# pySINAS: New STEP-TAS - FEM overlap module

| | |
|---|---|
| Alberto Pemán | (ATG Europe) |
| Arturo González-Llana | (ATG Europe) |
| Alexander van Oostrum | (ATG Europe) |
| James Etchells | (ESA) |
| Simon Appel | (ESA) |

26-10-2022

# CONTEXT

Previous presentations:

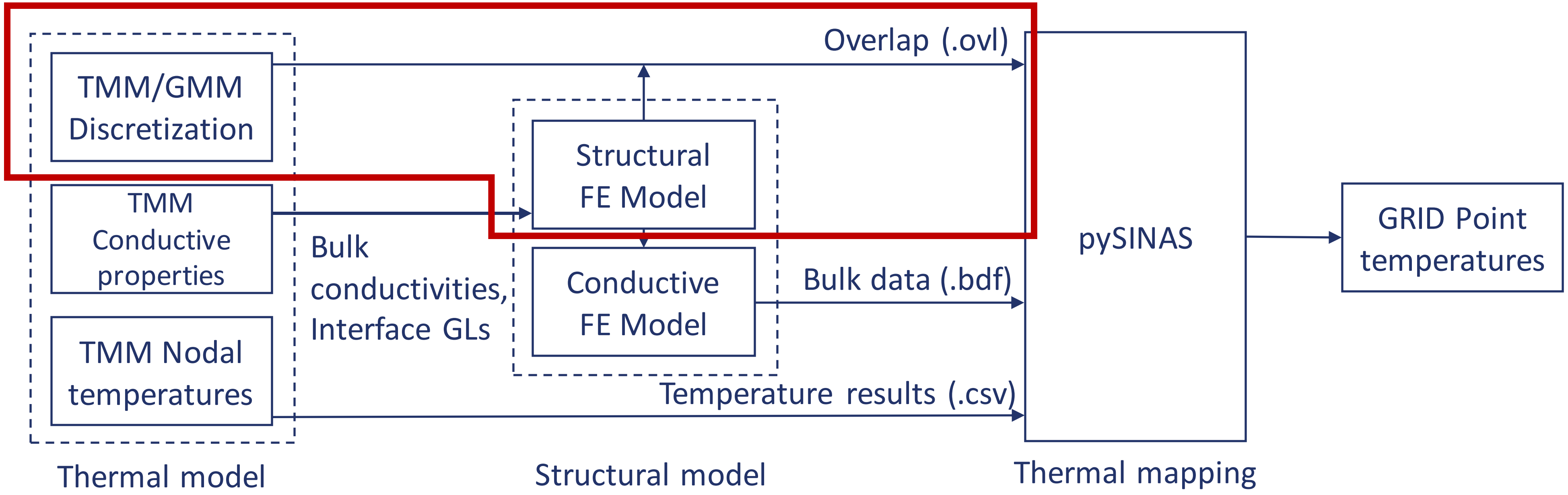
- SINAS made simple (ESTEW 2019)
- SINAS: Benefits and points of attention (ESTEW 2019)
- Guidelines for accurate Thermoelastic Analysis (ESTEW 2019)
- Temperature Mapping for Structural Thermo-Elastic Anaylses; Method Benchmarking (ECSSMET 2018)
- Thermal Conductor Generation for Thermal and Thermo-Elastic Analysis Using a Finite Element Model and SINAS (ECSSMET 2018)
- Accurate Thermal Mapping and Finite Element Model Based Conductor Generation; Extended Method Benchmarking Guidelines (ESTEW 2018)

# CONTENTS

- pySINAS method
- Overlap file (.ovl)
- New overlap module
- How to use the overlap module: Example 1
- How to use the overlap module: Example 2
- Main benefits and limitations

# PYSINAS METHOD

- Three inputs are required
  - Bulk data file: structural model with conductive properties
  - Temperature results: transient or steady state results from lumped parameter model
  - <u>Overlap file: correspondence between FE elements and thermal nodes</u>

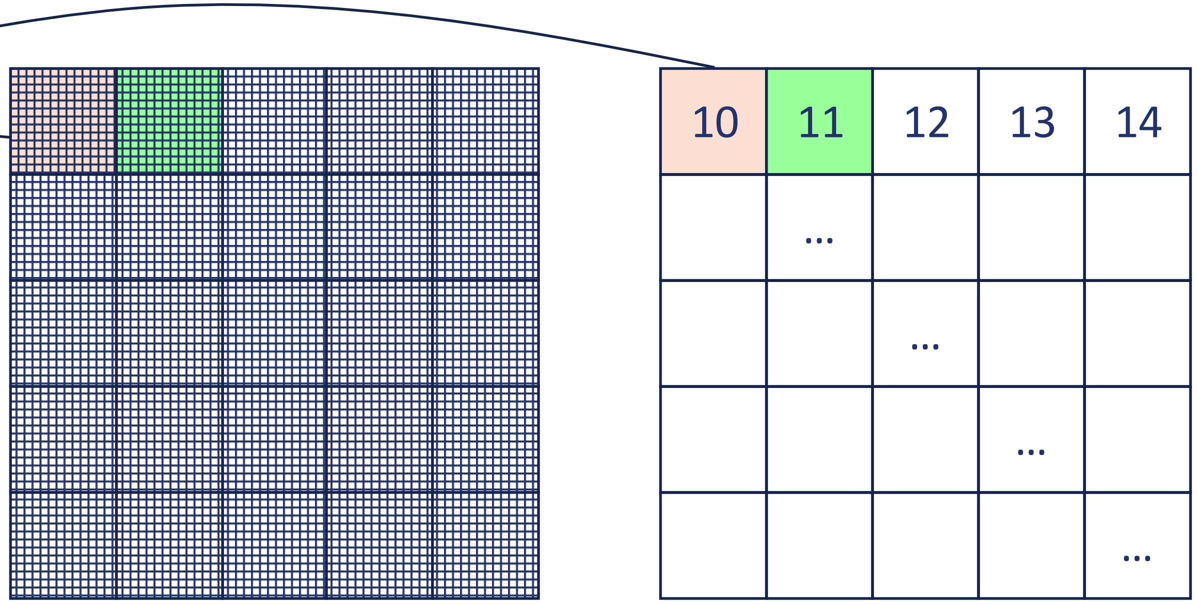


# OVERLAP FILE (.OVL)

- Defines the list of structural elements corresponding to each individual thermal node.
- Both the list of structural elements and thermal node should represent the same part of the structure.

- File format:

```
CSET 10
   ELEMENTS
    1, … , 100
   ENDSET
CSET 11
   ELEMENTS
    101, … , 200
   .
   .
```



