



# **A Novel Solution for Achieving Lightweight, Safe Vehicle Structures Through Composites**

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**Paul Sills**  
**Lotus Engineering**

**ARB Symposium**  
**Greenhouse Gas Reduction**  
**Sacramento, California**  
**April 21, 2008**

# An illustrious history .....

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Colin Chapman's philosophies are Lotus' Values:

- Performance through lightweight
- Fun to drive
- Great ride and handling
- Innovation

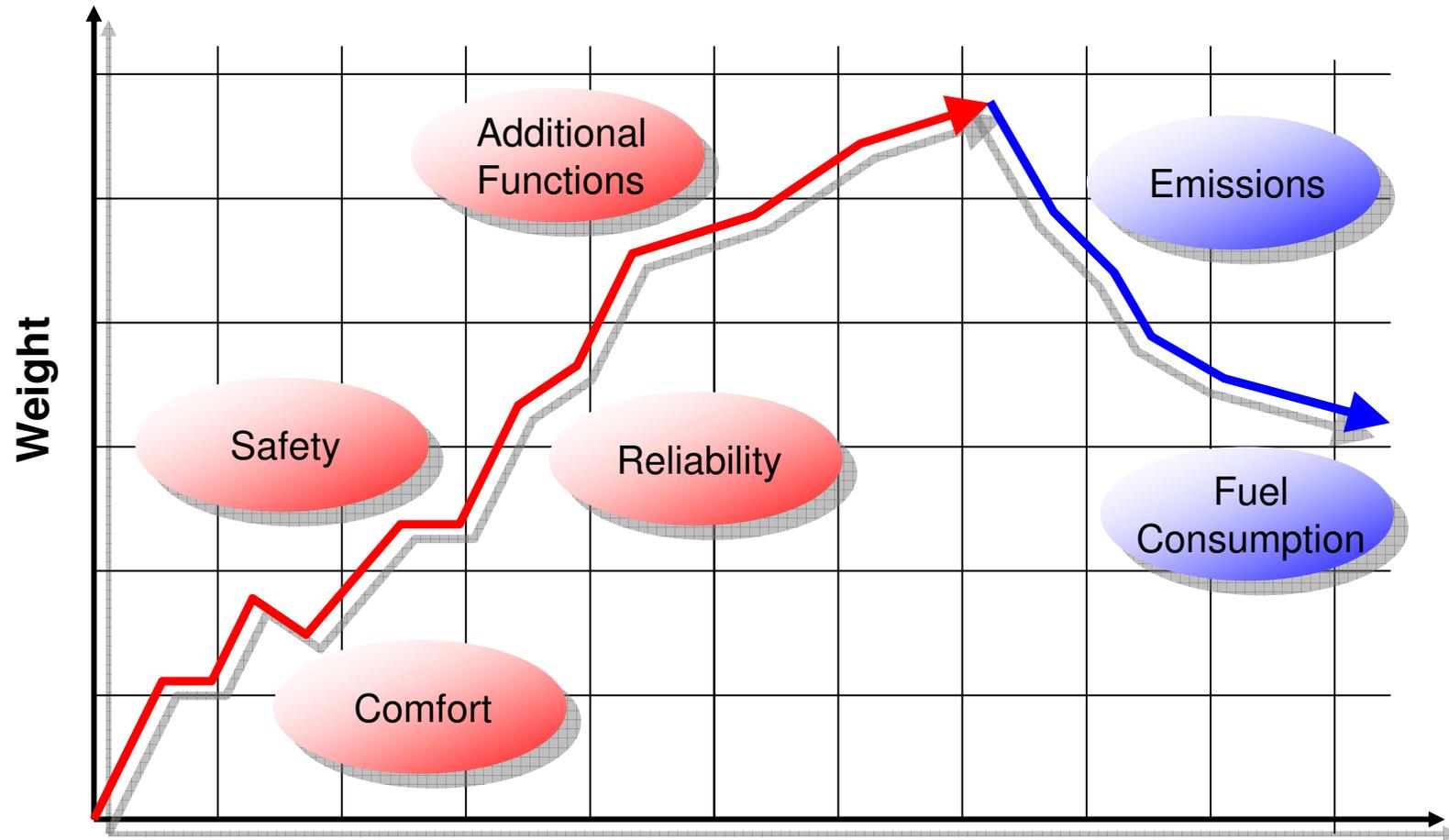


**“The most elegantly effective and traditionally Lotus solution is the one with the least number of parts, effectively deployed”.**

Colin Chapman 1975

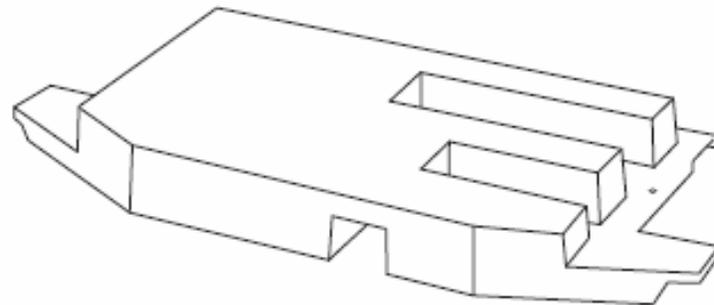


# Automotive Drivers – Weight



# Energy Absorption Using Composites

- Lotus have been developing composite crash structures over several years for both Lotus and Client Projects.
- Starting from observations on the behavior of the Esprit front end structure, which was not specifically designed with crash in mind, and its ability to absorb energy, (Circa 1976) the benefits of a specifically designed composite crash structure became evident.



