THE RIVAGE

High-tech model-making:
From zero to the road in just seven months

How a development record was set.

From sketch to presentation of a new sports car in just 7 months.

The head of model-maker ITH and Professor Kelly of Steinbeis-Transferzentrum Automotive Styling and Design had a brilliant idea in the spring of 2002: They were certain that the design study of a sports car could be turned into a real-life vehicle that would drive like any other car without anyone noticing that it was a prototype. And it could all be done in only 6 or 7 months.

The reason for their certainly was that they either possessed all the necessary skills, methods and high-tech components themselves or knew partners who could supply them: GOM and Tebis. Both companies were soon on board. All four firms became project partners, assuring one another that each would contribute the best they had to offer to turn the vision into reality, with the goal of presenting the prototype at Euromold 2002.

The project got underway by April. Stylists and model-makers, 3D metrologists and CAD/CAM experts spent the next seven months combining the expertise of their various disciplines in an atmosphere of flexible, non-hierarchical cooperation. As an added benefit, all parties involved were able to learn a great deal from each other.

PHASE 01

Sketches and design

Prof. Kelly set himself the goal of designing the sports car to evoke two different emotional responses: a sense of pure power - comparable to that of a Porsche model - and speed, which people tend to associate with the Ferrari's design. Four weeks later, Prof. Kelley submitted five preliminary designs to the project team.

Everyone quickly agreed on the front and rear parts and chose one generally popular design. The next step was to transfer it to the three-dimensional world, turning it from an idea in the designer's imagination into a real-life model that could be touched and assessed.

PHASE 02

The package model

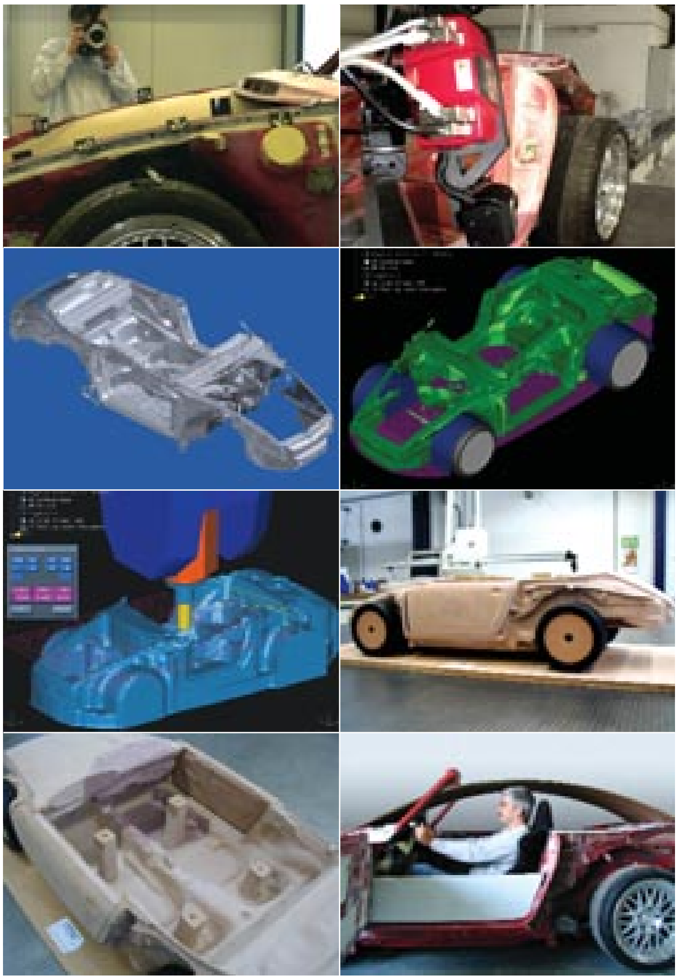
A 964 Series Porsche 911 C2 Targa was chosen as the drivable base for the sports car study. All parts of the new sports car model would then be attached to the 911's vehicle shell later on. The original design should be no longer recognizable; only the chassis, power train and electrical system of the classic sports car were to be reused.

To achieve this, all body parts of the 911 were removed until only the naked shell was left. This stripped 911 was then transferred to the virtual CAD world by scanning the vehicle shell three-dimensionally, using ATOS, the optical digitizing system from GOM.

Although geometries of such complexity are very difficult to digitize using conventional measuring machines, the flexible ATOS scanner offers high spatial mobility that allows highly complex objects to be quickly imaged almost in their entirety without sacrificing detail. Just four hours later, the digitized data was available in STL format and could be imported into one of the Tebis systems that ITH has been using ever since the company was founded in 1998. In this system, the mesh data was then edited, trimmed and reduced by a scale of 1:4.

