# *Advanced composite materials: designing real cars with carbon fiber bodies today*

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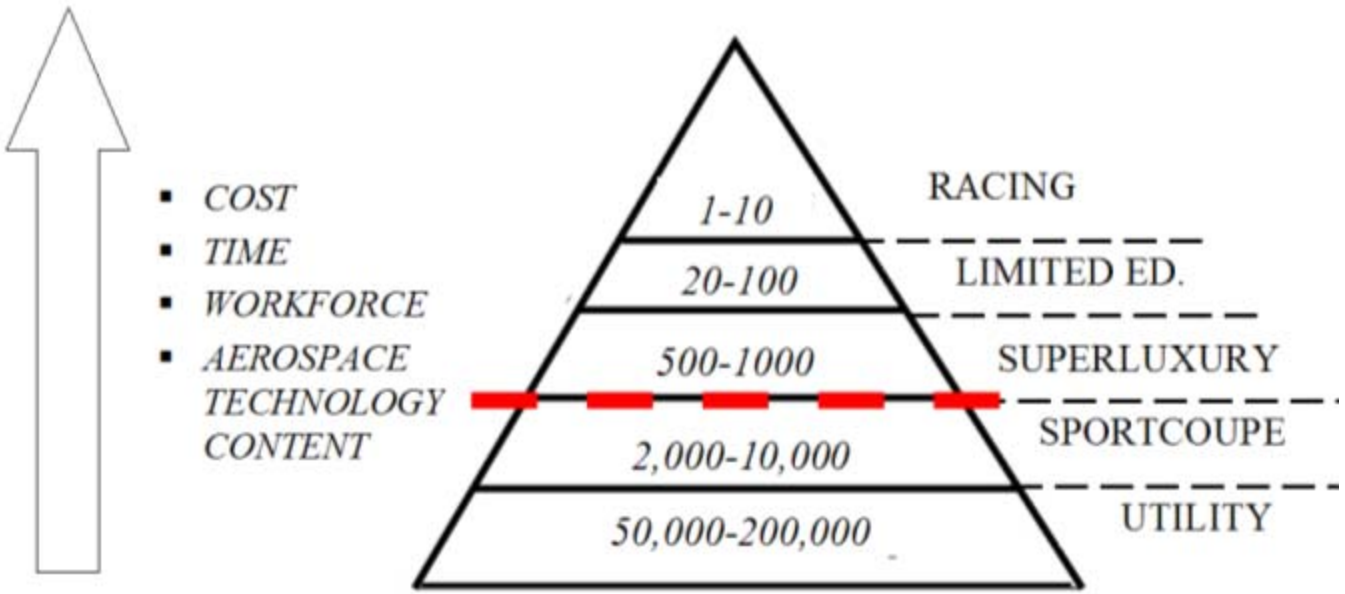
## Many different composites

- Superluxury industry vs. mass automotive — Volume issue
- Structural composites vs. body panels — Structures issue



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**Reasons for accident fatality:**

- Contusion.
- Excessive deceleration.
- Fire and smoke.

**Conditions for survivability – a systems approach:**

1. maintaining sufficient occupant space
2. providing adequate occupant restraint
3. employing energy-absorbing devices
4. and allowing for a safe post-crash egress from the craft.



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**CFRP monocoque:**

- Expensive material & process deriving from racecar technology and suitable for limited production
- Designed to provide undeformable, survivable space: operates mostly in linear-elastic range
- Prepreg technology (autoclave and vacuum bag)
- 24K tow fabric (2x2 twill) with toughened epoxy



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**CFRP monocoque but metallic crash-box:**

- Ferrari Enzo (Ferrari F50, Maserati MC12)
- Bugatti Veyron
- Porsche Carrera GT
- Mclaren F1
- Pagani Zonda