FEM model

Thermal model

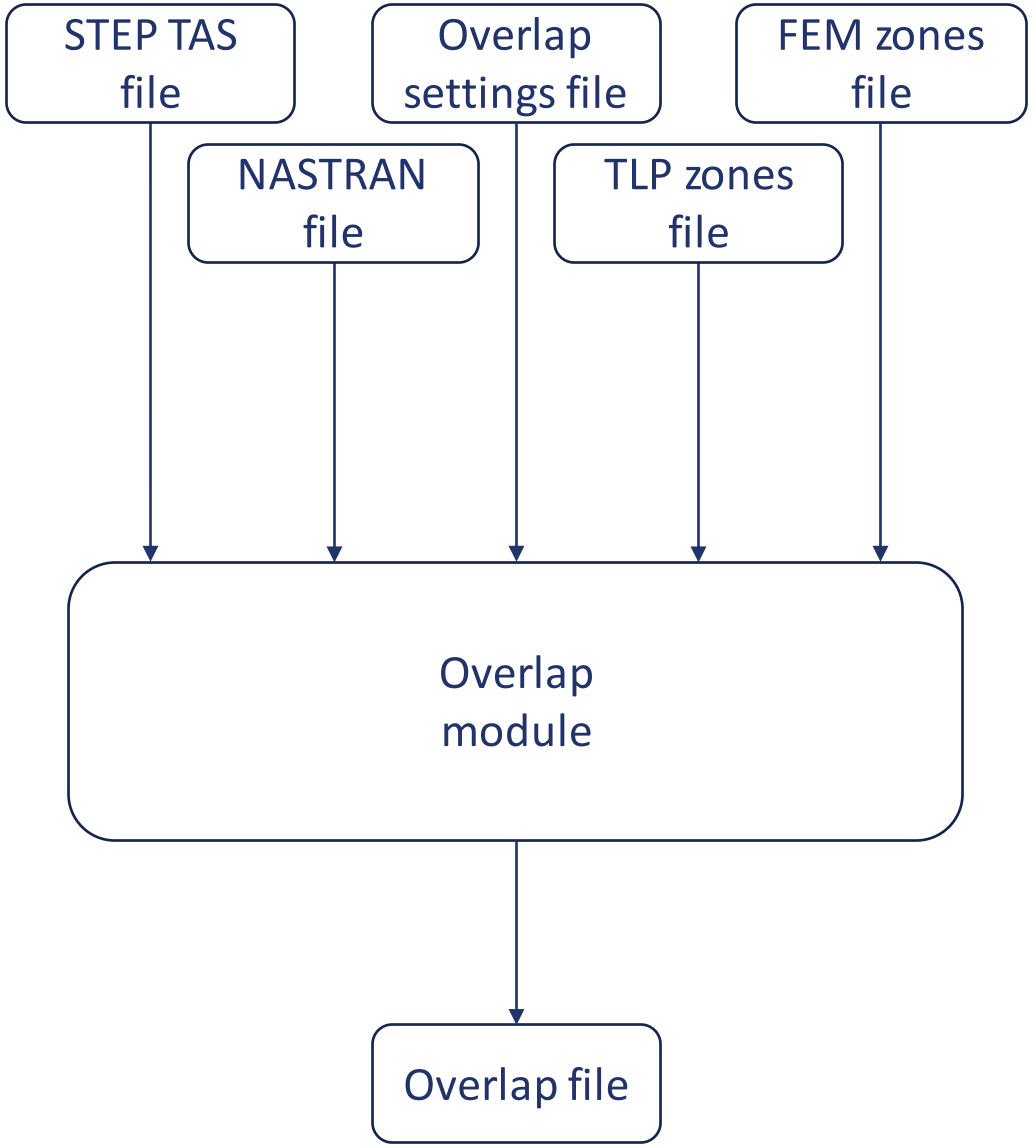
# NEW OVERLAP MODULE

- Up until now, the generation of the overlap file:
  - using PATRAN module (still available)
    - there was no organization of overall project.
    - reduced usage of PATRAN across industry.
  - users had to develop their own tools:
    - requires high investment
  - file had to be written manually:
    - was generally a cumbersome task;
    - was prone to errors.
- All these drawbacks limited the usage of pySINAS, in most cases, to simple cases, or required a high investment from the user to develop tools to automate the overlap file generation.
- **The new overlap module automatically generates the overlap file with minimum input from the user.**

# NEW OVERLAP MODULE

- Overlap module method requires:
  - thermal model geometry file (STEP TAS file)
  - structural model file (NASTRAN bulk data file)
  - overlap settings and zone definition files (JSON files)

- Overlap module files:
  - STEP TAS file (thermal model)
  - NASTRAN file (FEM model)
  - Overlap settings file
  - TLP zones file
  - FEM zones file



# NEW OVERLAP MODULE

- Overlap settings file used to define:
  - currently in JSON format
  - any FEM translation and/or rotation, if needed, to align both models
  - thermal geometry model .stp file to use
  - conductive FE model .bdf file to use
  - thermal model zone .json file
  - FE model zone .json file
  - Define correspondence between thermal and structural zones

```
{"global_settings": {
    "title":             “plate_overlap",
    "fem_translation":   [0.0, 0.0, 0.0],
    "fem_rot":           [0.0, 0.0, 0.0],
    "fem_rot_origin":    [0.0, 0.0, 0.0],
    "step_tas_file":     "plate.stp",
    "nastran_bdf_files": [{"name": "plate.bdf", "onlyBulk": true}],
    "fe_group_files":    ["plate_fe_groups.json"],
    "tlp_group_files":   ["plate_thermal_groups.json"],
    "ovl_file":          "plate.ovl" },

  "zones":
   [{ "type":       "shell_nograd",
      "title":      "zone_1",
      "fe_group":   “fe_zone_1",
      "tlp_group":  “thermal_zone_1",
      "method":     "min_distance"}]
}
```

Example Overlap settings file

# NEW OVERLAP MODULE

- Zones are user defined groups of FE elements and thermal nodes that are overlapped independently from the rest of the model.
  - Every FEM zone must have an equivalent thermal zone.

- Zone files (in JSON format)
  - FEM zones file
    - 1 or more zones can be used to define the elements to be used in the overlap

```
[
  {
    “name”:     “fe_zone_1”,
    “elements”: [1,2,3,4,5,…,1000]
  }
]
```

Example JSON FEM zone file

  - TLP zones file
    - 1 or more zones can be used to define the thermal nodes to be used in the overlap

```
[
  {
    “name”:  “thermal_zone_1”,
    “nodes”: [1,2,3,4,5,…,100]
  }
]
```

