



The Composites Centre

for research, modelling, testing and training in advanced composites

Finite Element Analysis of Composite Structures

Requirements for pre- and post- processing

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Requirements for pre- and post-processing

First, we need to define and understand the peculiarities found in the analysis of composite material structures:

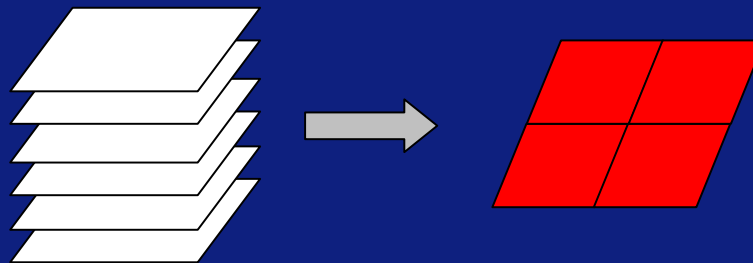
- multi-layered construction
- anisotropic properties

Restrict this topic to linear static analysis.

Requirements for pre- and post-processing

The **multi-layered construction** has a profound effect on both pre- and post-processing.

- In its simplest form, effective stiffness and strength properties must be calculated for groups of elements:



Requirements for pre- and post-processing

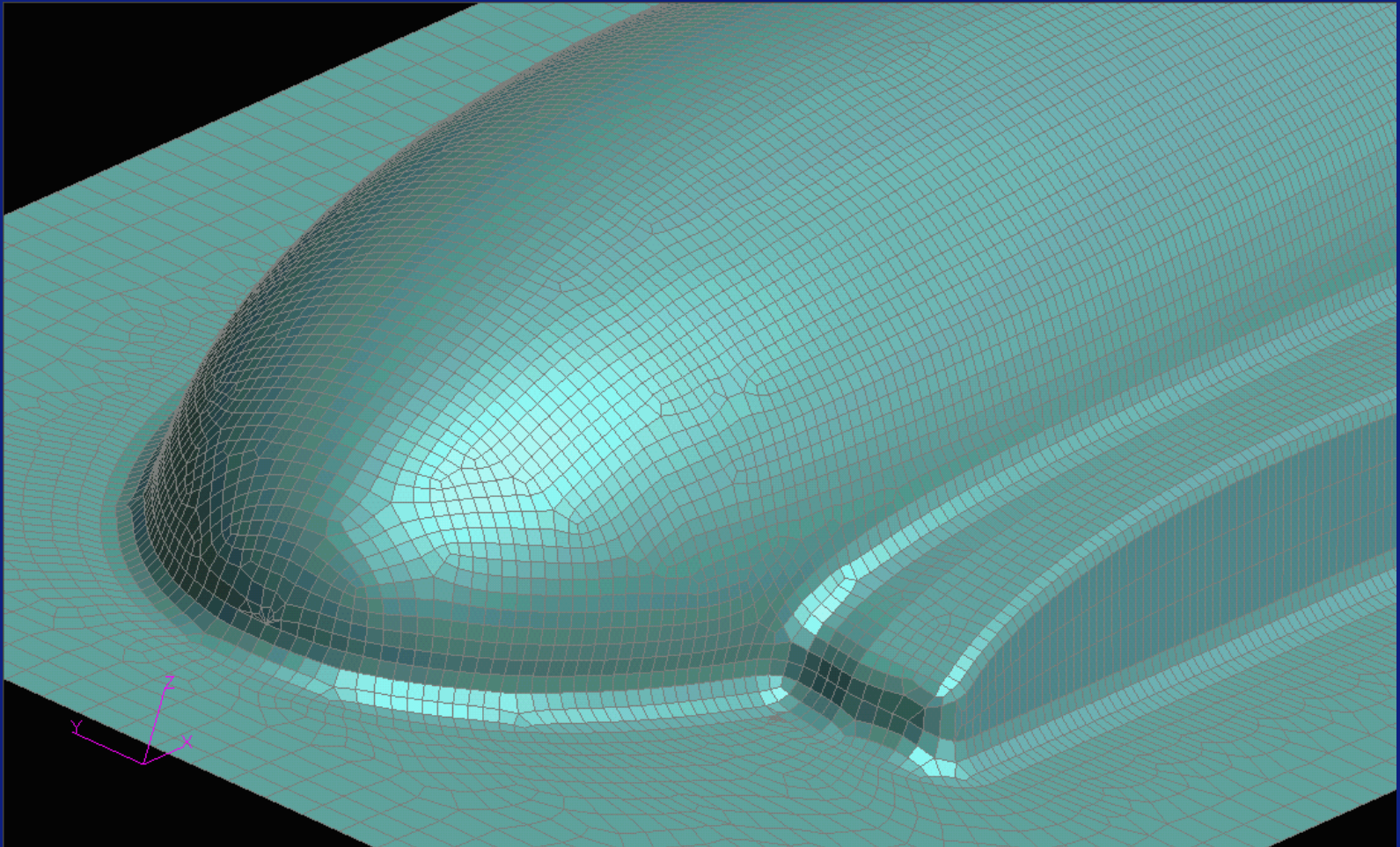
The **multi-layered construction** has a profound effect on both pre- and post-processing.

- Preferably, the local layup must be modelled as a laminated composite in the FEA, so that each element carries layered stiffness and strength data:

```
LAMINATE PROPERTY 1
      LAYER 1 MATERIAL THICKNESS ANGLE
      LAYER 2 MATERIAL THICKNESS ANGLE
      . . .
```

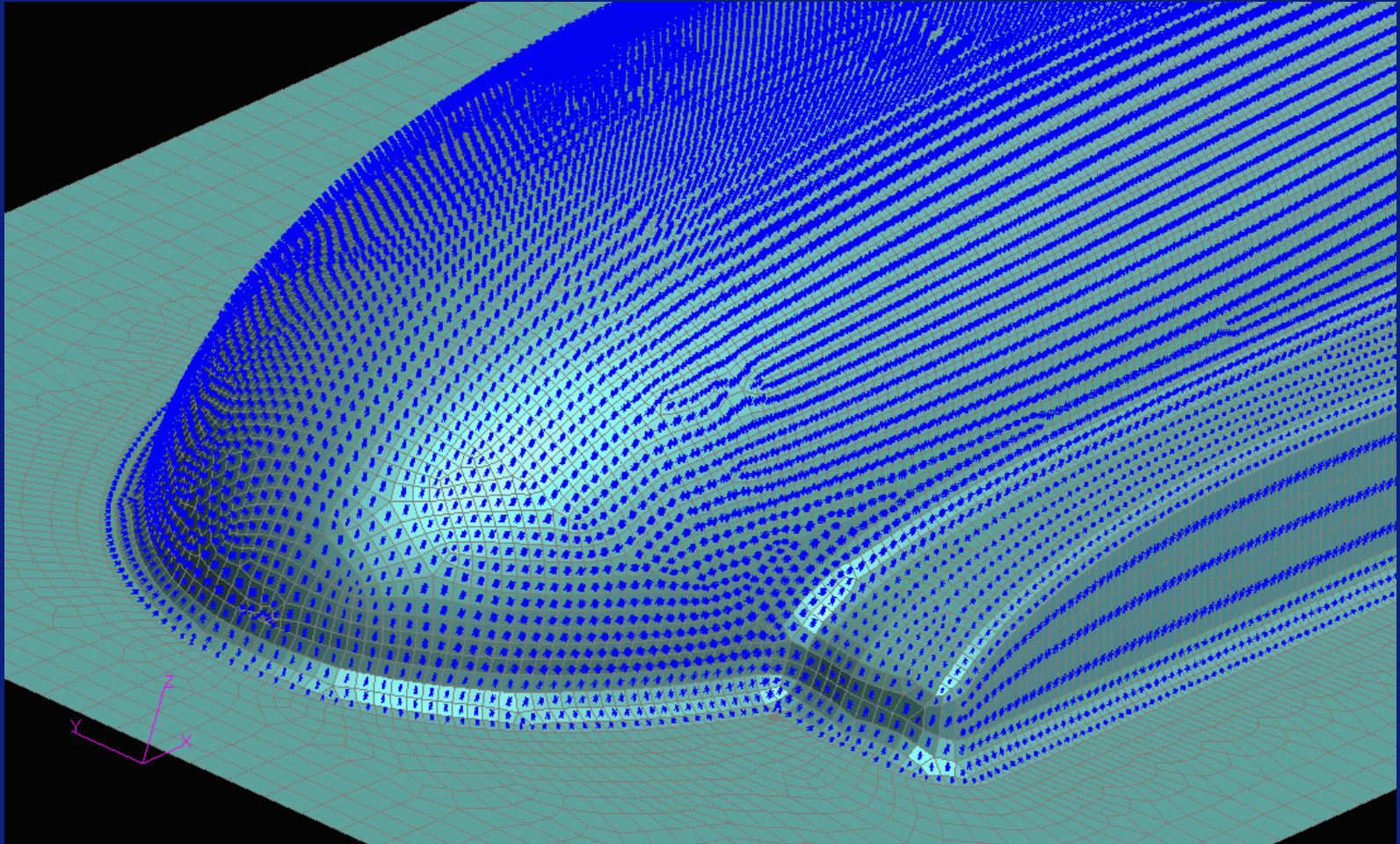
Requirements for pre- and post-processing

This latter method presents an enormous task to properly define the layer thickness and orientation for each element:



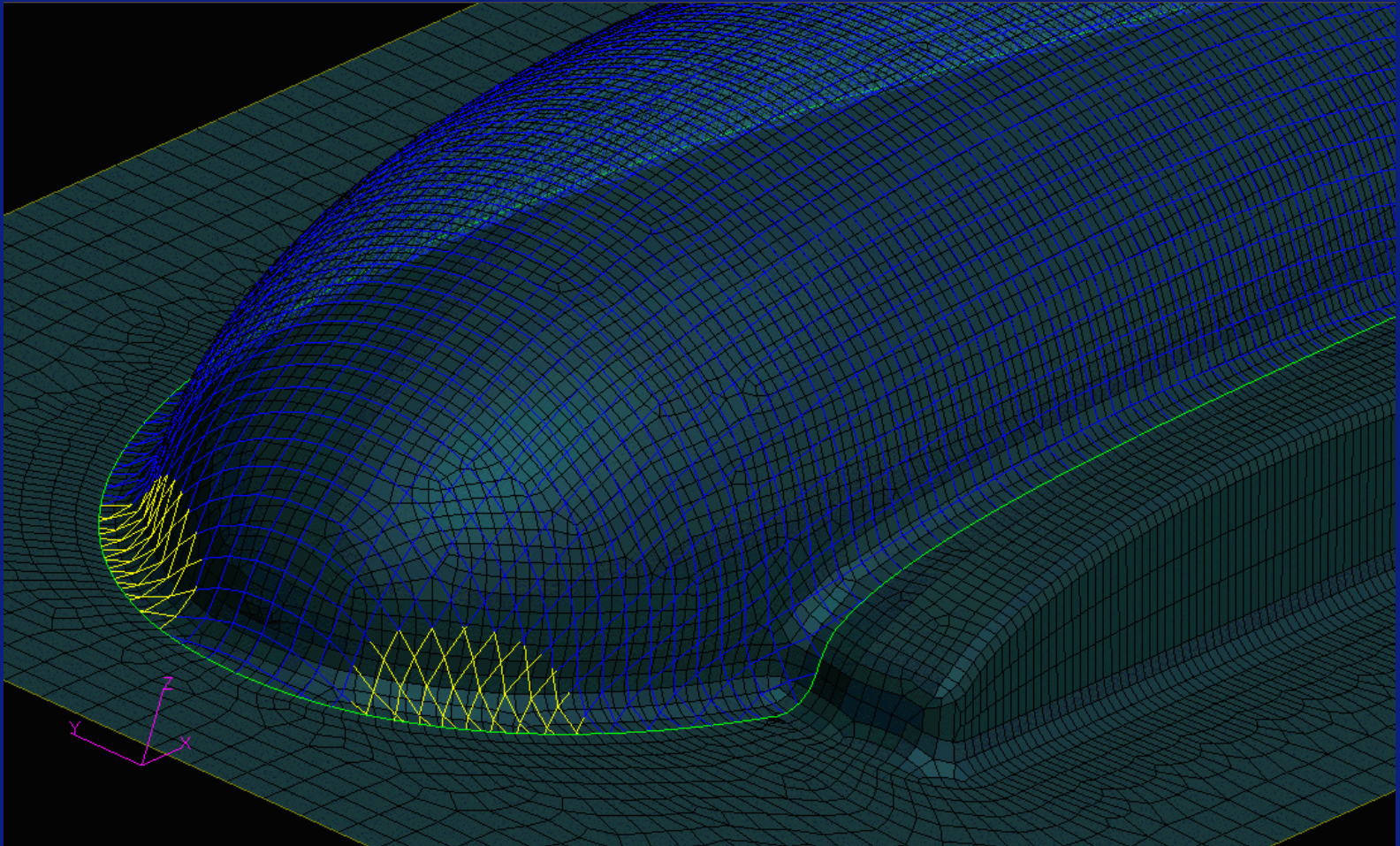
Requirements for pre- and post-processing

