GDT SPEEDSTER

PROCESS

The process used to design, develop and fabricate the GDT Speedster officially began on 6 February 2000 when the team held its first meeting. The first few meetings were held on Sunday afternoons at our workshop in Plymouth, Michigan. Due to schedules it was more convenient for the majority of the team members to meet near their regular work offices so the meetings were held at a restaurant in Allen Park or Dearborn, Michigan during lunch hours. Meetings were held approximately every two weeks for the next three years of the project. After the major components of the vehicle were assembled the meetings returned to our workshop.

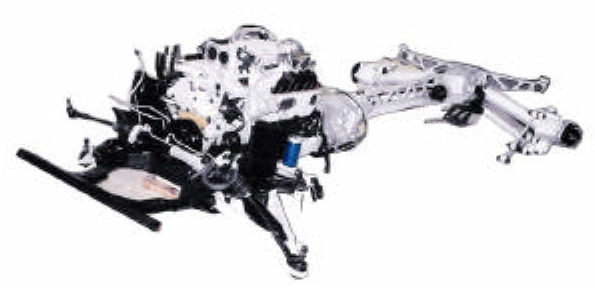
DEFINE ARCHITECHTURE

Craig Sandvigs rendering dated 2001 April 23

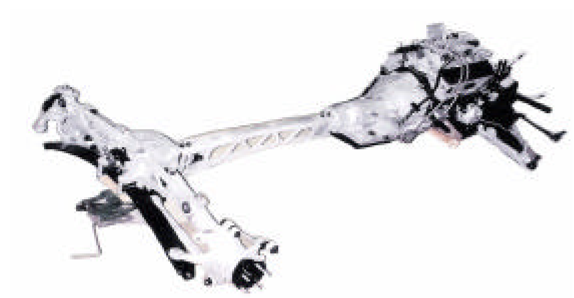
The first step was to define the vehicle architecture. After reviewing several alternatives it was decided the vehicle would be a full fendered speedster with modern styling. Ted Kearnan was very helpful with developing the vehicle assumptions.

Craig Sandvig and Larry Ronzi began preparing theme sketches for the team to review and select styling elements from. The theme that evolved was fresh and it was intended to retain its freshness for many years to come.

DRIVE TRAIN



Complete Drive train ~ front 3/4 view



Complete Drive train ~ rear 3/4 view

It was decided early on to use the drive train from a 1984-1996 "C4" Corvette. The C4 drive train was selected for several reasons:

1. **it is a well-engineered system,**
2. **it was fully developed by 1994,**
3. **service parts are readily available world wide,**
4. **the drive train is essentially "stand alone" in that the front suspension is connected to the engine that is connected to the transmission that is connected to the differential/rear suspension and therefore precisely establishes the wheelbase and drive shaft angle,**
5. **it produces world-class handling and top speed.**

CLAY MODEL - INITIATION

Wood model armature for 1:8 scale clay

L to R Larry Ronzi, Chuck Carlson, Craig Sandvig re-viewing early status of clay model at resturant "meeting place".

Craig Sandvig (L) and Chuck Carlson discussing "first draft" of the 1:8 scale clay model.

A detail being pointed out on the clay model.

After the basic architecture of driver location, shoulder room, cowl height, radiator package and wheel base were firm an armature for the 1:8 scale clay model was fabricated. Larry Ronzi then "loaded" clay onto the armature and began sculpting the exterior surface of the body the week of 30 May 2000.

DONOR VEHICLE

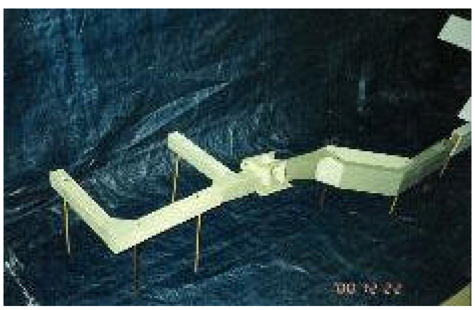
"Bridge" used to measure hundreds of points on the donor vehicle.

Set up for taking measurements on the donor vehicle.

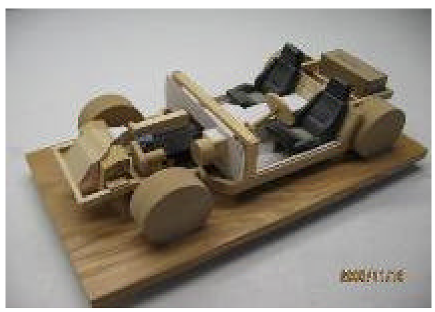
As the styling evolved a used 1994 Corvette was purchased on 9 August 2000. The "donor" vehicle had been in an accident that severely damaged the driver side of the body and "frame". The body panels, seats and interior trim had been removed by the recycling yard. The vehicle was placed upon jack stands and carefully leveled front to rear and side-to-side. Next a measuring "bridge" was constructed.

The bridge permitted accurate measurements of the vehicle with respect to a paper grid system. The donor vehicle was "reverse engineered" using the following items as cross references: the 1994 Corvette shop manual, a body shop frame straightening chart, a sectional view from a magazine road test and a Monogram 1:8 scale model kit of the 1985 Corvette. Hundreds of measurements were taken and recorded on freehand sketches of the component or region. The dimensioned sketches were the basis for designing the new vehicle on full size vellum layouts. Five full size layouts were drawn on 1067 mm (42 inch) rolls of vellum (up to 4.3 m [14 feet] long) showing the following views: side, plan left side, plan right side, front and rear. In addition, 79 full size layouts were drawn on "cut size" vellum 609 mm x 914 mm (24 inch x 36 inch) of numerous components and sub systems.

FRAME—DESIGN & FABRICATION



Mock up of the frame in foam core board.



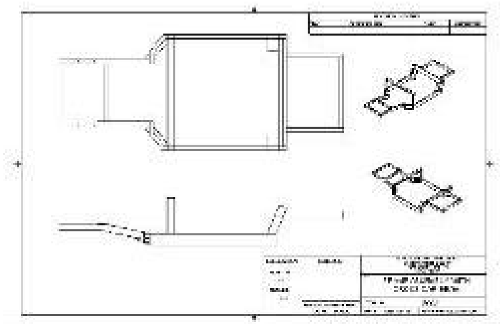
Wood model of frame in 1:8 scale.

Andy Milewski welding the frame at Starlight Welding.