# Crash Structure Development

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94      96      98      00      02      04      06      08

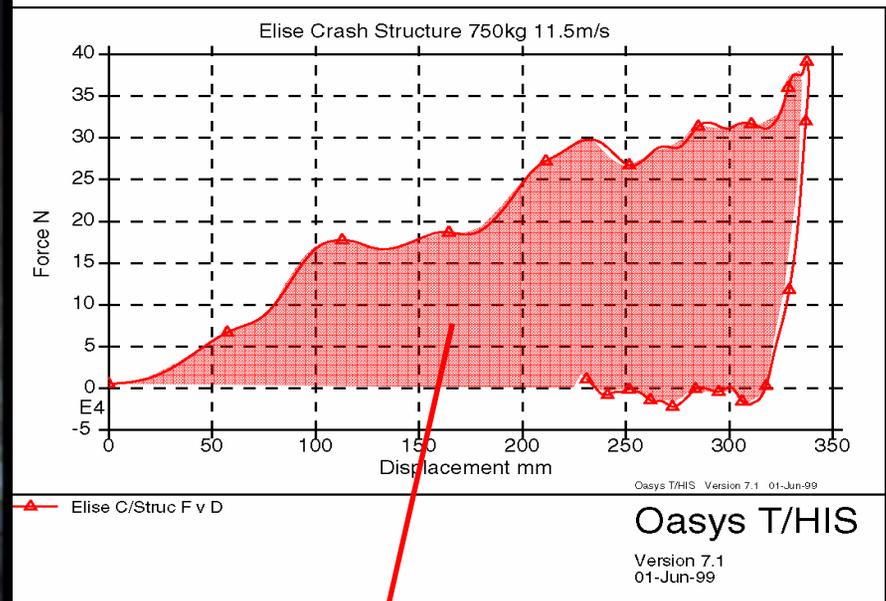
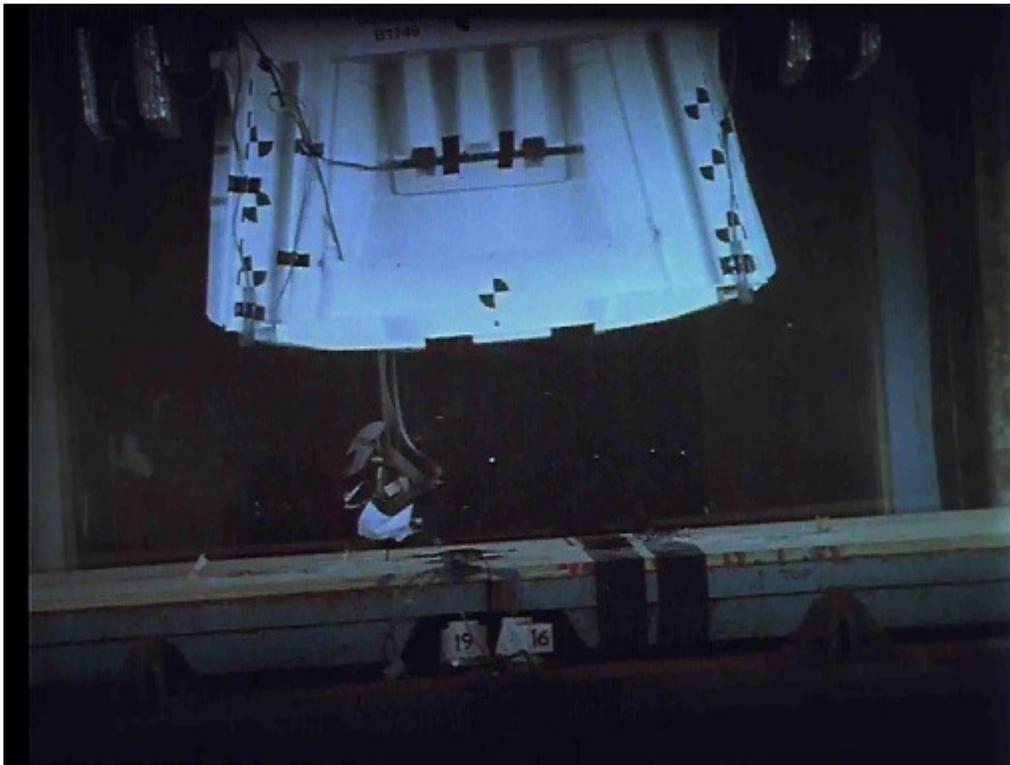