After attaching a few add-on surfaces, ITH's Tebis specialists calculated the necessary milling programs that would enable the 1:4 model of the 911 vehicle shell to be subsequently milled in ureol.

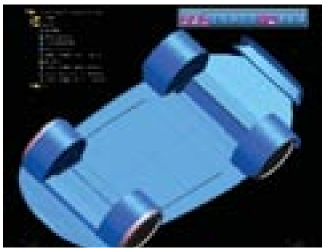
The package model for the design was therefore available just one day after digitizing the shell. Additional specifications for the vehicle interior and silhouette were prepared by package drawing and the whole thing handed over to Prof. Kelly.



PHASE 03

Styling the 1:4 clay model

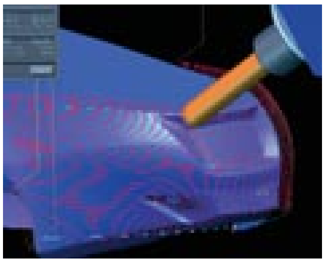
In April, modeling work began in Pforzheim on the basis of the package model and other specifications. Only half of the sports car was fully assembled in the form of a clay model. Although the modeled half was true to the preliminary design that the project partners already knew from the sketch on paper, it nevertheless amazed them at first glance, since everyone involved had already formed a specific image of the final sports car in his/her own mind. The fact that only half the clay model existed made it difficult to assess, since this is not the usual form in which we perceive objects - especially cars.



PHASE 04

Styling the symmetrical 1:4 ureol model

It was decided to further detail the model by preparing a 1:4 complete model with a symmetrical structure and using more stable materials. Once again, virtual CAD techniques were chosen, and ATOS was used for non contact scanning of the single-sided clay model. Because clay models have only limited inherent stability and cannot be safety transported, the digitization work had to be carried out right in Prof. Kelley's Pforzheim design studio; it was no problem to transport GOM's mobile ATOS system by truck.



The triangulated meshes of digitized data produced in the ATOS software were then imported via the STL interface directly into Tebis, where the mesh data was trimmed and mirrored on the vehicle's center plane. Special Tebis functions made it possible to deform the meshes to produce tangential transitions all along the center joint. After attaching the bottom of the vehicle, the virtual 1:4 model was complete and could be converted to NC programs using Tebis CAM commands. A 5-axis portal milling machine was then used to convert the symmetrical complete model to the real world. Now that the entire sports car could finally be seen in model form, the stylists could quickly determine where changes needed to be made: where to remove material or add clay, where to blend which transitions, and which edges needed to be straightened.

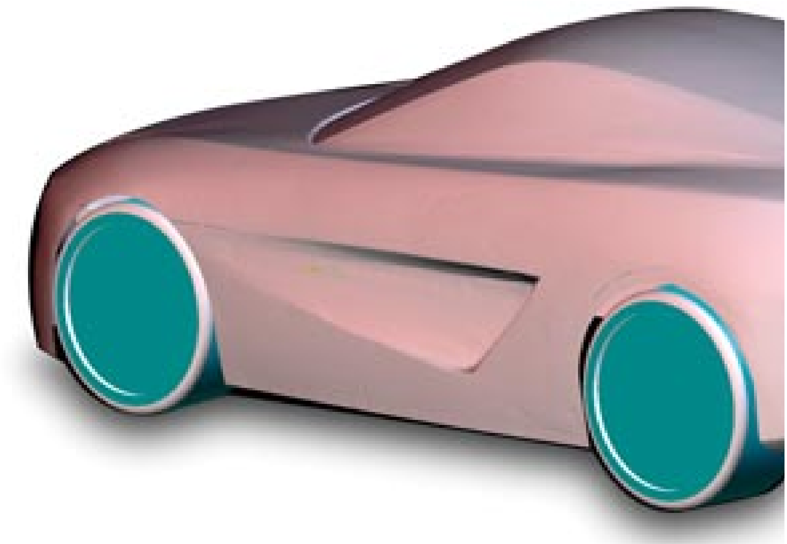
The model-makers then undertook to create a top-quality model, modeling, smoothing and finishing each detail with the utmost care. Everyone knew that any modelling error in the 1:4 model would be four times more obvious in the next model, which would be prepared on a scale of 1:1.

