SPACE SYSTEMS

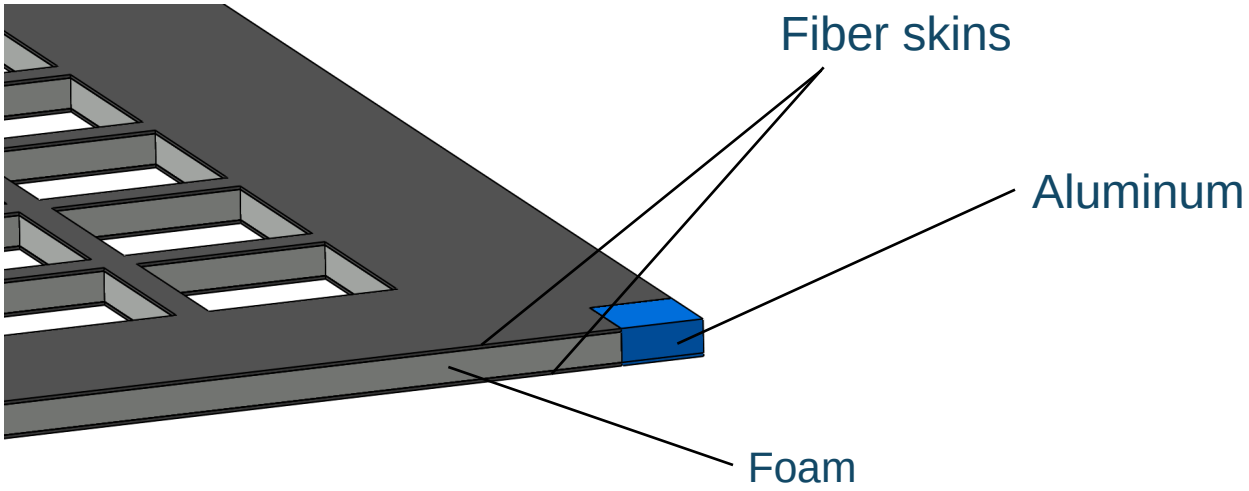
GAMMA-2 Silicon Tracker: preliminary structural analyses

Analyses Objectives

- Preliminary structural analyses have been performed for the Gamma-2 Silicon Tracker instrument in order to verify the feasibility of the proposed mechanical design.
- N.5 simplified Finite Element Models have been built, representative of the ST trays mass and mechanical structure, mainly aimed to the verification of the trays displacements. The trays are assembled together to form a single tower, the intra-tray spacing of 1 mm is supposed to be filled by a rubber tape in order to prevent the damage of silicon ladders due to relative scratching.
- The performed study is based on the following assumptions:
  - the ST instrument has been modeled stand-alone (assembly of 70 trays) constrained at the lower tray interface points.
  - The payload accommodation on the satellite is considered equivalent to AGILE, so that the launcher thrust axis is orthogonal to the ST trays plane.
  - The mechanical loads (derived from PRISMA envelope loads, taking into account the bus amplification) have been applied to the lower tray interface points.

Analyses Objectives

- The tray structure consists of a gridded sandwich plane composed of a low density thermoplastic polymer foam enclosed within high modulus carbon fiber skins.