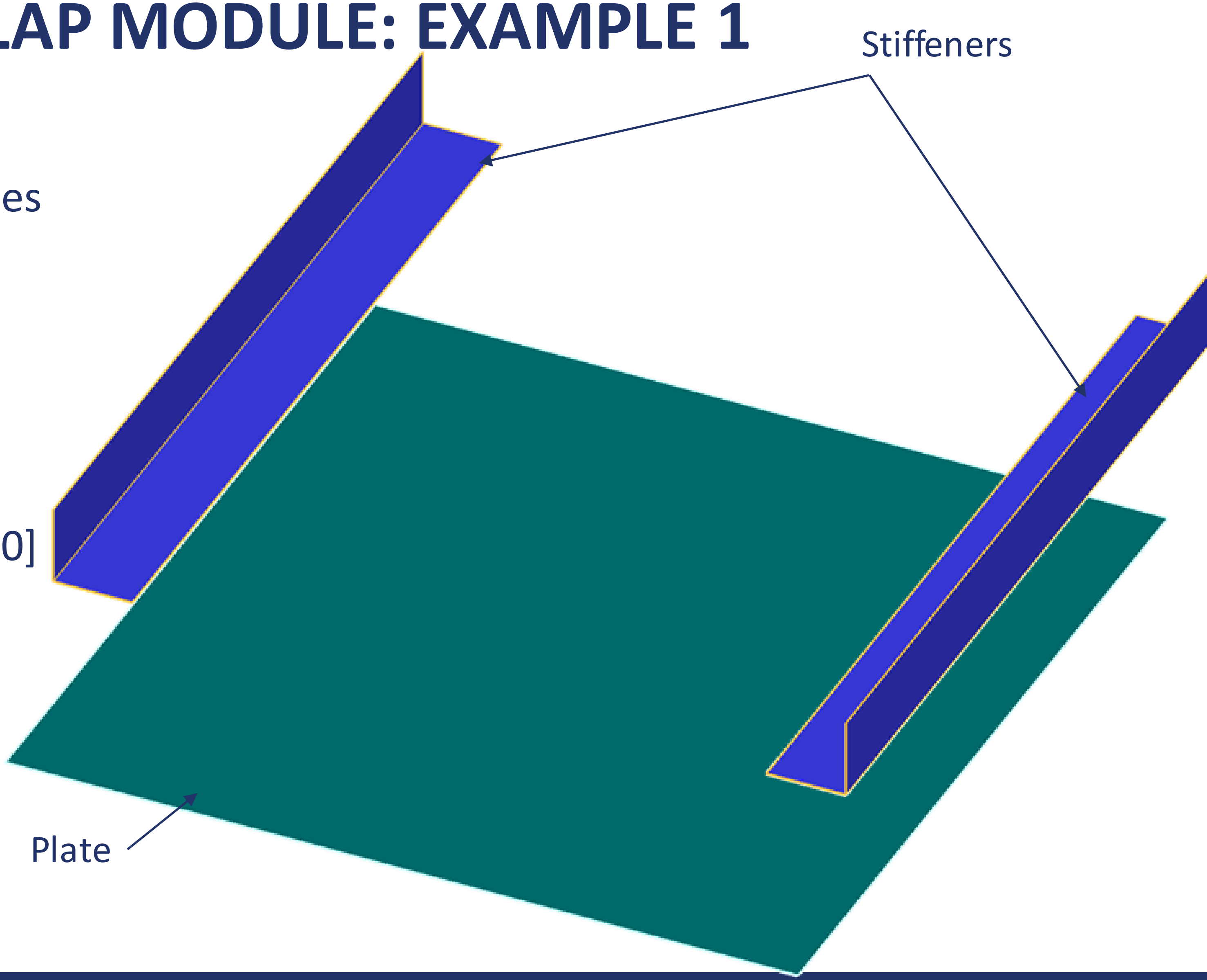
Example JSON thermal zone file

# NEW OVERLAP MODULE

- Why use FEM and TLP zones files?
  - Makes overlap process extremely flexible
    - For simple models only 1 zone that encompasses the entire model might be necessary
    - For complex models where the FEM and thermal geometry are not perfectly aligned, zones can be used to limit the overlap search of the algorithm
  - For large models, breaking the model up into zones makes the algorithm much more efficient as it limits the search of the algorithm.

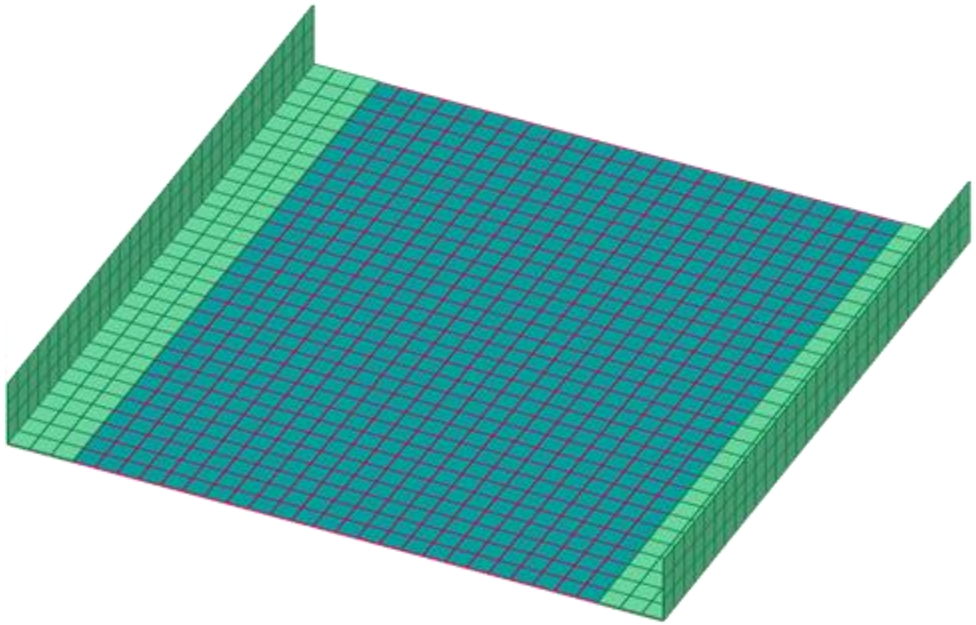
# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Stiffened plate (exploded view), 2 zones
  - Plate
    - FEM Elements [1-900]
    - GTMM TNs [10-90]
  - Stiffeners
    - FEM Elements [2000-2359]
    - GTMM TNs [200-230,300-330]

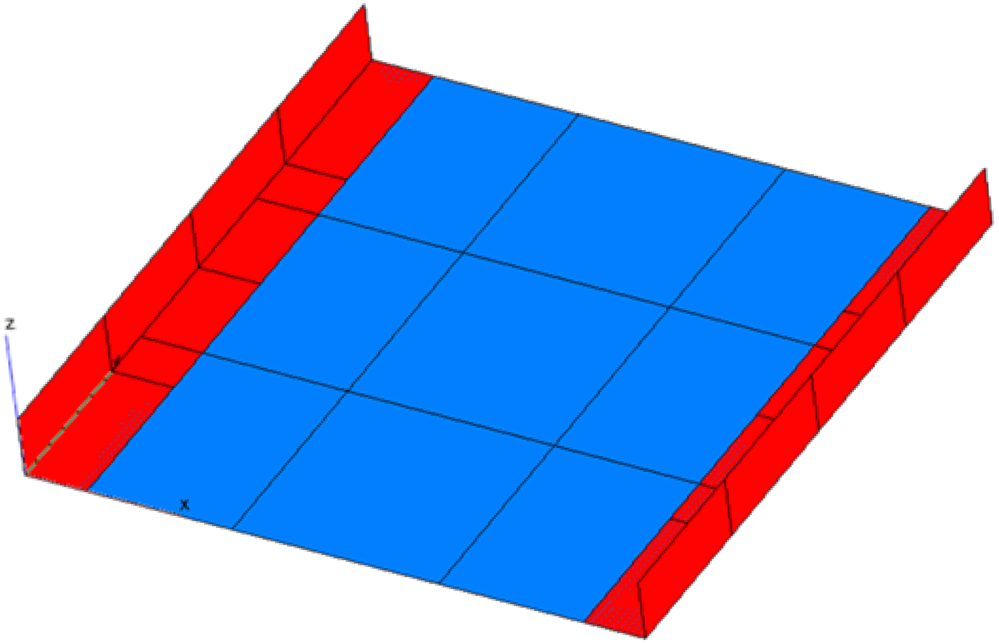


# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Stiffened plate models



FEM model



GMM model

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Stiffened plate
  - Overlap settings file (plate_spec.json)
    - Global overlap settings
    - FEM – GTMM zone association

```
{
  "global_settings": {
    "title": “example 1",
    "fem_translation":   [0.0,0.0,0.0],
    "fem_rot":           [0.0,0.0,0.0],
    "fem_rot_origin":    [0.0,0.0,0.0],
    "step_tas_file":     "plate_stiffeners.stp",
    "nastran_bdf_files": [{"name": "plate.bdf", "onlyBulk": true }],
    "fe_group_files":    ["plate_FEM.json"],
    "tlp_group_files":   ["plate_TMM.json"],
    "ovl_file":          "plate.ovl"},
```

```
  "zones": [
    { "type":          "shell_nograd",
      "title":         "plate",
      "fe_group":      "plate",
      "tlp_group":     "plate",
      "method":        "min_distance",
    },

    { "type":          "shell_nograd",
      "title":         "stiffener",
      "fe_group":      "stiffener",
      "tlp_group":     "stiffener",
      "method":        "min_distance“
    }
    ]
}
```

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Stiffened plate
  - FEM zones file

```
[
  {
    "name":     “plate",
    "elements": [1,2,3,4,5,…,900]
  },
  {
    "name":     “stiffener",
    "elements": [2000,…,2359]
}
]
```

  - TLP zones file

```
[
  {
    "name":  “plate",
    “nodes": [10,20,30,40,…,90]
  },
 {
    "name":  “stiffener",
    “nodes": [200,…,230,300,…,330]
  },
]
```