It was late June when the project partners released the 1:4 model, knowing very well that the vehicle's actual emotional impact would not be felt until it was seen in the original size.

PHASE 05

Digitizing the released 1:4 model

The tried-and-tested virtual CAD techniques, including scaling up to the 1:1 scale and outputting suitable NC programs, were again chosen for producing the 1:1 model. To do this, however, the model first had to be scanned with the highest possible precision. Thanks to its photogrammetrical concept and ingeneous fringe projection principle, the ATOS digitizing system is able to scan a 1:4 model with an accuracy down to several hundredths of a millimeter. It took around 2.5 hours to scan the 1:4 model with maximum accuracy. The high-precision cloud point was first reduced to roughly 2 million points, depending on curvature in the ATOS software and then imported into the Tebis CAD system via a direct interface.



PHASE 06

Scaling the 1:4 model to 1:1

After being imported, the digitized surfaces appear in Tebis as triangulated meshes. Tebis handles this type of geometric element the same way it does surfaces that are designed with curves and sections, making it possible to add any surfaces to the meshes, easily close gaps, optimize curvatures and trim edges smoothly along curves. Meshes can be added to optimized curves and attached surfaces and also limited, joined and scaled in size as needed.

To produce a high-quality 1:1 model, the imported digitized data of the 1:4 model needs to be only slightly edited and scaled, making the 1:1 model available in the virtual CAD space, where it can be viewed on screen with shading in nearly photographic quality.

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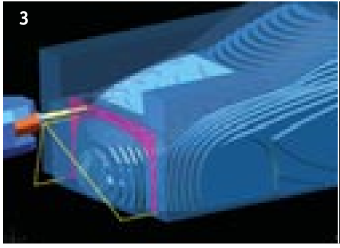

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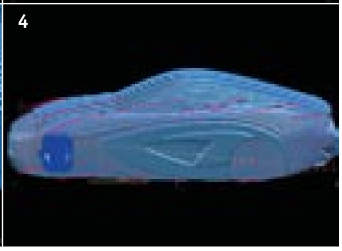


PHASE 07

Producing the 1:1 model

Instead of the conventional method of constructing the 1:1 model from ureol blocks that are mounted to a basic frame, the ITH model-makers chose a special volume sandwich technique that is suitable for very light-weight, yet extremely dimensionally stable models with a hard external skin. This method also uses economical materials and thus lowers production costs.

To do this, the NC programs for producing the core first had to be calculated in Tebis (see photos on the left). The core is first milled and then the actual outer layer applied, with a 1-4 mm stock allowance remaining universally on the model after curing. The external skin was then milled in only one clamping position on a large portal milling machine whose bed measured 5,000 x 2,500 mm. For this purpose, Tebis was used to calculate multiple milling programs with different cutters and different milling strategies so that the final finishing pass with a 16-mm ball-end mill left a smooth surface that perfectly matched the virtual 1:1 model in the many curved surface areas as well as in all detailed areas such as the lamps, air inlets and the diffusor.

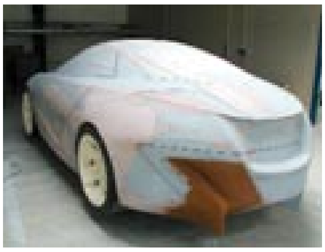
PHASE 08

Modelling work on the 1:1 model

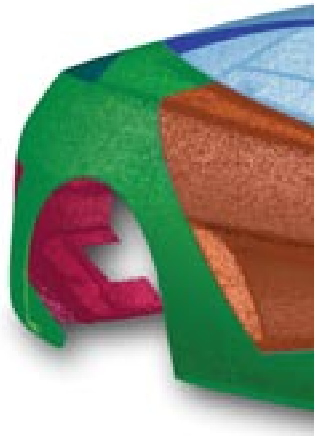
The care taken when setting up the 1:4 model and the precision of optical scanning pays off when detailing the 1:1 model. As shown by the reflection test, large areas of the external skin already demonstrated an excellent curvature that required only minor smoothing and blending. Other areas, however, needed more extensive modifications, some of them for stylistic and others for technical reasons.

In the diffusor area, therefore, major changes were modeled to avoid having to excessively limit the space available for mounting the engine and transmission.

Extensive modifications were also carried out in the area of the headlights and air inlets, and finally the joint images for the door and hood gaps were attached and the shapes of the head- and taillights marked.



In early August, Prof. Kelly okayed the work, and the 1:1 model was released. The next step was to build the individual model parts and mount them onto the vehicle shell. For the fourth time, the partners chose to use the virtual CAD techniques.