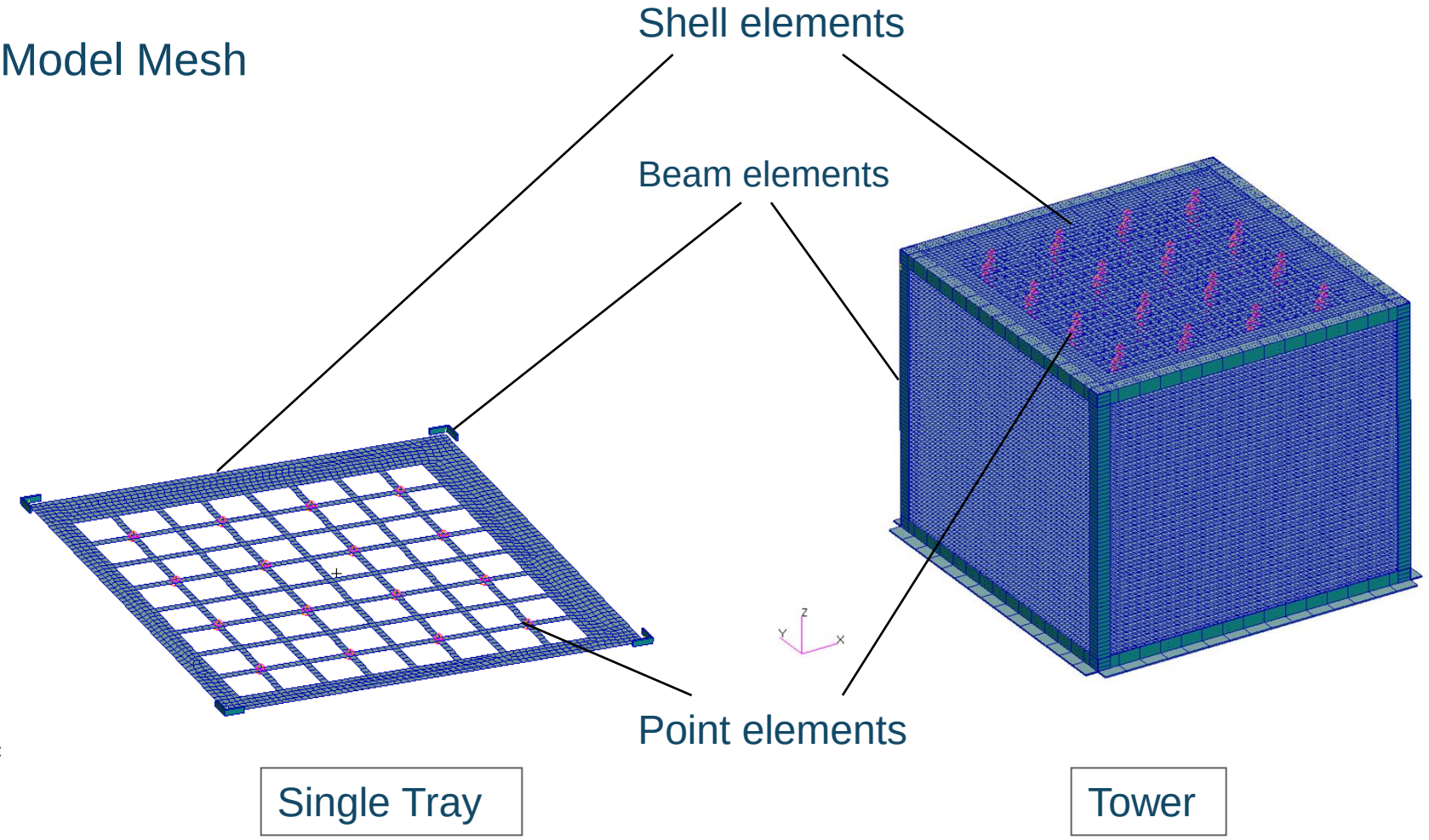
- The tray assembly is connected to an aluminum support structure (main frame) by corner elements located at the four vertexes of each tray.

Models Description

- Finite Element Models
  - A1: Single Tower (70 trays), Tray thickness 8 mm, Area 600x600, 1 mm rubber tape
  - A2: Single Tower (70 trays), Tray thickness 15 mm, Area 600x600, 1 mm rubber tape
  - A3: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, 1 mm rubber tape
  - A4: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, Grid 1 mm rubber (see model description)
  - A5: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, Central 1 mm rubber (see model description)