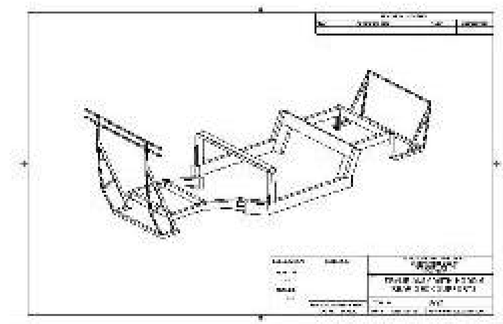
Chuck Carlson (L) and Gene Dickirson with the movable crane used to lift the donor body off the drive train and set the new frame on to the drive train.

Completed frame- 3/4 front view.

Frame painted and ready for assembly-3/4 rear view.



CAD detail drawing of the frame.



CAD detail drawing of the frame
with the hood & rear deck supports

Sketches were prepared of various frame concepts. Rectangular ASTM A 500 steel tubing rather than round tubing was selected as the material for fabricating the frame. Rectangular tubing is much easier to cut and join than round. Round tubing requires precise “fish mouth” cuts in order to achieve good fits for welding. Some of the early frame concepts assumed the rectangular steel tubing would be formed by bending to achieve the desired shape. However after visiting with Bob Shetrone and his team at Progressive Automotive, Inc., a hot rod frame fabrication shop in Baltimore, Ohio in July 2000 it was decided to miter cut and weld the tubing rather than bend it to construct the frame. Musa Azzouz reviewed the frame concept proposals and offered suggestions on ways to achieve the desired strength. A preliminary frame design was prepared using CAD detail drawings of the frame components. A 1:8 scale model of the frame was constructed using balsa wood and components from the Monogram plastic kit. Based upon an analysis of the 1:8 scale frame model the design of the frame was revised to improve fabrication feasibility and design strength. A full-scale model of the driver side half of the frame was then constructed using 5 mm (3/16”) thick foam core board and hot melt adhesive. Only the driver side half was modeled in order to reduce the fabrication time and to minimize the floor space required to study the mock up.

Musa Azzouz reviewed the full size model and made recommendations for improving the design.

In addition to the full size mock up of the frame a 1:8 scale model was built in wood. The model included the frame, engine, cooling system module, dash panel, cross car beam, differential, fuel tank, seats, wheel & tire envelope and transmission tunnel and cockpit floor. The model proved to be very useful in visualizing many aspects of the vehicle before functional components were fabricated.

After the design was modified on the full size layouts CAD detail drawings (“blue prints”) were prepared for each structural member of the frame. The CAD detail drawings were “solid models” i.e. 3 dimensional representations of each part rather than conventional 2 dimensional. Solid models can be easily manipulated and “assembled ” into a complete structure in the computer.

The detail drawings were sent to several different suppliers to obtain quotes for the steel frame components. Weldtube Inc. in Dearborn, Michigan was selected to fabricate the tubular components. Weldtube made all of the precision cuts on the tubing to obtain the basic shapes. Federal Pipe & Supply in Detroit, Michigan was selected to fabricate several of the frame components from heavy gauge steel plate.
Fixtures for holding the frame components in place with respect to each other for welding were fabricated using a piece of 1219 mm x 1829 mm x 19 mm (4 foot x 6 foot x ¾inch) plywood, 51 mm x 102 mm (2 inch x 4 inch) blocks and machine screws driven into “cleat nuts” (three pronged T nuts). Several different fixture setups were made in order to weld the entire frame. The fixtures were fabricated in our workshop and transported to Starlight Welding in Redford, MI for final placement and welding. The Milewski’s, Wally, Joe and Andy each had a hand in all of the 61 hours of welding done at Starlight Welding.

The body/frame was removed from the donor vehicle drive train using a four wheeled movable crane especially fabricated for the task.

The new frame was fitted to the drive train and attached using the same 12 fastener locations as on the donor vehicle. The new vehicle frame and drive train was “rolled out” on 19 April 2001.

EXHAUST SYSTEM

Tail pipes mocked up in plastic tubing, plywood and polystyrene foam.

Complete exhaust system.

Tail pipe tips mocked up in corrugated paperboard and fiberboard.

The new exhaust system was developed on the frame/ drive train and on the full size layouts. The precise locations of the ends of the donor exhaust pipes were found thru numerous measurements to the new frame. The ends of the donor exhaust pipes (downstream of the catalytic converters) were the beginning of the new exhaust system. A custom “Siamese” muffler was designed and CAD detail drawings were prepared. The detail drawings were sent to Spin Tech Performance Mufflers in Riverside, CA who fabricated the muffler and shipped it to our shop.

The tail pipes were designed then mocked up using 3” diameter plastic tubing and plywood and polystyrene foam. The mock up revealed areas that could be improved and changes were made to the design. CAD detail drawings were prepared of the tail pipes and the drawings were sent out for quotes to several firms. Stainless Works in Chagrin Falls, Ohio mandrel bent the stainless steel tubing and shipped the tail pipes to our shop.

The tail pipe tips were designed by Craig Sandvig to match the opening on the lower area of the rear deck.

The tips were mocked up using corrugated paperboard and plywood. The mock-ups were disassembled and their flat patterns along with CAD details were used by Stewart Steel Specialties in Farmington Hills, Michigan to fabricate the tips in aluminum. A stainless steel “adapter plate” was designed and fabricated. The stainless steel plate was welded to the stainless steel tail pipes and the aluminum tips were bolted to the plate using stainless steel fasteners. The pipes are attached to the muffler using stainless steel “T bolt” clamps. A bracket assembly fabricated from stainless steel is used to precisely position the rear end of the muffler laterally by tying it to the aluminum beam that connects the transmission to the differential. A stainless steel draw bar coil spring supports the tail pipes and tip assembly from the frame rear cross member. A set of draw bar coil springs support the tail pipes to the differential.

FRAME -DOOR PILLARS, DASH PANEL & TRANSMISSION TUNNEL

Mock up of dash pockets for brake and steering column mounts.

Mock up of transmission tunnel

The door pillars and cross car beam serve as a primary structural element of the vehicle and they were fabricated from 51 mm x 102 mm (2 inch x 4 inch) rectangular steel tubing. They also establish the height of the cowl and the mounting surface for the door hinges. The location of the door hinges is critical because they directly affect the door opening geometry.

The dash panel, transmission tunnel, floor panels and rear storage compartment were developed on the vehicle and on full size layouts. The dash panel was mocked-up using 5 mm (.20 inch) Lauan plywood. Mock-ups of the "pockets" for the steering column mount and the brake vacuum booster mount were fabricated from 5 mm (.20 inch) Lauan plywood and steel drywall corner strips. The pockets were attached to the dash panel mock up using # 6 x 3/8 inch pan head sheet metal screws. The transmission tunnel top was also fabricated from 5 mm (.20 inch) Lauan and drywall corner strips.