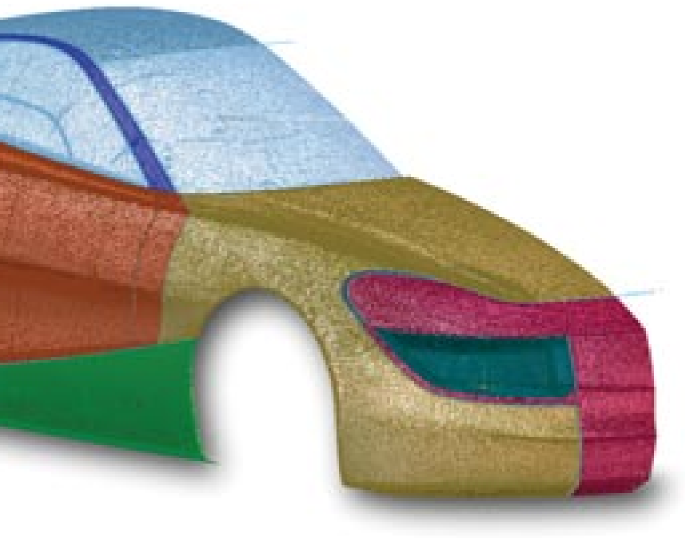


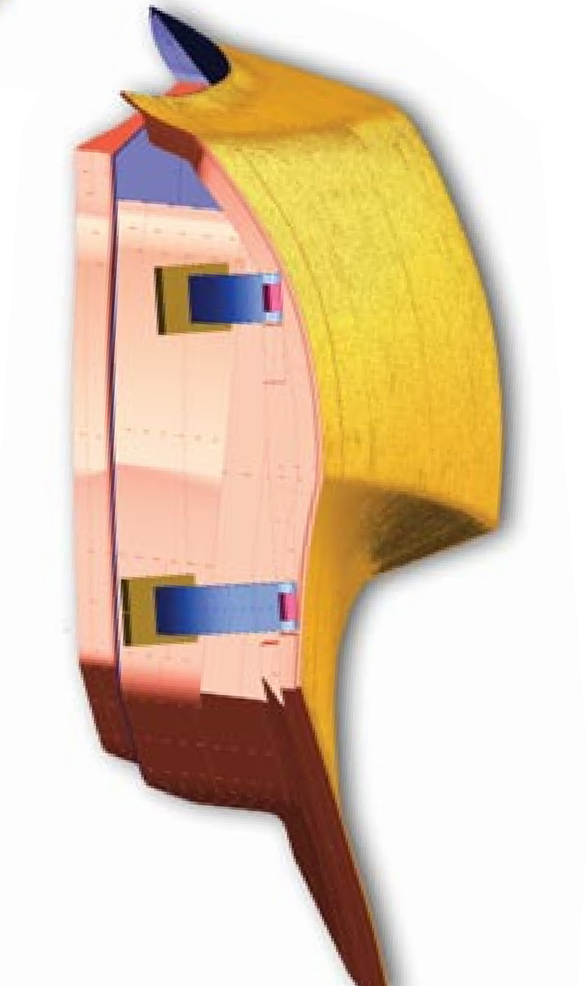
PHASE 09

Digitizing the released 1:1 model

For measurement purposes, circular adhesive markers were first attached to the model as reference points and then photographed from different directions using a digital mirror reflex camera. The images were transferred to a computer on a PC card and evaluated using GOM’s TRITOP photogrammetry system, making it possible to precisely define the higher-level coordinate system on large components without even using a measuring machine. The processed vehicle half was then scanned field by field using the variable-position ATOS scanner. While the surfaces were being measured, the tape-marked joints and other characteristic lines for the lights were measured three-dimensionally on the basis of the digital photos, using the convenient GOM feature line module. In the later design, the lines would serve as important reference points for limiting the surfaces and would lie precisely in the surface measurement coordinate system.

Combining photogrammetry with fringe projection made it possible to achieve absolute accuracy down to a tenth of a millimeter over the entire vehicle body, an important requirement for successful assembly later on. After only six hours of measuring and analysis, the high quality surface data was available in STL format and the lines in IGES format.





PHASE 07

Designing the model parts

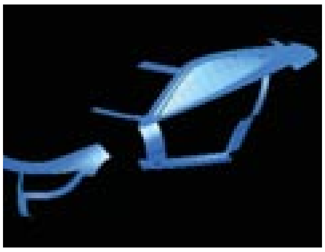
ITH had to design the individual model parts so that their exteriors matched the scanned external skin of the 1:1 model and interiors fit together with the digitized vehicle shell of the 911, where they would be attached. The individual model parts had to be separated along the scanned tape and marking curves.