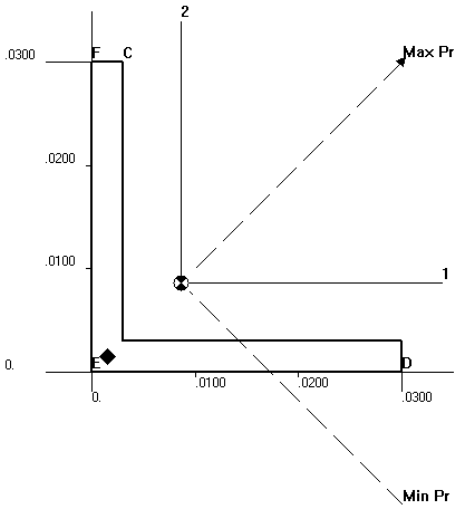
Models Description

- Model Mesh



Models Description

- Main Frame Structure Beam Sections



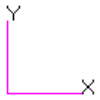
Typical

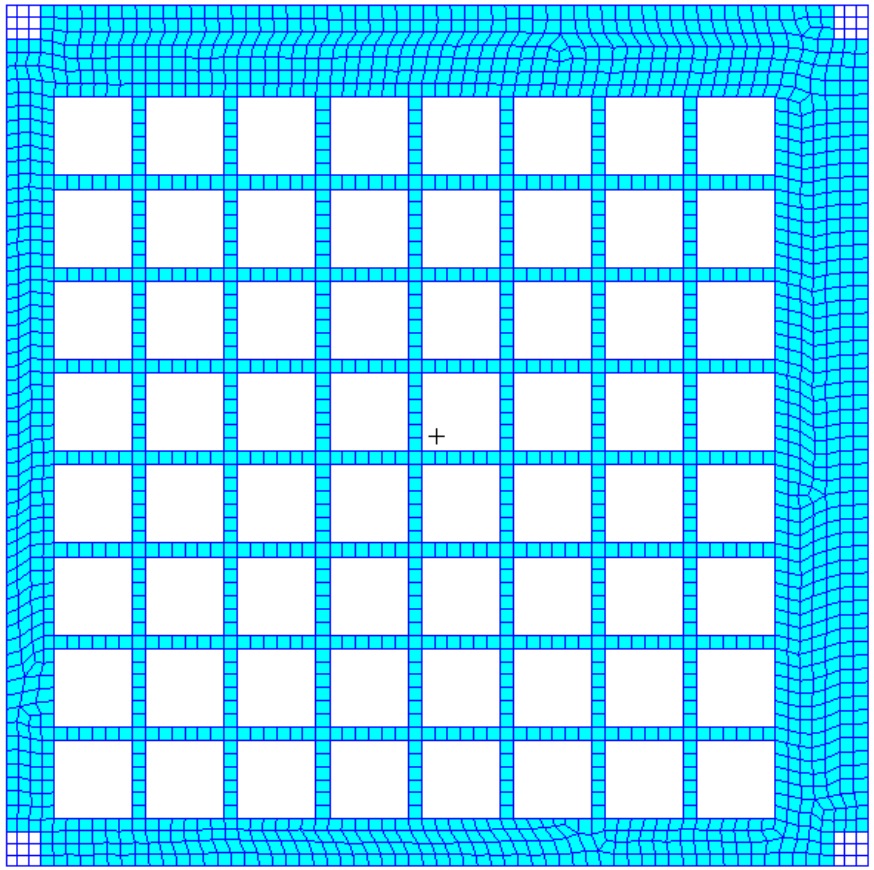
Models Description

- Tray Model

Laminate

Corners





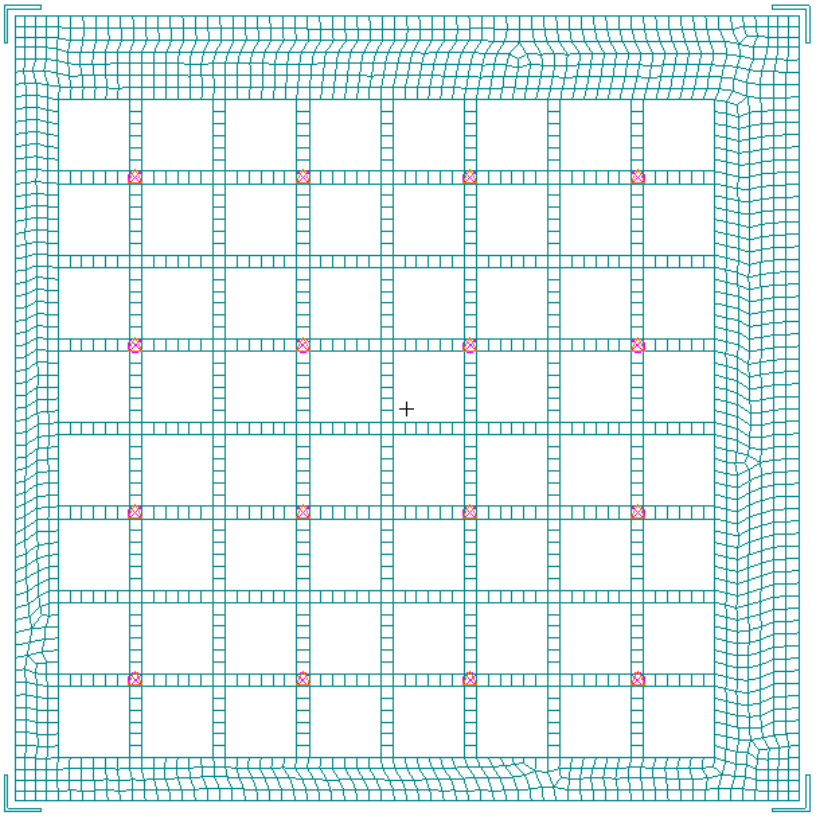
Typical (Tray)

Models Description

- Tray Model

Si Lumped Masses △

Internal constraints X



Typical (Tray)

- Silicon ladders, harness, glue and rubber are represented in the model as nonstructural masses.