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Stiffened plate
  - Create plate.job file

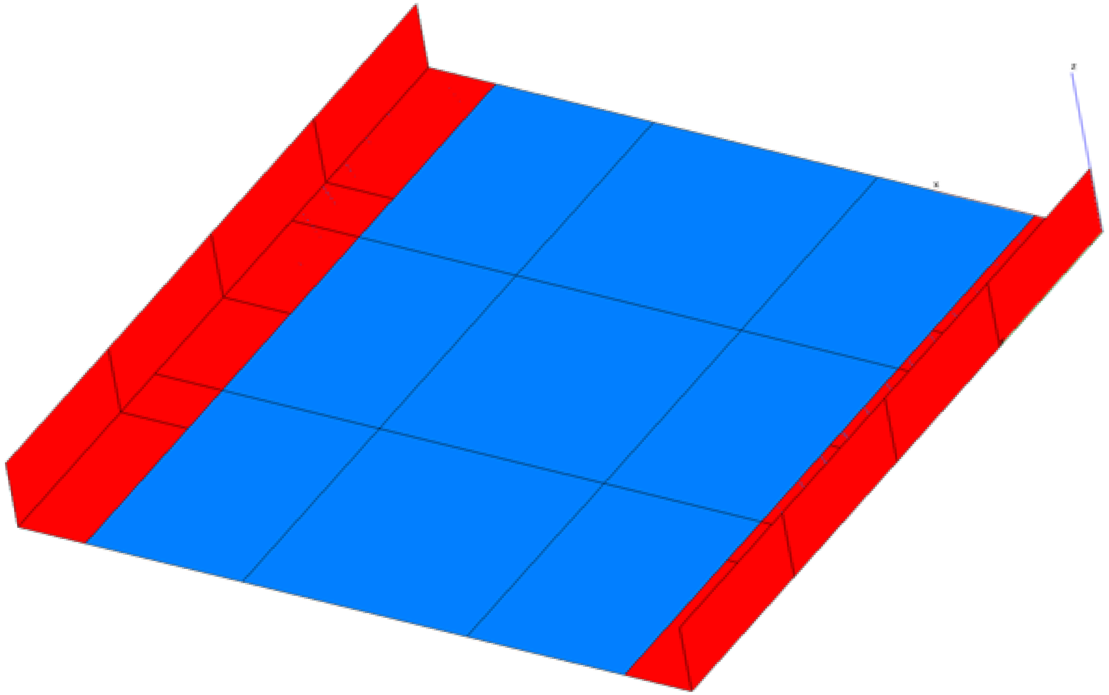
```
[task_00]
task = overlap
ovlsettings = plate_spec.json
```

  - run_pysinas.exe --job plate.job

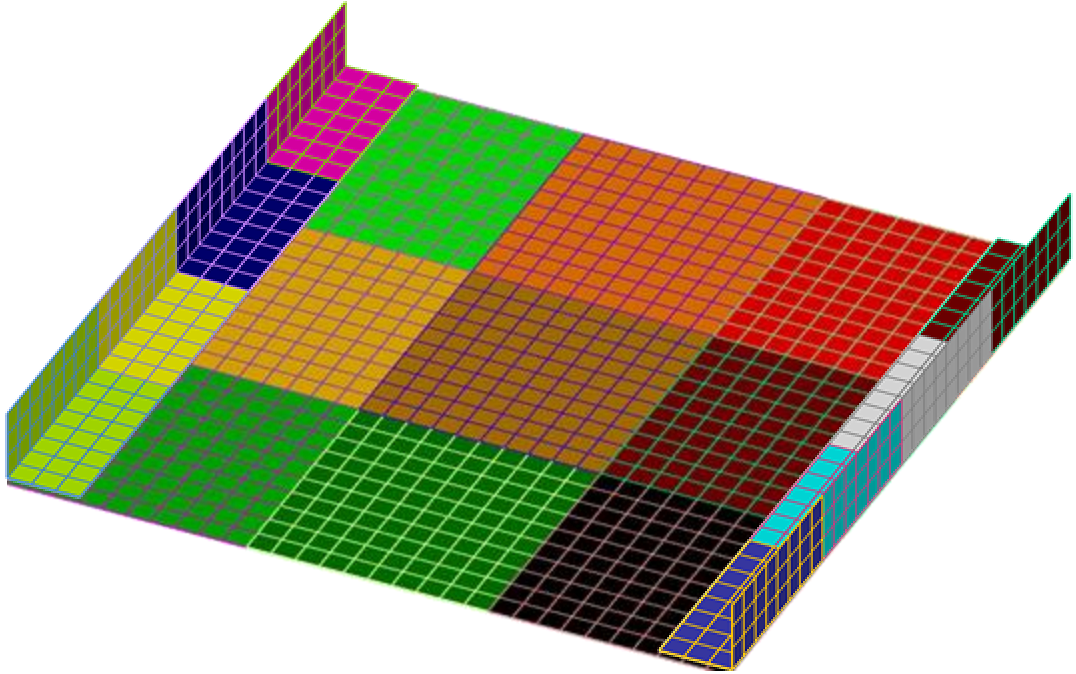
```
09/22/2022  10:24:13  INFO   | PySinas development version: 2022-05-17T17:00
09/22/2022  10:24:13  INFO   |
09/22/2022  10:24:13  INFO   | ########################################
09/22/2022  10:24:13  INFO   | Section definition:
09/22/2022  10:24:13  INFO   | [task_00]
09/22/2022  10:24:13  INFO   | task = overlap
09/22/2022  10:24:13  INFO   | json  = plate_spec.json
09/22/2022  10:24:13  INFO   |
09/22/2022  10:24:13  INFO   | Starting load of NASTRAN BDF file plate.bdf
09/22/2022  10:24:13  INFO   | Completed load of NASTRAN BDF file plate.bdf
09/22/2022  10:24:13  INFO   | Transforming FE grids to global frame...
09/22/2022  10:24:13  INFO   | Completed transforming FE grids to global frame
09/22/2022  10:24:13  INFO   | Reading FE group file plate_FEM.json
09/22/2022  10:24:13  INFO   | Starting load of STEP-TAS file plate_stiffeners.stp
09/22/2022  10:24:14  INFO   | Completed load of STEP-TAS file plate_stiffeners.stp
09/22/2022  10:24:14  INFO   |
09/22/2022  10:24:14  INFO   | Overlapping zones with minimum distance method:

09/22/2022  10:24:14  INFO   | Overlapping zone: plate
09/22/2022  10:24:14  INFO   | Overlapping zone: stiffener
09/22/2022  10:24:14  INFO   | Time taken by overlap function: 0.077s

09/22/2022  10:24:14  INFO   | Task "overlap" completed
09/22/2022  10:24:14  INFO   | ########################################
09/22/2022  10:24:14  INFO   |
09/22/2022  10:24:14  INFO   | All tasks in plate.job completed
```

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 1

- Overlap result stiffened plate → Each colour represents a different thermal node



