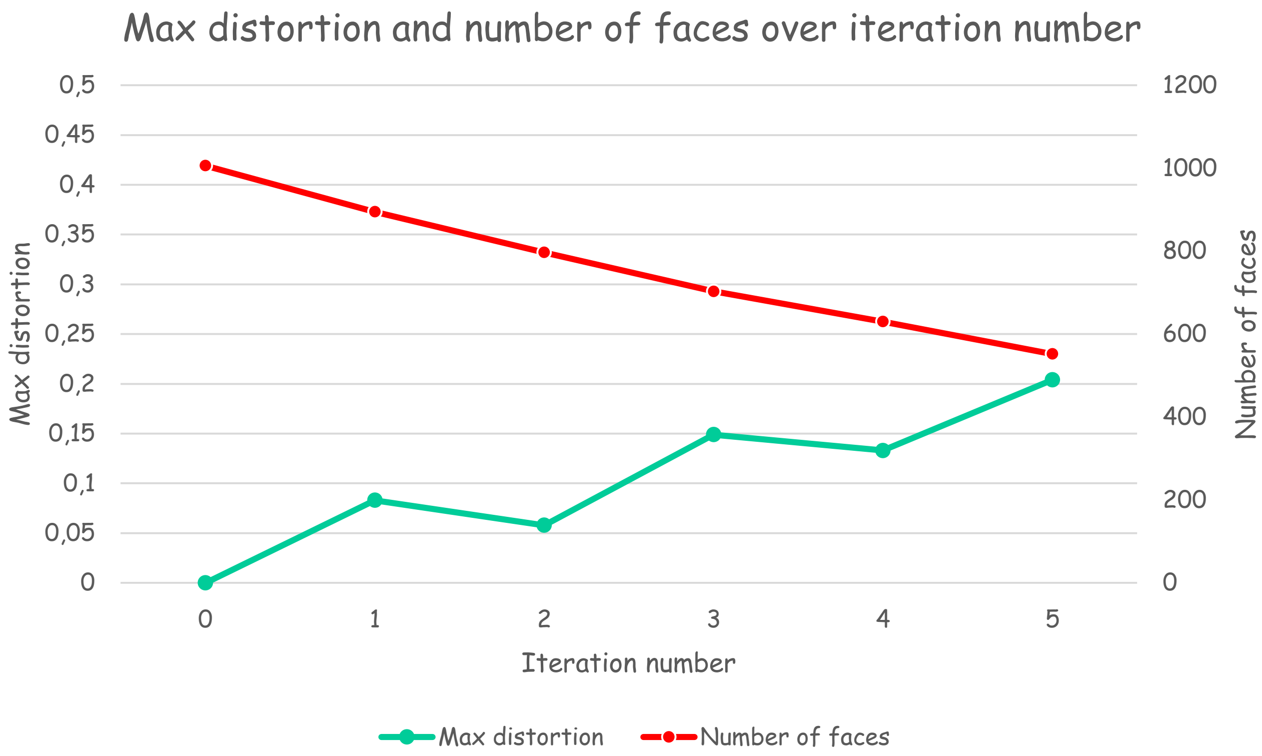
Physics driven geometrical model reduction

Iteration 5:

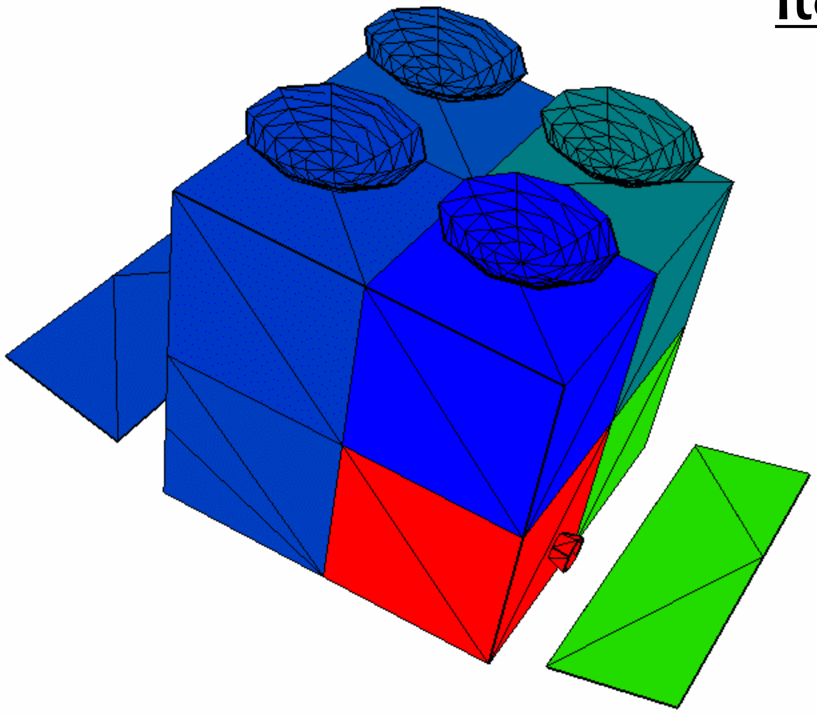
552 faces over 1006 original faces (55%)