Models Description

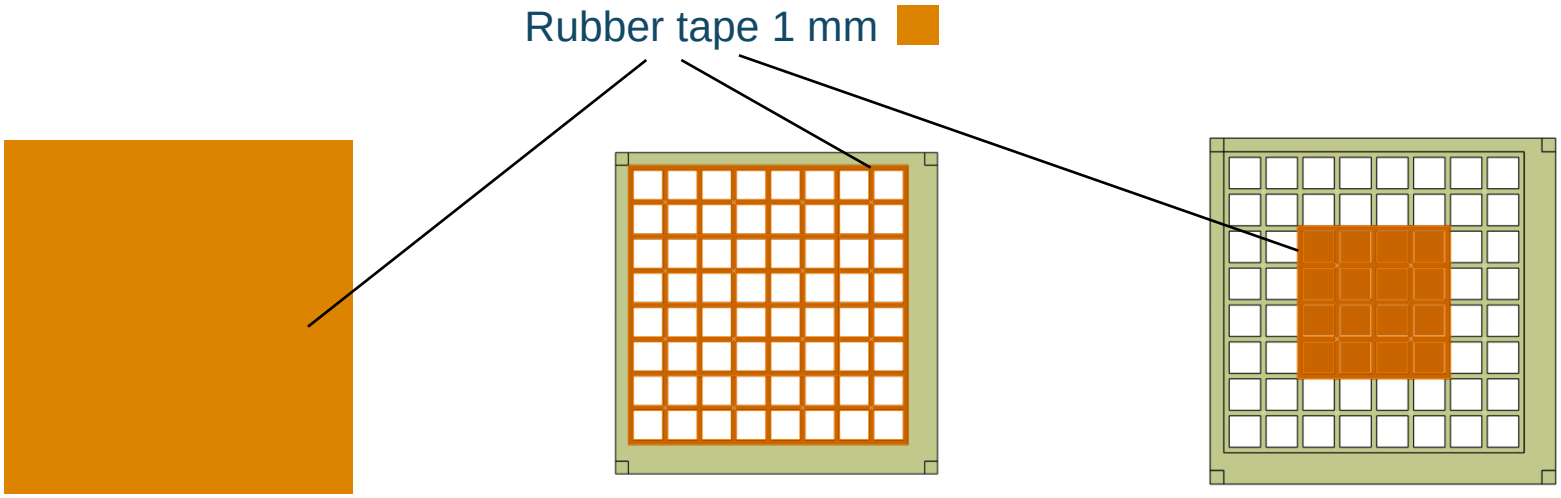
- Materials
  - BEAMS: Al 6061 T6
  - CORNERS: Al 7075 T6
  - Single Si mass : (Total Si Area/16) x (0,4 mm Thickness) x (Si density)
  - Laminate Area: Laminate with N.4 Ply High Modulus Carbon Fiber and Foam

	Material Name	Thickness	Orientation	Global Ply ID
1	Ply_Tape	1.250000E-4	0.000000E+0	1
2	Ply_Tape	1.250000E-4	9.000000E+1	2
3	Foam	7.500000E-3	0.000000E+0	3
4	Ply_Tape	1.250000E-4	9.000000E+1	4
5	Ply_Tape	1.250000E-4	0.000000E+0	5

Laminate levels for A1 model

Models Description

- Rubber distributions:



Full 1 mm rubber tape (model A1, A2, A3)	Grid 1 mm rubber tape (model A4)	Central 1 mm rubber tape (model A5)

Models Description

- Mass Budgets

1) A1: Single Tower (70 trays), Tray thickness 8 mm, Area 600x600, 1 mm rubber tape → **115,4 kg**
2) A2: Single Tower (70 trays), Tray thickness 15 mm, Area 600x600, 1 mm rubber tape → **134,4 kg**
3) A3: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, 1 mm rubber tape → **121,24 kg**
4) A4: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, rubber distr. 1 → **91,674 kg**
5) A5: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, rubber distr. 2 → **94,32 kg**

Nonstructural masses (NSM) contributions are added in every configuration.

NSM are related to:

- Harness
- Glue
- Rubber

ITEM	Assigned NSM (kg)
Rubber	variable for each model (density 1200 kg/m2)
harness	15
Glue	7

NSM contributions

Analysis Cases and Trade-Off

- Due to their intensity, static mechanical loads result to be driving for design respect dynamic loads.
- A first set of analyses has been performed for A1 model, which represents the starting study case according to the results of the previous trade-off on instrument configurations.
- Basing on A1 model results, the sensitivity analysis guideline is the minimization of the displacement in Z direction of the trays. The variable parameters in mechanical structure are:
  - Materials of laminate (Fibers, Foams)
  - Structure of grid (Thicknesses, geometry of the tray)
  - Tray height (8 – 10 - 15 mm)
  - Tray area dimensions

Analysis Cases and Trade-Off

- 4 solutions have been studied in more detail, related to the subsequent models A2, A3, A4, A5. With respect to A3 model, A4 and A5 models take into account the effect of different rubber distributions.

- Basing on the performed trade off, two factors significantly affect the tray assembly structural behaviour:
  - the tray thickness
  - the tray in-plane tray area

- According to the indications coming from instrument side, the tray mechanical design has been developed considering a maximum tray thickness of 10 mm and a minimum tray area of 600 x 600 mm.