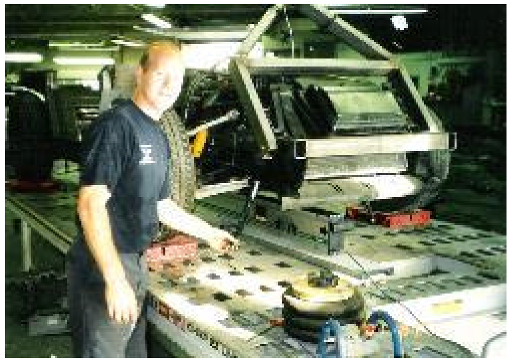
The transmission tunnel sides were mocked up using corrugated paperboard and masking tape. The floor panel toe boards were located with the same relationship to the driver and passenger as in the donor vehicle i.e. same angle and same distance from the H Point. The H point is the location of the occupants' hip joints. The toe boards also are fitted with steel sheet metal heat shields on the underside to minimize the heat transfer from the catalytic converters to the passenger compartment and to shield the brake lines. After the design was finalized CAD details were prepared of the numerous components and sent out for quotes. Stewart Steel Specialties fabricated several of the sheet metal components and coordinated the laser cutting of the dash panel from heavy gauge steel plate.

Plywood fixtures were fabricated to hold the transmission tunnel components in place for welding.

INTERIOR - REAR STORAGE COMPARTMENT

The rear storage compartment contains the battery on the driver side and the power train control module on the passenger side below its floor. The mounting panel for all of the major electrical components-relays, fuses and the On Board Diagnostics port- is housed on the rear wall of the storage compartment. The electrical component-mounting panel is fitted with a steel cover that has an electrical insulator made of acrylic sheet attached to its inner wall. A handle is attached to the top of the electrical panel cover to facilitate removal/ installation. Also the cover has three knobs to attach it to the rear wall of the storage compartment. The knobs eliminate the need for tools to service the fuses. Stewart Steel Specialties fabricated the storage compartment steel components using CAD details. It is a welded module and it is attached to the rear frame rails and rear bulkhead by ten M6 hex head cap screws.

FRAME - DIMENSIONAL CHECK



Dimensional check of frame indicated all points were within tolerance of +- 4 mm.

The vehicle was towed to Starlight Welding on 21 August 2001 where the door pillars, cross car beam, transmission tunnel, dash panel, floor panels and the rear bulkhead panel were welded in place using continuous welds. The vehicle was later towed to Les Stanford Chevrolet in Dearborn, Michigan where the frame was checked for dimensional accuracy. It was found to be well within the factory specifications of plus or minus 4mm (.16 inches).

BRAKE & FUEL LINES

Gene Dickirson with fuel lines mocked up with wood dowel rods.

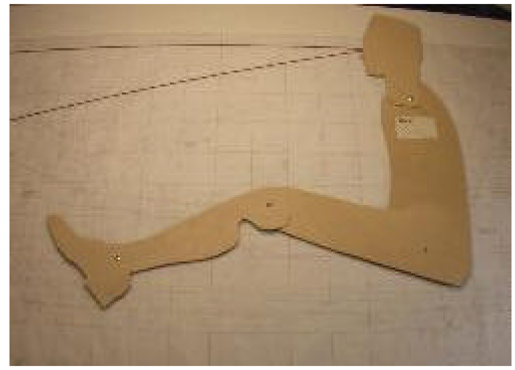
Stainless steel fuel & brake lines.

The brake and fuel lines were developed on the vehicle and on the full size layouts. Mock-ups of the lines were fabricated using 9.5 mm (.375 inch) diameter wood dowel rod and plywood corner braces and hot melt adhesive.

Detail drawings were prepared of the tubes. In Line Tube located in Shelby Township, Michigan fabricated the tubes in stainless steel. The tubes are fitted with stainless steel coil spring stone shields. In Line Tube fabricated the tubes by scanning the wood mock ups rather than from the dimensions on the detail drawings.

WINDSHIELD

Musa Azzouz (L) and Larry Ronzi evaluating windshield angle alternatives.



"Biff" the mannequin being used to develop the windshield sight line.

Rick Walsh of Laird's Glass applying adhesive for bonding the windshield to the support structure.

Substrate used to mold the windshield trim panel.

The windshield was selected based upon its shape and size. The windshields on 28 different cars were measured (on vehicles in used car lots) and the dimensions were tabulated on a spreadsheet. The measurements were taken on the length of the centerline section of the windshield, the width at the bottom and the width at the top. Tom Laird at Laird's Glass and Trim in Plymouth, Michigan provided samples of cracked windshields from a 1965 Pontiac LeMans and a 2001 Jeep Cherokee for evaluation. The broken windshields were fixtured and measured and 1:8 scale drawings were made. The drawings were used to "cut sections" on the full size layouts and thereby permit the selection of the "optimum" windshield. Glassline in Plymouth, Michigan fabricated a mock up of a Mustang windshield in fiberglass. The Mustang windshield was rejected because it was too "tall" and the sides sloped in too much at the top. The windshield type used on 2001 Jeep Cherokees was selected because it was the best fit for height and width and its upper corner radii were well proportioned.

Several incline angles were evaluated for the windshield. It was desired to have the angle as shallow as possible (close to horizontal) and still permit an acceptable viewing area between the hood of the vehicle and the block out mask at the top of the windshield. Evaluations of various angles were conducted on full size layouts using the nominal eye point location and the centerline section of the hood. The eye point location was determined on the layout by placing a seating mannequin on the layout. The mannequin's "H POINT" or hip point was placed on the seat H Point on the layout. The seat H Point was determined by placing a prototype Cerullo seat on the workshop floor and measuring the distance from the floor to the tops of the heads of two different people.

Then knowing the distance from the floor to the top of the "average" head the H Point could be determined by using the mannequin on the layout. Dave Maran fabricated the seating mannequin from 5 mm (.20 inch) Lauan plywood. Larry Ronzi compiled the dimensions and patterns for the mannequin from published data. Dave named the mannequin "Biff". The team also evaluated the sight line alternatives in the vehicle using the cracked Cherokee windshield held at various angles using a temporary wooden support structure. A temporary seat, steering column and steering wheel were used for the in-vehicle evaluations. The final angle selected was 19 degrees from the horizontal.