**RTM Thermoset Part**  
**16.5 lb**  
**5-10k units per year**

**Lotus**  
**Elise**



# Elise Crash Structure Test



Energy dissipation of  
up to 75 kJ

# Crash Structure Development



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**Lotus  
Elise**

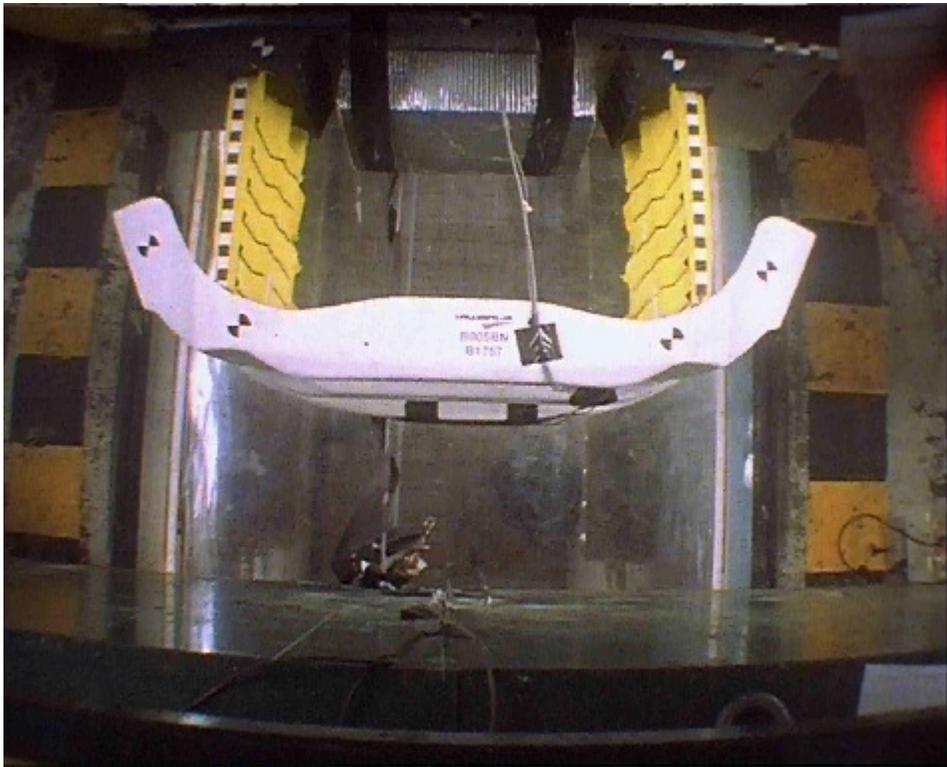


**AML  
Vanquish**

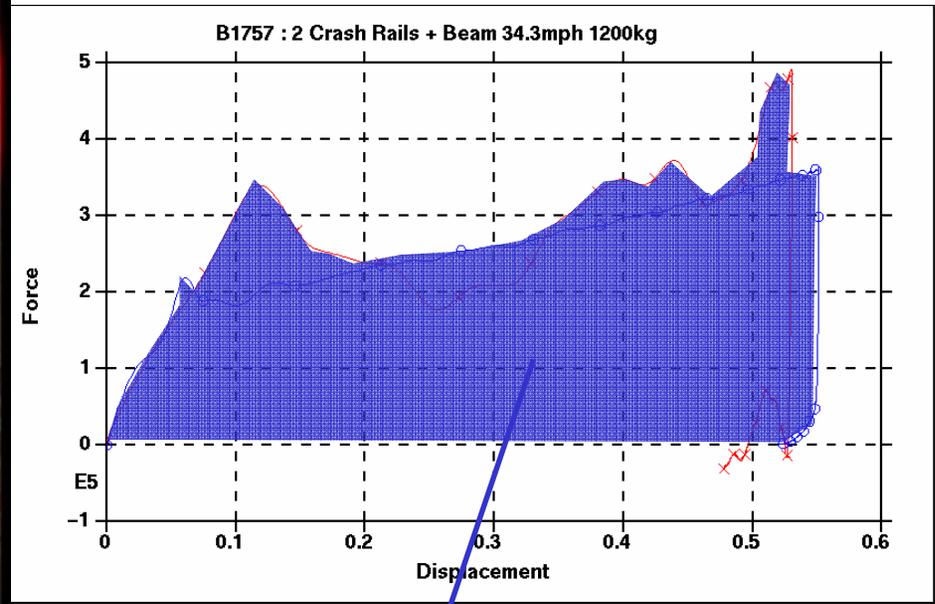
**RTM Thermoset Part  
49.6 lb  
500-1000 units per year**