This latter method presents an enormous task to properly define the layer thickness and orientation for each element:



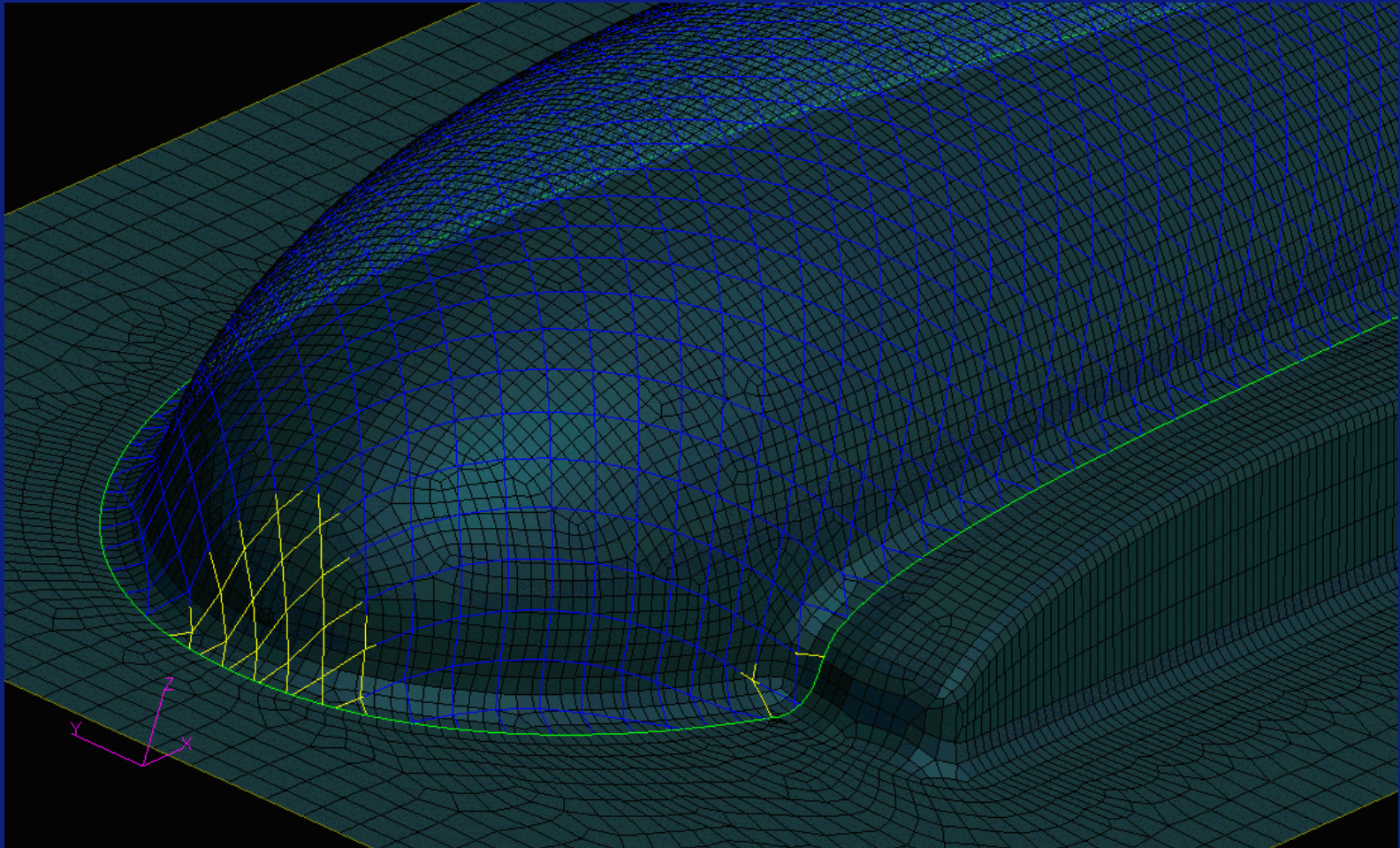
Requirements for pre- and post-processing

Draping software can be used to simulate the way fabric layers will form over the structure:



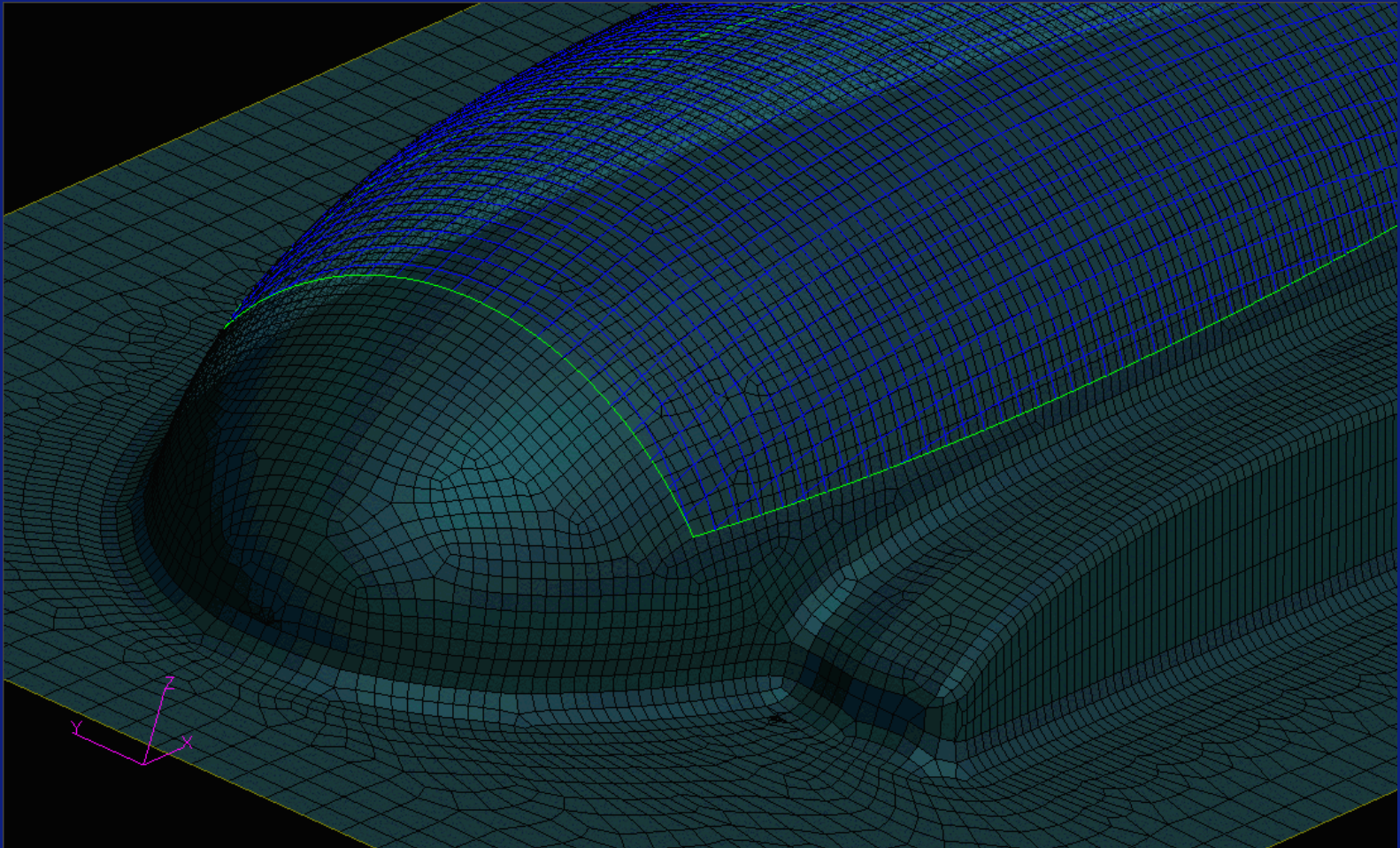
Requirements for pre- and post-processing

Draping software can be used to simulate the way fabric layers will form over the structure:



Requirements for pre- and post-processing

Draping software can be used to simulate the way fabric layers will form over the structure:



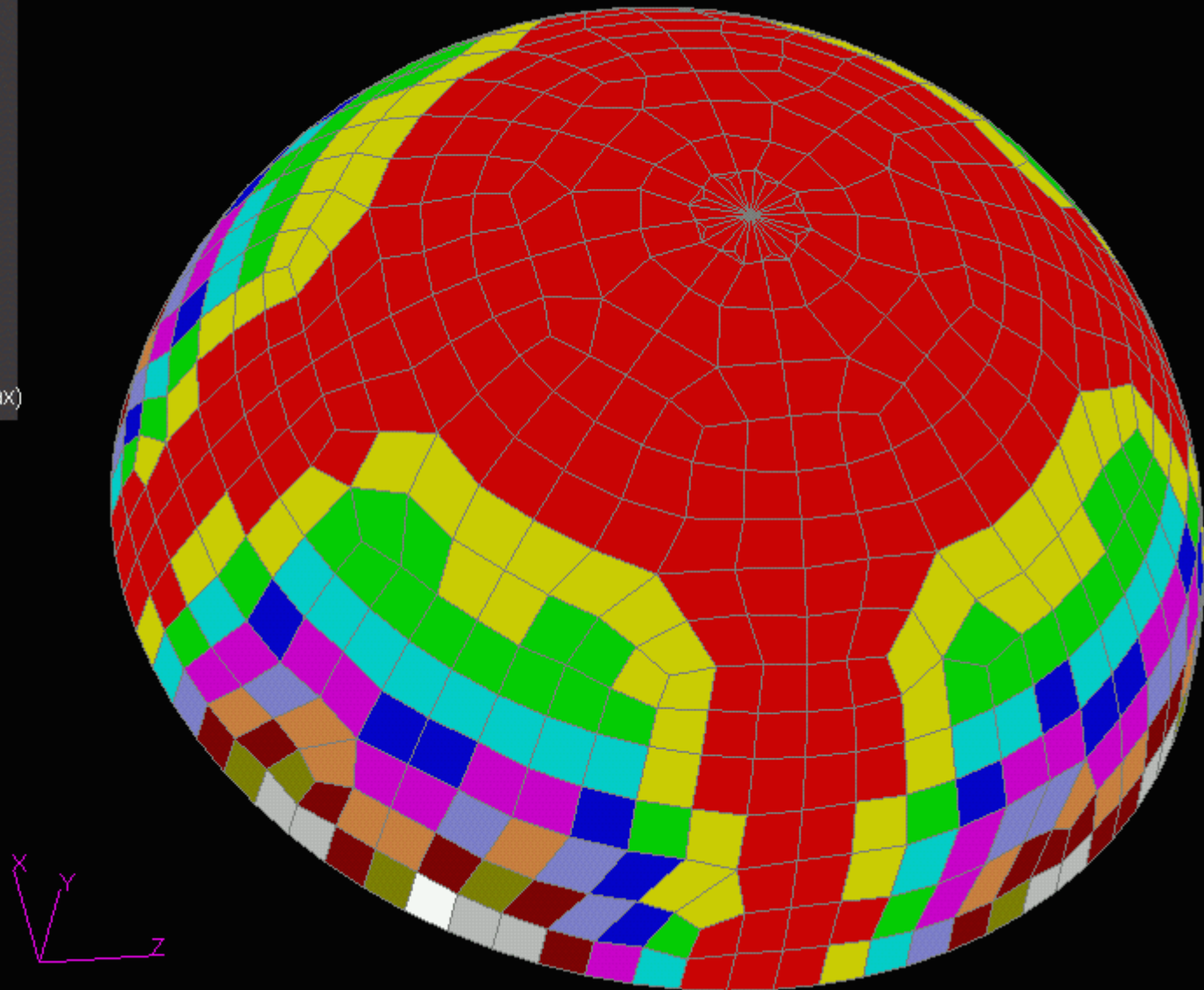
Requirements for pre- and post-processing

The draping software:

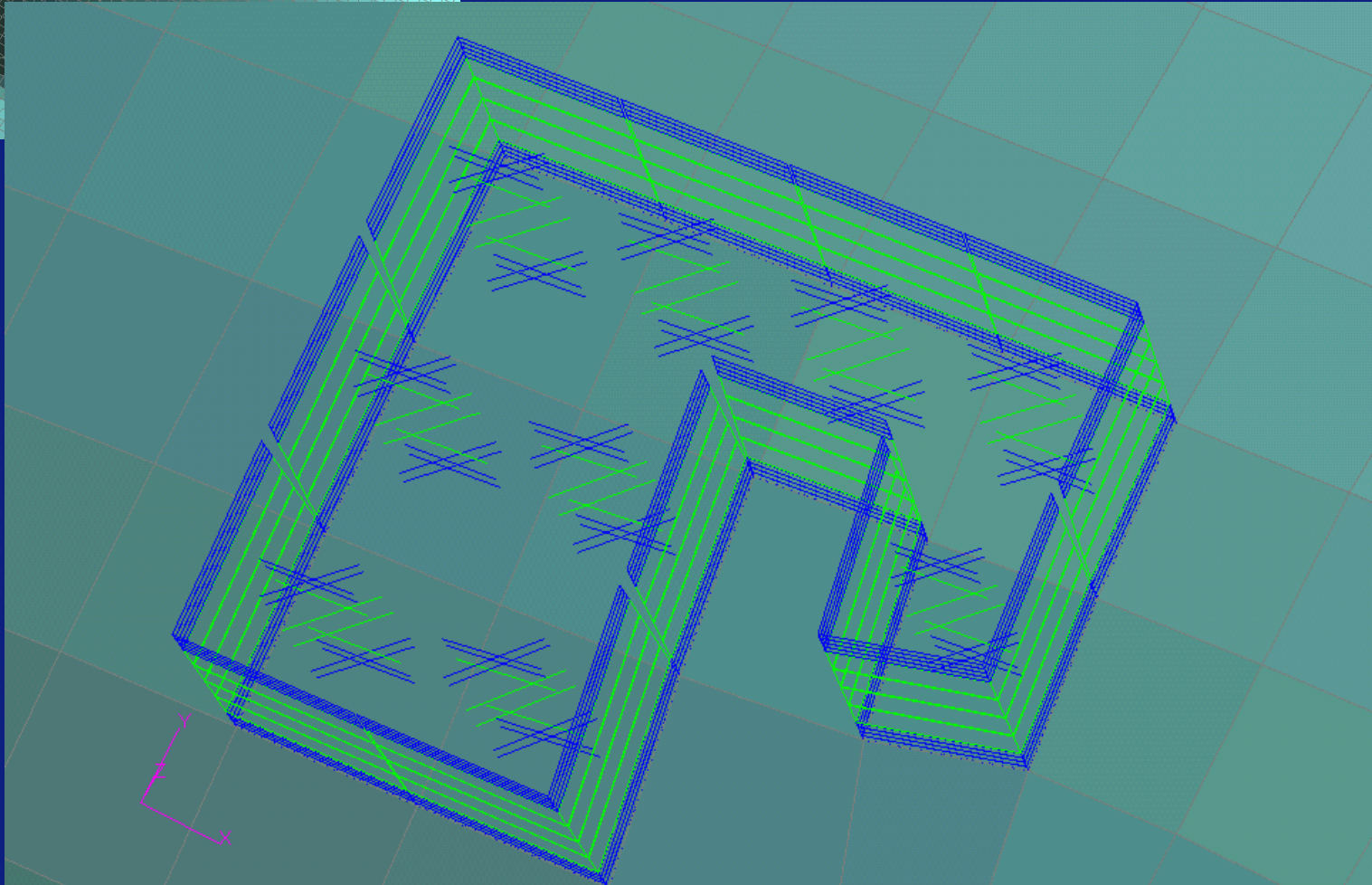
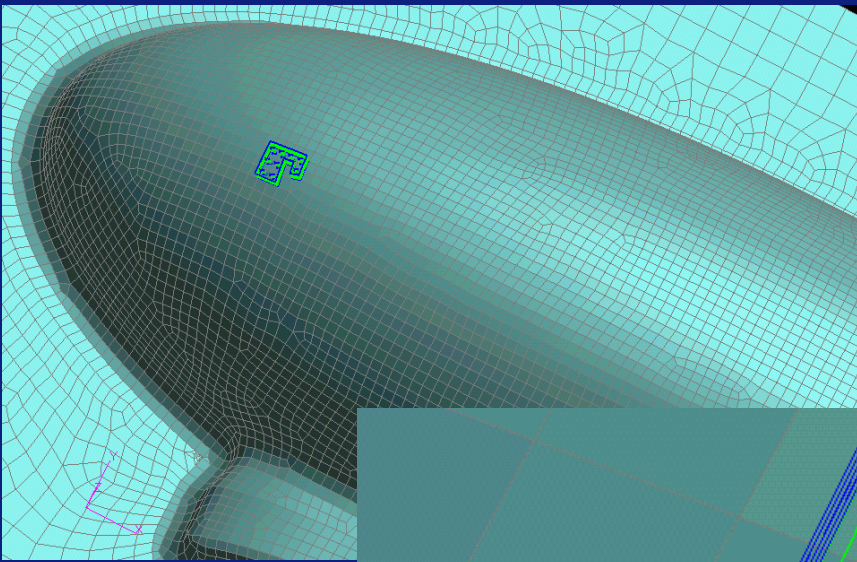
- calculates the local fibre orientation
- calculates the local layer thickness
- automatically prepares the FEA material property deck
- helps us visualise and check the above

Layer thickness distortion as a result of draping

Layup Thickness distribution



Laminate configuration
for a group of elements

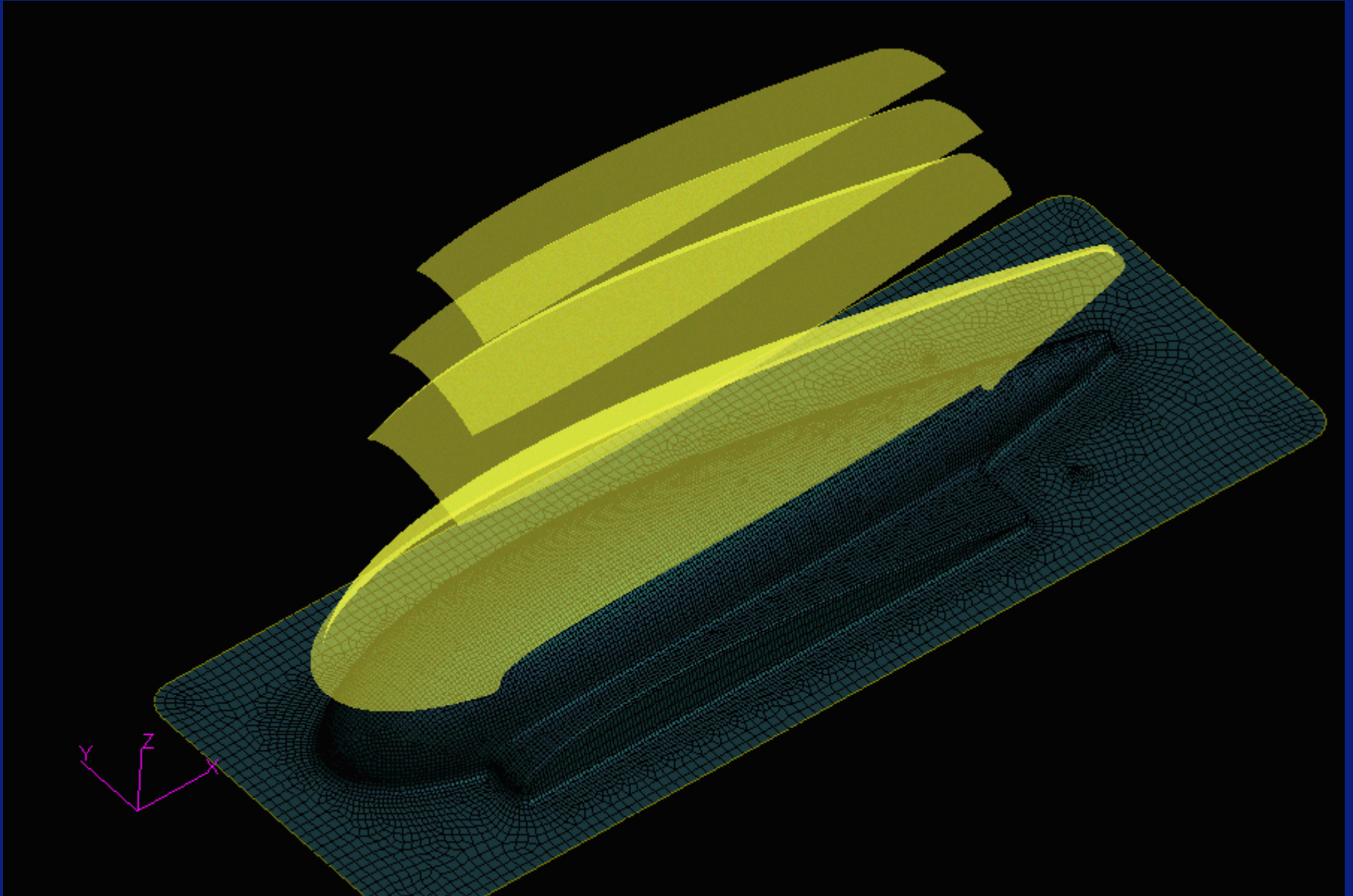


Requirements for pre- and post-processing

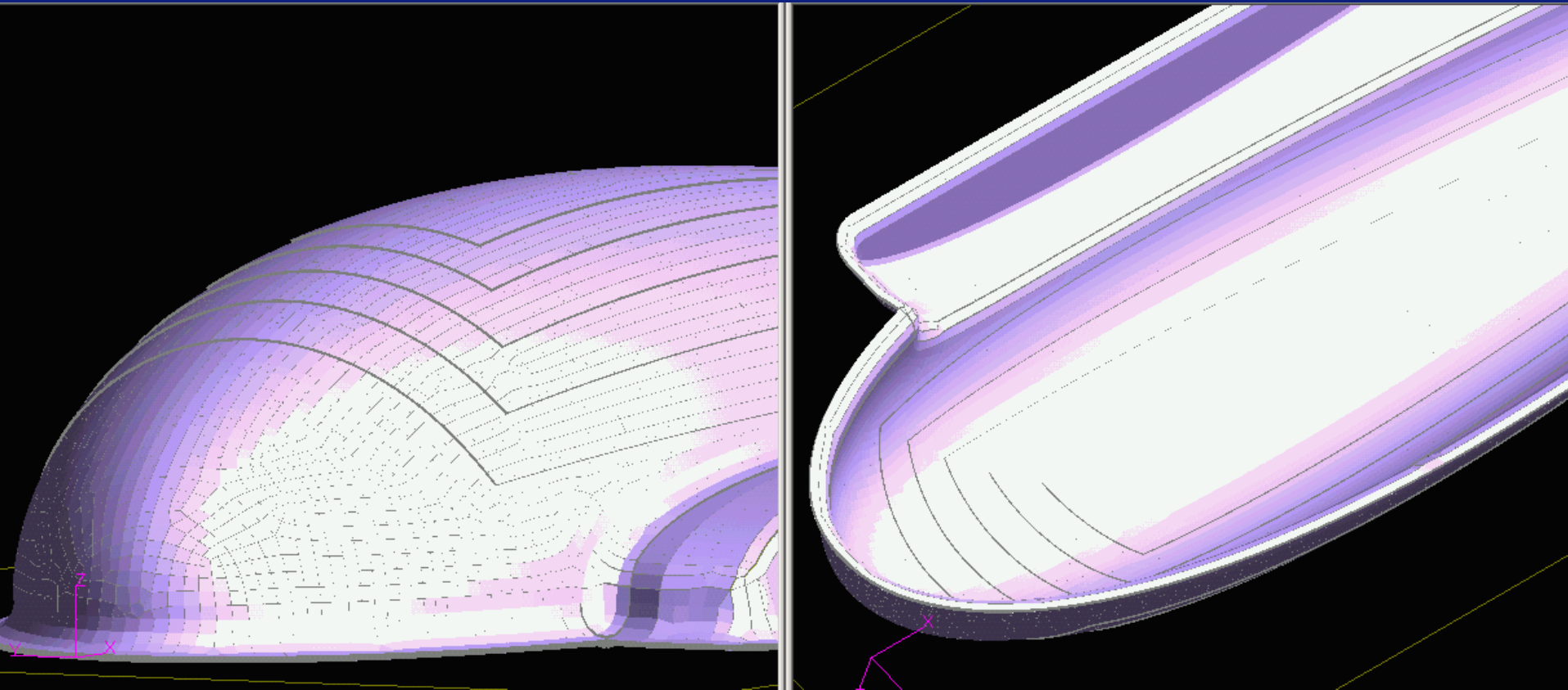
In addition, the draping software:

- helps us visualise and check layer coverage
- helps us visualise layer drop-off and offsets
- helps us modify and re-apply layers
- helps us inspect and generate reliable and realistic manufacturing data