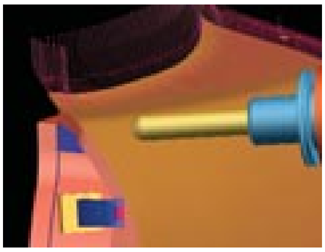
The surface data of the 1:1 model and separating curves were first imported and the number of mesh triangles subsequently reduced in Tebis wherever possible without resulting a loss of quality. This nevertheless left a 970 MB data record, which had to be further processed.

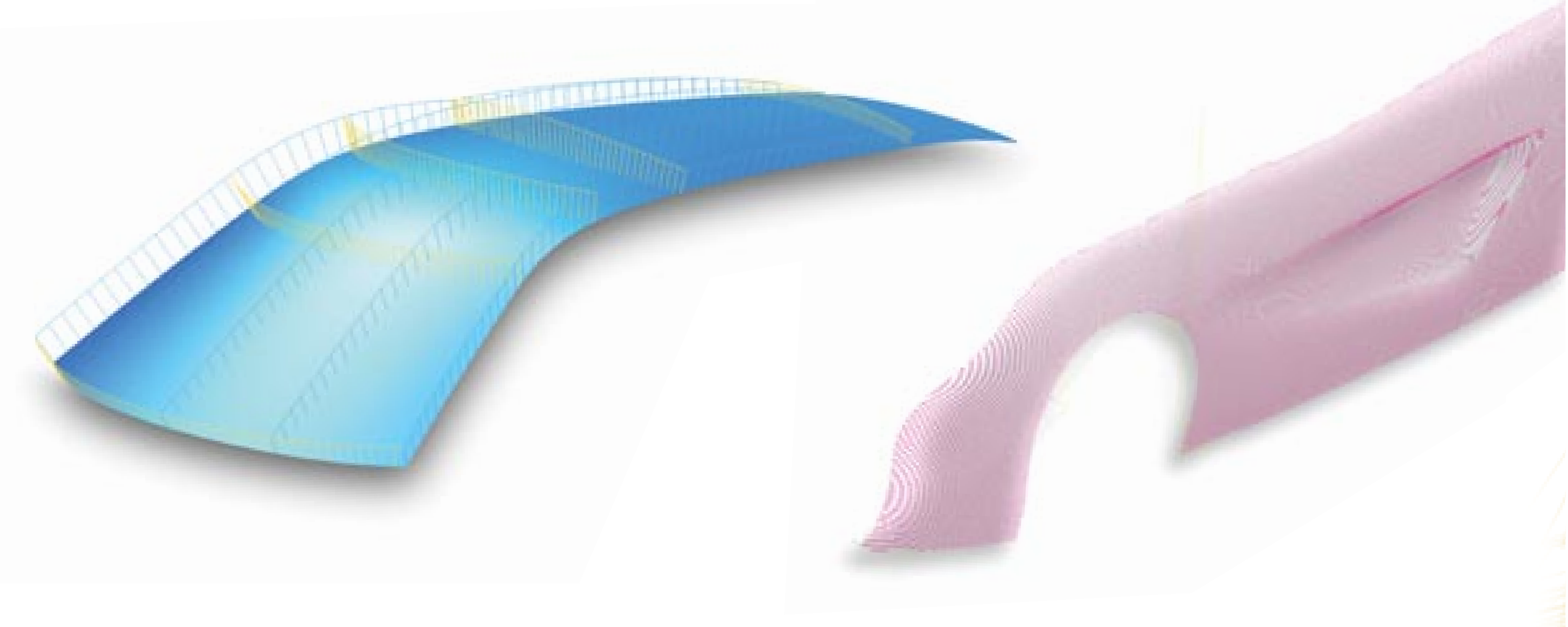
To allow the redesign work to progress at an acceptable speed, CAD surface strips measuring from 80 to 100 mm wide and never deviating from the underlying mesh data by more than 0.2 mm were generated with a highly accurate surface quality in all areas containing separating and marking curves.

With the help of the scanned vehicle shell data, mounting seats for the individual model parts were attached to the interior, and the inner surfaces were constructed using points and curves. Instead of using the comprehensive mesh data, which is somewhat cumbersome to work with, all further design steps could continue with exact CAD surfaces. All individual model parts could be easily separated by approximating a smooth center curve relative to the imported tape lines, generating the gap curve and breaking the underlying surfaces against this curve.

