LITEBUS
MODULAR LIGHTWEIGHT SANDWICH BUS CONCEPT

Contract 031321
TST5 – CT – 2006 – 031321
- The Project
- The Consortium
- Strategic Importance
- Project Goal
- Research Objectives
- Implementation Plan
The Project
The project

Commencement date: 1st October 2006

Duration: 36 months

Commission Grant: 2 Million Euros

Selected Topic for Call 3B:

Development of advanced, low-mass material structures and systems for vehicles and vessels offering product structural and functional integrity for rated performance at low cost.
The Consortium
The consortium

- INEGI (Coordinator)
- CaetanoBus
- Fibersensing
- CIMNE
- Giugiaro–Italdesign
- UP Milano
- U Oxford
- KTH

- NTET
- Clausthal Univ.
- SUNSUNDEGUI
- MAURI
- UP Madrid

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Tel: + 351 22508 1491
Strategic Importance
Buses and coaches play a key role in public transport

730,000 buses/coaches in the EU (EU 25, 2005)

Cost-effective

Safe

7.5 million jobs in industry

Environmentally friendly

Cost comparison: bus and coach versus light railway
(Total cost/day, based on 60,000 km/yr.)

Buses and coaches – the most cost-effective means of passenger transport!

Carbon dioxide emissions in passenger transport
(EU countries, grammes/passenger-km)

ENERGY & TRANSPORT IN FIGURES 2006 Part 3 : Transport, EU DG Energy and Transport

International Road transport Union, 2000
Comparison EU-25 – World: Passenger Transport

### EU-25 Performance by Mode for Passenger Transport

<table>
<thead>
<tr>
<th>Mode</th>
<th>EU-25</th>
<th>USA</th>
<th>Japan</th>
<th>China</th>
<th>Russia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td>4,438.1</td>
<td>7,165.0</td>
<td>755.0</td>
<td>874.8</td>
<td></td>
</tr>
<tr>
<td>Bus / coach</td>
<td>501.8</td>
<td>226.0</td>
<td>86.0</td>
<td>96.3</td>
<td></td>
</tr>
<tr>
<td>Railway</td>
<td>351.7</td>
<td>22.0</td>
<td>385.0</td>
<td>571.2</td>
<td>171.6</td>
</tr>
<tr>
<td>Tram + metro</td>
<td>75.2</td>
<td>18.0</td>
<td></td>
<td>71.9</td>
<td></td>
</tr>
<tr>
<td>Waterborne</td>
<td>49.0</td>
<td>1.0</td>
<td>4.0</td>
<td>6.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Air (domestic / intra-EU-25)</td>
<td>482.5</td>
<td>896.0</td>
<td>83.0</td>
<td>178.2</td>
<td>85.8</td>
</tr>
</tbody>
</table>

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*International Road Transport Union, 2000*

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**Market share in public transport in Europe (passenger-km):**

55% Buses & coaches

45% Railways, trams, metros
# Road Fatalities by Type of User

<table>
<thead>
<tr>
<th></th>
<th>EU15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total persons killed</td>
<td>32,836</td>
</tr>
<tr>
<td>of which:</td>
<td></td>
</tr>
<tr>
<td>driver</td>
<td>21,589</td>
</tr>
<tr>
<td>passenger</td>
<td>6,473</td>
</tr>
<tr>
<td>pedestrian</td>
<td>4,592</td>
</tr>
<tr>
<td>other/not specified</td>
<td>182</td>
</tr>
<tr>
<td>by type of vehicle:</td>
<td></td>
</tr>
<tr>
<td>car and taxi</td>
<td>17,698</td>
</tr>
<tr>
<td>motor cycle</td>
<td>6,464</td>
</tr>
<tr>
<td>moped</td>
<td></td>
</tr>
<tr>
<td>bus or coach</td>
<td>148</td>
</tr>
<tr>
<td>pedal cycle</td>
<td>1,685</td>
</tr>
<tr>
<td>agricultural tractor</td>
<td>222</td>
</tr>
<tr>
<td>heavy goods vehicle</td>
<td>465</td>
</tr>
<tr>
<td>lorry, under 3.5 tonnes</td>
<td>956</td>
</tr>
<tr>
<td>other/not specified</td>
<td>5,198</td>
</tr>
</tbody>
</table>

Safety in passenger transport
(Fatalities per billion passenger-km, Germany)

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*ENERGY & TRANSPORT IN FIGURES 2006 Part 3: Transport, EU DG Energy and Transport*

*International Road transport Union, 2000*
Project Goal
GOAL

- Contribute to reduction of CO2 Emissions
- Reduce Total Cost of Ownership of Buses/Coaches

GROSS BUS WEIGHT REDUCTION OF 20% ALONE WILL RESULT IN AT LEAST 20% IMPROVEMENT IN FUEL EFFICIENCY AT GROSS WEIGHT
Research Objectives
Objectives

The total weight of a “body in white” of a Bus/Coach will be 60% lighter than comparable steel bodies.

The stiffness of the body will be equivalent to steel body

Crashworthiness and passive safety performance will be greater than bolted aluminium alloy structures and better than welded steel structures.

20% noise reduction and enhanced vibration properties.

The cost of the structure should be 10% lower than comparable steel body through reduction of production lead time.

