Porsche Engineering Services, Inc.

1 ULSAB-AVC Program Background

The ULSAB-AVC Program focused on the development of steel applications for the year 2004 and beyond.

1.1. PROGRAM OBJECTIVE

The objective of the ULSAB-AVC Program was to demonstrate and communicate the capabilities of steel to help fulfil society's demands for safe, affordable and environmentally responsible vehicles for the 21st Century. By doing so, the global steel industry aims to retain the ongoing commitment of the automotive industry to select steel as the material of choice for vehicle construction.

The ULSAB-AVC Program focused on the development of steel applications for vehicles for the year 2004 and beyond. To achieve this goal, the same holistic approach used on the ULSAB Program, which focused only on the body structure, was applied in the ULSAB-AVC Program. In this case the complete vehicle was considered, which meant that all of its subsystems and components had to be treated as a whole. The understanding of the interactions of all subsystems and their optimization led to an optimized body structure and its integrated subsystems. Additionally, social and political trends, as well as new and anticipated government regulations, were monitored and considered for incorporation into the program scope of work, when appropriate. This aspect was especially important since the program began in March 1999 and results were intended to reflect the automotive interests for the year 2004 and beyond.

An important factor for the success of this program was the combination of advanced vehicle design, exploiting the properties of a range of new steels together with suitable advanced as well as traditional manufacturing and assembly processes, to achieve significant mass reduction for the body structure, as well as for the total vehicle.

The ULSAB-AVC Program concentrated on the conceptual design of lightweight vehicles. The main drivers for program were the U.S. PNGV (Partnership for a New Generation of Vehicles) and EUCAR (The European CO_2 reduction program) projects. Since they both focused on two different size (or class) vehicles the following decision was made. Porsche Engineering Services was asked to develop concepts for the most popular European C-Class (so-called Golf class) and the North American Midsize-Class, which is the target for the PNGV program (in the project referred to as PNGV-Class vehicle). The targets of the ULSAB-AVC Program were set after the benchmarking phase (which will be described later) and were monitored throughout the course of the program, considering technological progress in the development of the vehicle subsystems, such as engine and transmission and the resulting environmental aspects.

1.2. Scope of Work

To achieve the program goals, the scope of work was defined prior to the start of the program and included the following tasks.

1.2.1. Benchmarking

Benchmarking data was gathered from current vehicles in the European C-Class and North American Midsize-Class size ranges, as well as vehicles with a curb mass in the range of 900 kg (2000 lb.), which are in the target range of the ULSAB-AVC total vehicle mass including their subsystems. Additionally, two recently launched vehicles were purchased and torn down for the purpose of collecting data. Midsize vehicles were selected and benchmarked from existing data.

1.2.2. Target Setting

Based on the benchmarking results and relevant PNGV-Class (Partnership for a New Generation of Vehicles) requirements, the targets for the C-Class vehicle and the PNGV Class vehicle were set and mutually agreed upon with the ULSAB-AVC Consortium. Due to differences in size and performance requirements, two sets of targets, one for the C-Class vehicle and one for the PNGV-Class vehicle were established for:

- Mass of complete vehicle
- Mass of subsystems and components
- Vehicle dimensions

- Vehicle performance (US standard and European standard)
  - ⇒ Acceleration
  - ⇒ CO_2 emissions
- Vehicle equipment
  - ⇒ Safety
  - ⇒ Comfort (e.g. air conditioning, audio system, electric adjustable seats)
- Crashworthiness (i.e., 2004 anticipated safety requirements)
- Structural performances of body structure
  - ⇒ Torsional rigidity
  - ⇒ Bending rigidity
  - ⇒ Normal mode frequencies
- Aerodynamic drag
- Affordability (i.e., from none to limited or nominal cost increase)

1.2.3. Package

Package studies provided the basis for the development of the vehicle concepts. In these studies, the location of subsystems and package dimensions for the vehicles' exterior and interior were defined.

In the package concept design, the following tasks were performed:

- Definition and confirmation of dimensional data (e.g. exterior, interior, wheelbase, etc.)
- Definition of hardpoints (e.g. A-pillar, interior dimensions, seating positions)
- Technical support for the exterior styling (e.g. vision angles for exterior definition of windshield, A-pillar)
- Package investigations of subsystems and components including their selection and location in the vehicle
- Development of vehicle front end and vehicle rear ends
- Development of interior concepts
- Package of exhaust system

1.2.4. Styling

The overall goal of styling was to design a family of vehicles that would be suitable for the year 2004 and beyond, but would not detract from the program focus of technology and steel materials. The desired design statement should be contemporary without being a focal point in order to showcase the technology. The following elements were created:

- Exterior styling sketches (2D) for C-Class and PNGV-Class vehicles
- C-Class platform family sketches (2D) showing a two-door hatchback, four-door hatchback, four-door sedan and four-door wagon.
- Interior styling sketches (2D)
- Exterior styling surfaces (3D) for C-Class two-door hatchback and PNGV-Class four-door sedan utilizing Computer Aided Styling (CAS)
- Basic interior styling surface (3D) to show geometry of instrument panel, steering wheel and column, center console, A-pillars, base of seats and headers, 45 degrees either side of the driver's sight line with rendered instrumentation, switches, openings and grilles

1.2.5. Body-in-white Concepts

The fundamental prerequisites for ULSAB-AVC was to develop two different vehicle-type body structures that met program targets of:

- Crashworthiness
- Mass
- Structural performance
- Vehicle dimensions
- Common platform

Tasks for the development of the body-in-white included:

- Development of body-in-white concept
- Mass calculation
- Material selection
- Parts List
- Definition of requirements (dimensions for subsystems and components such as engine, suspension)
- Development of typical sections

1.2.5.1. Platform Concept Development

Combining the packaging concept designs, a platform concept for the body-in-white C-Class and PNGV-Class vehicles was developed using as many common parts as possible. This common platform approach includes body structure parts and closure parts, as well as components for subsystems (e.g. front end, rear suspension).