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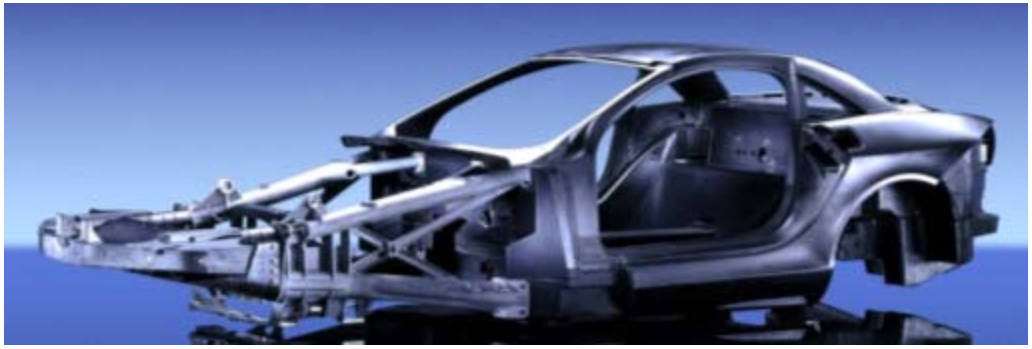
**Mercedes/ Mclaren SLR composite technologies:**

- 3.5 BIW per day/ 700 vehicles per year/ Total production 3000 vehicles
- Upper safety cell (Roof structure) – RTM
- Quarter panels (body panels) - Low density Advanced SMC
- Tub (passenger compartment) – RFI
- Most body panels (hood, rear, etc.) - Liquid infusion
- XMC (CF molding compounds) - Rear lid
- Doors - Carbon Fiber Prepreg with steel intrusion beam
- Crash box (2 cones) – braided preforms for RTM infusion





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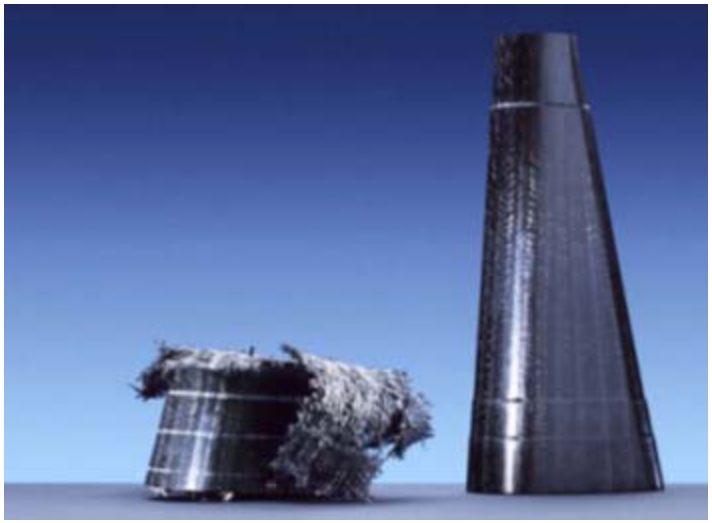
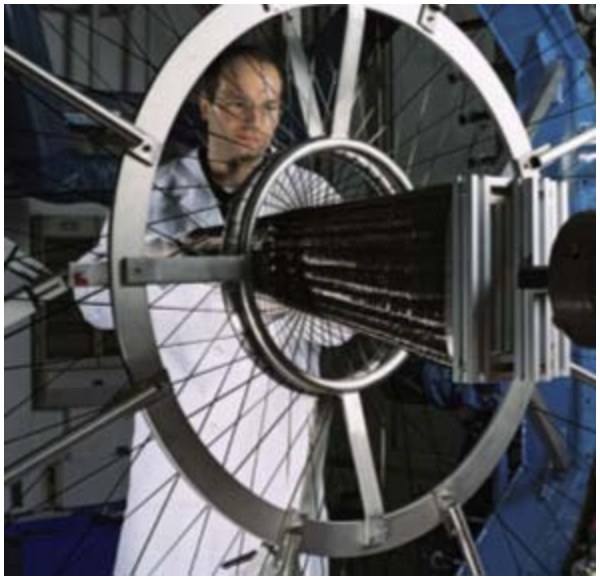
**Front crash-box on the Mercedes / McLaren SLR:**

- Weigh 7.5 lbs each
- Triaxial CF braids that are RTM
- Transverse prepreg member distributes load across the cones







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## And it works….