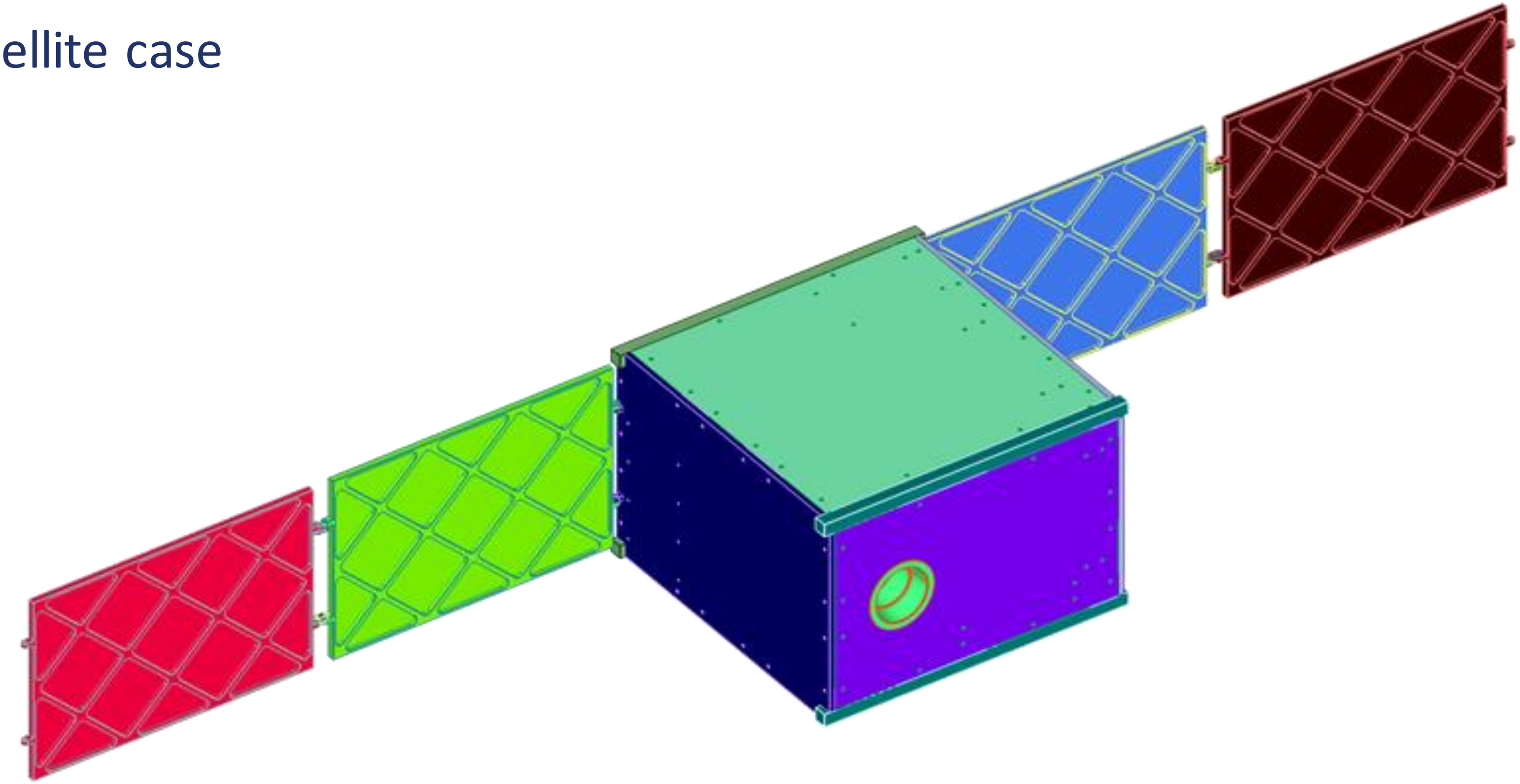
GMM model



Overlapped FEM model

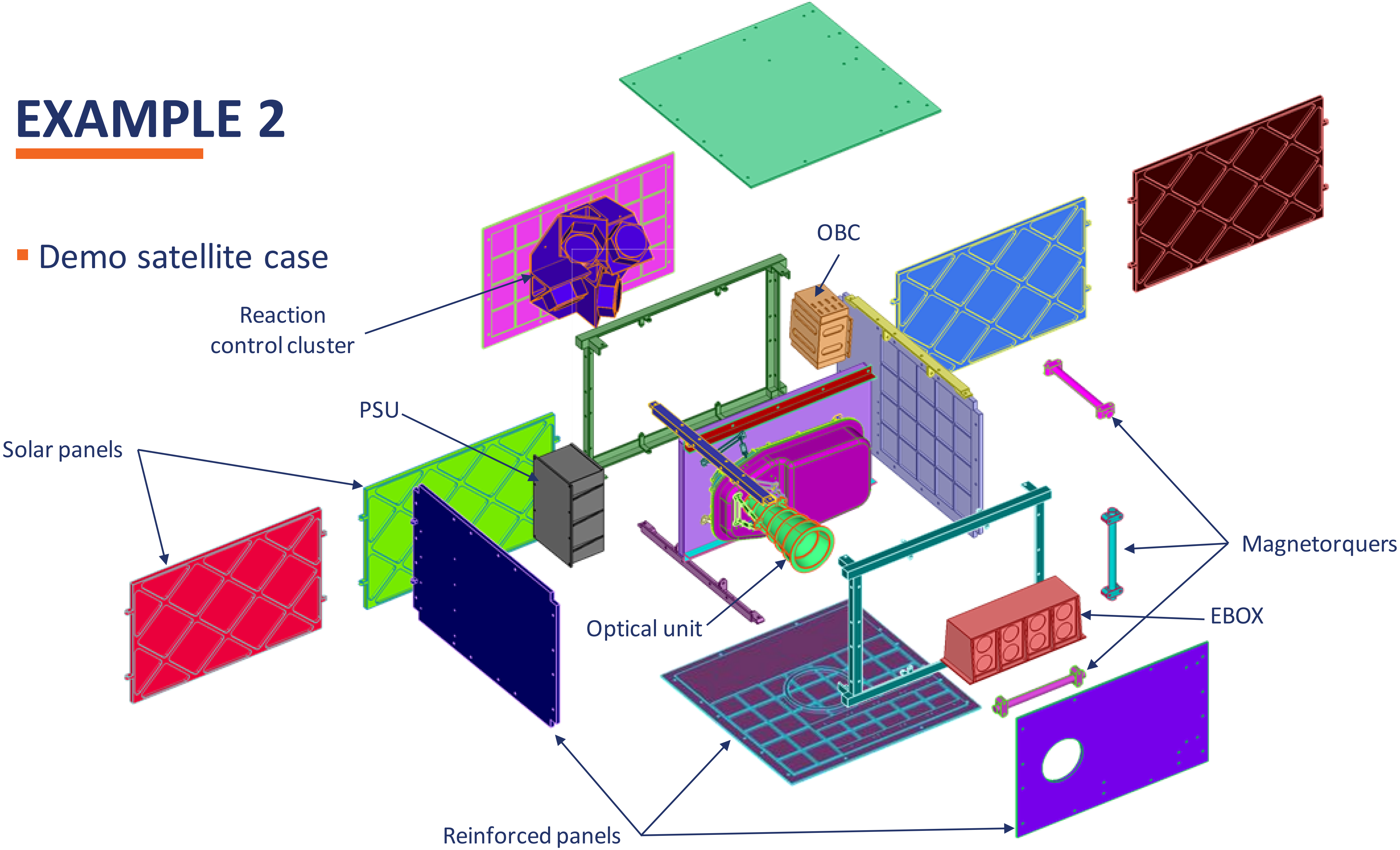
# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case



