e-light, Work Package 4, Structural Dynamics Study

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GA No: 266284

e-light, BIW, CAE Study

- **WP4 Objective: CAE work conducted by Ricardo**

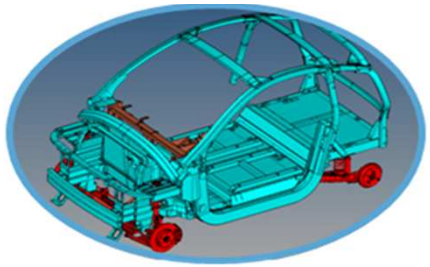
  To assess the behavior of BIW of e-light structure from static and dynamic performance point of view, to achieve class leading stiffness, durability and NVH performance while optimising the mass of CFRP components

- Crash assessments were also made to validate the design, however these were conducted by Cidaut

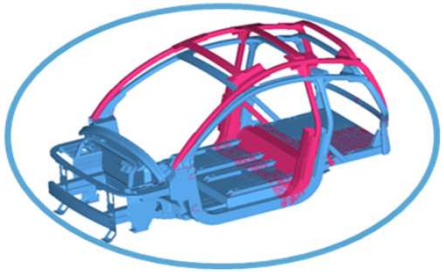
e-light, BIW, CAE Study

- Story of the design of e-light body structure – process overview

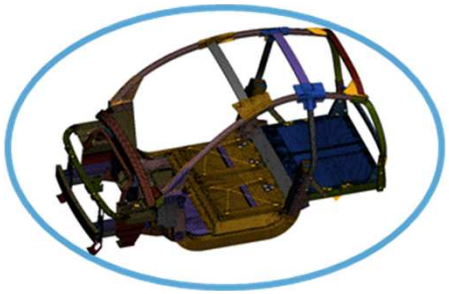
Pininfarina Nido Concept



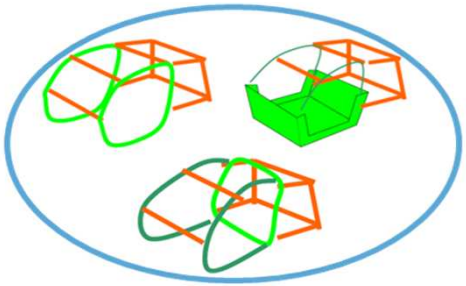
Nido size and package study



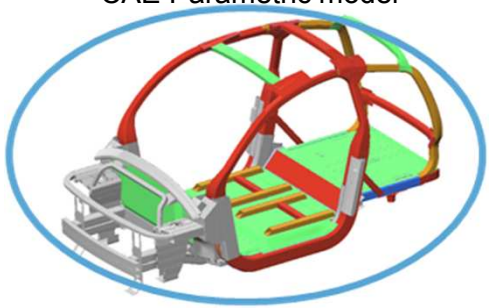
Target definition from resized Nido



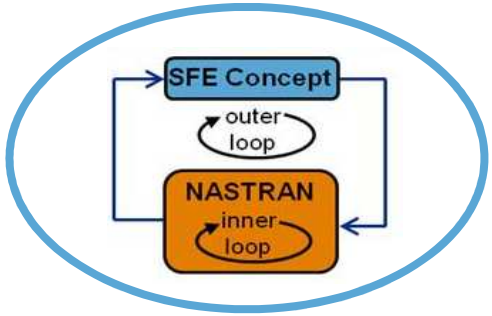
e-light concept exploration



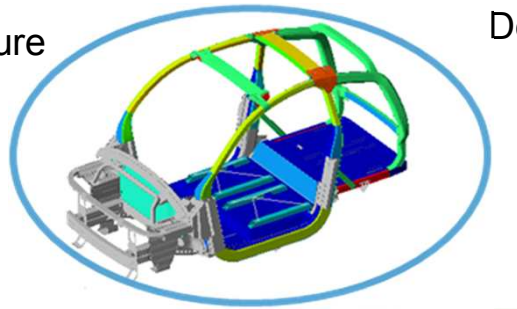
Initial e-light design
CAE Parametric model