With the help of Tebis CAD functions, ITH's CAD specialist was able to design all model parts in only seven weeks, including concept development, seal design, definition of the hinges on side and rear doors, the trunk lid and all fastening and reinforcing elements. The CAD data was then passed on to the NC programming station, leaving only seven more weeks for producing all model components on schedule.







PHASE 11

Special design requirements for window pane and lamp production

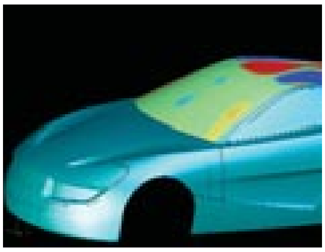
While nearly all model parts attached to the outer skin were created with the typical Tebis hybrid of mixed mesh and surface data, this procedure could not be used for the windows and certain lamp components for production reasons. These components required polynomial surfaces of class A surface quality, or continuous curves and tangents. The Tebis system specialists from Tebis' Munich headquarters and the software development project managers in Hamburg quickly agreed that the current prototype of the Tebis surface modeling software was fully up to this task. They were right, for each time ITH requested class A surface quality, the Tebis CAD specialists were able to immediately deliver the high quality surface data needed for a new production process used to produce transparent polycarbonate components. This new innovative process allows complex geometries to be produced very quickly and accurately. Although manufacturers used to have to live with dimensional deviations of several millimeters when working with complex contours, ITH was able to establish accuracies of +/- 0.5 mm.

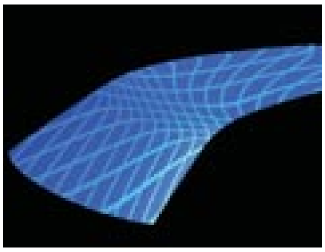
PHASE 12

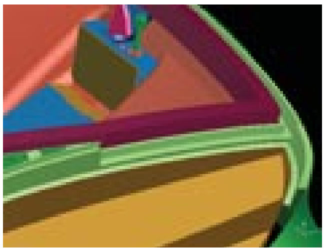
Producing the model parts

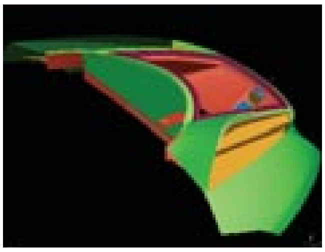
As was the case when producing the 1:1 model, most of these model parts were also created using sandwich and laminate techniques, which made it possible to use thin materials comparable to sheet metal components. The first step was to produce a substrate core by calculating NC programs with corresponding negative stock allowances in Tebis and then milling them in different clamping positions.
After applying and curing various coatings and laminates, the individual model parts were produced on 3- and 5-axis milling machines. Some of the underlying NC programs were calculated on the basis of surface data, others on the basis of mesh or hybrid data, the Tebis hybrid technology making it easy to handle mixed data in this manner.

The large weight-bearing parts, such as side walls, door sills and fenders were assembled before being milled and finished. For this purpose, the parts were first mounted on the 911 vehicle shell. Then the entire vehicle was clamped onto the portal milling machine and subsequently finished to the target dimension using a narrow line spacing.
All mechanical components such as the mounting seats as well as the door and hood hinges, including the drill templates, were incorporated into the model parts in the same clamping position to achieve maximum accuracy.









PHASE 13

Assembly and painting

After the parts to be mounted were finished, the vehicle was painted for the first time, starting with the entire interior, engine compartment and trunk. The side parts, sillguard, fender and all mechanical components were primed for subseqent finishing.

The vehicle was then transported to tolimit Motorsport, an internationally renowned auto racing specialist that provided mechanical engineering work for the vehicle. Tolimit's engineers had completely rebuilt the existing engine ahead of time and optimized its performance. Now they had to reinstall all units within the remaining two weeks.

Another important advantage of the manufacturing process became apparent during assembly. Because there was a CAD representation of the entire mounting area, making all interfering edges visible at all times, the supply lines, exhaust system and the entire electrical system could be adjusted without having to conduct expensive tests. Because the newly styled wheel rims had already been produced, the brake system could be mounted and the entire chassis installed and measured.

The final step was to conduct a bench test to certify that the brake system and chassis were working properly and that the engine achieved an output of 300 HP. These tasks were completed in only seven working days.