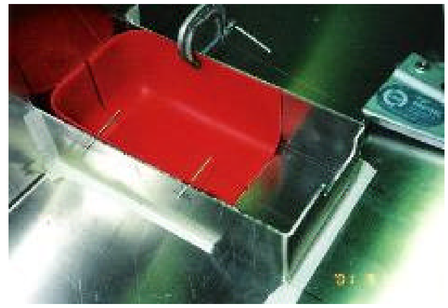
Two windshield support structures were designed and fabricated using 19 mm (.75 inch) square steel tubing with 3 mm (.12 inch) wall thickness. The first windshield support structure had a header. It also had a fully molded cross section running around the "A Pillars" and the header. The first structure was evaluated on the vehicle and was judged to be too bulky in appearance. A second structure was designed and fabricated without a header and was judged by the team to be ideal for achieving the desired "speedster" image of the vehicle. The windshield edge was coated with a layer of Super Fil epoxy putty, primed and painted. Eight different adhesives and coatings were tested on a broken windshield in order to identify the best material for the edge filler application. The windshield block out pattern was modified to suit the GDT Speedster by placing the windshield in the vehicle and using masking tape to determine the line that would cover the leading edge of the instrument panel and the "A Pillars". Plastic masking tape (3M 218) and the PPG RS 21&22 two-part primer system were used to apply the new mask. Rick of Laird's Glass adhesively bonded the windshield to the support structure using the PPG RS polyurethane system.

The lower edge of the windshield is covered with a trim panel that also covers portions of the sides of the instrument panel. The trim panel is fabricated from vinyl ester resin and fiberglass cloth. The part was molded using the "splash" technique i.e. rough side out then smoothed. The lay up was done directly on the windshield glass covered with wax paper and on temporary forms made of chipboard and modeling clay. The panel is held in place using stainless steel #6 sheet metal screws at the sides and middle.

FUEL TANK

Filling fuel tank with water for leak testing.

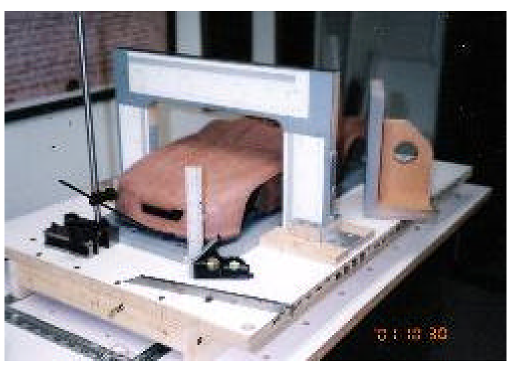
Leak test set up for fuel tank using air pressure on top of water.



Fuel tank "anti slosh" reservoir inside tank.

The fuel tank was designed to fit between the rear frame rails, the rear cross member, the rear panel of the storage compartment, the rear deck support structure and the rear suspension support bracket. An expert on fuel tanks was consulted on several aspects of the tank including material, venting system, anti slosh reservoir, fuel level indicator sending unit and others. The 60 L (16 US gal) tank was designed to utilize a Corvette fuel pump/fuel level sending unit/filler neck/cap module. The new tank package required the fuel level float arm to be modified to fit inside the tank. The tank is fabricated from 5052 H aluminum sheet 2.3 mm (.09 inch) thick welded together. The aluminum tank mounts are welded to the tank and the mounts are attached to the frame via rubber isolators. An electrical ground strap connects the tank to the vehicle frame. The tank includes an internal reservoir that surrounds the fuel pump and maintains a small quantity of fuel to minimize the risk of fuel starvation during cornering/braking when the tank fuel level is very low. The fuel tank was leak tested after welding by filling it with water then pressurizing it with air to represent actual operating conditions.

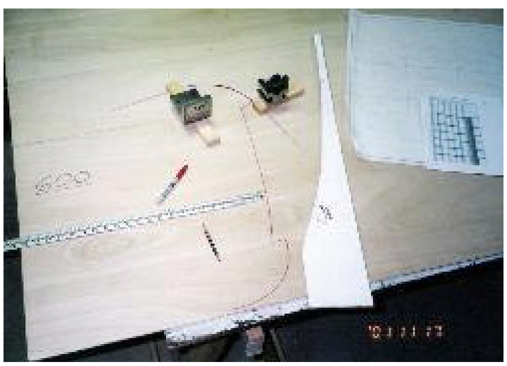
CLAY MODEL - SECTIONS



Taking measurements of the surface of the 1:8 scale clay model.

By 30 October 2001 Larry Ronzi had the 1:8 scale clay model of the body approximately 80% complete. Larry had been developing the model based upon some early "hard points" listed above (wheel base, shoulder room, etc.). It was now necessary to begin "cutting sections" thru the clay. The sections were necessary to verify clearance would exist between the body panels and the underlying structural/drive train components. More than 30 sections were "cut" thru the clay model. To "cut" the sections the model was held firmly in place on a surface plate lines were lightly scribed in the clay every 25 mm (0.98 inches) which was the equivalent of 200 mm (7.87 inches) on the full size vehicle. At selected scribed lines several points were measured. The vertical location of each point was measured from the surface plate (height). The side-to-side location of each point was measured from a "0" line scribed on the surface plate that was parallel to the longitudinal centerline of the model (width). The front to rear location of each point was measured from a "0" line scribed on the surface plate that was perpendicular to the longitudinal centerline and located approximately 72 mm (2.83 inches) behind the front axle. The dimensions were tabulated on a spreadsheet. The dimensions were used to prepare 1:8 scale drawings on vellum of each section.

BODY - FULL SIZE MOCK



Full size foam mock up Lauan plywood station marked for cutting.

Three sections of the for full size foam mock up.

The first two stations being attached to platform for full size foam mock up.

Exploded view of full size mock up.

Design review of full size foam mock up by several of the team members.

Full size foam mock up for review in an outdoor setting.

It was decided that a full size mock up of the body surface would be highly desirable in order to obtain a more realistic image of the shape and size of the vehicle before going to the future steps of scanning/digitizing/surfacing/mold building/molding. It would be extremely beneficial if the mock up could be viewed out doors in sunlight from various distances and angles.

The first step in designing/fabricating the full size mock up was to modify the spreadsheet listing the 1:8 scale section dimensions. The spreadsheet was modified to calculate the full size dimensions of each point in each section by multiplying each dimension by 8.

A platform was designed to support the full size mock up of the vehicle. Because of limited floor space in the workshop the platform was fabricated in three sections. The width of each platform section had to be carefully designed to ensure that it could pass thru the workshop doors. In addition, the weight of each section had to be known in advance to ensure that it could be easily moved from the workshop to other viewing areas. The three platform sections were fabricated using 50 mm x 203 mm x 3657 mm (2 inch x 8 inch x 12 feet) pine boards with 5 mm (.20 inch) Lauan tops fastened with drywall screws.