Max distortion: 0.204° C





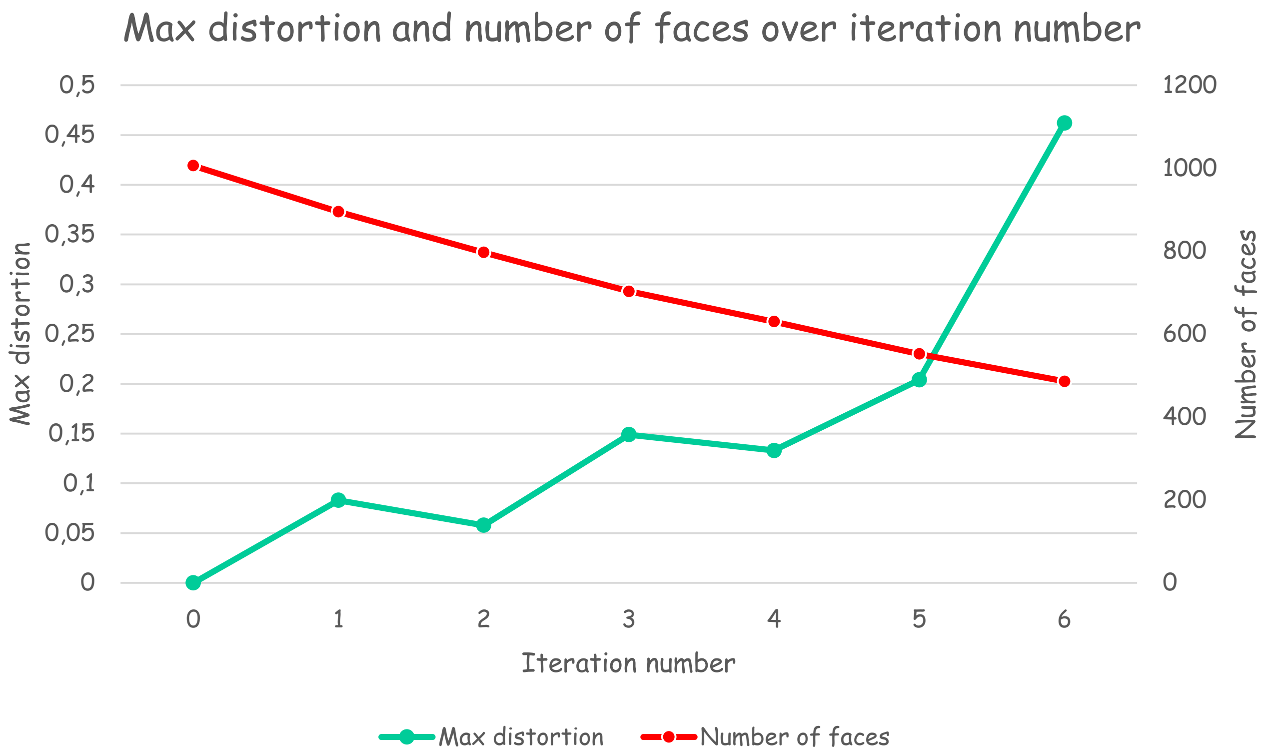
Physics driven geometrical model reduction



Iteration 6:

486 faces over 1006 original faces (48%)