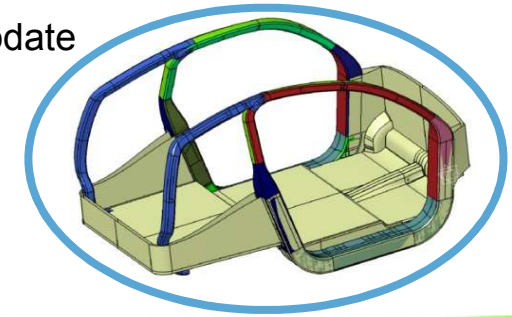
Structural Optimisation



Optimised CFRP structure

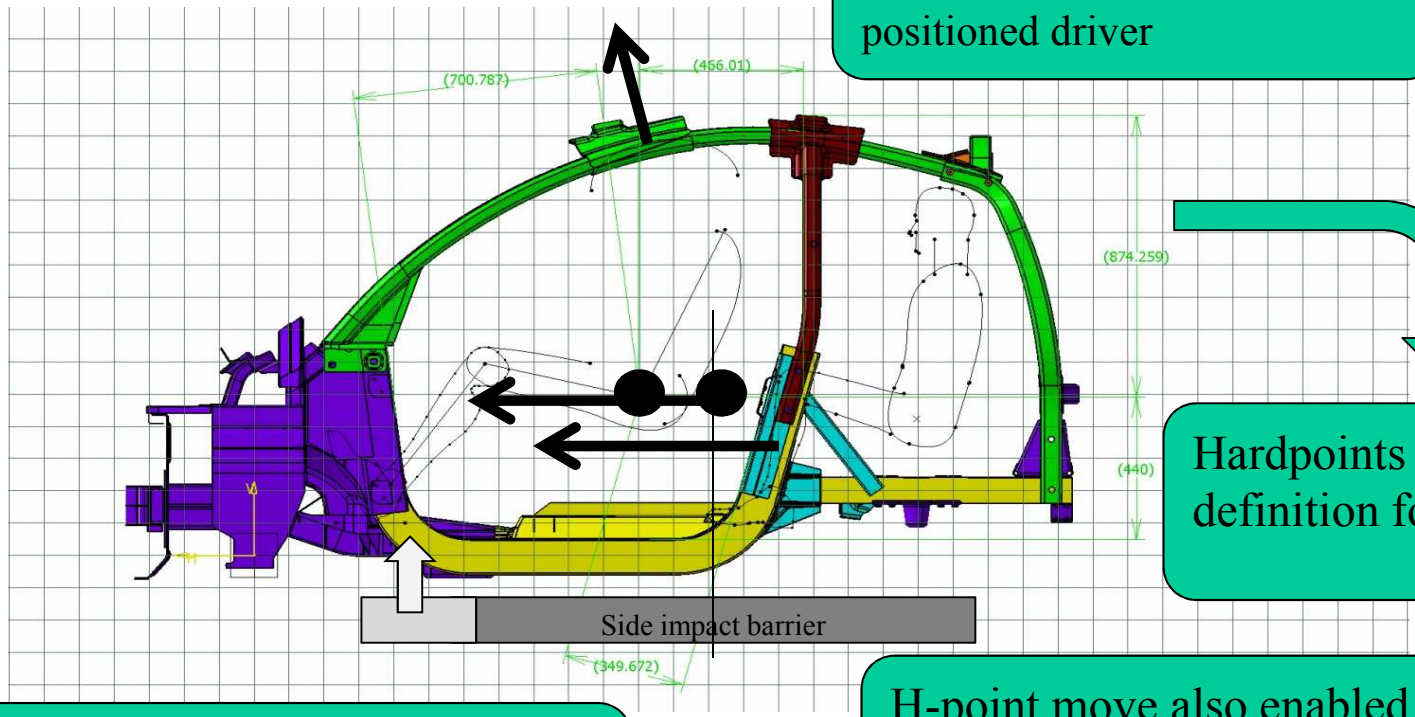


Design update



- **Nido package and size study**

Roof line increased to achieve head clearance with re-positioned driver



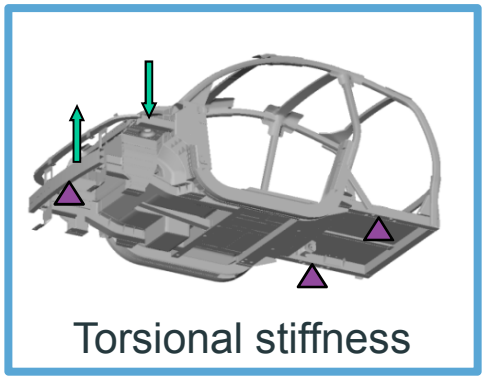
Hardpoints and a surface definition for e-light

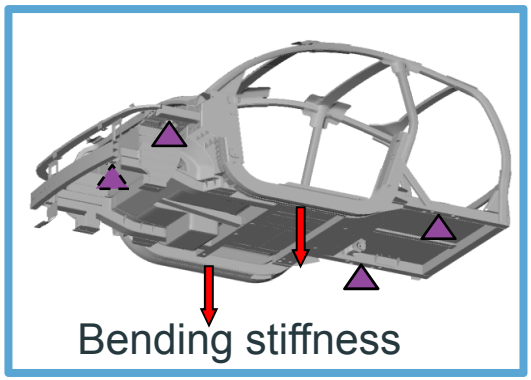
Driver H-point and b-pillar moved forwards to accomodate e-light requirement for 2+2 passengers

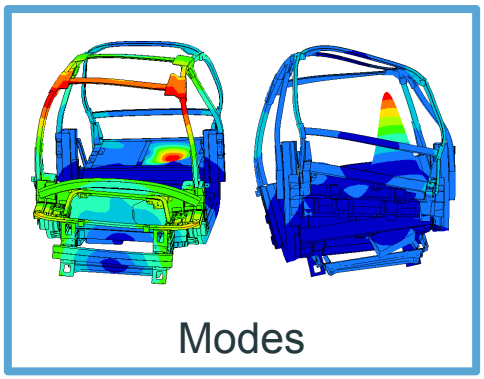
H-point move also enabled side impact barrier to contact a-pillar

- Definition of e-light structural targets from resized Nido

  - The Nido resized Model was benchmarked for all assessments
  - Static torsional and bending stiffness
  - First torsional modal frequency as a target for dynamic stiffness