Analysis Cases and Trade-Off

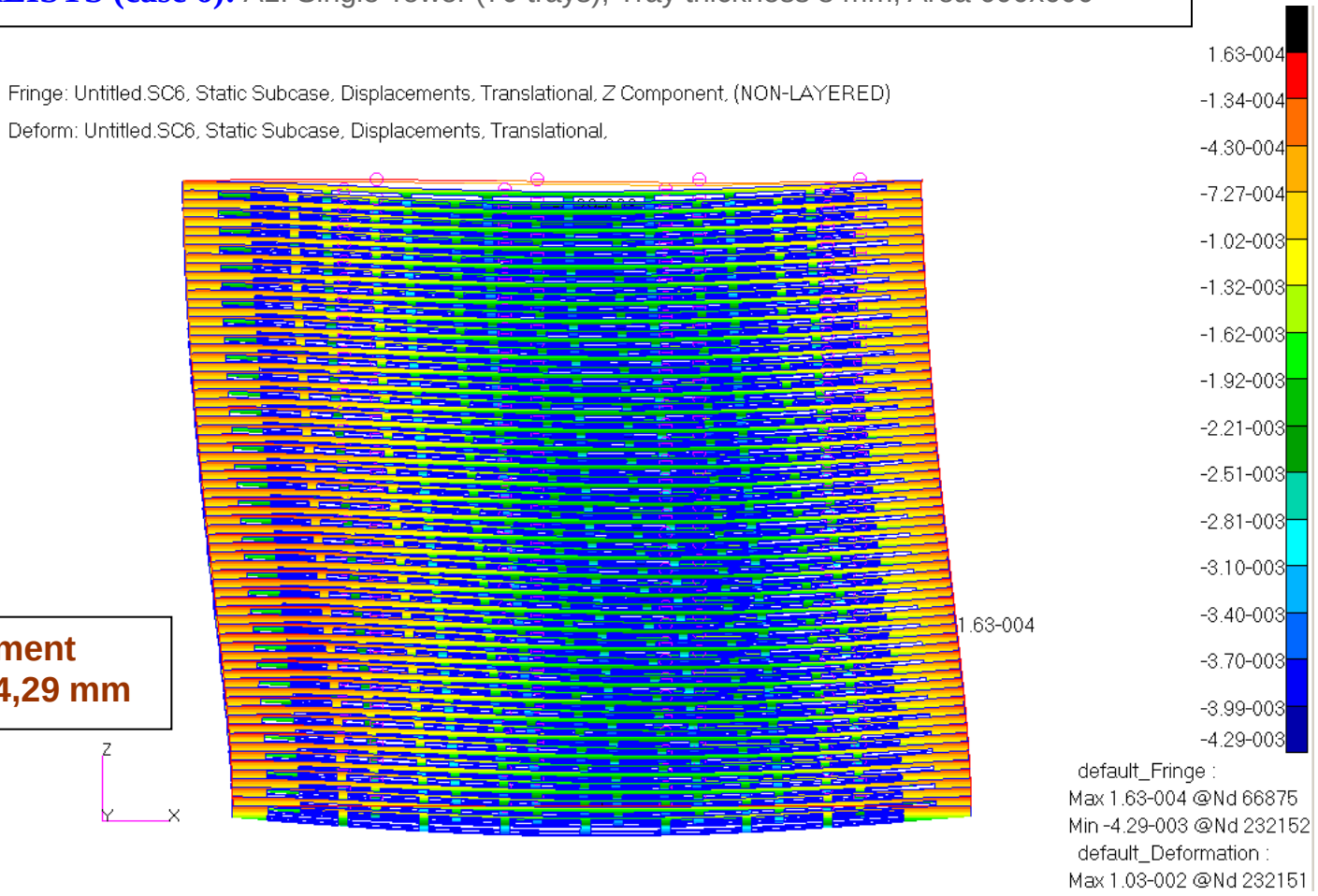
- Static Load cases

Case	Load Type	Load factor X (g)	Load factor Y (g)	Load factor Z (g)
1	Inertial load	-6,16	-6,16	11,95
2	Inertial load	-6,16	6,16	11,95
3	Inertial load	6,16	6,16	11,95
4	Inertial load	6,16	-6,16	11,95
5	Inertial load	-6,16	-6,16	-19,54
6	Inertial load	-6,16	6,16	-19,54
7	Inertial load	6,16	6,16	-19,54
8	Inertial load	6,16	-6,16	-19,54
9	Inertial load	-6,16	-6,16	13,58
10	Inertial load	-6,16	6,16	13,58
11	Inertial load	6,16	6,16	13,58
12	Inertial load	6,16	-6,16	13,58