Max distortion: 0.462° C

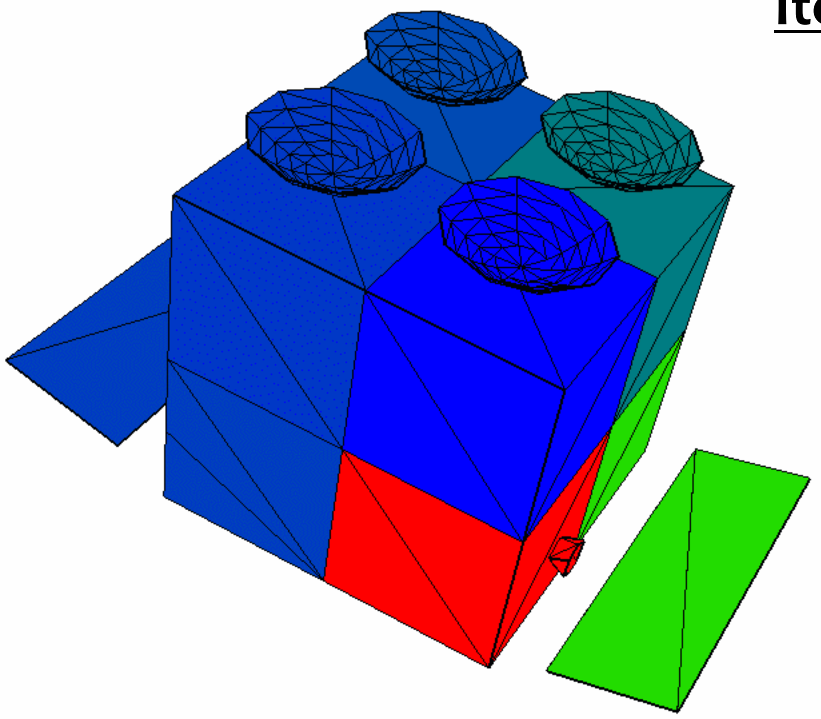


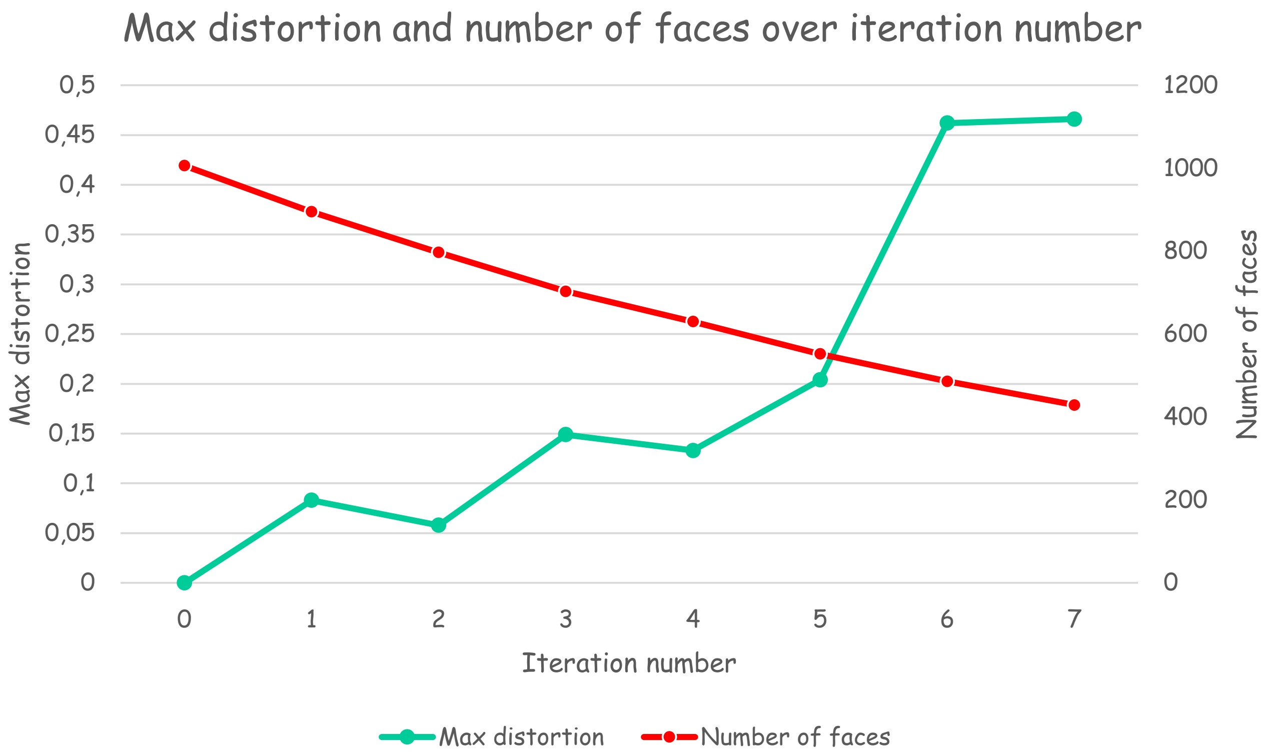
Physics driven geometrical model reduction