# AML Vanquish Crash Structure Test



Rails and Bumper Beam Assembly for Federal and European Markets



Energy dissipation of up to 140 kJ

# Crash Structure Development



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**Lotus  
Elise**



**AML  
Vanquish**



**BMW  
M3**

**PA6GF Thermoplastic Parts  
6.8 lb (each)  
20k units per year (each)**



# Ecolite – Thermoplastic Crash Structure

**Lotus Elise**



High speed crash management

**Thermoset Composite**

**AML Vanquish**



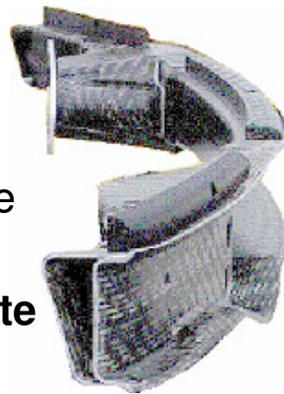
High speed crash management.

**Thermoset Composite**

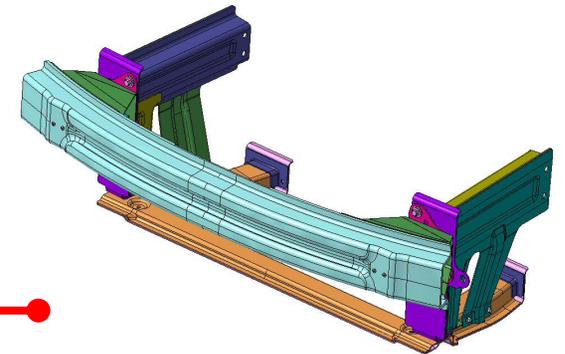
**BMW M3**

Low speed crash management. Recyclable solution

**Thermoplastic Composite**



**Ecolite Structure**



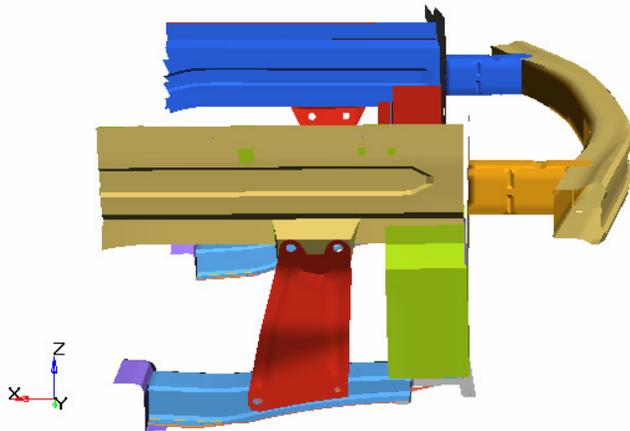
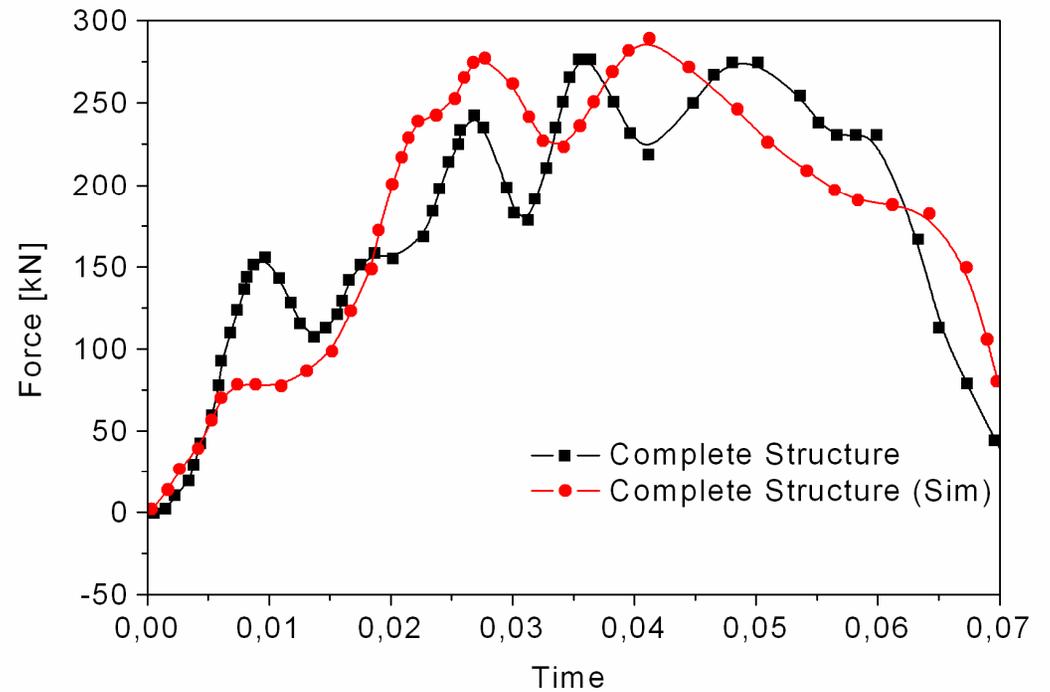
Complete integration of low and high speed crash management, in a single recyclable module for world car requirements