Dimensioning case

Obtained Results

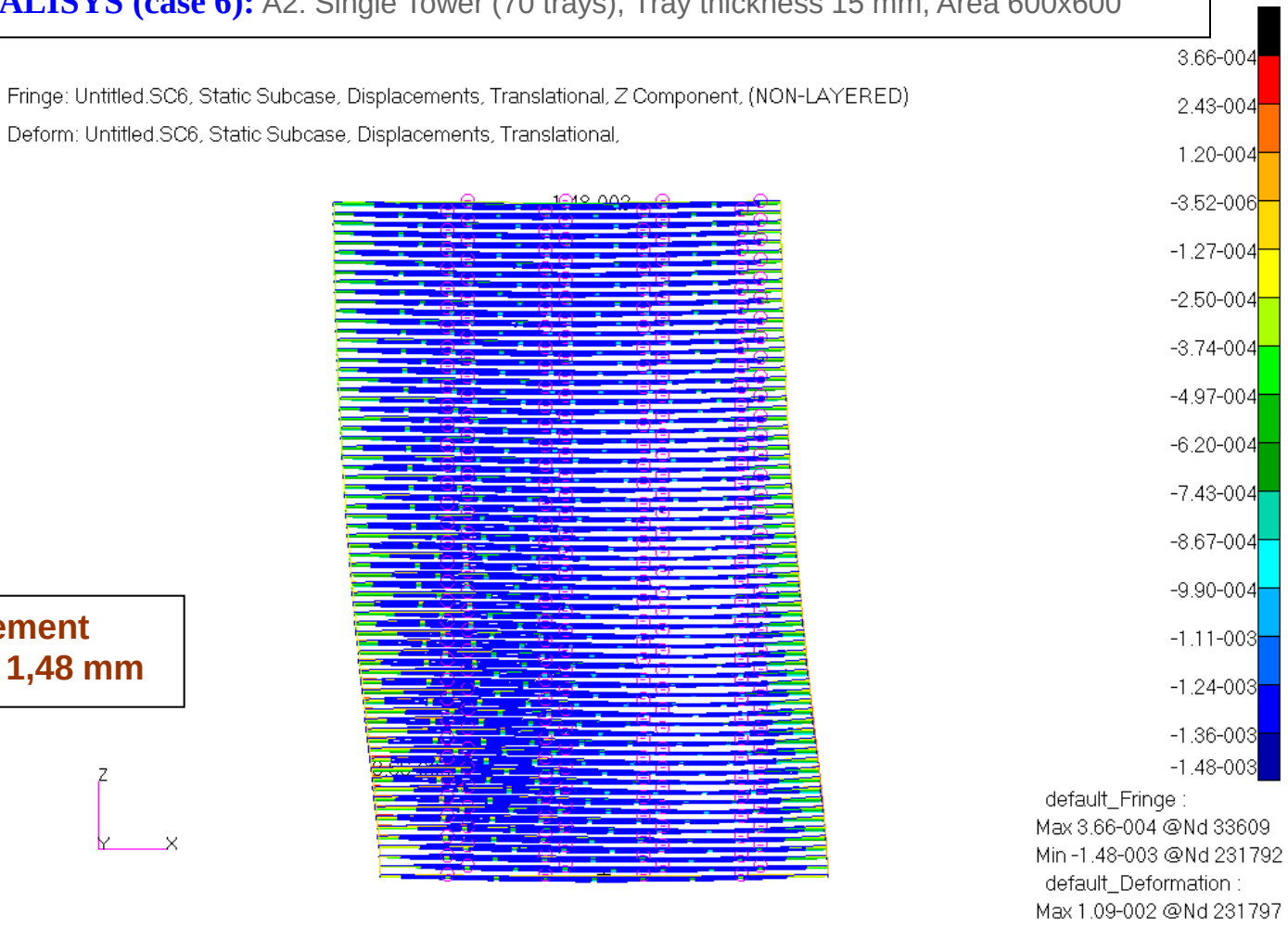
- **STATIC ANALISYS (case 6):** A1: Single Tower (70 trays), Tray thickness 8 mm, Area 600x600



Displacement
Z direction: 4,29 mm

Obtained Results

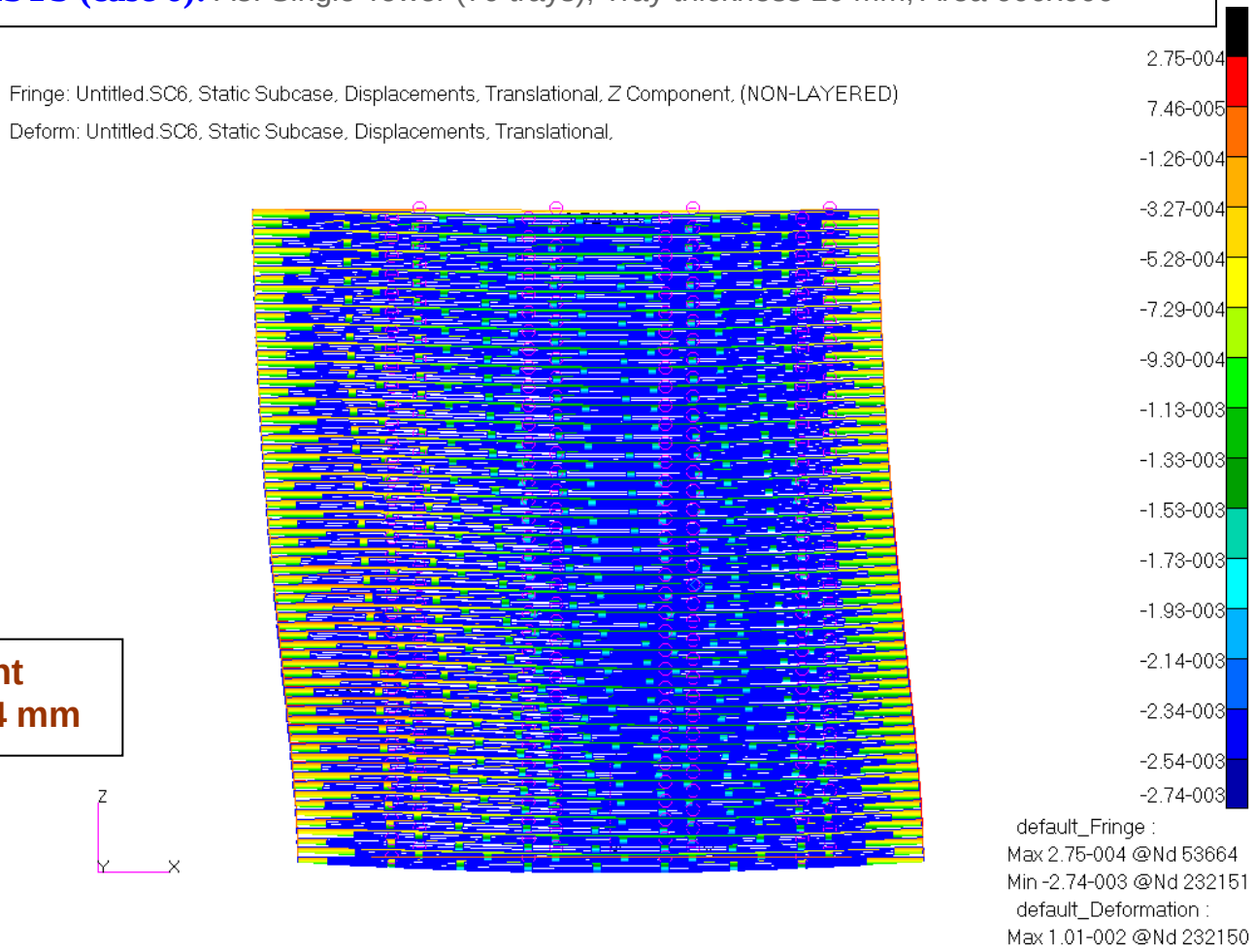
- **STATIC ANALISYS (case 6):** A2: Single Tower (70 trays), Tray thickness 15 mm, Area 600x600