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**Lamborghini Murcièlago-follower:**

- CFRP Monocoque
- Metallic front and rear frames



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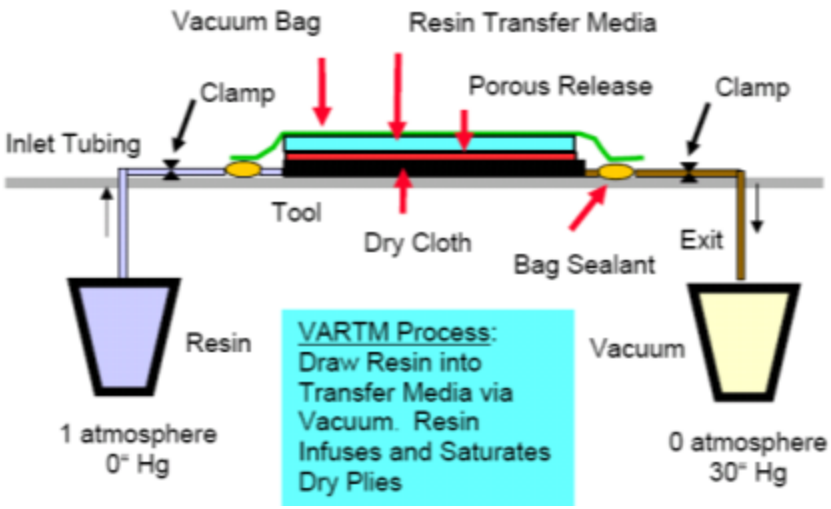
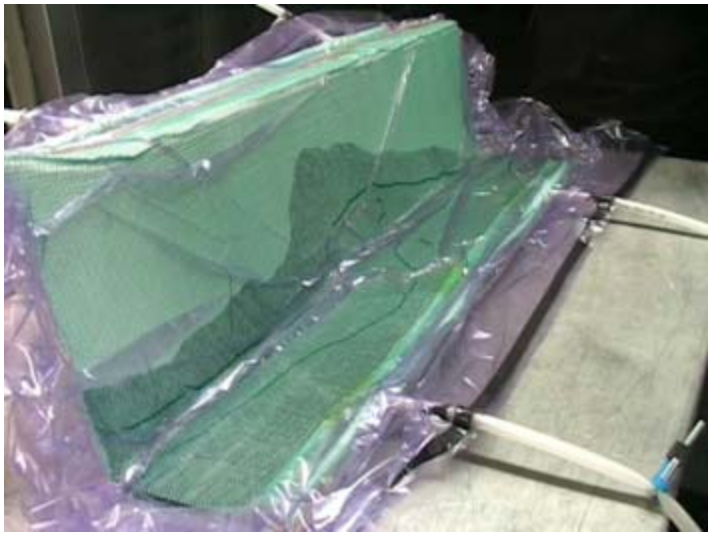
**Lamborghini Murcièlago-follower:**

- VaRTM and RTM-light technologies
- Liquid resin infusion/ injection
- Lower material costs, but even lower processing costs