**Thermoplastic Composite**

# Serial Metallic Front End Structure



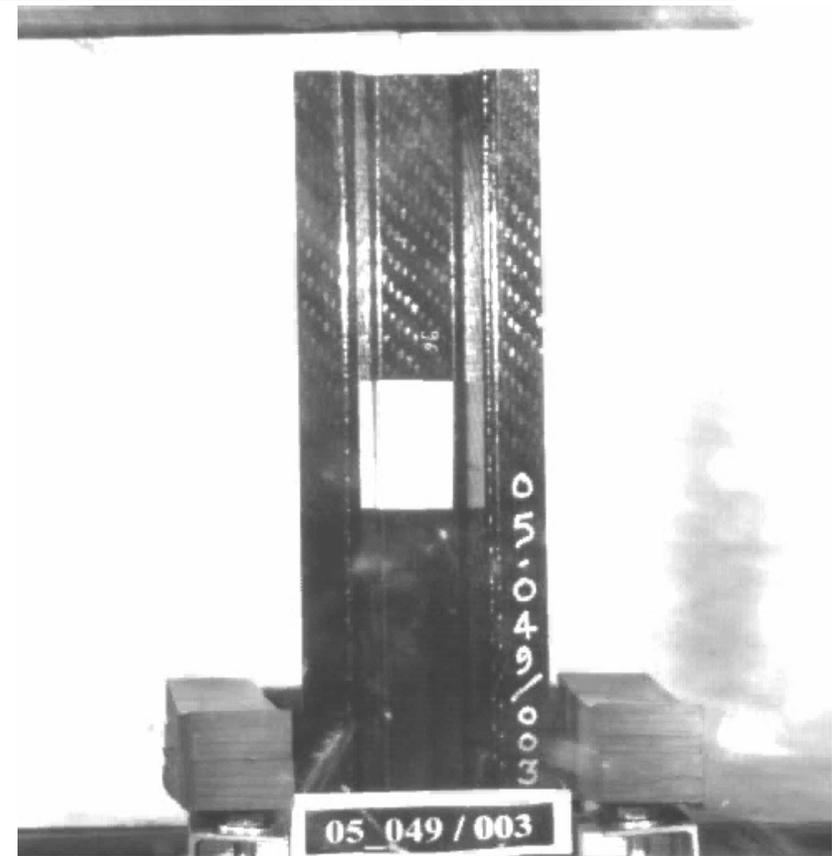
m = 49.6 lb



# Rails – Thermoset vs. Thermoplastic

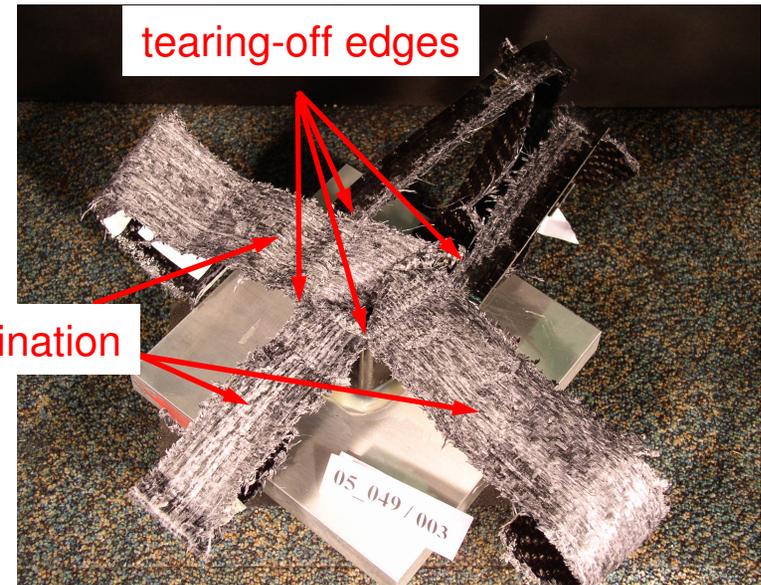
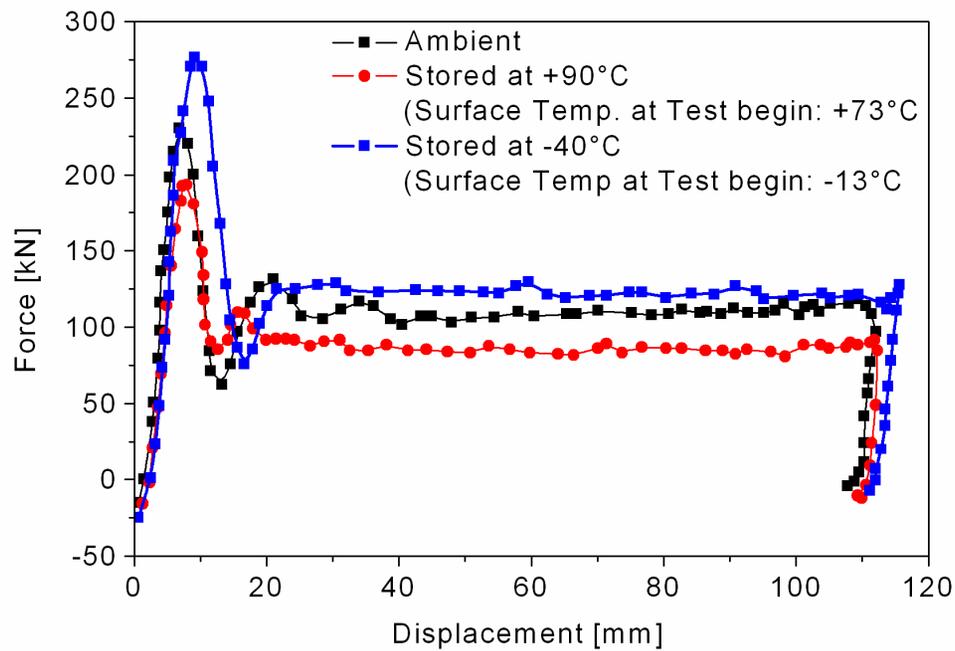