Iteration 7:

429 faces over 1006 original faces (48%)

Max distortion: 0.466° C

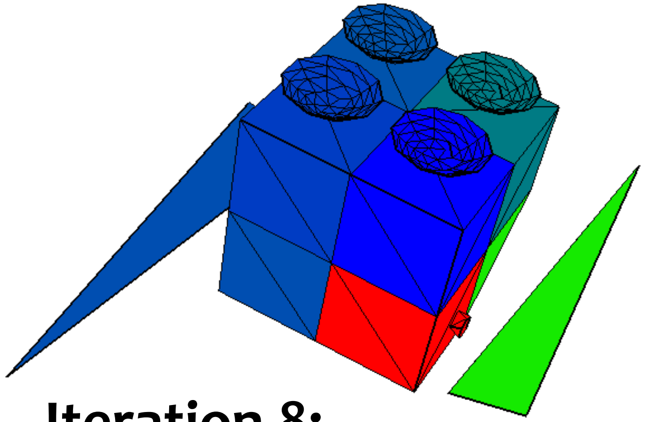




Physics driven geometrical model reduction

- **Conclusion**
  - Volume and boundaries preserved thanks to Lindstrom-Turk edge collapse
  - Results are acceptable until geometry is too much approximated
  - Fast computation times (around 2 minutes for reduction and thermal calculus for this model). And faster at each iteration.

Note: The prototype shows that the algorithm can be improved. Even if the geometry is drastically corrupted, the temperatures are still acceptable thanks to the chosen reduction metric preserving the areas.



Iteration 8:

370 faces

Distortion: 1.838° C

But antennas can still be reduced without altering too much the global geometry!

Physics driven geometrical model reduction

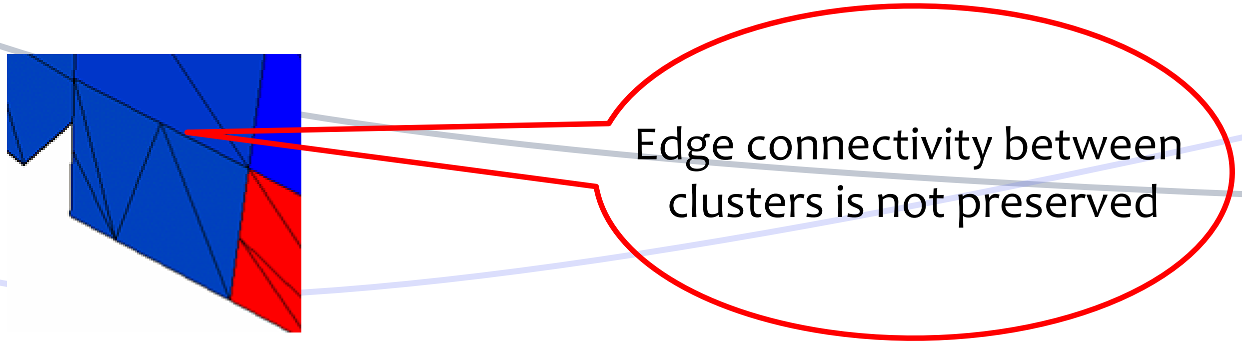
- **Future works on geometric model reduction**
  - Progressive reduction (with adaptive ratio for each reduction step)
  - Reduce large clusters first to avoid small clusters to be too much approximated

- **Future works for thermal simulation**
  - Test on a complete radiative model by adding maskings & shadows for incident fluxes (albedo, solar & Earth)
  - Test on a real model, with ESA permission Sentinel-3 and BepiColombo are good candidates
  - Examine standard exchange formats between our reduction outputs and STEP-TAS & STEP AP203
  - Sensitivity analysis on thermo-optical properties, use of machine learning to acquire thermal expertise about what drives the reduction process

Physics driven geometrical model reduction

- **Future works for 3D conductive couplings**
  - Implement a new oracle for 3D conductive couplings (finite elements computations)
  - Max distortion based on conservation of defined interface nodes conductive couplings
  - The oracle could be improved to preserve mechanical structures characteristics

<u>Note:</u> Edge connectivity conforming is not required for the radiative calculation. Due to finite elements (volumic connectivity), the edge connectivity between clusters is mandatory.



Thank you for your attention!

Questions are welcomed!