It was initially planned to use 11 mm (.44 inch) OSB (oriented strand board) for each of the 19 stations in the full size mock up. However after loading and hauling 453 kg (1,000 pounds) of the OSB to the workshop weight calculations were made. The calculations revealed the OSB was too heavy for the application. Lightweight Lauan 5 mm (.20 inch) thick was selected for the stations. The full size dimensions from the spreadsheet discussed above were used to place points (“dots”) on the Lauan sheets.

The points were joined using a felt tip pin and a 3 mm (.12 inch) diameter flexible plastic dowel rod. The stations were cut using a band saw and smoothed using a belt sander.

The three platform sections were “tacked together” using drywall screws and furring. A centerline was scribed on the top of the middle platform front to rear. Lines perpendicular to the centerline were scribed on the tops of the platforms every 200 mm (7.9 inches) front to rear. Pine “furring blocks” 25 mm x 50 mm x 75 mm (1 inch x 2 inch x 3 inch) were attached to the platforms at each station line using hot melt adhesive. The 19 Lauan stations were attached to the platform furring blocks using dry wall screws. Spacers were placed near the tops of the stations to prevent a “domino effect”.

The spaces between the Lauan stations were filled with pink polystyrene foam 38 mm (1.5 inch) thick using hot melt adhesive. The nose and tail sections and a windshield module were fabricated as separate pieces in order to make them portable. The foam was shaped using a Stanley Surform Shaver tool. A coat of Sheetrock Lightweight All Purpose Joint Compound was applied to the foam. The drywall joint compound was smoothed and then a coat of latex primer was applied. The topcoat was high gloss red latex paint.

The wheels and tires were mocked up using paper pictures applied to Lauan plywood substrates. The headlamps were also mocked up using paper pictures glued to the foam. For the design review the joints between the various modules were covered with masking tape pre painted with the red latex paint.

On 15 February 2002 the mock up was moved from the workshop out doors thru ice and snow then back inside to the adjacent family room. A design review was held with several of the team members present. The design review of the mock up indicated several revisions would be need to the clay model before proceeding to the “OK to TOOL” phase. The completed full size foam mock was reviewed in an outdoor setting as soon as the weather permitted on 31 March 2002.

BODY - TIRE CLEARANCE TO FENDERS

One of the most obvious visual concerns identified with the mock up was the relationship between the front wheel/ tire and the wheel well opening in the “front fender”. The fender extended outward past the plane of the wheel/tire too far. This concern required that the front wheel tire jounce, rebound, left turn and right turn geometry be fully understood to ensure the tire did not strike the fender opening under extreme conditions. To determine one aspect of the geometry the vehicle was again positioned on jack stands and the left turn and right turn wheel/tire locations were carefully measured and the information was added to the layout. To determine the jounce/rebound geometry it requires the front control arms be free to move i.e. the spring must be removed and it is difficult to gather accurate measurements without a surface plate or a computerized measuring machine. Rather than attempt to directly measure jounce/rebound it was decided to measure the relationship between the tire and fender opening on several production C4 Corvettes. A special measuring aid was fabricated and taken to the Les Stanford Chevrolet used car lot. The salesman on duty authorized us to measure several of the Corvettes on the lot. The measurements were compiled and the average values were used to design the front tire/ fender gap on the new vehicle.
A jounce/rebound study was conducted on the rear wheel/tire. The vehicle was supported on jack stands and the rear spring was disconnected from the suspension system. The angle of the wheel was measured as the axle hub was raised then lowered to several different positions using a floor jack. This information was then added to the full size layout and used to position the rear fender opening with respect to the new wheels/tires.

BODY - HEAD REST DEVELOPMENT

"Biff" the mannequin being used to develop the head rest location.

A late design change required revising the region between the head rests.

The headrests were not fully developed in the full size mock up reviewed on 15 February 2002. The head rests were subsequently developed using “Biff”, the seating mannequin in the vehicle. The head rests were developed so that they would be located approximately 150 mm (5.9 inches) behind the occupants' heads and provide adequate clearance to their shoulders. The space between the headrests was modified after the fiberglass rear deck panel was reviewed on the vehicle with a seat in place. The area between the headrests looked “too heavy”. This required cutting the fiberglass between the headrests and then bonding in 21 fiberglass segments to achieve the desired shape.

BODY - DOOR CUT LINES & HARDWARE

Door cut line study model mocked up in chipboard.

The door cut lines represented a major challenge. They had to be attractive and functional. The doors had to clear the rocker panels and hood as they opened and they could not touch the rocker panels when they were fully opened. Several design iterations and models were built to achieve the desired results. The door hinges were selected based upon their shape, size and robustness. They are the type used on the 1999 Ford F Series.

The hinges had to be precisely located on the door pillars and the hinge pin centerlines had to be absolutely collinear in order for the doors to open and close properly. Door hinge technical specialists were consulted to gather numerous design considerations. The door latches, strikers, interior handles and cables were also the type used on the 1999 Ford F Series. The door handles were located so that they would be at the ergonomically correct position when the occupant reached for them. Their location was developed by measuring the handle location on several production vehicles with respect to the driver's arm while setting in the vehicle seat. The measurements were averaged and the values used as the starting point for the handle location. The door structural frames were fabricated from 38.1 mm (1.5 inch) square steel tubing with 3.1 mm (.12 inch) wall thickness. The door latches are mounted in fabricated five-sided steel "boxes" that are welded to the door structural members.

BODY - DOOR SILLS & ROCKER PANELS

Door sill mocked up in corrugated paper board.

The latch pocket mock up in the rocker panel door sill model.

The doorsills in the sides of the rocker panels were also a major design challenge. They have steps and pockets for the rear deck latches that were very intricate to design. A full-scale mock up was fabricated using corrugated paperboard and hot melt adhesive in order to fully visualize the surfaces during the design.

CLAY MODEL - SCANNING & DIGITIZING

"OK to tool" 1:8 scale clay model. L to R Craig Sandvig, Larry Ronzi, Gene Dickirson.

Point Cloud after scanning

Clay model immediately before it was digitally scanned -3/4 front view.

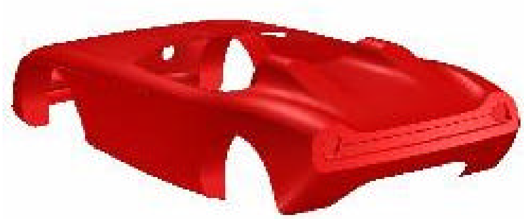
Clay model immediately before it was digitally scanned -3/4 rear view.

Larry Ronzi completed the 1:8 scale clay model on 17 October 2002 after incorporating all of the changes identified during the design review.