Thermoset  
Epoxy and Carbon (vf 45%)  
>70J/g  
(this impact @ 19kJ)



Thermoplastic  
PA6 and Glass (vf 45%)  
>55J/g  
(this impact @ 19kJ)

# Thermoplastic Rail Failure

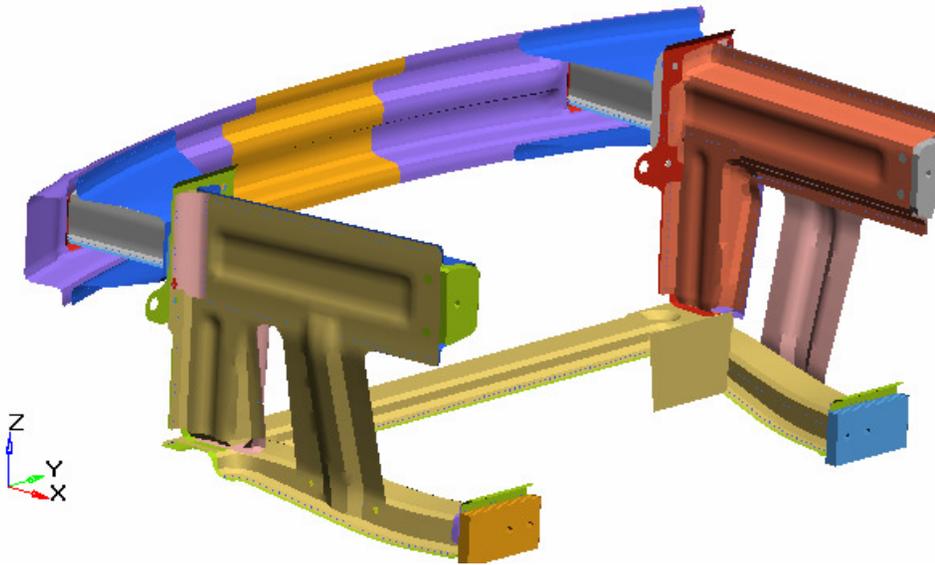


# Components in High Speed Impact

Component	Process	Section	SEA (J/g)
Aluminium 6063 T7	Extrusion	Tube	15 – 20
Glass / Polyester	RTM	Rail	25 – 40
Carbon / Epoxy	RTM	Rail	35 – 80
Glass / Polyamide 6	Thermoformed	Rail	35 - 55