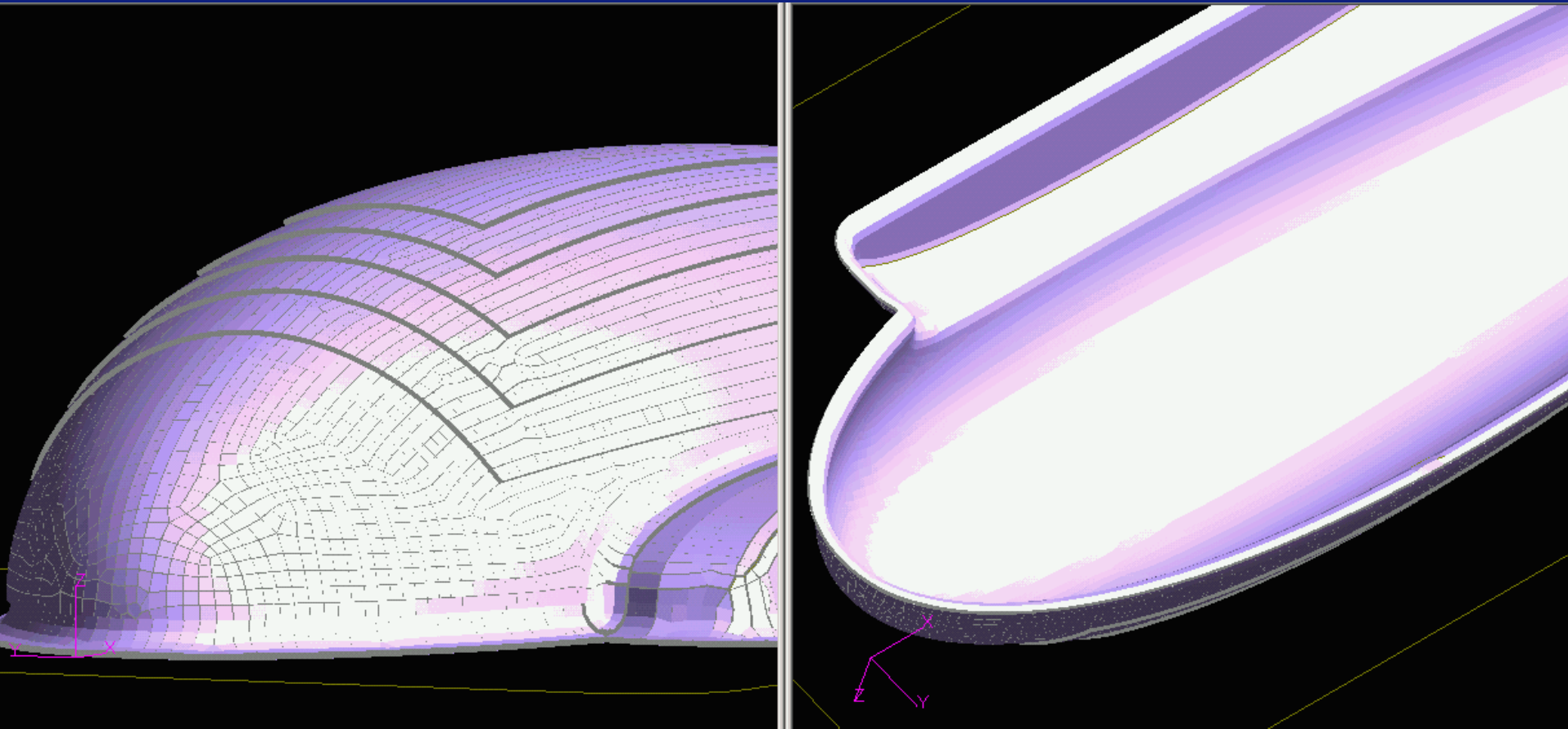
Layer application (manufacturing aid)



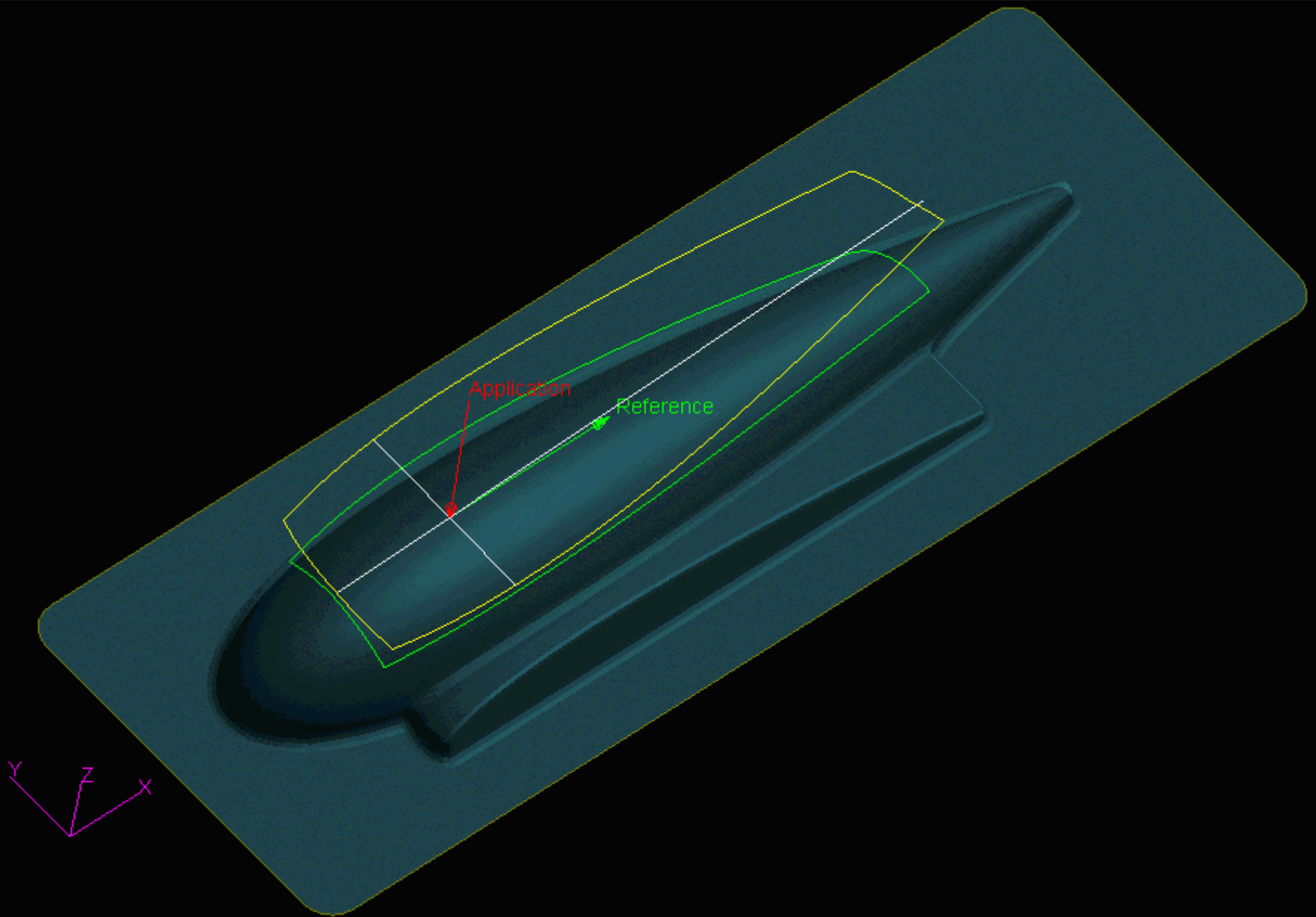
Incorrect offsets



Correct offsets



Layer flat pattern and in-place boundary



Requirements for pre- and post-processing

Given the above functionality, we need:

- interfaces to composite material databases
- interfaces to CAD (import model surfaces, export manufacturing data, nest)
- interfaces to manufacturing hardware (cutters, lasers)
- procedures for team work (layer design and global ply identification)

Requirements for pre- and post-processing

At the post-processing stage, we have:

- layer stresses (in the fibre axis system)
- layer failure indices, or margins of safety, or reserve factors
- complex failure mechanisms require complex failure criteria (calculations and interpretation)
- interlaminar stresses and failure calculations
- relation to the global plies?

Requirements for pre- and post-processing

The large amount of information for post-processing generates large result files and slows down all operations.

The process can benefit from generating some of the results only when needed (layer stresses, layer failure calculations).

Requirements for pre- and post-processing

What do we do with the results?

- ensure that we have adequate stiffness
- ensure that no part of the structure fails
- consider individual loadcases as well as combinations
- ensure an efficient design by making good use of material (ideally, have even stresses throughout)
- consider additional local stress concentrations

Requirements for pre- and post-processing

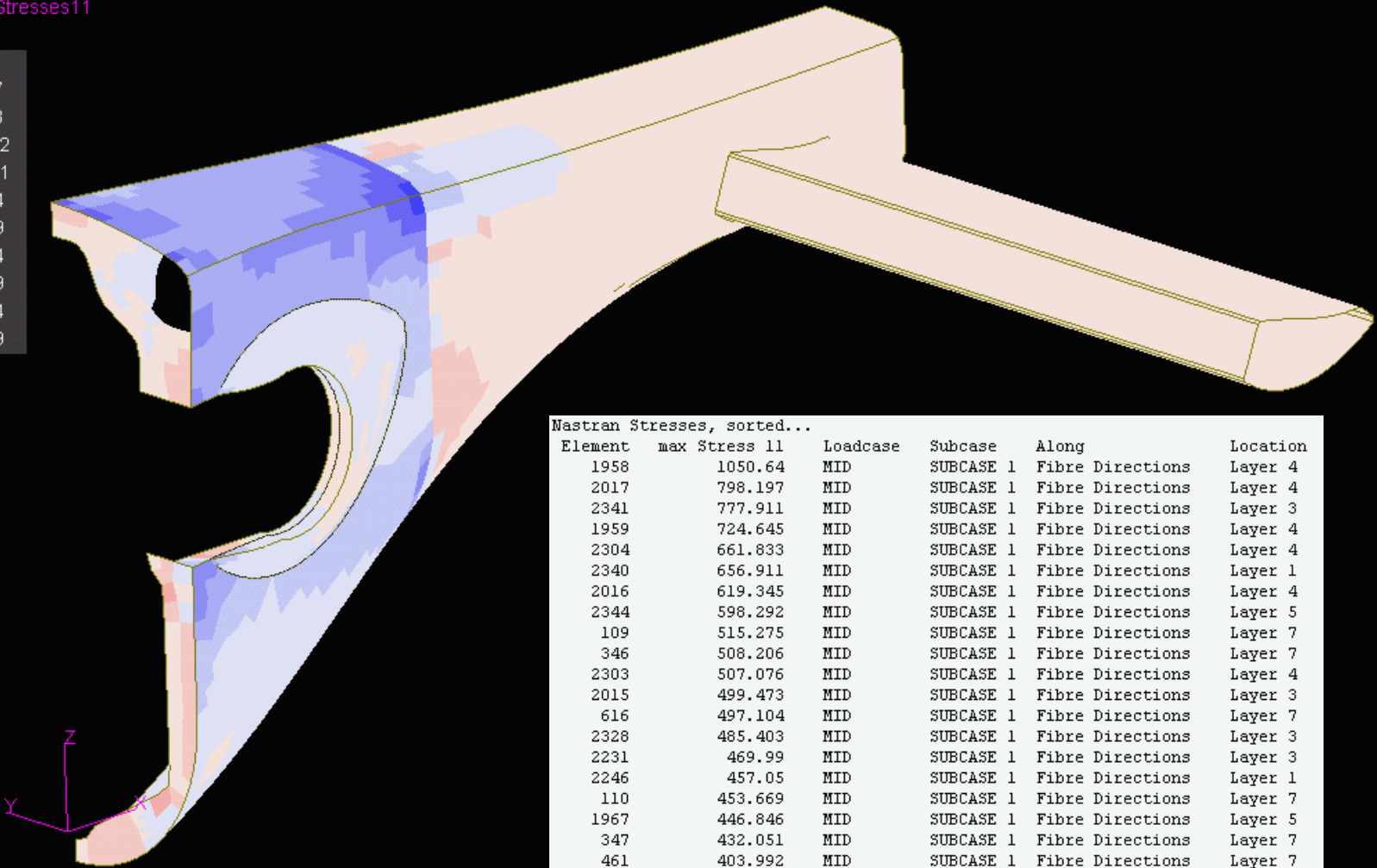
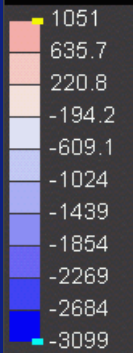
What tools do we need to process the results?