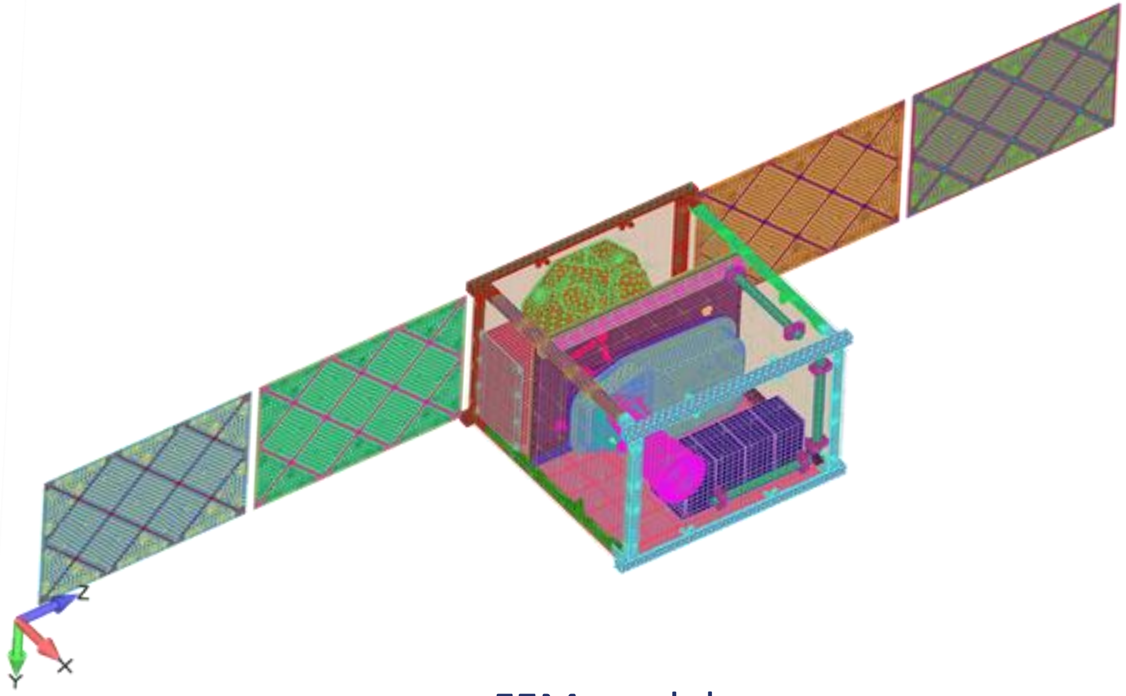
# EXAMPLE 2

- Demo satellite case

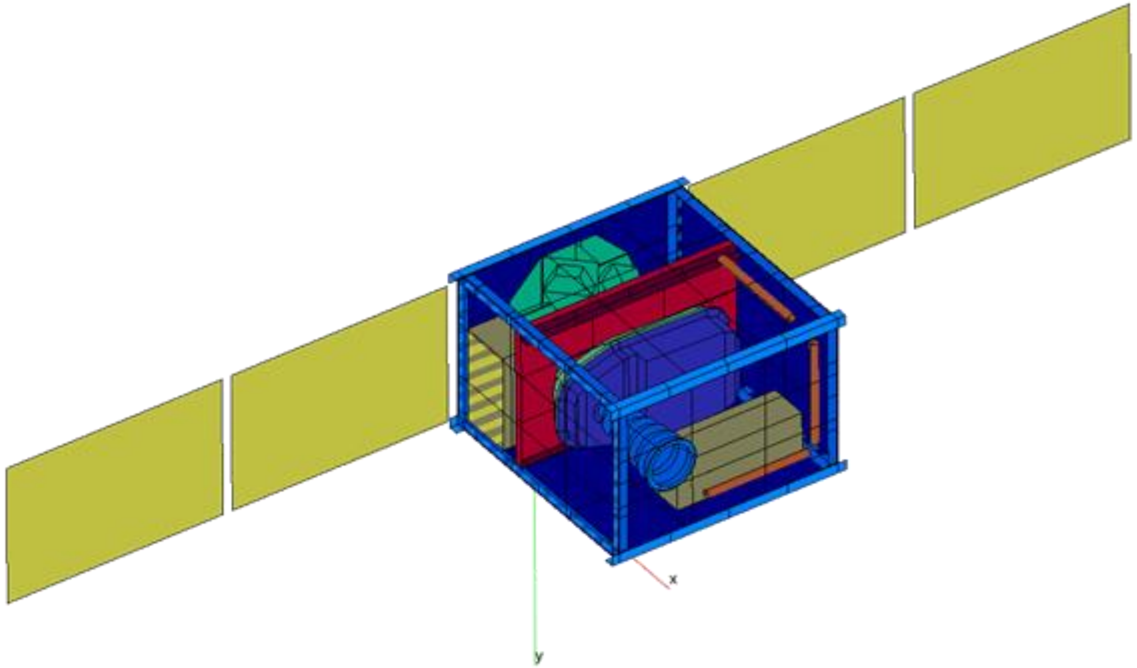


# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case



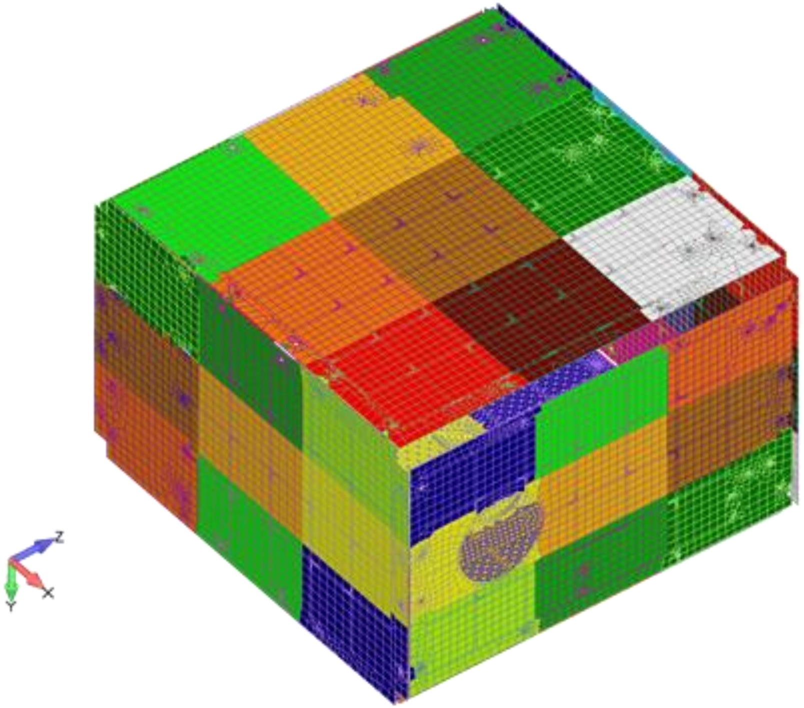
FEM model

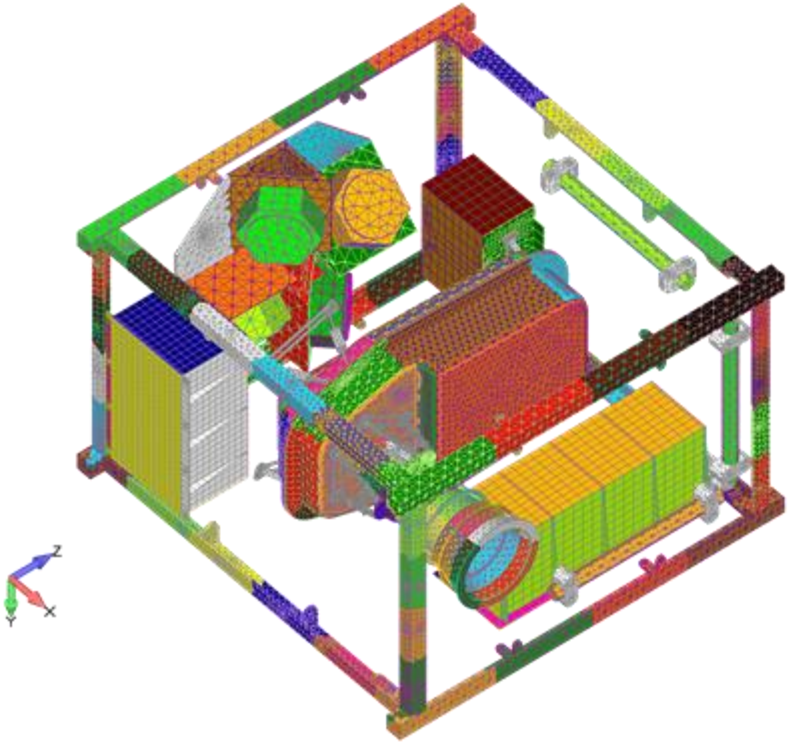


GMM model

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