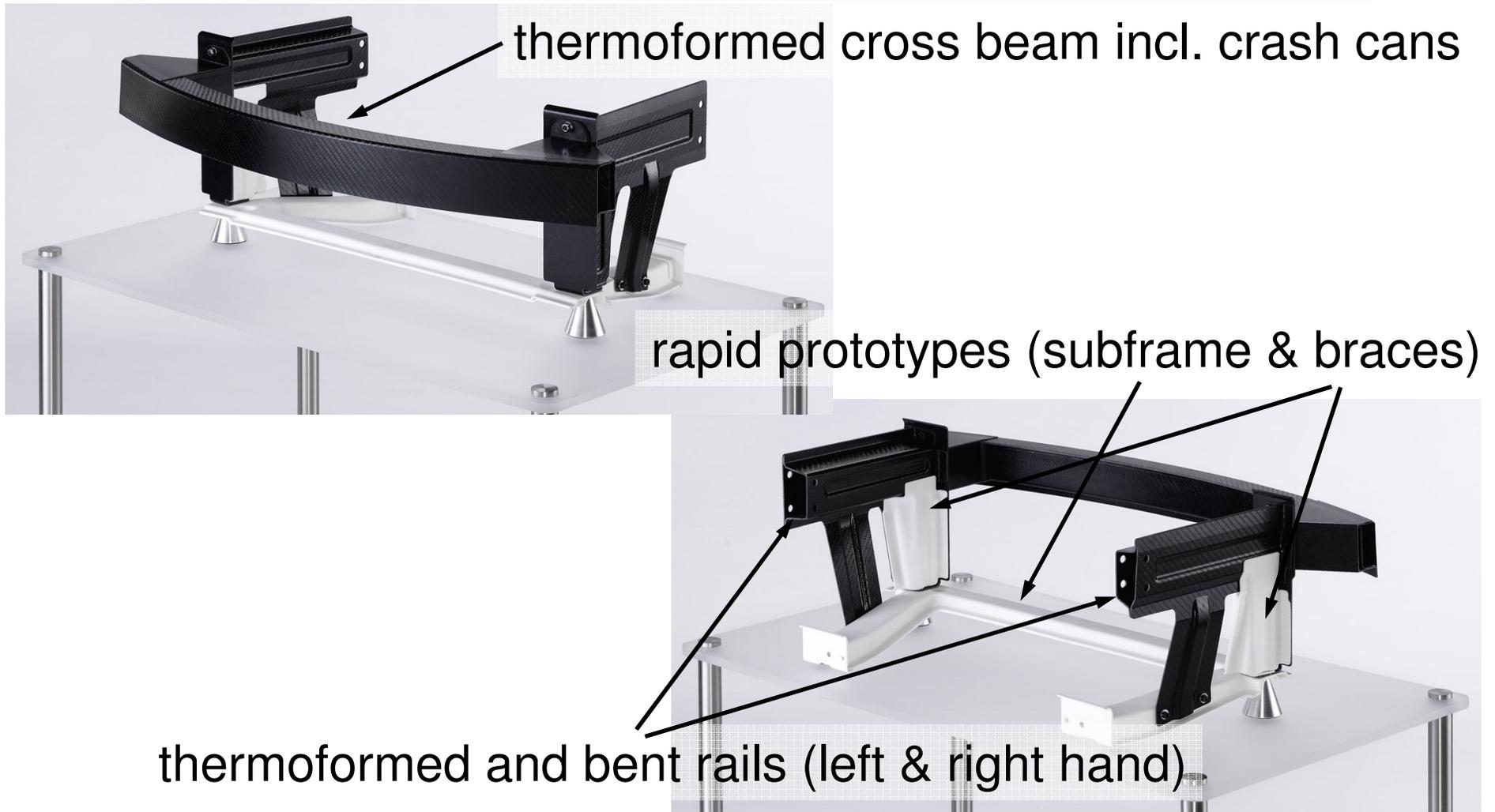
# Ecolite Front End Structure Design



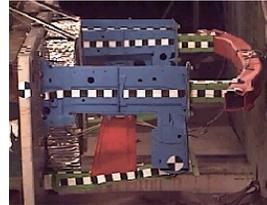
- Non-optimized Ecolite Thermoplastic / Glass Structure = 16kg
- Serial steel structure = 49.6 lb

- Optimization of design to reduce part count
  - Co-molded parts (open rib sections)
  - Removal of subframe (optimize Rail performance)
  - Part simplification (greater use of symmetry)
  - Use of flat sheet for closures
  - Gauge reduction and layup development
- Possible Hybrid solution
  - Aluminium bumper
  - use of polypropylene with steel reinforcement