- identify worst stress components per element (11, 22, 13, etc., with layer source) for all loadcases, to focus on load paths
- similarly for failure calculations, to interpret strength capacity and failure mechanisms
- obtain a global picture of stresses and failure calculations (components, theories, loadcases, layers) to interpret structural efficiency
- project any results on global plies

Requirements for pre- and post-processing

- identify worst **stress components** per element

Nastran Stresses11



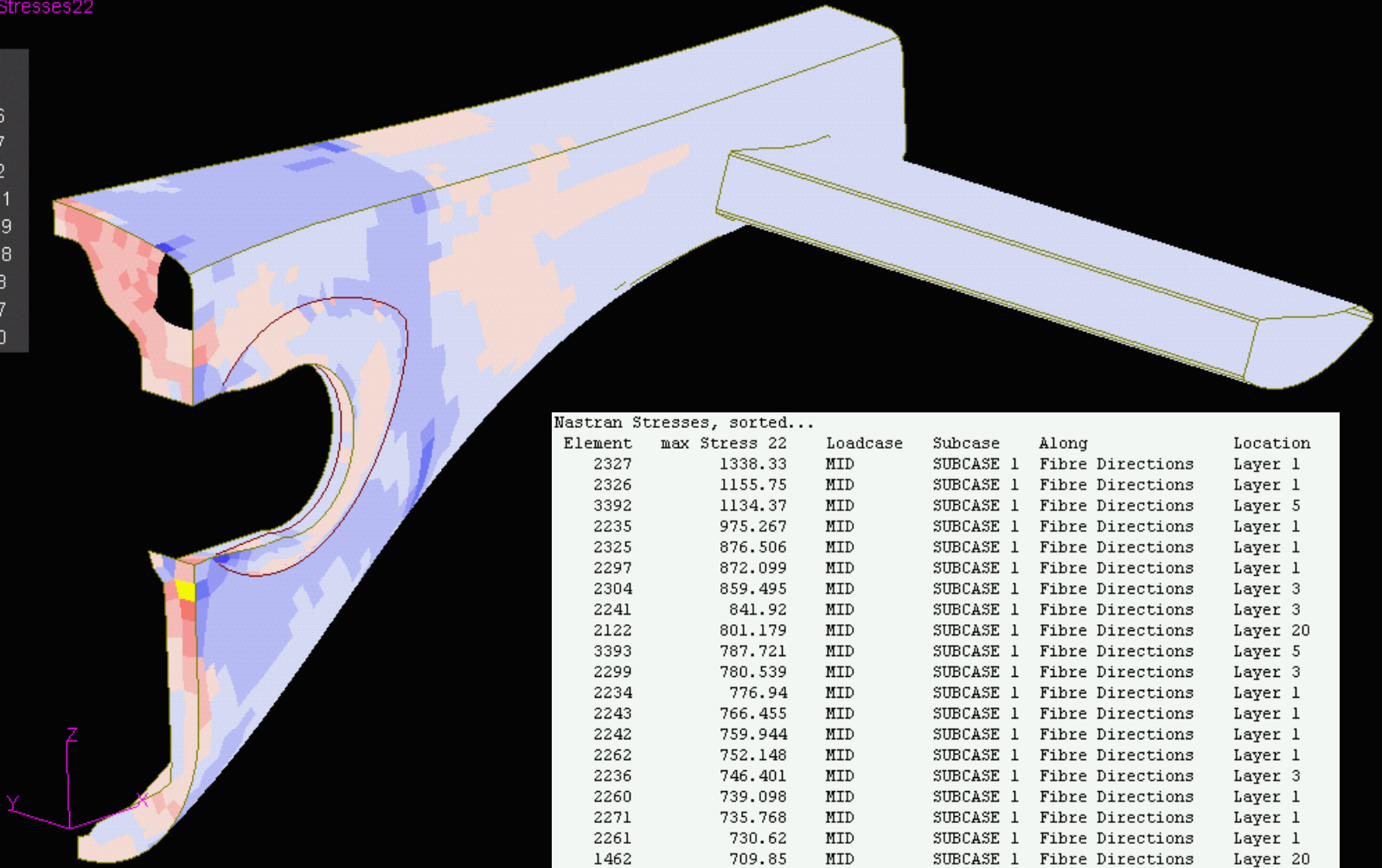
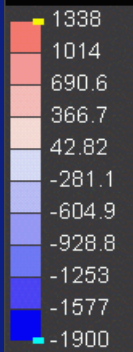
Nastran Stresses, sorted...

Element	max Stress 11	Loadcase	Subcase	Along	Location
1958	1050.64	MID	SUBCASE 1	Fibre Directions	Layer 4
2017	798.197	MID	SUBCASE 1	Fibre Directions	Layer 4
2341	777.911	MID	SUBCASE 1	Fibre Directions	Layer 3
1959	724.645	MID	SUBCASE 1	Fibre Directions	Layer 4
2304	661.833	MID	SUBCASE 1	Fibre Directions	Layer 4
2340	656.911	MID	SUBCASE 1	Fibre Directions	Layer 1
2016	619.345	MID	SUBCASE 1	Fibre Directions	Layer 4
2344	598.292	MID	SUBCASE 1	Fibre Directions	Layer 5
109	515.275	MID	SUBCASE 1	Fibre Directions	Layer 7
346	508.206	MID	SUBCASE 1	Fibre Directions	Layer 7
2303	507.076	MID	SUBCASE 1	Fibre Directions	Layer 4
2015	499.473	MID	SUBCASE 1	Fibre Directions	Layer 3
616	497.104	MID	SUBCASE 1	Fibre Directions	Layer 7
2328	485.403	MID	SUBCASE 1	Fibre Directions	Layer 3
2231	469.99	MID	SUBCASE 1	Fibre Directions	Layer 3
2246	457.05	MID	SUBCASE 1	Fibre Directions	Layer 1
110	453.669	MID	SUBCASE 1	Fibre Directions	Layer 7
1967	446.846	MID	SUBCASE 1	Fibre Directions	Layer 5
347	432.051	MID	SUBCASE 1	Fibre Directions	Layer 7
461	403.992	MID	SUBCASE 1	Fibre Directions	Layer 7
1960	397.668	MID	SUBCASE 1	Fibre Directions	Layer 3

Requirements for pre- and post-processing

- identify worst **stress components** per element

Nastran Stresses22



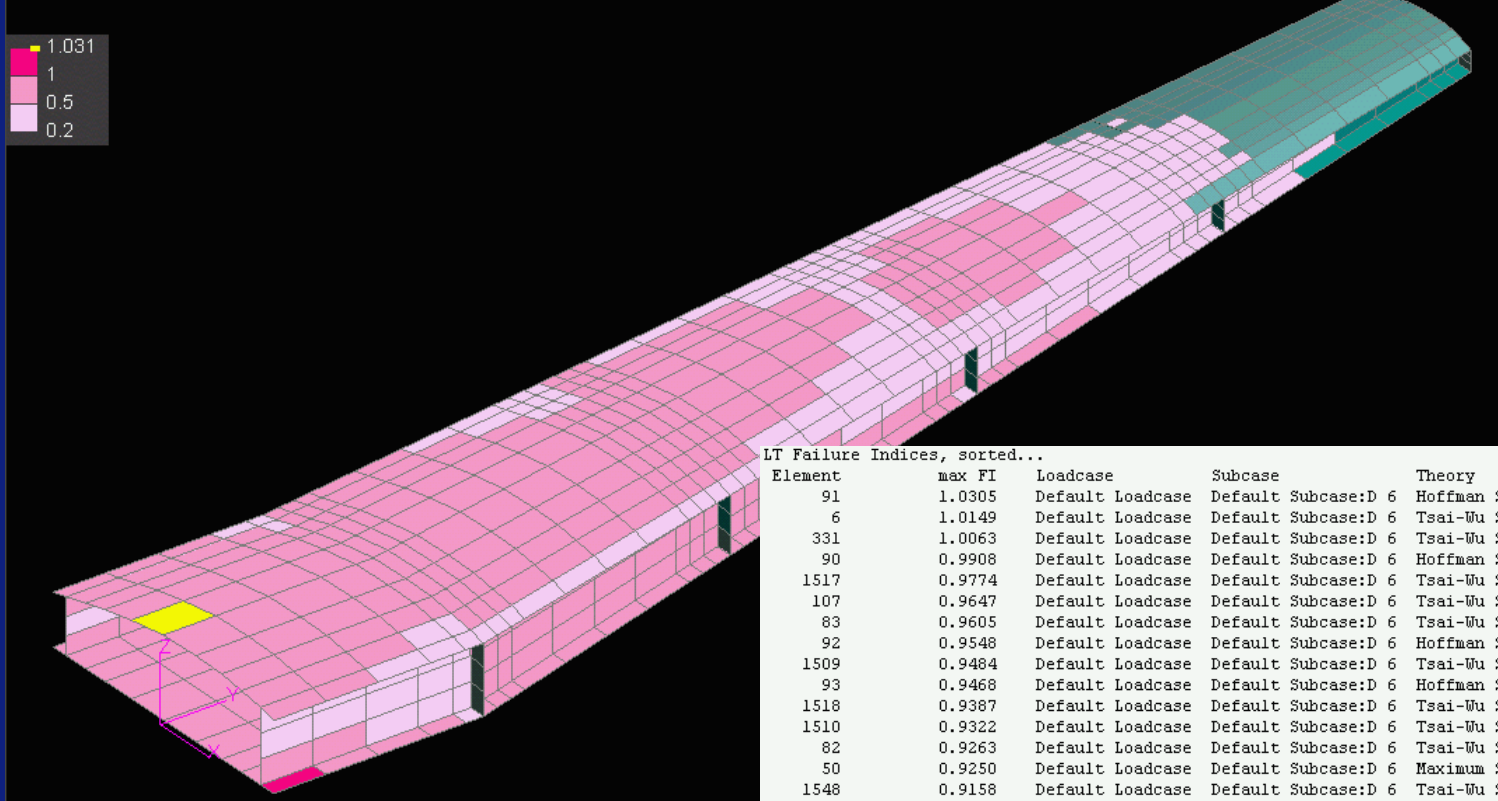
Nastran Stresses, sorted...

Element	max Stress 22	Loadcase	Subcase	Along	Location
2327	1338.33	MID	SUBCASE 1	Fibre Directions	Layer 1
2326	1155.75	MID	SUBCASE 1	Fibre Directions	Layer 1
3392	1134.37	MID	SUBCASE 1	Fibre Directions	Layer 5
2235	975.267	MID	SUBCASE 1	Fibre Directions	Layer 1
2325	876.506	MID	SUBCASE 1	Fibre Directions	Layer 1
2297	872.099	MID	SUBCASE 1	Fibre Directions	Layer 1
2304	859.495	MID	SUBCASE 1	Fibre Directions	Layer 3
2241	841.92	MID	SUBCASE 1	Fibre Directions	Layer 3
2122	801.179	MID	SUBCASE 1	Fibre Directions	Layer 20
3393	787.721	MID	SUBCASE 1	Fibre Directions	Layer 5
2299	780.539	MID	SUBCASE 1	Fibre Directions	Layer 3
2234	776.94	MID	SUBCASE 1	Fibre Directions	Layer 1
2243	766.455	MID	SUBCASE 1	Fibre Directions	Layer 1
2242	759.944	MID	SUBCASE 1	Fibre Directions	Layer 1
2262	752.148	MID	SUBCASE 1	Fibre Directions	Layer 1
2236	746.401	MID	SUBCASE 1	Fibre Directions	Layer 3
2260	739.098	MID	SUBCASE 1	Fibre Directions	Layer 1
2271	735.768	MID	SUBCASE 1	Fibre Directions	Layer 1
2261	730.62	MID	SUBCASE 1	Fibre Directions	Layer 1
1462	709.85	MID	SUBCASE 1	Fibre Directions	Layer 20
2291	706.992	MID	SUBCASE 1	Fibre Directions	Layer 3