The clay model was then delivered to GKS Inspection Services, Inc. in Livonia, Michigan. The people at GKS scanned and digitized the model. The scanned data was in the form of a "point cloud" which consisted of the precise location of millions of points (dots) on the surface of the clay model.

The data was recorded on a CD.

BODY - SURFACING



Body surface data used to machine the molds developed by Larry Conger .

The scanned data CD was then given to Larry Conger. Using a powerful CAD design tool (software package) called ICEM/Surf Larry converted the point cloud to a surface. He expanded the surface from 1:8 scale to full scale in his computer data file. He then smoothed the surface. Even though the clay model that Larry Ronzi sculpted looked and felt smooth it actually contained subtle imperfections that would become visible when expanded 8 times to full size. Next, Larry Conger made the right side of the body surface exactly symmetrical with the left side. In order to save time and enormous effort the 1:8 scale clay model was only finished on the left side, the front, the rear and the top. The right side of the clay was intentionally left rough. Larry Conger then developed the edges of each of the body panels. He also checked the door swing geometry to ensure all of the conditions discussed earlier were met.

After Craig Sandvig was satisfied that the body surfaces would look good in physical form, Larry Conger E-mailed the CAD file to Chris Mason at Method Industries in North Carolina.

BODY - PANEL CONSTRUCTION

Door mold with jel coat applied prior to laying up fiberglass and vinyl ester.

Fiberglass rear deck components after being trimmed.

Rear deck components fixtured for bonding.

Chris and his brother Andy then used the CAD file to develop cutter paths for their 3 axis-milling machine. Cutter paths are the routes- up/down/left/right/fore/aft- the tip of the router must take to accurately remove material from each chunk of foam used for the molds. The molds for each part were made up of several chunks or segments of 64 kg/m^3 (4 lb/ft^3) polyurethane foam that were adhesively bonded together. After machining, the "working cavity" of each mold segment was sprayed with a coat of Duratec resin that would serve as the "working surface" for the mold. After the resin hardened the working surface was smoothed then coated with a special "mold release" wax. The wax would prevent the molded fiberglass parts from sticking to the Duratec surface. The mold working cavities were sprayed with a "gel coat" that served as the top surface of the molded parts. Up to 8 layers of fiberglass fabric, some Kevlar fabric and vinyl ester resin were then applied to each cavity to make the parts approximately 3 to 7 mm (.12 to .30 inches) thick. After the vinyl ester resin cured in a couple of days the parts could be removed from the molds. The molds were destroyed after the fiberglass parts were removed. The molded parts were then trimmed. They were then placed on fixtures and bonded to adjoining parts to make up the final body panels. The finished body panels were then packaged in special shipping containers we had designed. The containers were designed with input from the Fed Ex Freight people at their Romulus, Michigan depot. The panels were shipped from Chris and Andy's shop to the Fed Ex depot in Romulus, where Chuck and I collected them and transported them to our work shop on a trailer.

The first two body panels were received from Chris and Andy Mason on 11 September 2003. They were the driver side door and rocker panel. They were temporarily attached to the vehicle and were judged to be excellent for finish. Fit would be evaluated later when the hood and rear deck were fabricated and installed.

MEMO: *A hurricane struck North Carolina about 20 September 2003 during the period the remainder of the body panels were being fabricated. The hurricane skipped over the workshop where the body panels were being fabricated however it inflicted extensive damage to the home of Chris and Andy Mason. They set up bunks and slept in their workshop until their home was repaired.*

BODY - HOOD & REAR DECK SUPPORT STRUC-

Measuring plane used to accurately determine location of engine components.

Rear deck alignment pins and bumpers ensure body panels are flush and properly spaced.

The hood support structure was designed using the full size layouts. The precise location of the upper engine components had to be shown on the layouts in order to ensure the structural components would clear them. To determine the location of the upper engine components a “measuring plane” was established above the engine compartment. Measurements were taken between the engine components and the plane then the location data was transferred to the full size layout. The front of the structure is hinged on 38.1 mm (1.5 inch) square steel tubes welded to the front frame rails. The hood latches, strikers, cables and release handle are the type used on the 1994 Corvette. The hood release handle is mounted in the lower rear surface of the left front wheel well. The striker pins had to be positioned on the movable structure so that they would enter the stationary latches perpendicularly as the hood closed. Also the spacing between the striker pins and the latches had to be exactly the same in order for them to function properly. The structure is fabricated from 19 mm (.75 inch) square steel tubing with 19 mm x 38.1 mm (.75 inch x 1.5 inch) steel struts and 19 mm (1.5 inch) square steel hinge columns all welded together. See engineering drawing 0721 in the FRAME section of this web site. The hood structure has a check cable on each side to prevent over travel. The hood contains two gas assist springs that provide a high force to assist with opening the hood. The gas assist springs were developed in conjunction with Gary Weber at Arvin Meritor in Marion, South Carolina. Drawings of the hood structure and the vehicle frame along with the projected weight of the hood assembly (support structure and fiberglass panel) were sent to Gary. He used the information in a proprietary computer program and identified a production gas spring that he recommended for our application. The hood can be easily removed from the vehicle by disconnecting the two check cables, disconnecting the headlamp wiring connectors and removing the two hinge bolts.

The rear deck support structure is similar in construction to the hood support structure. The rear deck latch system is incorporated into pockets molded into the fiberglass rear deck panel and the fiberglass rocker panels. The latch strikers are attached to steel alignment brackets located on the under side of the fiberglass rear deck panel. The latches are attached to steel brackets located on the rear surface of the fiberglass rocker panels containing stainless steel alignment pins and rubber bumpers. The stainless steel pins enter holes in the rear deck alignment brackets to ensure the rear deck sides are flush with the rocker panels when the rear deck is closed. The rubber bumpers ensure the design gap is maintained between rear deck and rocker panels and they ensure the latches are in tension with the strikers. The rear deck support structure contains a steel sheet metal partition to separate the fuel tank area from the passenger compartment. The partition closes against an elastomer edge seal. The rear deck contains a chain and draw bar coil spring check system that is intended to cushion the stop as the rear deck reaches the full open position. The springs are wrapped with foam and leather to minimize rattles.

INTERIOR - STEERING COLUMN

Completed steering column in vehicle.

Steering column with mounting brackets welded in place.