Torsional stiffness


Bending stiffness


Modes

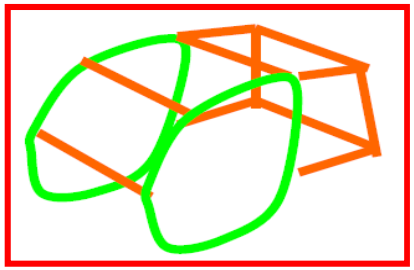
e-light structural performance targets

11.5kN/mm	8.8kN/mm	43.3Hz

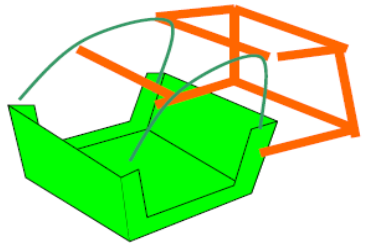
e-light, BIW, CAE Study

- e-light concept established through brainstorming and selection process

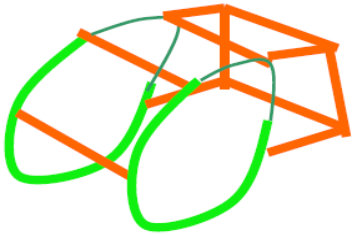
A) Door Ring



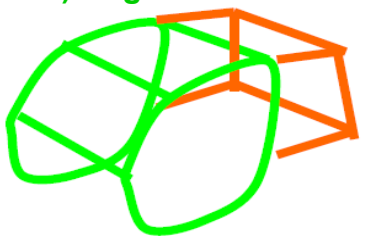
C) Half Monocoque



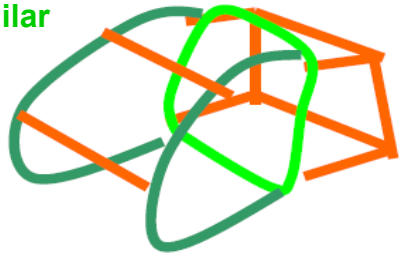
D) Open Ring



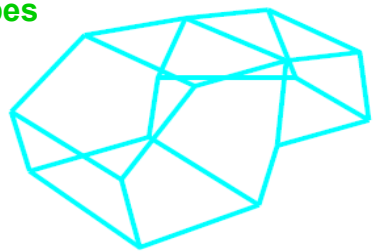
F) Cage



E) B-Pilar



G) Tubes



Concepts / ideas

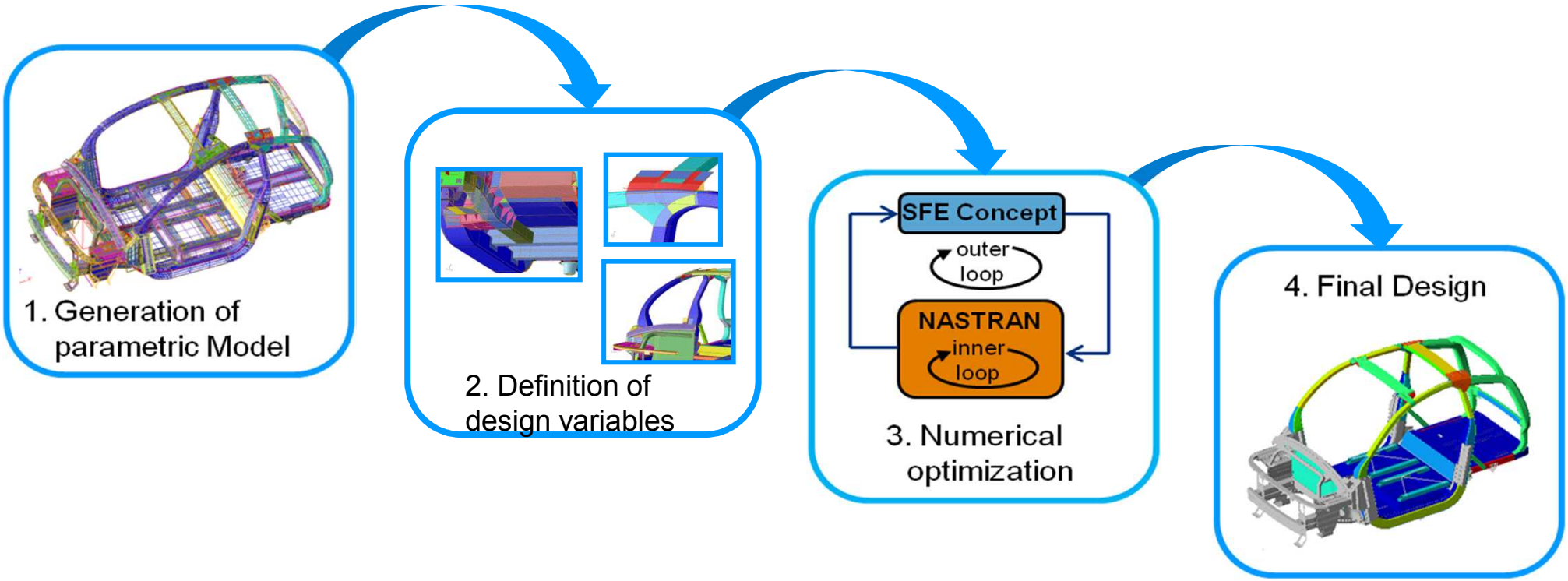
Criteria

Factor (1 to 5)	A	B	C	D	E	F	G	H
Weight	5	2	3	4	2	3	5	3	1
Manufacturing easiness	1	3	3	4	3	3	1	5	4
Side impact	3	5	3	3	3	4	5	1	4
Modularity	2	1	4	4	4	1	1	3	1
Front impact	1	3	2	2	2	3	4	3	3
Joining complexity	1	3	3	3	3	3	5	2	3
Robustness / damage tolerance	1	3	2	2	3	3	4	1	3
Torsional Stiffness	2	4	3	3	3	3	5	3	3
Bending stiffness	1	4	2	2	3	3	5	3	3
NVH	2	3	3	3	3	3	4	2	3