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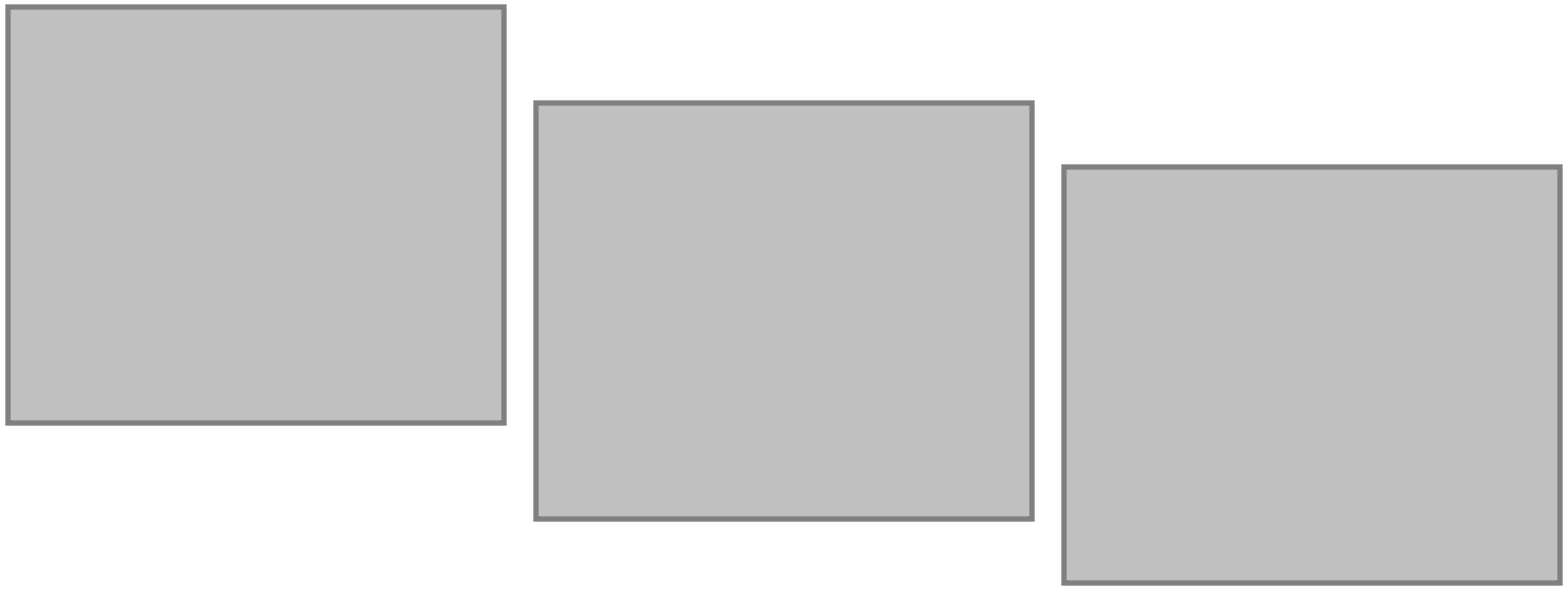
**Lamborghini Murcièlago-follower:**

- Evolving FMVSS requirements impose advances in technology
- New 214 SS pole-impact test very stringent requirements on monocoque
- Previous 214 tests were less severe on the monocoque
- All CFRP monocoques of existing supercars to date were not certified by this test: need to design monocoque for CFRP crashworthiness





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**Lamborghini Murcièlago-follower:**

- Advanced Progressive failure analysis:
- Building block philosophy: from coupon to full-scale vehicle
- Design and test for energy absorption
- Partnership of automotive with aerospace: UW and Boeing



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**Problems unique to composites**

- Composites are anisotropic
  - However lamination theory predicts well elastic response
- Composites are non-homogeneous
  - No accepted failure criteria!!
  - Damage progression is not self-similar
  - Difficulty modeling post-elastic behavior
- Scaling issues
  - Coupon to component differences
  - Macroscopic effects associated with length-scale of reinforcement