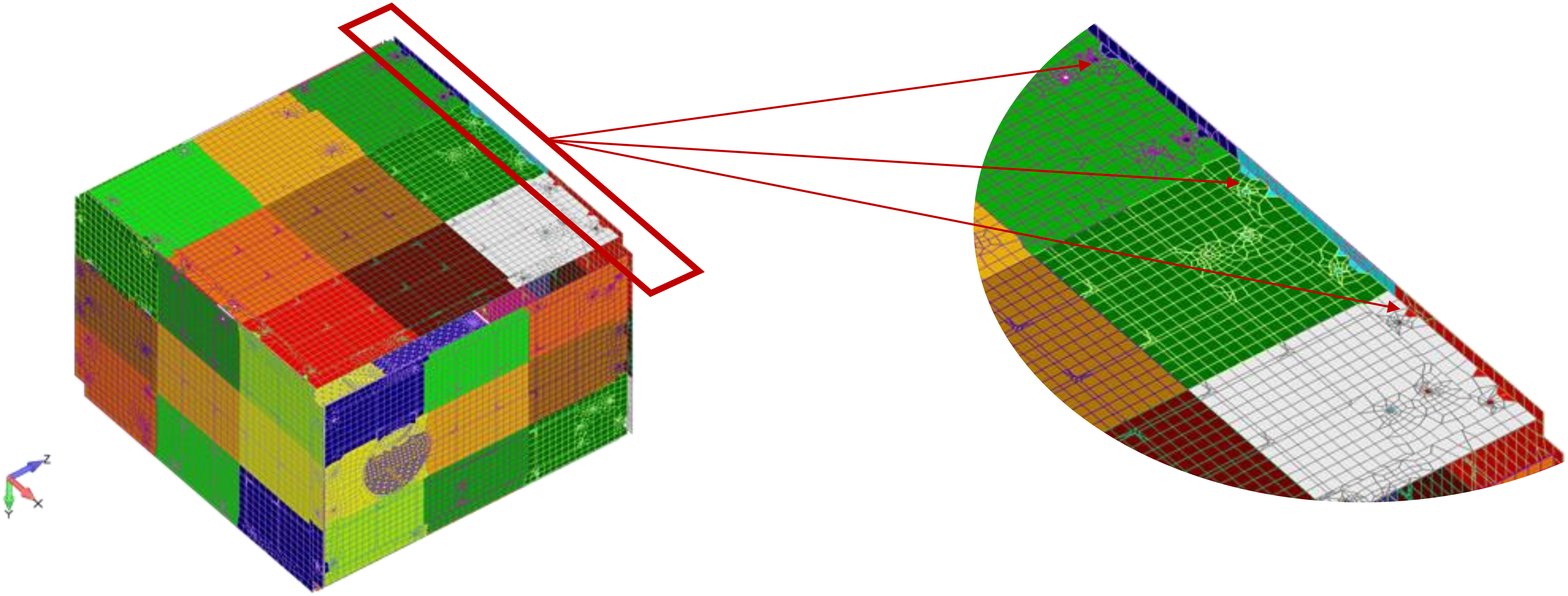
- Demo satellite case overlap results





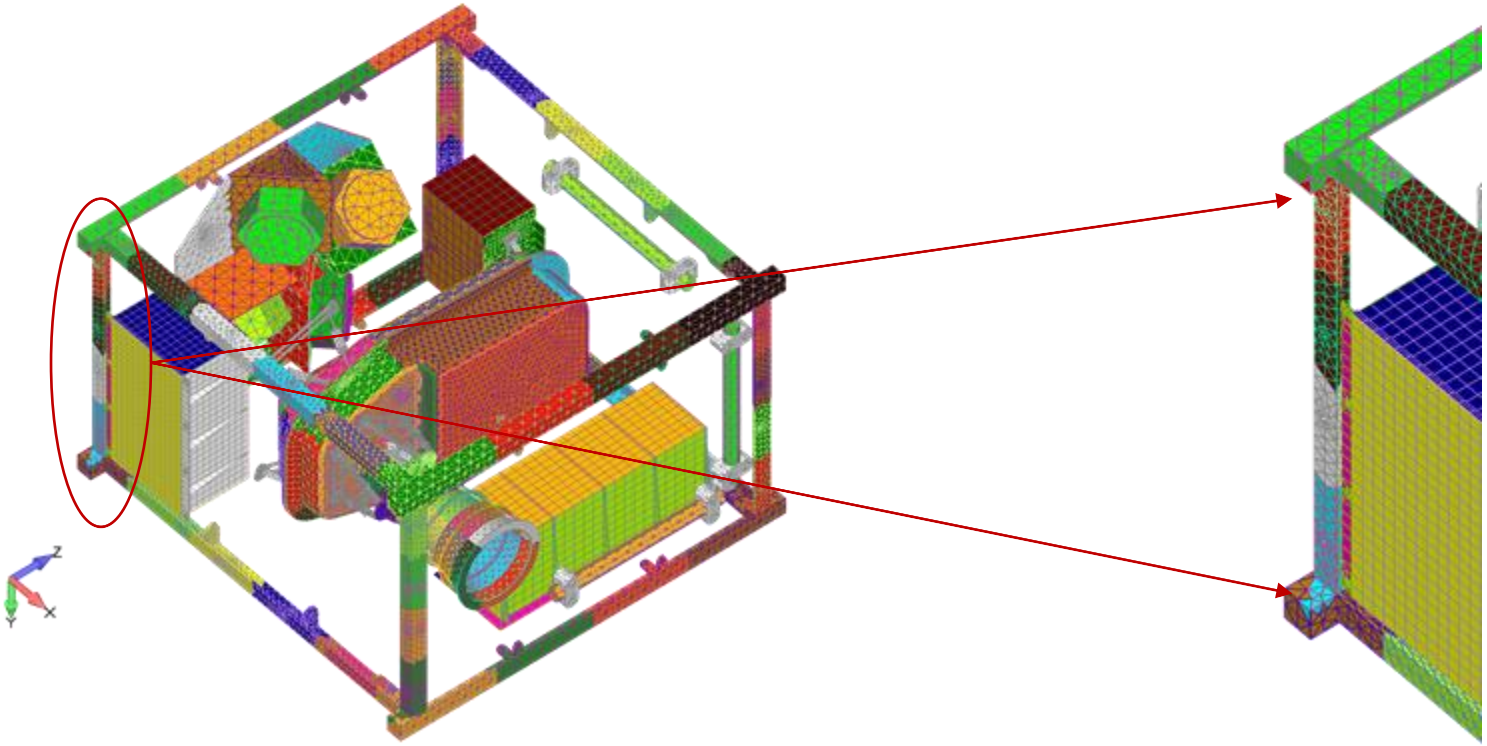
# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case overlap limitations and fixes



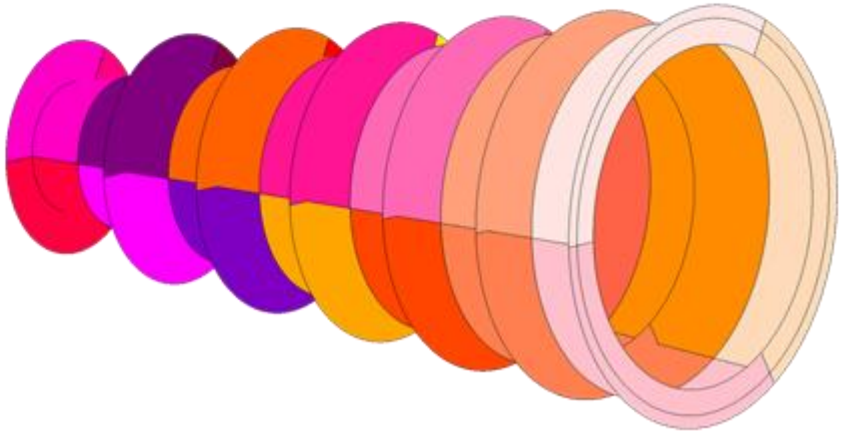
# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case overlap results