Greater corrosion resistance and fire safety (structural and toxicity)
Objectives

Interior space increase (at least 10%), thus improving quality of journey and increased passenger capacity

Manufacturing lead time should be reduced 30% through the use of modular large panels, easier and faster to assemble and join together, with built in functions.

Tooling costs will be reduced 50%, since sandwich panel jigs are considerably less expensive than stamping dies or jigs for welded construction.
Implementation Plan
LiteBus “Front-loaded” Development Schedule

Project Schedule – Time = 36 Months

% Time Before Launch

<table>
<thead>
<tr>
<th>Capability-Building Phase</th>
<th>Concept</th>
<th>Concept Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>%1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Confirm Vision</td>
<td>Agree on Goals</td>
<td>Confirm Bus Concept</td>
</tr>
</tbody>
</table>

Gateways

- Package Development
- Exterior Styling
- Simulations, Digital Mock Ups, Digital assembly
  - 1st Prototypes

Advanced Development

- Integration Verification
- Prototype Verification
- Component Verification
- Durability Tests

Rollover Test

Adapted from S H Thomke, 2007
Generation of new concept vehicle architecture
Current State of the Art
Package 2D
Package 3D
Idea Generation
Isometric Views
Isometric Views

- Window Cutout
- L Billet
- Sandwich U Panel
- Window Double glass
Isometric Views

Ring Pillars

Sandwich U Panel
Isometric Views

- Reinforcement shape
- Flap for fixation
- Window Cutout

- Sandwich U Panel
- Ring Pillars
- L Billet

- Window Double glass
Isometric Views

- Front View
- Cross Section View
- Window
  - Double glass
- Sandwich U Panel
- Ring Pillar
Materials & Assembly Process

Joints for disconnection: riveting, screwing
Joints for durable connections: bonding, welding

Inserts:
- Solid laminate
- sandwich
Different possible Assembly Concepts
Selected Assembly Concept

With processing techniques for different parts of the “Litebus”

Sandwich with Foam Core

Pultruded Corner Profile

Overroll–Panel in Infusion Technique
**Processing Technique: Infusion Techniques**

**LCM**
- RTM
- VARTM
- VARI
- VAP
- SCRIMP

**RTM:**
1. Inserting dry fibres
2. Closing the mold
3. Injection of resin
4. Curing
5. Demolding
6. Trimming
Adhesive Bonding Experiment

AV118
- High strength steel
- 12.5mm overlap
- Adherend thickness 2mm
- Adhesive thickness 0.2 and 0.5mm

Sikaflex 552
- Mild steel
- 25mm overlap
- Adherend thickness 2mm
- Adhesive thickness 0.2
Experiments
Failure Mode – AV118

a) RT–mixed mode failure

b1) –40°C–mixed mode failure

b2) –40°C– cohesive failure

c) 80°C – adhesive failure
Engineering CAE
First model, worst case (with SUNSUNDEGUI)

We can obtain the efforts in a section in normal conditions
Efforts on rail and guide of seat's anchorage

<table>
<thead>
<tr>
<th>(N)</th>
<th>FZ</th>
<th>FY</th>
<th>FX</th>
</tr>
</thead>
<tbody>
<tr>
<td>F11 – front screw lateral</td>
<td>-5750</td>
<td>-1900</td>
<td>6275</td>
</tr>
<tr>
<td>F12 – rear screw lateral</td>
<td>14800</td>
<td>2850</td>
<td>300</td>
</tr>
<tr>
<td>Ff1 – front screw floor</td>
<td>-22000</td>
<td>195</td>
<td>5000</td>
</tr>
<tr>
<td>Ff2 – rear screw floor</td>
<td>26350</td>
<td>-390</td>
<td>4440</td>
</tr>
</tbody>
</table>

RERAINT SYSTEMS:
SEATS, ANCHORAGES AND SAFETY BELTS

Static for the anchorage of seats
Benchmark FEM Analysis

FEM analysis of sections with the initial dimensions (only one window)
Tests on CAETANO’s section
Rollover Test – Current Structure

CRASHWORTHINESS Studies

WP2. – FEM first models for collapse properties under rollover

EXTERIOR:
- Pultrusion w/it Carbon/Epoxy
- SHELL 99
- Two Layer
- Matroc:
  - YOUNG=4.e+3
  - POISS=0.35
  - Glass fibre
  - YOUNG=86.e+3
  - POISS=0.22
  - EYY=86.e+3
  - EZZ=86.e+3

INTERIOR:
- Foam
- VOLUM 95
New geometry for analysis including:

- New low-corner pultrusion profile
- Lateral and roof panels
- Lateral metallic rail
- Windows
- Foams (rough approx.)
Materials

inner [80%_0°, 20%_45°]
shear [80%_45, 20%_0°] ; outer = shear
Innshear = inner + shear (10.mm)
Analysis results

Displacements for 40.0kN horizontal force at each frame

Material parameters (mechanical characterisation) must be updated according to experimental tests

updated glass-fibre and matrix mechanical properties
Health Monitoring – Fiber Optic

Nervous system architecture providing 30 sensors on each fibre and fibre failure
Evolution

1947

1949

1960

1970

1997

The future
litebus

end

thank you