Requirements for pre- and post-processing

- identify worst **failure index** per element

LT Failure Indices

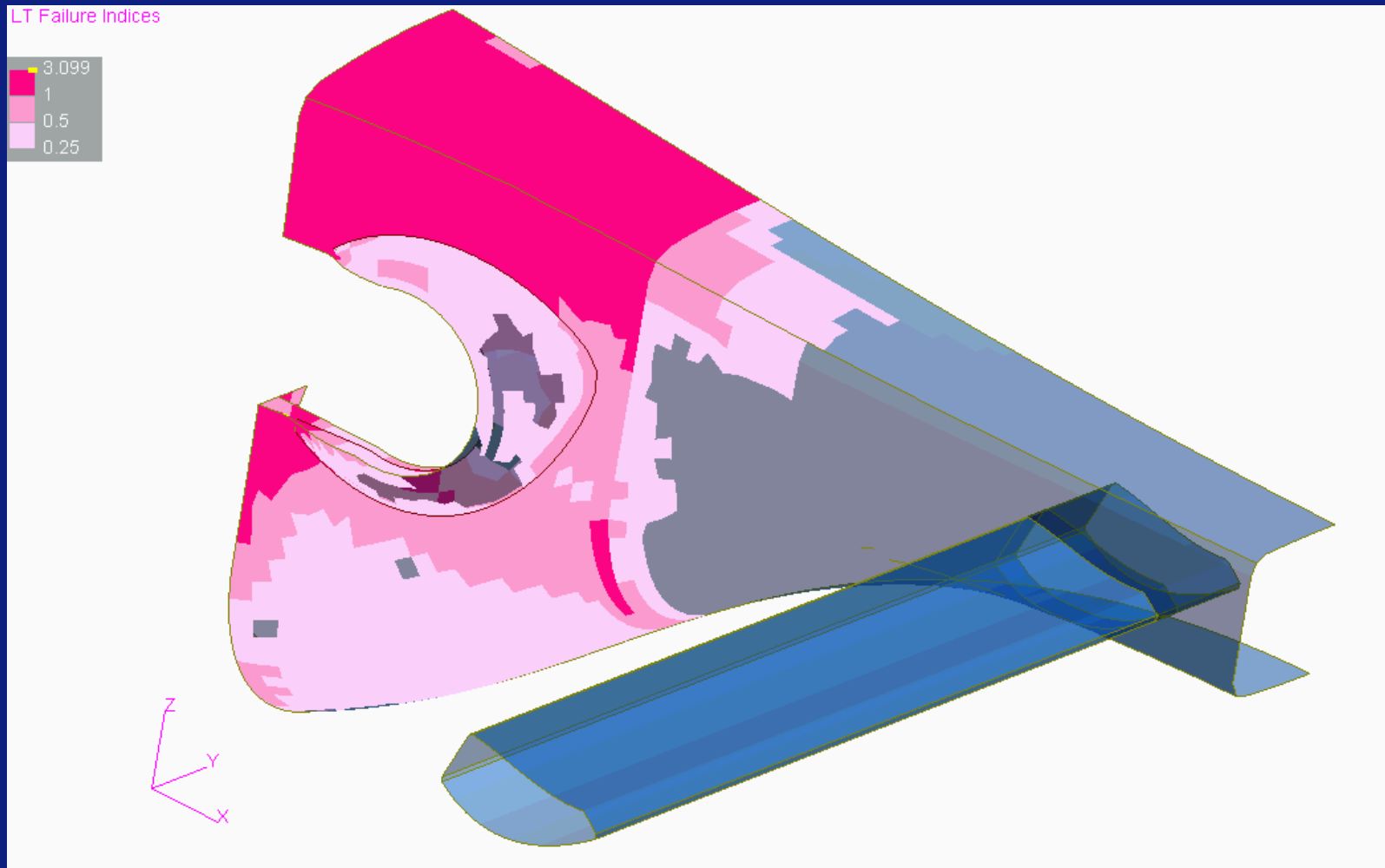


LT Failure Indices, sorted...

Element	max FI	Loadcase	Subcase	Theory	Location	Component
91	1.0305	Default Loadcase	Default Subcase:D 6	Hoffman Stress	Layer 1	in-plane
6	1.0149	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
331	1.0063	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 6	in-plane
90	0.9908	Default Loadcase	Default Subcase:D 6	Hoffman Stress	Layer 1	in-plane
1517	0.9774	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 9	in-plane
107	0.9647	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
83	0.9605	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
92	0.9548	Default Loadcase	Default Subcase:D 6	Hoffman Stress	Layer 1	in-plane
1509	0.9484	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 1	in-plane
93	0.9468	Default Loadcase	Default Subcase:D 6	Hoffman Stress	Layer 1	in-plane
1518	0.9387	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 9	in-plane
1510	0.9322	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 1	in-plane
82	0.9263	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
50	0.9250	Default Loadcase	Default Subcase:D 6	Maximum Stress	Layer 9	-11
1548	0.9158	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 9	in-plane
1516	0.9108	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 9	in-plane
106	0.9059	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
99	0.9028	Default Loadcase	Default Subcase:D 6	Maximum Stress	Layer 1	-11
100	0.8873	Default Loadcase	Default Subcase:D 6	Maximum Stress	Layer 1	-11
1542	0.8831	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 9	in-plane
332	0.8813	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 6	in-plane
89	0.8797	Default Loadcase	Default Subcase:D 6	Maximum Stress	Layer 1	-11
343	0.8733	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 7	in-plane
108	0.8728	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 4	in-plane
1222	0.8694	Default Loadcase	Default Subcase:D 6	Tsai-Wu Stress	Layer 6	in-plane
98	0.8687	Default Loadcase	Default Subcase:D 6	Maximum Stress	Layer 1	-11

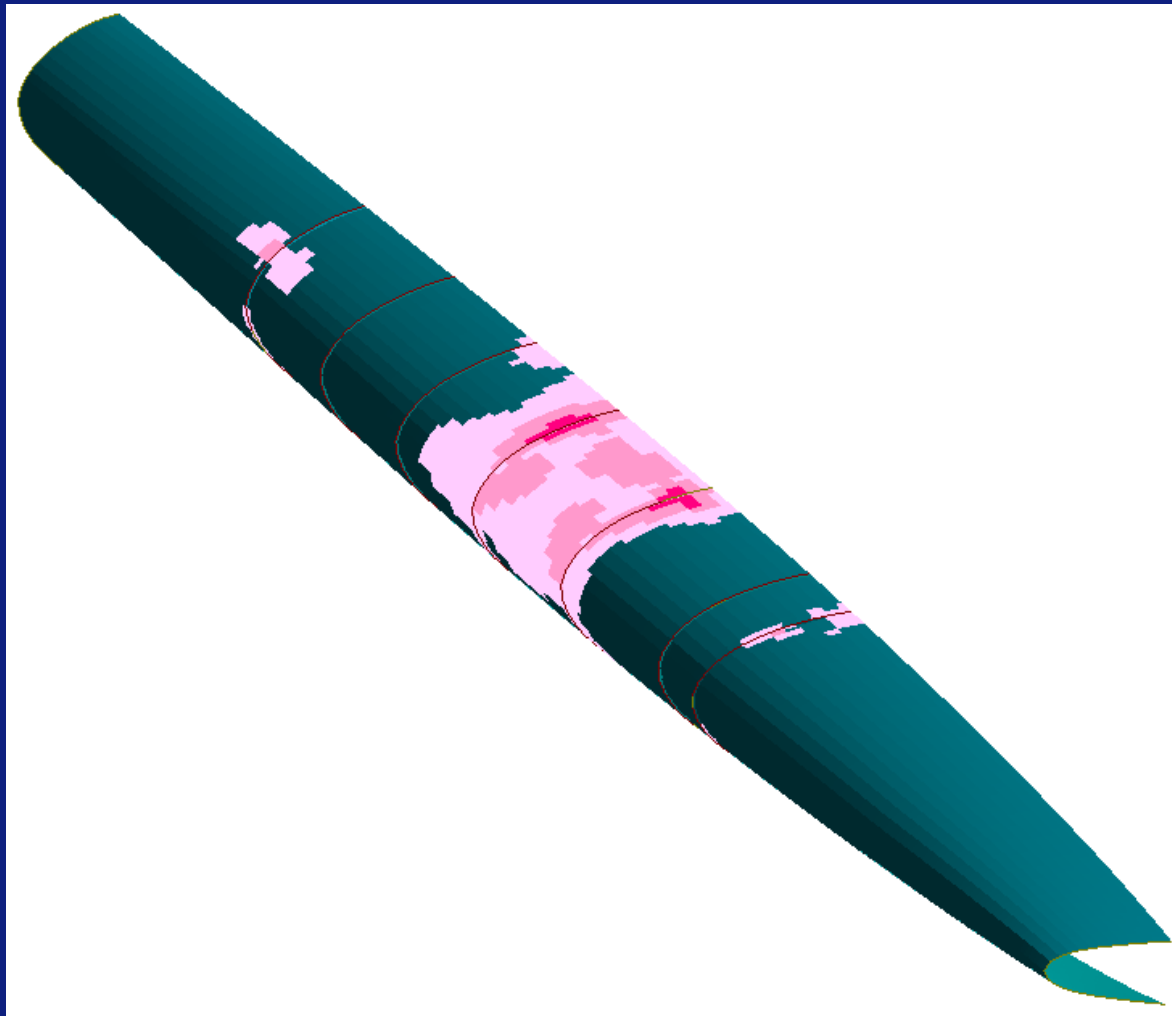
Requirements for pre- and post-processing

- identify worst **failure index** per element



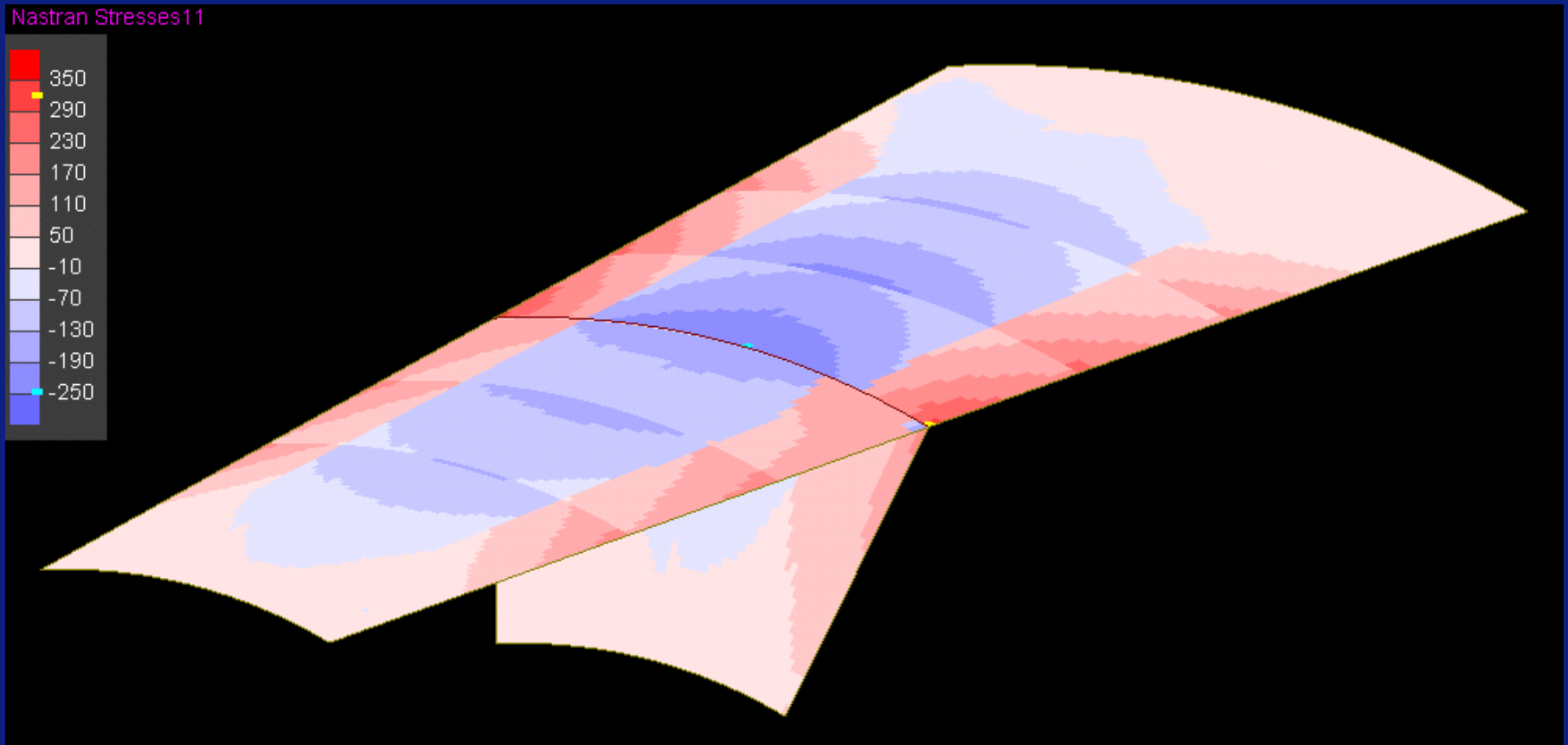
Requirements for pre- and post-processing