Costs	5	3	3	3	3	3	3	3	4
Life cycle CO2	1	3	3	3	3	3	3	3	3
Innovation	3	4	3	2	3	3	5	2	1
Technical risk	1	3	3	3	3	3	1	3	5
Scaleability	2	3	3	3	3	3	3	2	3
Total =	96	92	95	89	92	119	79	84
Std. Dev.=	4,5	4,4	5,1	3,7	4,5	6,8	4,2	4,7

Concept selection matrix

e-light, BIW, CAE Study

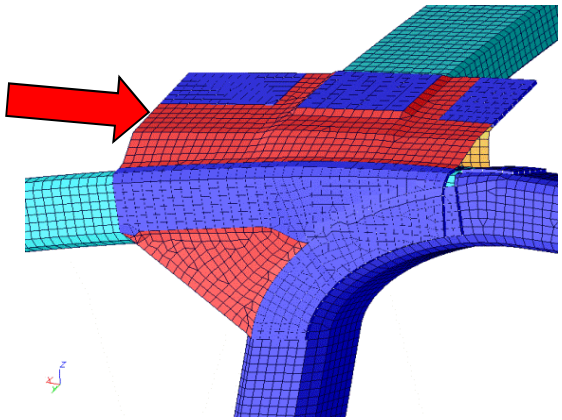
- Novel optimisation approach based on parametrically defined FE-model using software SFE Concept
  - Geometry optimised for cross-section shape, thickness and ply fibre orientation simultaneously
  - Objective to minimise mass and meet stiffness requirements
  - Automatic update of CAE model after each optimization run



e-light, BIW, CAE Study

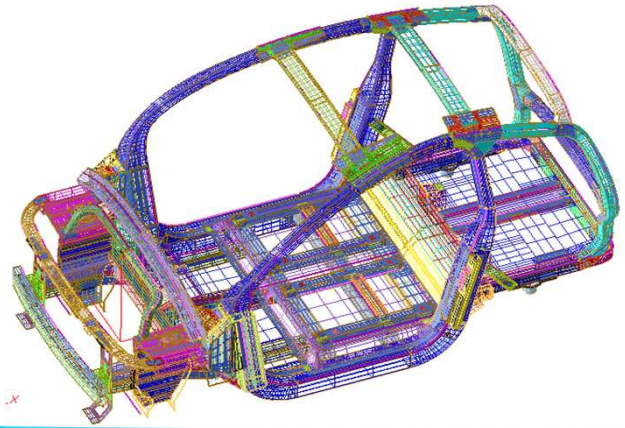
- Definition of design variables for optimisation
  - Parametric model defined to allow panel shape, size, position and section control
  - Entire e-light baseline model defined with parametric variables

SFE Concept, Official Demo
(Copyright © 2013 SFE GmbH)