The steering column was developed on the layout and using a wood mock up in the vehicle. The steering wheel location was starting point of the process of designing the steering column. The steering wheel was located on the layout in the same relationship to the driver as in the 1994 Corvette, i.e. on the same plan view centerline as the driver seat, the same distance up and forward from the H Point and at the same angle. The column mounting brackets were developed to attach the column to the cross car beam and to the pocket in the dash panel. The brackets were designed and CAD details were prepared of all of the steering column components including the steering shaft. The steering shaft has a unique cross-section, i.e. different than the standard shafts used in aftermarket steering columns, to mate to the Corvette universal joint. The CAD details were sent to the ididit factory in Tecumseh, Michigan. The column, shaft and head were fabricated less the turn signal switch and wiring and returned to us. We fabricated the mounting brackets and built a weld fixture to hold them in the correct relationship to the column while Starlight Welding welded them. The column was then returned to ididit for final assembly of the electrical components and the shaft bearing. The steering wheel was custom fabricated by Lecarra using leather supplied by our team. The horn button features the laser etched team logo.

REAR WHEEL TOE ADJUSTERS

Racecar type toe adjuster.

A unique set of adjusters were designed and fabricated for adjusting the toe angle of the rear wheels. The adjusters were designed on a full size layout. They use racecar double threaded knurled aluminum tubes and Heim joints supplied by Speedway Motors. The outer Heim joint ends are attached to the tapered holes in the rear knuckles using adapters supplied by Vette Brakes. The central mounting bracket is fabricated from welded steel plate. It is attached to the differential at the same location as the 1994 Corvette.

FRAME - PAINT & ASSEMBLY

Components refurbished from the donor vehicle.

Chuck Carlson painting the frame.

The frame was painted using a PPG paint system. The steel structure was cleaned with an acid system, rinsed with water and dried immediately. A coat of PPG epoxy primer was applied. The joints in the floor panels and dash panel were sealed with Fusor 809 sealer. The dash panel was filled and smoothed. The frame was then painted with PPG DCC 5716 Concept in "Dark Shadow Grey Metallic" color.

Abrasive blasting using a mixture of glass beads and aluminum oxide cleaned the aluminum components used from the donor vehicle. The steel parts were cleaned then painted with Krylon Industrial "Rust Tough" black.

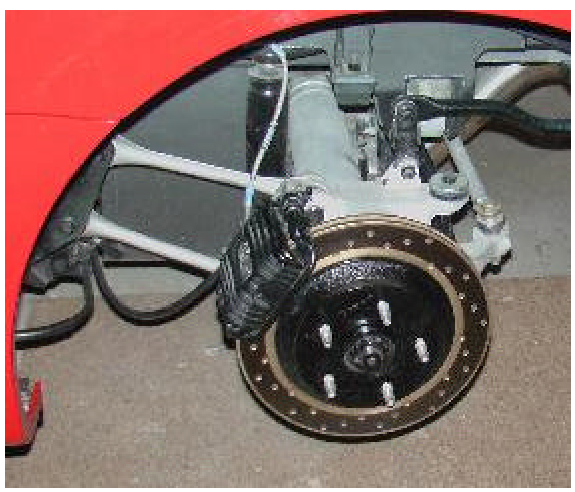
The frame was assembled to the drive train using the wheeled frame-lifting crane. The fuel and brake lines were installed and the tail pipes were loosely fitted.

BRAKE PEDAL PADS

The bright stainless steel trim moldings highlight the brake and accelerator pedals.

A new brake pedal pad steel substrate was developed to accept a new rubber pad like the type used on the 1968-1974 Corvette. A new hinge/spring mechanism was developed to accept an accelerator pedal pad from the 1968-1974 Corvette. The pads were selected because they feature bright stainless steel accent moldings.

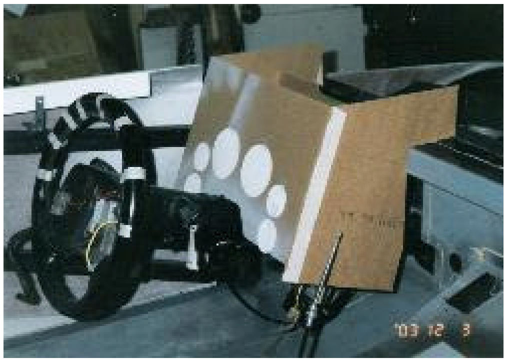
BRAKE ROTORS & FLEX LINES



The brakes feature cross drilled rotors and stainless steel braided flex hoses.

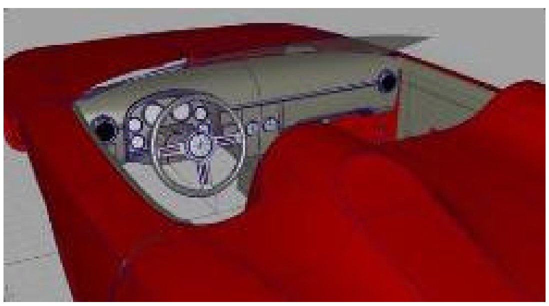
The brake rotors are cross-drilled cast iron units supplied by Power Stop division of TRW. The hubs of the rotors have been painted black. The brake fluid flexible lines have braided stainless steel covers and are supplied by Russell.

INTERIOR - INSTRUMENT



Field of vision study using corrugated paper board mock up to develop optimum location of gauges.

Instrument panel mocked up in plywood to verify switch and gauge locations.



CAD drawing of interior prepared by Craig Sandvig.

CAD drawing by Larry Conger of instrument panel used to machine the molds.

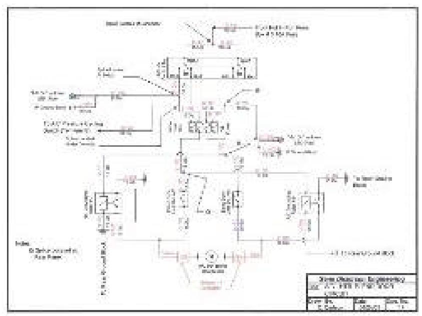
The instrument panel was developed using full size layouts, reduced scale layouts, wood mock-ups and CAD tools. The first step in developing the instrument panel was to establish the plane of the gauges and the field of view thru the steering wheel. The gauge plane was located 260 mm (10.24 inches) forward of the front plane of the steering wheel and perpendicular to the centerline of the steering column. The field of view was established on the layout and verified by fitting a corrugated paperboard “plane” to the vehicle.The gauges to be used were selected from the catalog of Classic Instruments. The gauges were drawn in on the layout using the published dimensions. Paper cut out drawings of the gauges were added to the corrugated paperboard plane to verify readability from the driver’s seat.