At the same time that the work described above was in progress, ITH was producing additional model parts. Thanks to the development and production strategy described above, all model parts fit together wonderfully, so that the vehicle required very few adjustments. The costly and time-consuming work that conventional methods require to adjust the model parts to the vehicle shell could be eliminated without sacrificing dimensional accuracy. It was also possible to dramatically reduce extensive gap image adjustments that are otherwise necessary.

PHASE 14

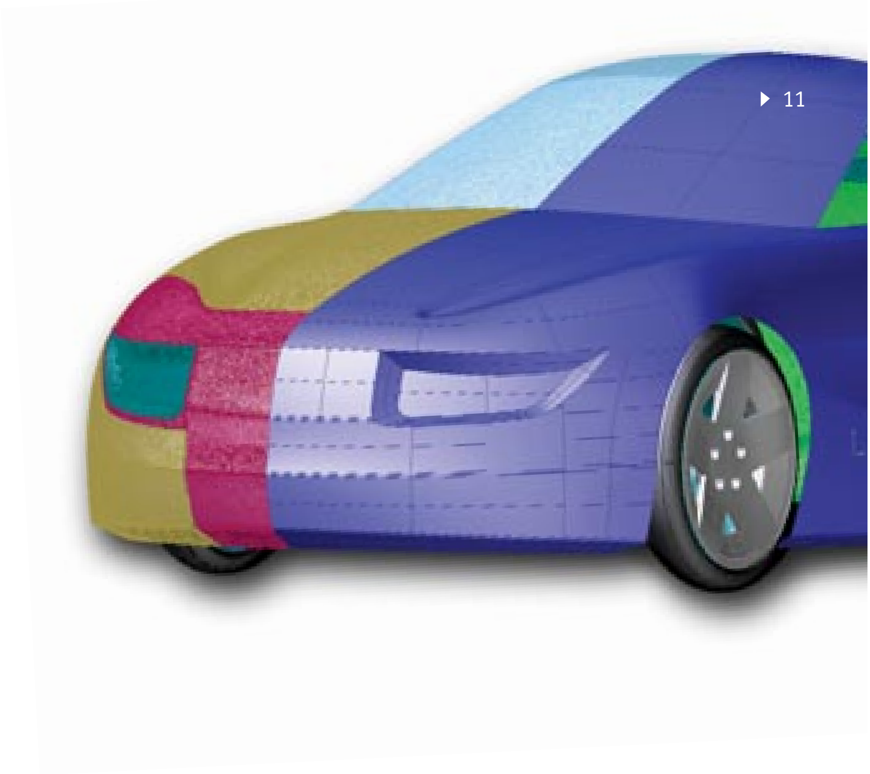
Interior

The Rivage's interior was supposed to feel just like a racing car. The design came together on sketches, and the manually produced conversion component was partially created in CAD using Tebis design functions. 2D datarecording, a leading international outfitter for Formula One and the Motor Bike World Championships, provided the integrated instruments, including the data recorder. Along with displaying all standard information such as engine and vehicle speed, oil pressure and oil temperature, this system has special sensors that record and analyze all vehicle states, including brakes, chassis and engine management.

PHASE 15

Wheel rim design and production

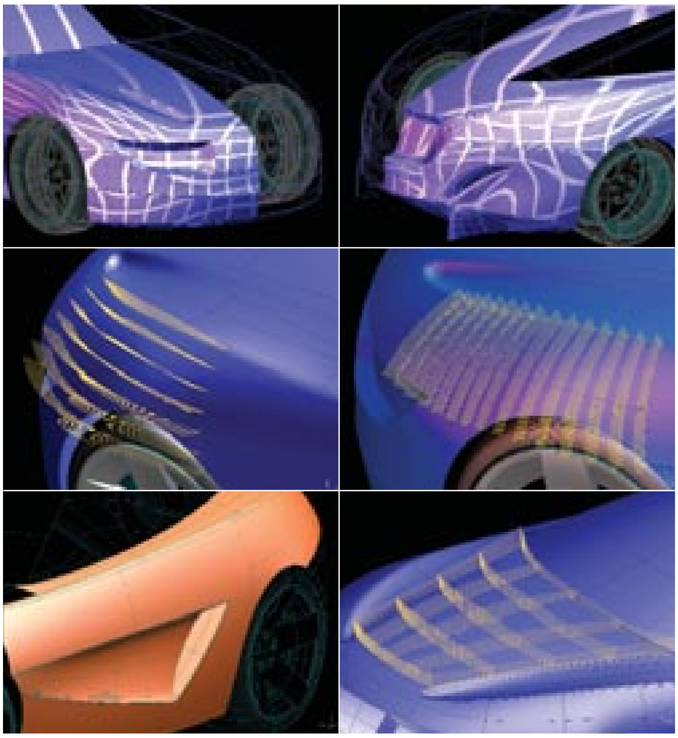
Unlike the vehicle body components, the wheel rims were produced by conventional manual styling. ITH's CAD specialists converted Professor Kelly's preliminary design the very same day, using the Tebis system, thus designing the rim entirely in Tebis and transferring the NC programs to the milling machine that evening. To the professor's amazement, the first visualization model of the wheel rim was ready the next morning, only ten hours after the paper sketch had been prepared. After a number of minor modifications, the CAD model for the wheel rims was approved and passed on to internal manufacturing.