Displacement
Z direction: 1,48 mm

Obtained Results

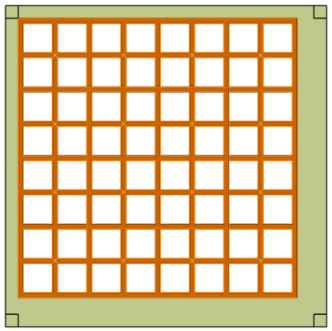
- **STATIC ANALISYS (case 6):** A3: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600



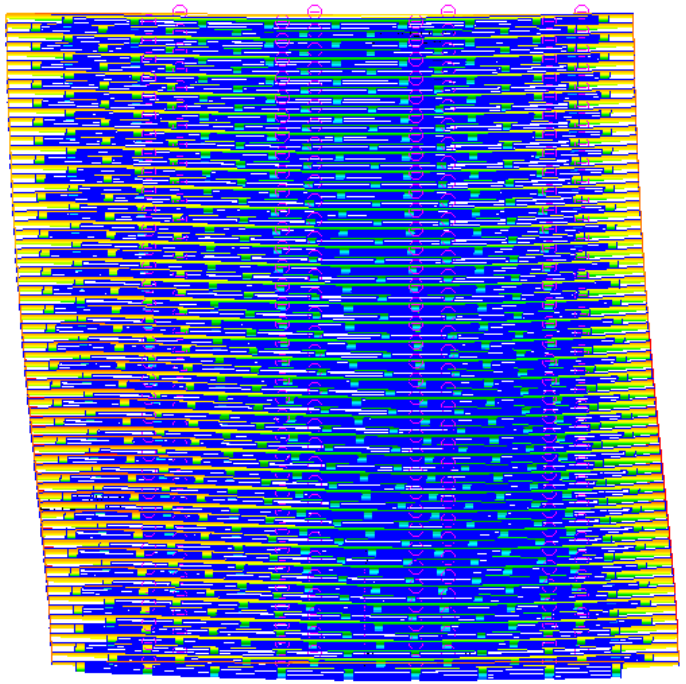
Displacement
Z direction: 2,74 mm

Obtained Results

- **STATIC ANALISYS (case 6):** A4: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600