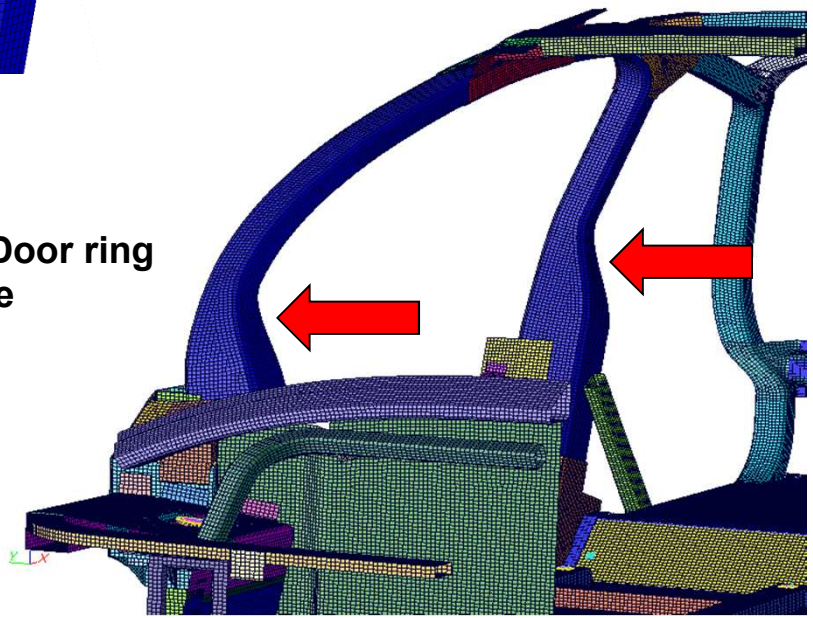


Bracket-post example

e-light, BIW, Parametric Model



e-light Door ring example

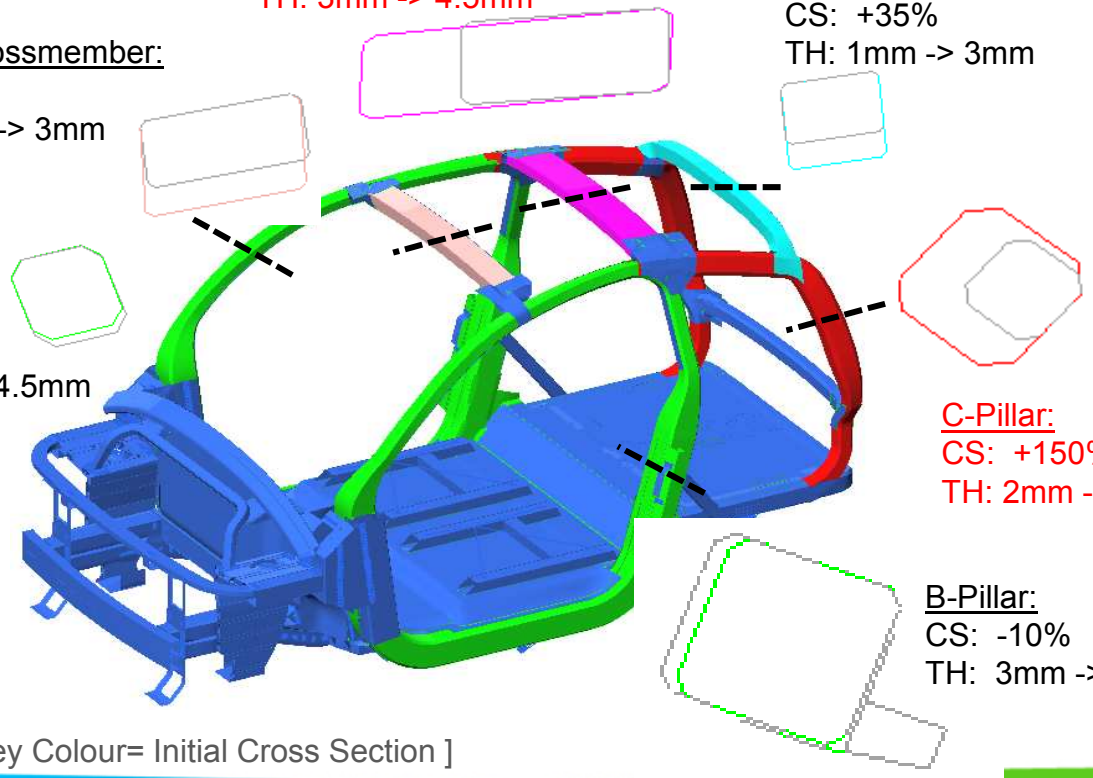


- Summary of optimisation output
  - Change of cross sections (CS) combined with change of thickness (TH) of main components after numerical optimization
  - Ply thickness and orientation output shown for one panel