1.2.5.2. Body Structure Development

Based on the common platform concept, the body structures for C-Class and PNGV-Class vehicles, using steel, were developed and optimized for:

- Structural performance
- Crashworthiness
- Mass
- Manufacturing requirements
- Package restrictions
- Assembly processes
- Joining technologies

1.2.5.3. Closures Concepts

Incorporating the results and technologies developed and applied in the UltraLight Steel Auto Closures (ULSAC) Program, concept layout of closure geometry was optimized with regard to the following considerations/requirements:

- Package
- Assembly/Joining processes
- Manufacturing requirements

1.2.6. Interior Design Concept

The interior design concept provided the mass of the interior components, necessary for the calculation of the total vehicle mass. The interior subsystems were treated in a holistic approach with the body structure to benefit its performances (e.g. crash) and reduce mass.

This task included the following elements:

- Support of package development with typical cross sections
- Mass estimation
- Material selection
- Concept parts list

1.2.7. Subsystems Concept

- Support of package design
- Definition of hard points for styling
- Definition of requirements for electrics, engine, chassis package
- Mass estimation
- Material selection
- Concept parts list

1.2.8. Engine and Transmission Concept

- Selection of hypothetical powertrains (one gasoline engine and one diesel engine) based on information accessible to the general public showing development trends for powertrains of the future. Conceptual or detail design of selected engine and transmission is not included in the scope of work of this program.
- Selection of hypothetical powertrains studied and considered the impact of other powertrains such as increased engine size or hybrid powertrain solutions for crashworthiness, fuel consumption and overall vehicle targets to arrive at the final concepts
- Package drawings, FE-Analysis for crashworthiness, the analysis of fuel consumption, etc. for alternative powertrains are not included in the scope of work for this program
- Mass estimation
- Description of concepts
- Layout of hypothetical powertrains
- Selection and description of auxiliaries (e.g. exhaust system)

1.2.9. Suspension Concepts

The goal for the development of front and rear suspensions of the ULSAB-AVC concept vehicles (C-Class and PNGV-Class) was to design lightweight suspension concepts utilizing steel. The approach taken was to achieve lowest overall mass of the complete vehicles and not to develop suspension concepts with the lowest mass possible. A suspension system with low mass may not contribute to achieve the lowest overall vehicle mass. It could, for instance, cause mass increase in other components (e.g., body structure).

Tasks for the development of front and rear suspension included:

- Support of package design
- Definition of hard points
- Concept design
- Mass estimation
- Material selection
- Suspension geometry layout (engineering judgement)
- Selection of wheels and tires
- Selection of brake system
- Concept drawings
- Concept parts list

1.2.10. CAE Analysis

Computer Aided Engineering (CAE) techniques were used in the ULSAB-AVC concept design program as a tool to evaluate the structural concepts and to optimize the structure. The two principal areas of focus were safety and structural performance.

A complete discussion of CAE Analysis can be found in Chapter 7; with detailed information on:

- CAE analysis was utilized to determine vehicle crashworthiness. The crash models did not include occupants since no full interior model was developed in the crash simulations.

- The crash events considered in this program were:
  - ⇒ US-NCAP (35mph, full overlap rigid barrier)
  - ⇒ Euro-NCAP (64km/h, 40% offset deformable barrier)
  - ⇒ Rear Impact (FMVSS 301, 35mph)
  - ⇒ US-SINCAP (38.5mph side impact, barrier mass 1370kg)
  - ⇒ Side Pole (D=254mm, 32km/h)
  - ⇒ Roof crush/Rollover (loading 2.5 times curb mass)
  - ⇒ 15 km/h low speed bumper test

- Star Rating assessment
  - ⇒ The objective was to analyze the vehicle structure for its integrity and potential to achieve the performance necessary to obtain high star ratings in both the USA (US-NCAP & IIHS) and Europe (Euro-NCAP).

- Static torsional rigidity (body structure only)
- Static bending rigidity (body structure only)
- Normal mode frequencies (body structure only)

1.2.11. NVH

CAE model analysis and engineering judgement provided the local BIW mode frequencies to optimize the design to achieve the defined targets.

1.2.12. Vehicle Cost Assessment

Part of the ULSAB-AVC program was an assessment to estimate the manufacturing costs of both ULSAB-AVC vehicles (C-Class and PNGV-Class).

To undertake this program, Porsche Engineering Services, Inc. (PES) organized an interactive process between product designers, process engineers and assembly line designers and cost analysts.

A complete discussion of Cost Model Development and Results can be found in Chapter 17, including information on:

- Assessment of manufacturing and assembly costs for C-Class and PNGV-Class vehicle
- Cost model development
- Parts list
- Definition of ranges for cost estimates of concept vehicle components

1.2.13. Vehicle Assembly Sequence

- Graphical and brief text description of vehicle assembly sequence considering main components only