- identify worst **failure index** per element



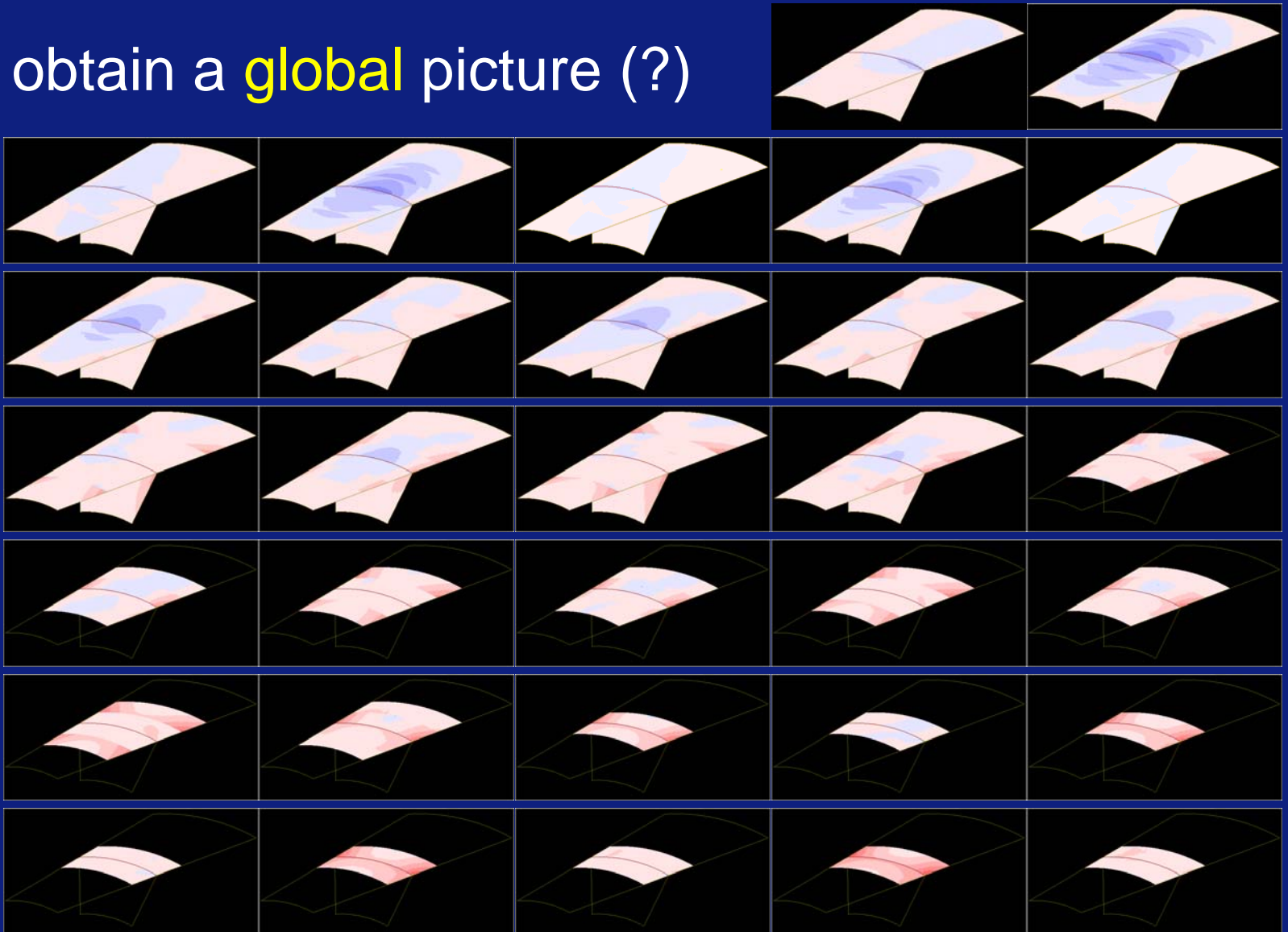
Requirements for pre- and post-processing

- obtain a **global** picture

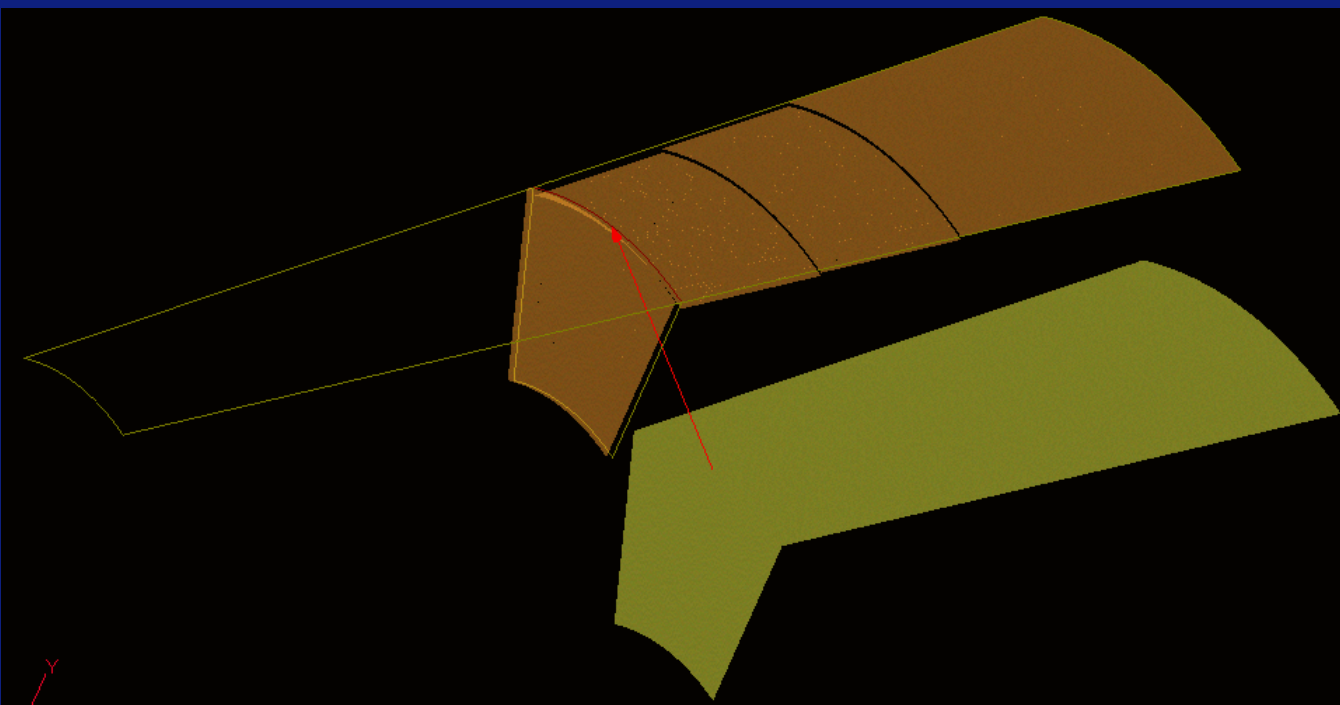


Requirements for pre- and post-processing

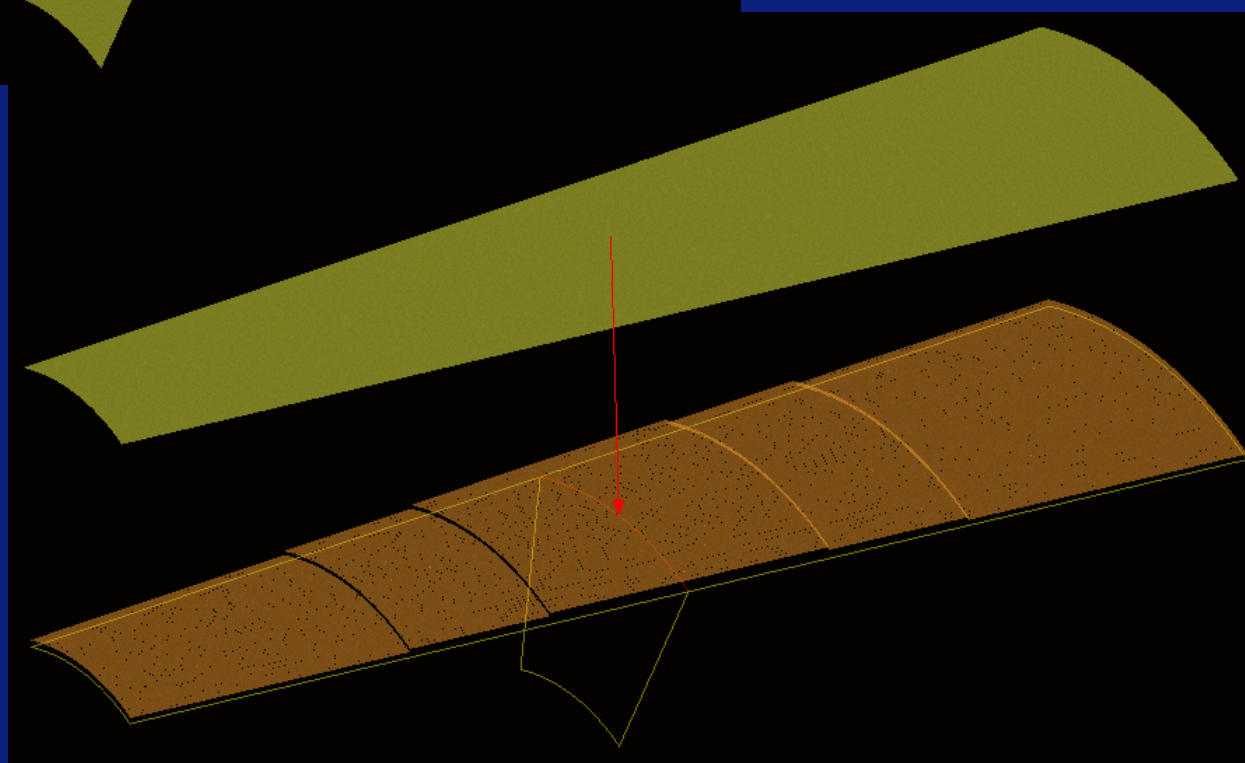
- obtain a **global** picture (?)



first ply

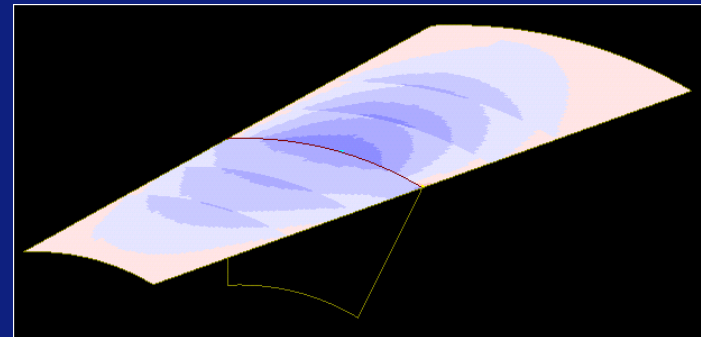
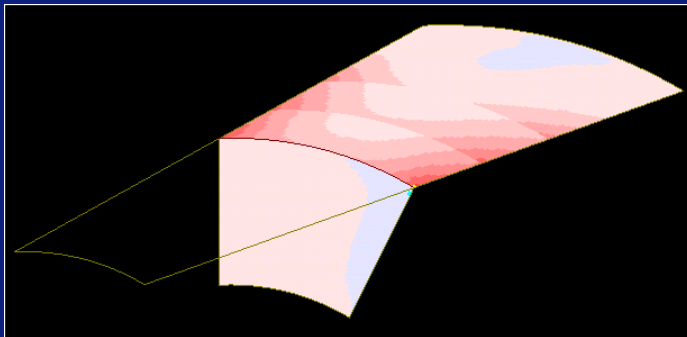
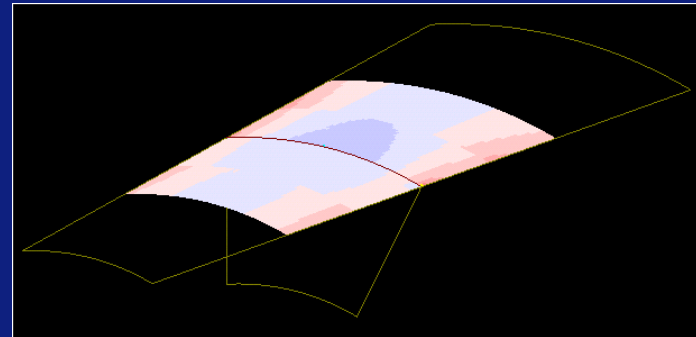
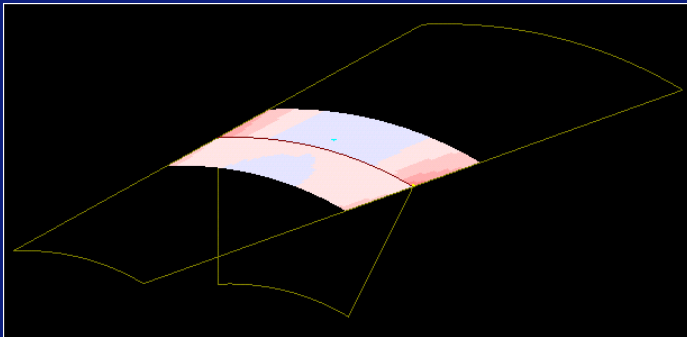
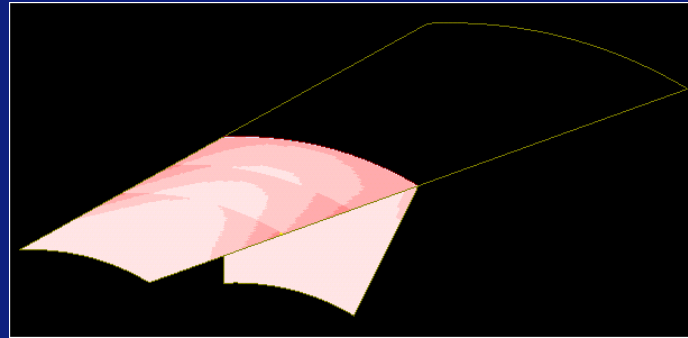
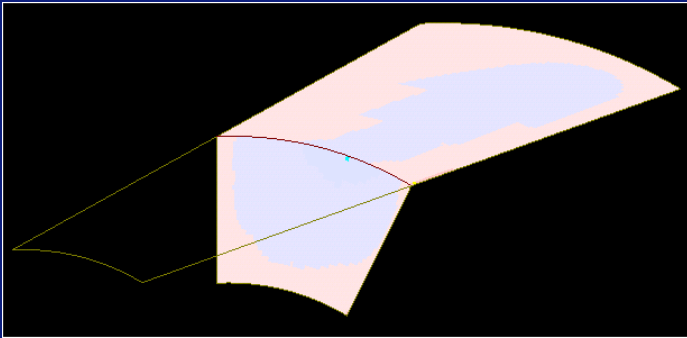