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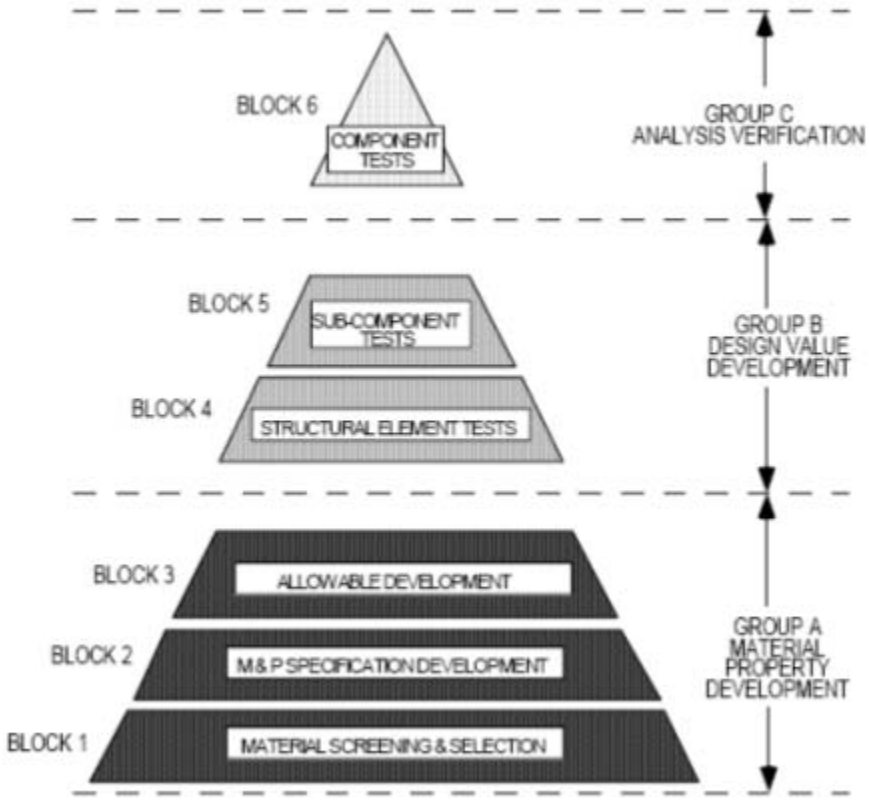
## Building Block Approach

- As per CMH-17 (former MIL-HDBK-17) Volume 3
- Lead in to Prof. Lagace's presentation



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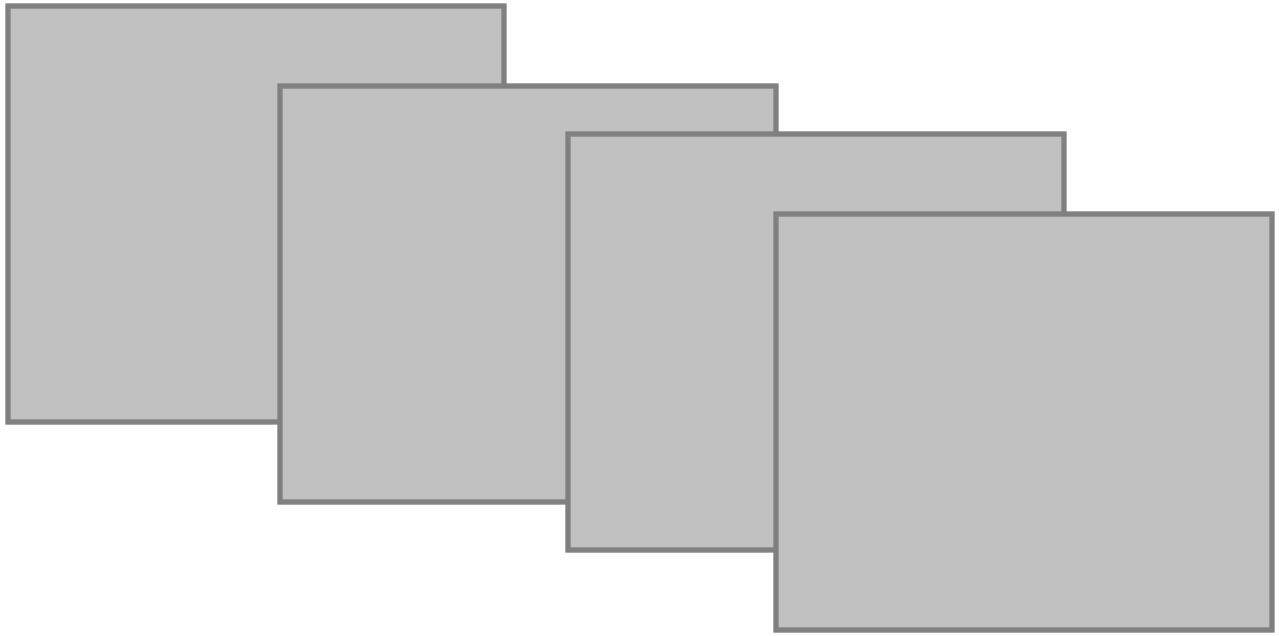
**Boeing 787 first CFRP crushable subfloor**