Top Middle Crossmember:
CS: +60%
TH: 3mm -> 4.5mm

Top Rear Crossmember:
CS: +35%
TH: 1mm -> 3mm

Top Fr. Crossmember:
CS: +40%
TH: 1mm -> 3mm



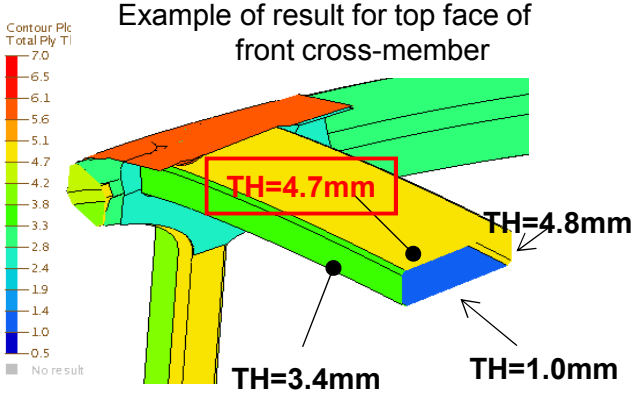
A-Pillar:
CS: -10%
TH: 3mm -> 4.5mm

C-Pillar:
CS: +150%
TH: 2mm -> 3mm

B-Pillar:
CS: -10%
TH: 3mm -> 3mm

[Grey Colour= Initial Cross Section]

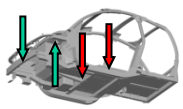
Example of result for top face of front cross-member

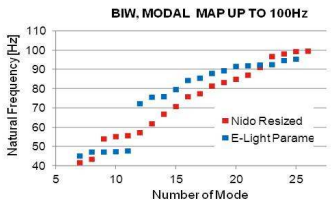


Layer no.	Thickness Initial [mm]	Thickness Optim.[mm]	Fibers [DEG]	Fibers Optim. [DEG]
1	0.25	0.6	≡≡≡ 0°	3
2	0.25	0.54	////// 45°	30
3	0.25	0.06	||||| 90°	105
4	0.25	0.54	\\\\\\ -45°	-30
5	0.25	0.06	|||||	-75
6	0.25	0.6	≡≡≡	3
7	0.25	0.6	≡≡≡	3
8	0.25	0.06	|||||	-105
9	0.25	0.54	\\\\\\	-30
10	0.25	0.06	|||||	105
11	0.25	0.54	//////	30
12	0.25	0.6	≡≡≡	3
Total	3.0	4.7	N/A	N/A

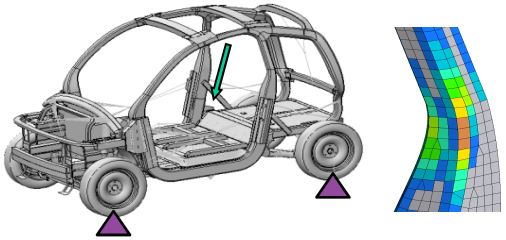
e-light, BIW, CAE Study

- Structural performance of optimized CFRP E-light structure
  - The final model was validated for all assessments
  - Static and dynamic stiffness of E-light structure increased
  - Inertance and VTF's generally consistent with benchmark model Nido
  - Durability performance acceptable