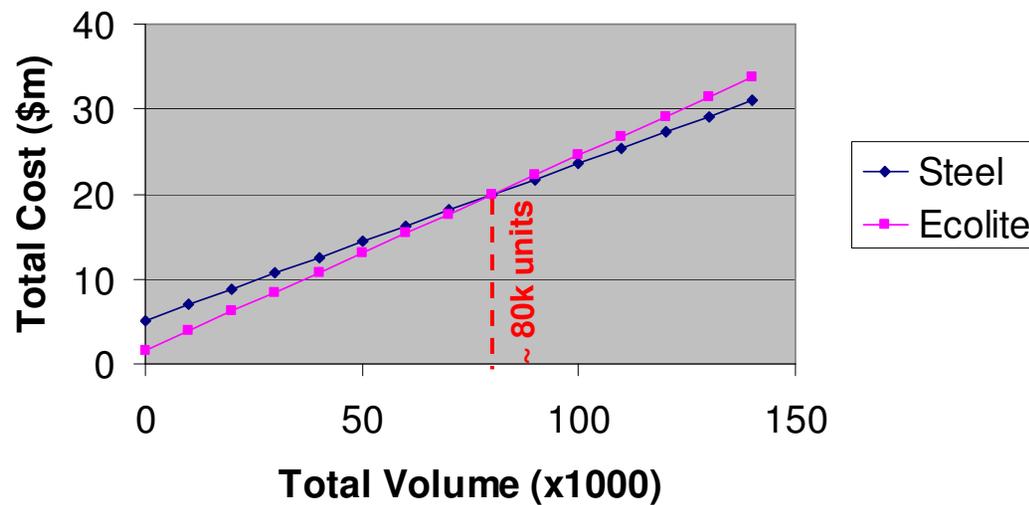
# Ecolite Front End Structure Design



# Ecolite Structure Costs

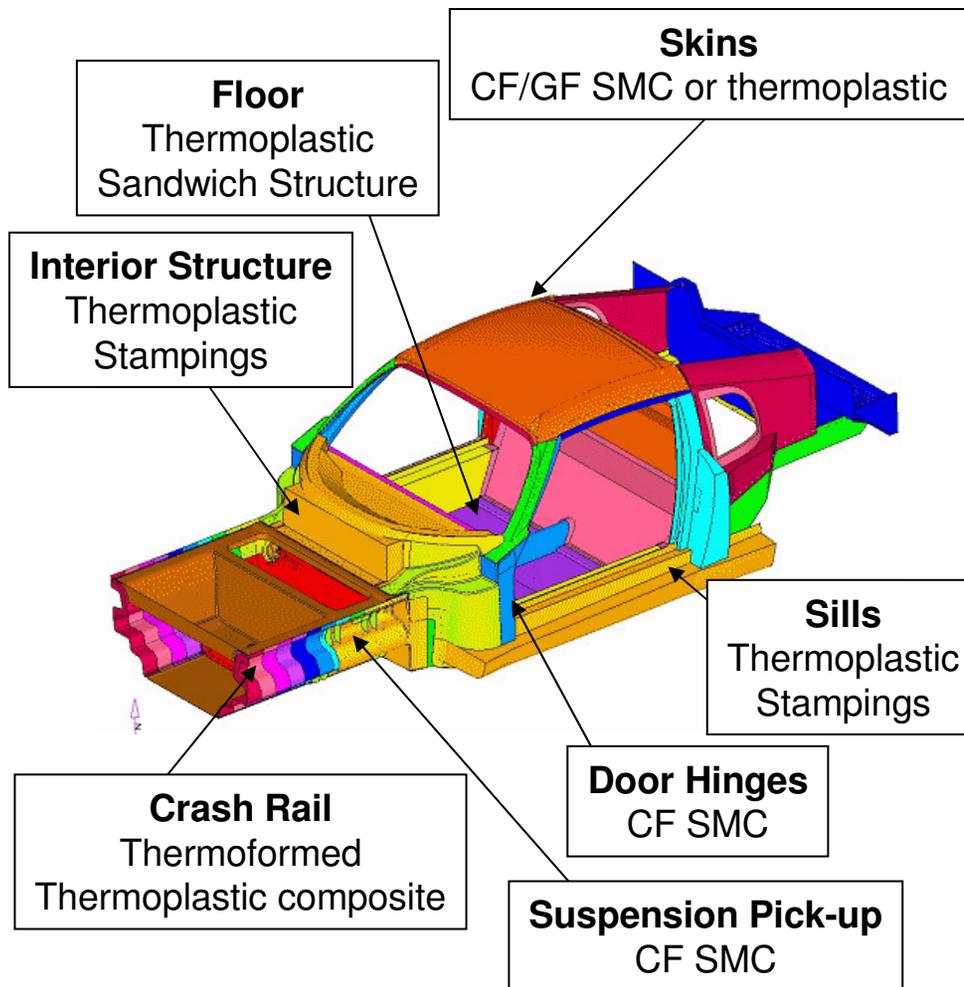


	Steel	Optimised Ecolite
Assembly Cost (\$)	185	229
Investment (\$m)	5.10	1.60



# Composite Intensive Car

## Architecture / Concept



## Programme

- Collaborative Research Programme.
- To fully evaluate the technical, economic and environmental performance of the vehicle under in-service conditions.

## Technology / Product

- 20% weight reduction
- Volumes ca. 30 - 50k upa
- Innovative unitary ultra-light composite vehicle platform
- Class 'A' surface finish.
- Adhesive and thermoplastic welding technologies to give a totally fused/bonded structure.

# Summary of Benefits

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- Federal and European
- High Specific Energy Absorption – consistently at extremes of conditions
- Low residual crush length - package benefits
- 30% saving in weight versus the steel equivalent structure
- 4% overall weight reduction in vehicle using similar lightweight technologies
- Resultant 2.2% CO<sub>2</sub> reduction
- Part integration / Reduced complexity
- 50+% reduction in tooling investment
- Competitive piece cost allowing realistic business cases at 30,000 units per year
- Recyclable





# Thank You

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