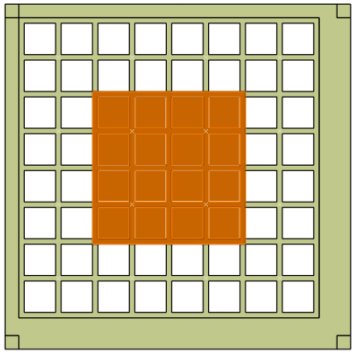


Displacement
Z direction: 2,2 mm

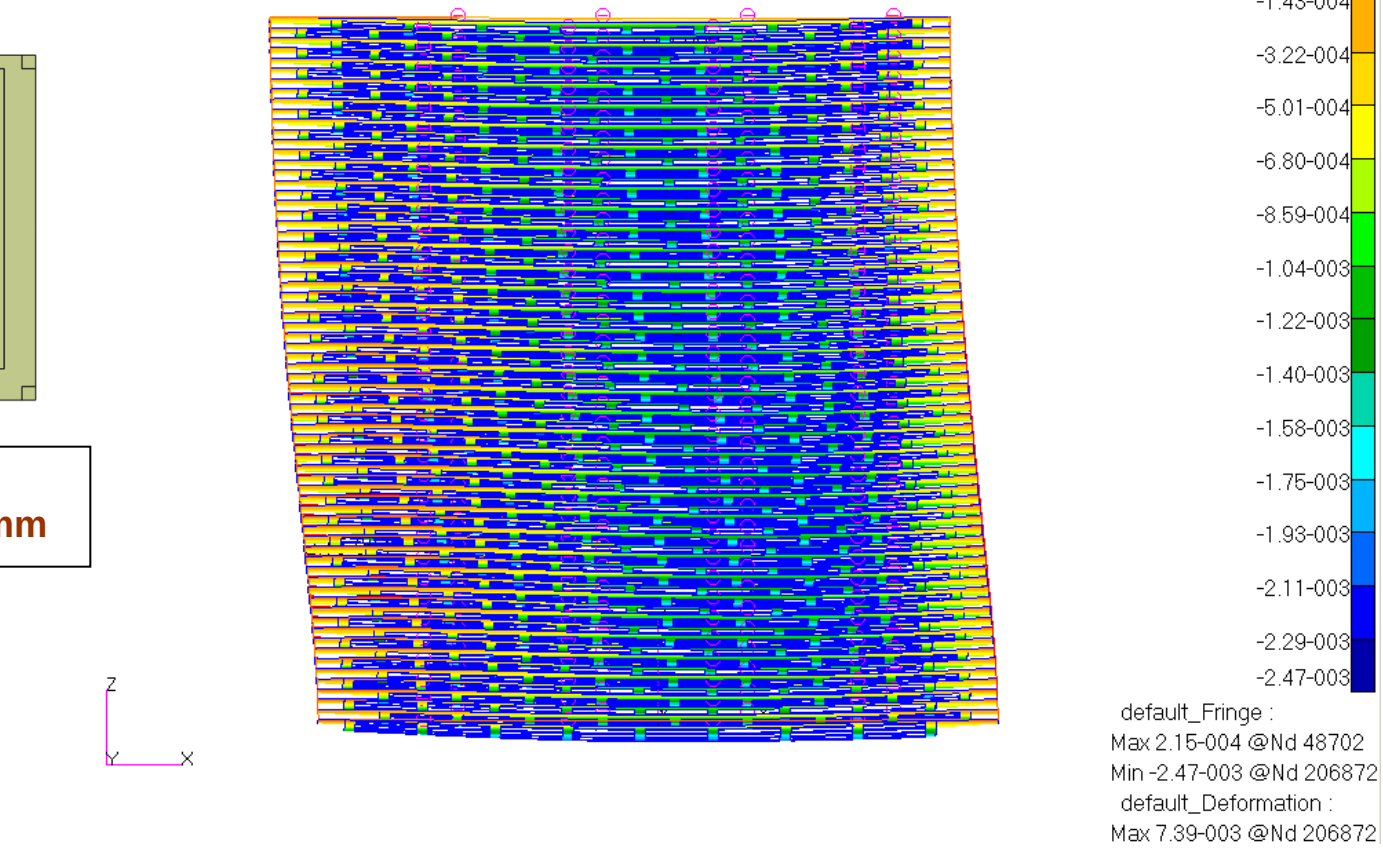


Obtained Results

- **STATIC ANALISYS (case 6):** A5: Single Tower (70 trays), Tray thickness 10 mm, Area 600x600



Displacement
Z direction: 2,47 mm



Obtained Results

Summary Table

Model	Description	Displacement Z direction (mm)
A1	Single Tower (70 trays), Tray thickness 8 mm, Area 600x600, 1 mm rubber tape	**4,29**
A2	Single Tower (70 trays), Tray thickness 15 mm, Area 600x600, 1 mm rubber tape	**1,48**
A3	Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, 1 mm rubber tape	**2,74**
A4	Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, Grid 1 mm rubber	**2,2**
A5	Single Tower (70 trays), Tray thickness 10 mm, Area 600x600, Central 1 mm	**2,47**

Conclusions

- The study shows the structural behaviour of trays assembly for the different analyzed configurations varying the main parameters:
  - Materials of laminate
  - Structure of grid
  - Tray height
  - Tray area dimensions
- The tray thickness and in-plane tray area significantly affect the tray assembly structural behaviour and especially vertical displacements.
- Among the analyzed solutions, the following configurations:
  - A4: Single Tower (70 trays), *Tray thickness 10 mm, Area 600x600*, Grid 1 mm rubber
  - A5: Single Tower (70 trays), *Tray thickness 10 mm, Area 600x600*, Central 1 mm rubber

  show results compatible with a range of *2- 2,5 mm* vertical displacement in compliance with the indicated tray thickness and in plane dimensions.