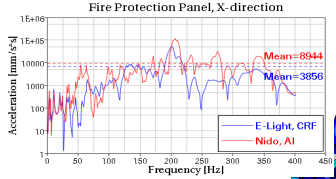


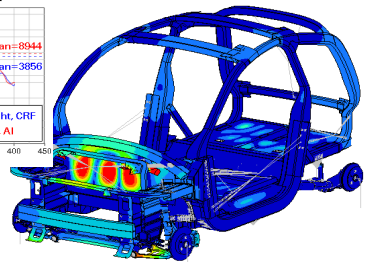


Stiffness: static bending and torsional and first torsional mode



Durability: body loads applied to assess durability of lamina & bonding





VTFs: wheel to cabin panel response assessed to understand likely interior noise

e-light structural performance generally better in comparison to benchmark Nido

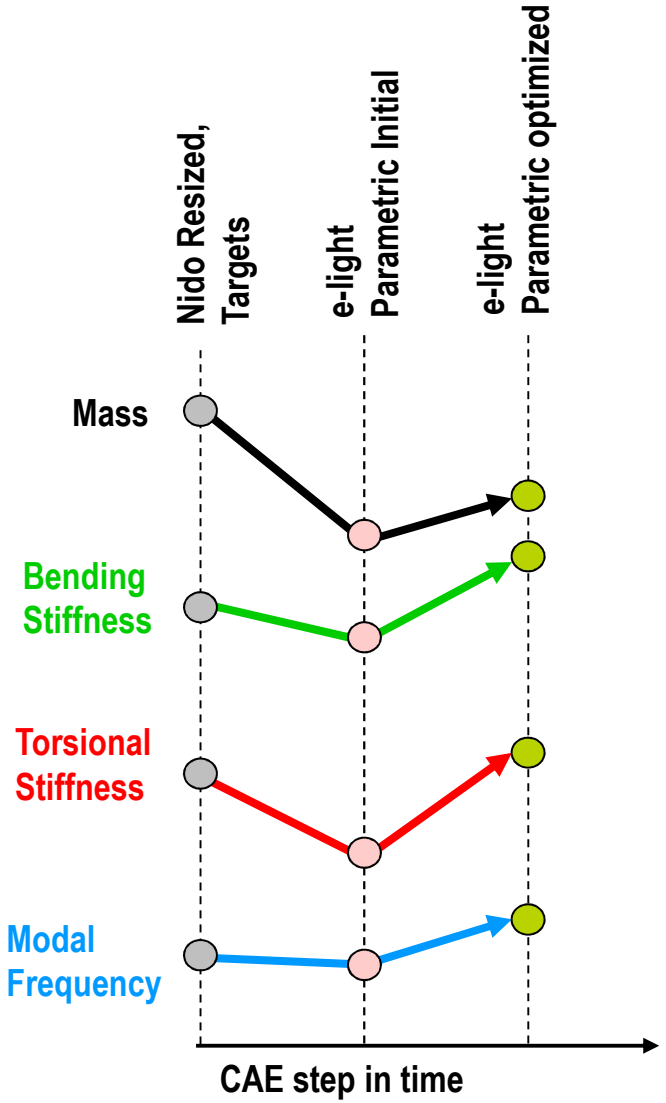
Stiffness:
- bending … increase 7%
- torsion … increase 12%
- 1st frequency …increase 4%

Failure index <<1.0

Generally consistent with benchmark model

- Summary of results
  - 32% reduction in mass
  - Improved static stiffness and modal performance
  - Durability performance maintained, worst case result in interlaminar bonding gives good safety factor of 3.6
  - VTF results show lower overall responses in key panels indicating lower noise radiation into cabin

	Mass [kg]	Stiffness		1st Torsional Mode [Hz]
		Bending [kN/mm]	Torsion [kNm/DEG]	
Nido Pininfarina (Al-Baseline, Target)	**140.4**	**8.8**	**11.5**	**43.3**
e-light Parametric (THs initial)	**99.6** (-40%)	**8.1** (-8.6%)	**8.6** (-33.7%)	**42.8** (-1.1%)
e-light Parametric (THs optimized)	**106.1** (-32%)	**9.4** (+6.7%)	**12.1** (+5.2%)	**45.0** (+3.9%)



- Conclusion

  - A novel approach has been demonstrated to optimising CFRP lightweight body structures

  - The approach has delivered an attractive 32% weight saving through only optimizing the CFRP part of the BIW structure.

  - Body structural performance generally improved

THANK YOU FOR YOUR ATTENTION