- Certification by analysis supported by test evidence (Standard FAA FAR Part 25)
- Aerospace building block approach needed





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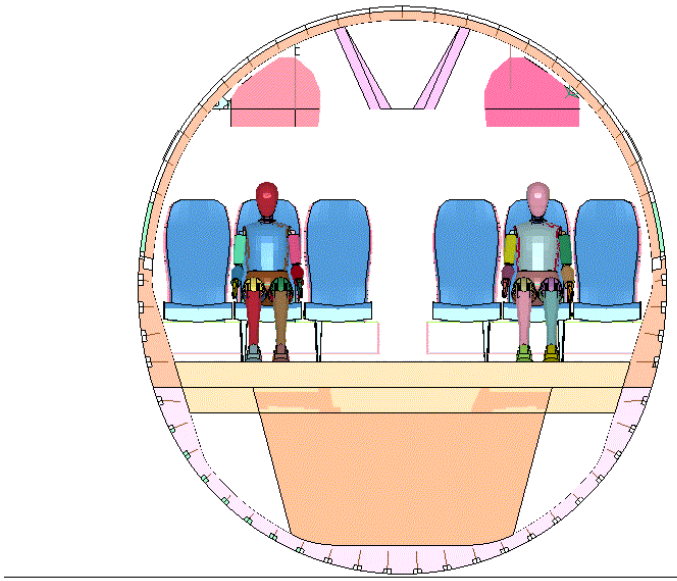
## Airframe fuselage section drop test

- 20+ ft/sec or ~15 mph





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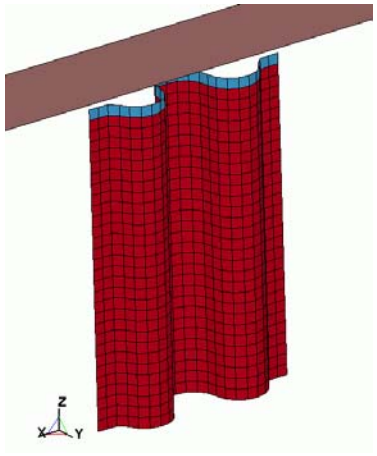
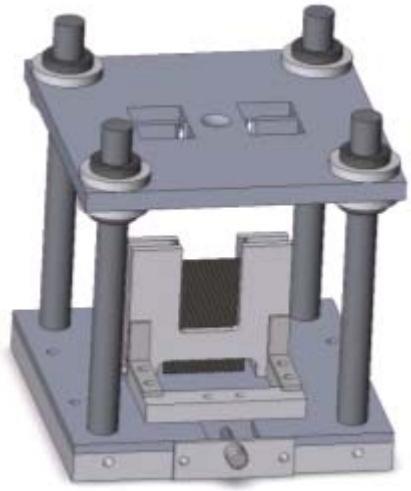
## Current needs

- Need for specialized test standards
- Need for suitable analysis tools and guidelines
- Need for lower-cost materials and processes
- Need for shared databases







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**CMH-17 (former MIL-HDBK-17) effort**

- Crashworthiness Working Group founded in March 2004
  - Current Chaired in conjunction with Mostafa Rassaian (Boeing Phantom Works) and Xinran Xiao (General Motors)
- Currently funded by FAA through Joint Advanced Materials Structures (JAMS) Center of Excellence at UW
- Develop coupon level test standard for crushing composite structures
  - Self-supporting specimen, possibly not tubular
- Review state-of-the-art FEA modelling practices and develop guidelines
  - Several approaches are phenomenological or otherwise semi-empirical
  - While waiting for truly predictive FEA tools, need to develop sensitivity about the effectiveness of the current crashworthiness modelling strategies



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**Concluding remarks**

- CFRP crashworthiness is a young field
- Composite education needs to increase at all levels
- Research in this field needs to be fostered
- Need for standardization and guidelines


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