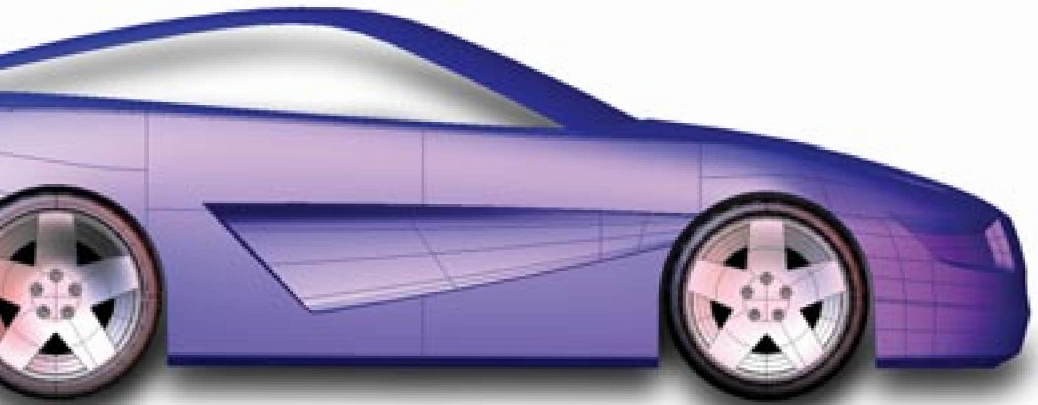


PHASE 15

The Rivage as a Class A surface model

While the model parts were being produced, the Tebis application specialists took the opportunity to built a CAD model of the vehicle's entire external skin, using the new Tebis surface modeling software. They set themselves the goal of creating class A surface quality, which means minimal deviation from the original digitized data of continuous-curve and continuous-tangent surfaces. The first step was to derive the characteristic curves from the mesh model and optimize their curvature along with the joint curves delivered by the ATOS scanner. Smooth cut curves were then stretched over the mesh surface and the surfaces extrapolated. The surfaces were trimmed to the joint curves, radii and runouts modeled and sharp edges produced in the locations where the STL meshes were ground. All activities were carried out under the control of the new Tebis analysis functions, which show the curvatures of curves and surfaces, display deviations from the original digitized data and magnify surface reflectance. As a side effect for Tebis product development, quite a lot of surface and analysis functions can be improved on the basis of practical examples. The Tebis CAD model for surface modelling was officially presented at Euromold 2002.





The Rivage at Euromold 2002

More than just a show car, the Rivage at the Tebis booth is a concept vehicle, data control model and prototype all at the same time. The partners have turned their vision into reality, making a spectacular sports car ready for the road in record time: from zero to the road in just seven months.

RIVAGE

Rivage Concept Car.
The project partners:

Design: Prof. Kelly, Steinbeis-Transferzentrum, Automotive Styling and Design, Pforzheim
Models, exterior and interior model parts: ITH Technik GmbH, Hilter, www.ith-gmbh.de
Component digitization: GOM - Optical Measuring Techniques, Braunschweig, www.gom.com
CAD/CAM systems, surface and model part design, NC programs: Tebis AG, www.tebis.com

gom ITH Technik GmbH STEINBEIS-TRANSFERZENTRUM AUTOMOTIVE STYLING AND DESIGN

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Tebis Technische Informationssysteme AG, Einsteinstr. 39, D–82152 Martinsried/München, Telefon 089 / 81 803-0, info@tebis.de, www.tebis.de
Tebis America Inc., I-75 Tech Park, 1389 Wheaton Rd., Suite 500, Troy, MI 48083 USA, Tel. +1/248/52 404-30, Fax +1/248/52 404-34, www.tebisusa.com
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