last ply



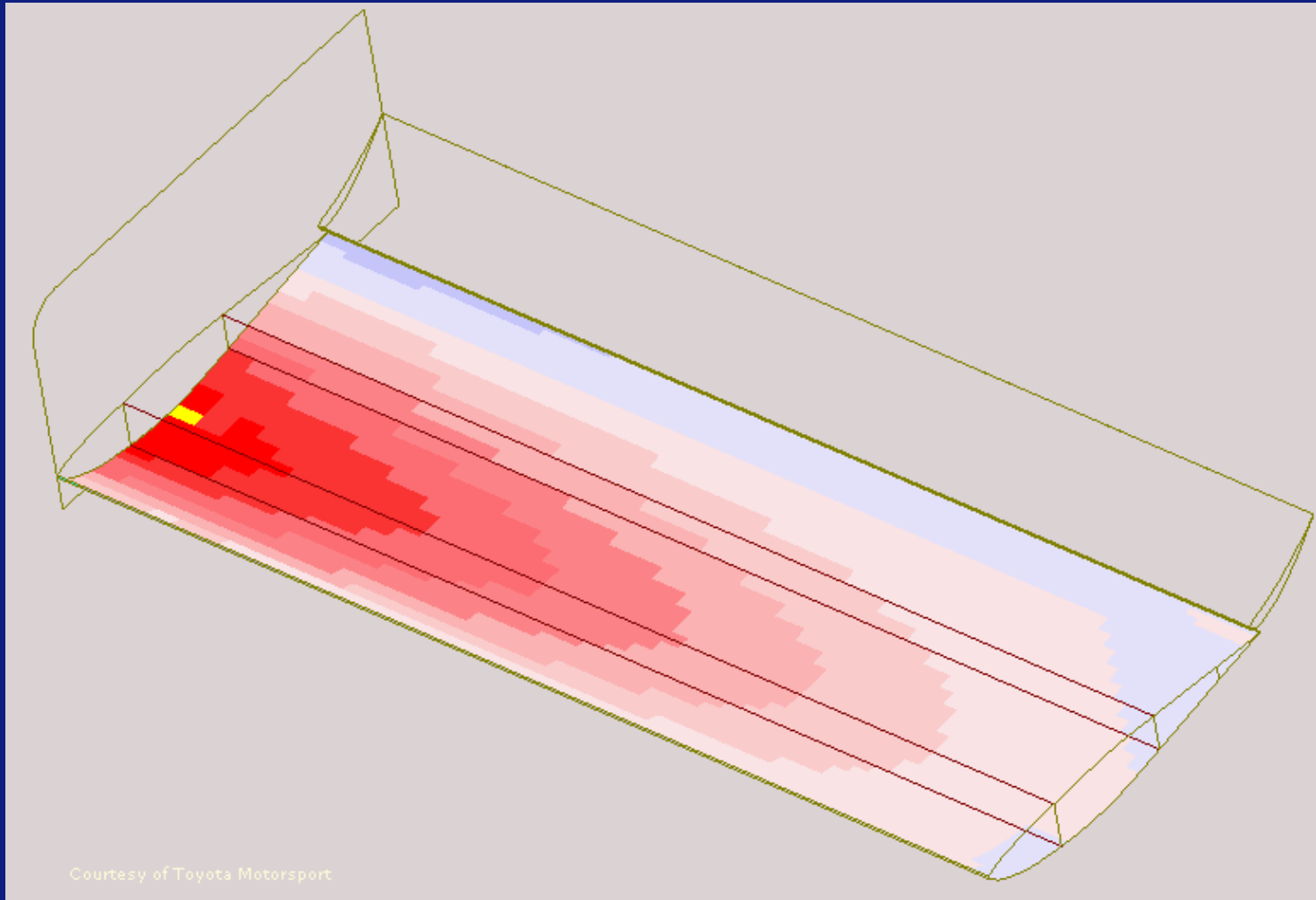
Requirements for pre- and post-processing

- project the results on **global** plies



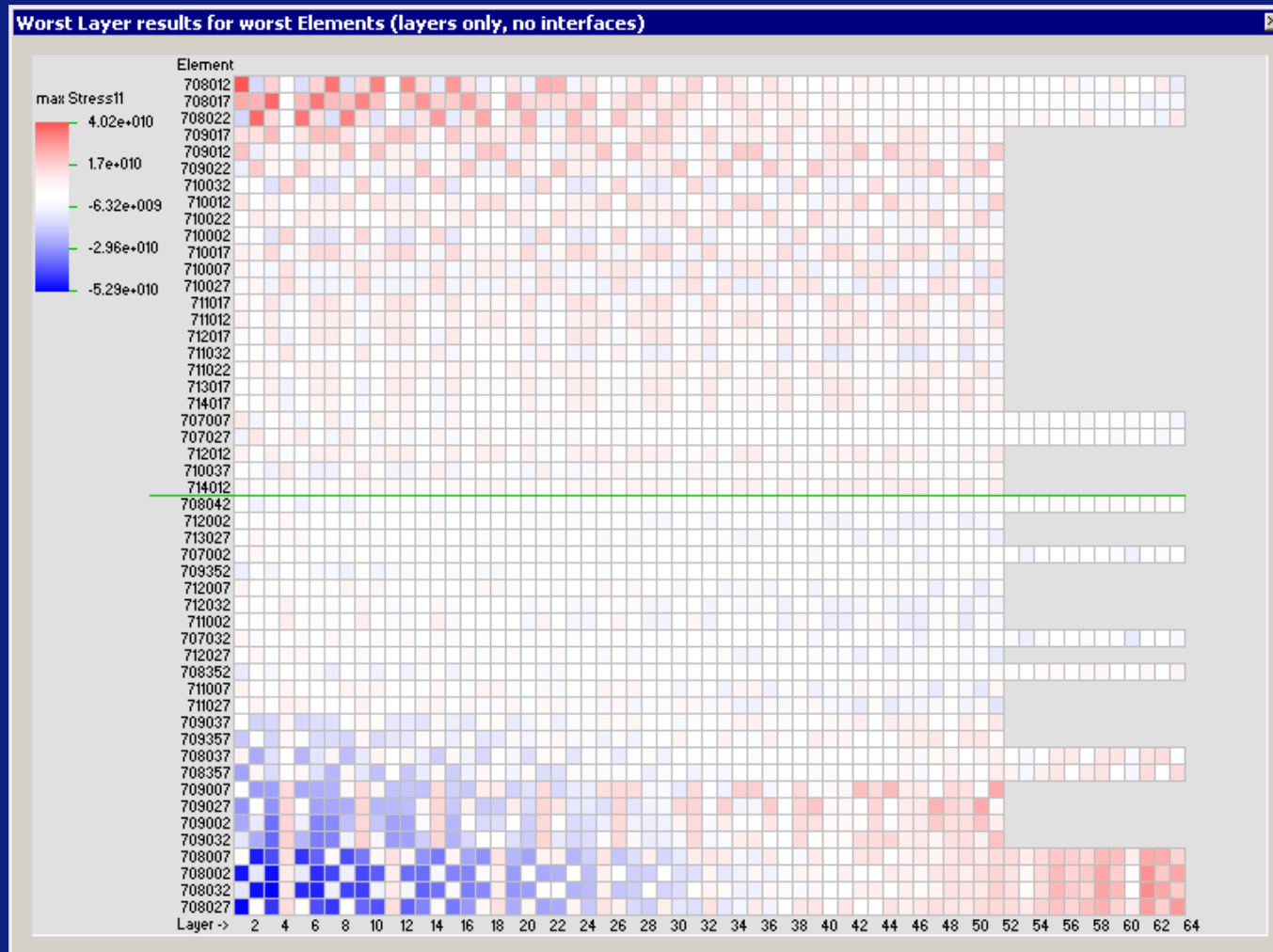
Requirements for pre- and post-processing

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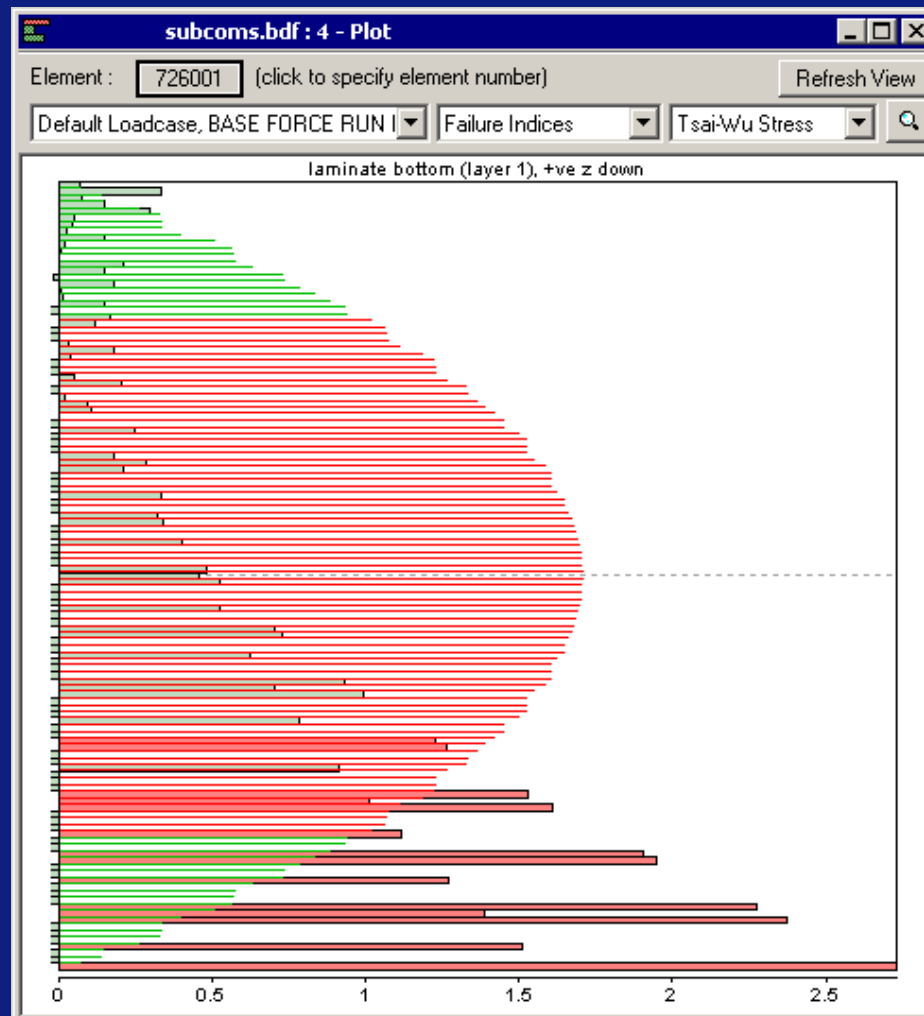
Requirements for pre- and post-processing

- obtain a **global** picture



Requirements for pre- and post-processing

- obtain a **global** picture



Requirements for pre- and post-processing

How do we fix any problems?

- understand the nature of the problem
- decide on a remedy (modify global ply coverage or orientation, add global ply, modify stacking sequence, change ply thickness or material, modify structural shape)
- try remedy using simple calculations or software
- apply remedy and re-run analysis.

Requirements for pre- and post-processing

CONCLUSIONS

- considerable time can be saved, and better results obtained, if we model global ply application prior to analysis
- visualisation of element laminates eliminates errors
- results processing must include tools to analyse, manipulate and present stresses and failure calculations from the layer level to the global ply level



Thank you