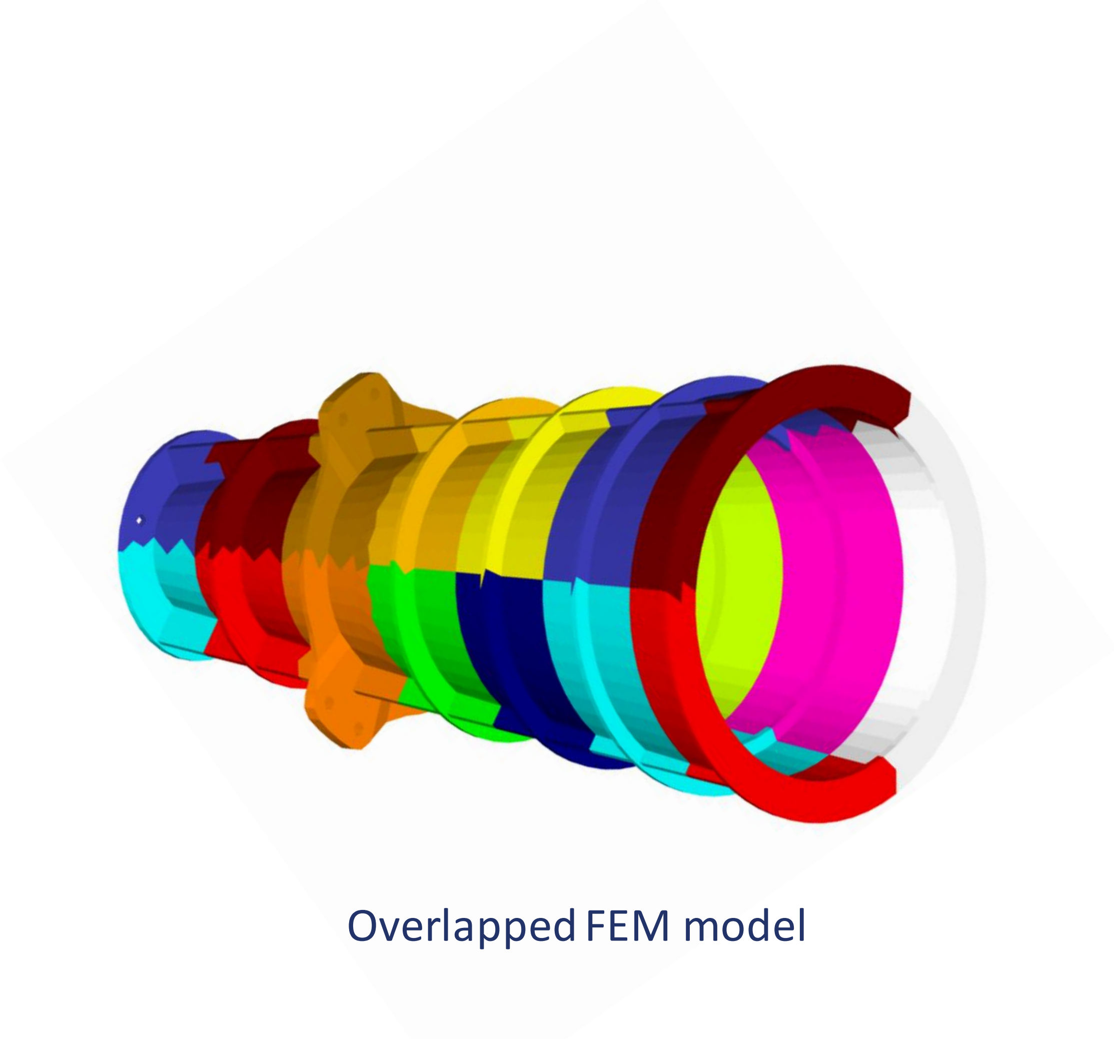


# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case: Baffle overlap



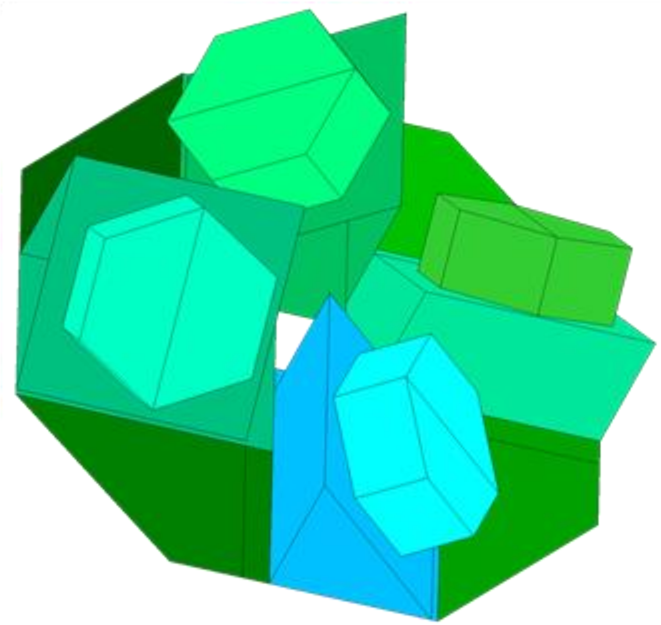
GMM model



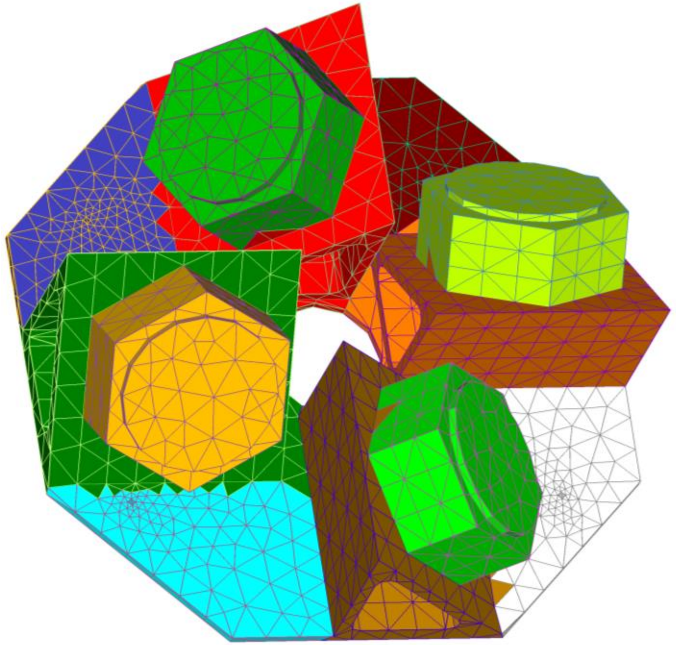
Overlapped FEM model

# HOW TO USE THE OVERLAP MODULE: EXAMPLE 2

- Demo satellite case: RCC overlap



GMM model



Overlapped FEM model

# MAIN BENEFITS AND LIMITATIONS

- Benefits:
  - Automatic process.
  - Efficient algorithm: during testing, overlaps of 150k FE elements and 8600 TNs in under 3 minutes.
  - Can adapt to misalignments between FE model and thermal model.

- Limitations:
  - Currently, it can’t handle non-geometric thermal nodes. These nodes still need to be overlapped manually.
  - For large zones the algorithm can require a large amount of RAM. This can be overcome by splitting the zone into smaller zones.