A mock up of the rough architecture of the instrument panel was fabricated from 12 mm (.50 inch) plywood, and 50 mm x 50 mm (2 inch x 2 inch) pine boards. The rough instrument panel mock up was fitted with a piece of 3 mm (.12 inch) particleboard with holes drilled to accept 3 dimensional mock-ups of the gauges. The gauges were mocked up using corrugated paperboard and hot melt adhesive. The gauge mock-ups were fitted to the cluster mock up to verify clearances to the steering column mounting brace. Copies of the paper layouts were given to Craig Sandvig that identified the locations of the “hard points” he would use for developing the surfaces of the instrument panel. Craig developed the overall “theme” of the panel and some of the details.

Craig transferred the information to Larry Conger who then developed the final surfaces of the instrument panel. Larry designed the panel on his computer taking into consideration the inside surface of the windshield, the door trim panels, the windshield support structure “A Pillars” and the transmission tunnel. Larry also designed a recess of 1 mm (.04 inch) to the entire upper surface of the instrument panel to accept the leather trim. After a review of Larry’s CAD drawing the team recommended some revisions. Larry made the revisions and then sent the CAD file to Chris Mason in North Carolina on 27 May 2004. The molded fiberglass instrument panel was completed on 26 July 2004 and shipped via UPS to our workshop.

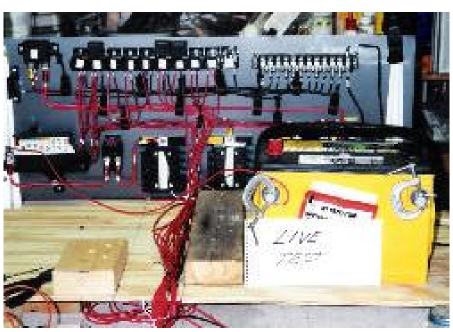
ELECTRIAL WIRING SYSTEM

PCM wiring harness mocked up using rope and wood.



Example of a typical wiring diagram of the 41diagrams created by Chuck Carlson on the computer.

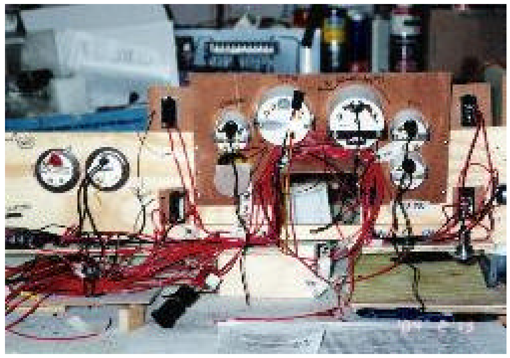
One of six pages of the bill of material for electrical wires, terminals and connectors.



Live test of the electrical system on work bench using the vehicle battery.

Developing the foot steady rest and head lamp dimmer switch location.

Transmission shifter PRNDL potentiometer and mounting bracket.



Gauges held in design position in fiberboard instrument panel for wire routing.

The electrical wiring system was designed on the computer and developed on a full size wood mock up of the electrical mounting panel, the transmission tunnel top and the instrument panel. James Wilber helped with the design by physically identifying and marking a majority of the circuits on the donor vehicle wiring harness and by reviewing the 1994 Corvette Service Manual. One of the major elements of the electrical system is the Power train Control Module (PCM) or engine computer. The PCM is securely mounted in a steel compartment under the floor of the rear storage compartment and has wires running from it to the engine, transmission and to the rear electrical component-mounting panel. The PCM wiring harness is very specialized because of the unique terminals, connectors and wire lengths to fit the vehicle. In addition, the PCM software is specialized to make it compatible with the vehicle electrical system. Howell Engine Developments in Marine City, Michigan was selected to fabricate the PCM wiring harness and to modify the PCM software. James, Chuck and I traveled to Marine City and met with the Howell Engine people twice before the design was finalized. Howell Engine people were provided with the PCM from the donor vehicle, a circuit specification sheet, an engineering drawing of the wiring harness as well as a mock up fabricated from rope and wood blocks to simulate the electrical connectors to use for fabricating the wiring harness.

The balance of the vehicle electrical system was designed around just four visible electrical switches on the instrument panel. The four instrument panel rocker switches were selected for their appearance and ergonomic feel. The START switch is located to the far left side of the instrument panel to minimize the risk of accidental actuation by the passenger. The start switch has a red actuator cover to further identify it as a special switch.

The ignition on/off switch has a green Light Emitting Diode (LED) mounted next to it that illuminates when the ignition is on. The climate control switch is a three-position rocker. When the switch is in the middle position the heater and A/C system is off and neither the red nor blue LED is illuminated. When the switch is in the down/on position the heater is on, the system blows hot air and the red LED is illuminated. When the switch is in the up/on position the system blows refrigerated air and the blue LED is illuminated. The wiring system to accomplish the simple on/off/on control is made up of relays and limit switches rather than an electronic module. It was a major challenge to design the control sub system because the polarity of the current feeding the temperature blend door must reverse in order for the door to move from the warm to cool or cool to warm positions.

The vehicle electrical system features 12 relays, 7 fuse blocks, 38 fuses, 5 terminal junction blocks, 240 electrical circuits, 8 LED's, 14 switches, 2 horns, a power point, a 1,000 cranking amp battery with both side and top terminals. Essentially every circuit has a self-adhesive number marker on each end of the wire. The electrical system is described on 41 computer drawn schematic sheets. Chuck Carlson drew the schematics using Microsoft Excel. The schematic sheets are included in the GDT Speedster Service Manual.

In addition, spreadsheets were prepared that listed every circuit by number, the length of each wire, the wire color, the inlet terminal part number, the outlet terminal part number, the inlet connector part number and the outlet connector part number. This spread sheet was used to order the appropriate quantity of components to fabricate the system.

The head light dimmer switch is located in the steady rest for the left foot. It was carefully packaged so that the switch would not be accidentally actuated by the driver's left foot while in the normal rest position and yet would not be located so high that the driver's foot would contact the instrument panel during actuation.

The instrument panel gauges were selected from the catalog of Classic Instruments. The speedometer and tachometer were custom fabricated for the GDT Speedster with the team logo printed on their faces. The gauges were placed in a pressed board panel located in design position during the wire routing phase.

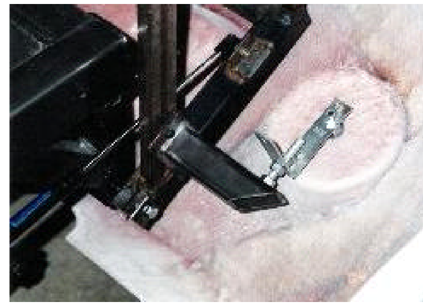
The vehicle features a "PRNDL" gauge located near the center of the instrument panel. The PRNDL gauge is electrically actuated from a signal from a potentiometer located on the gearshift lever mechanism. The design of the linkage to actuate the potentiometer and the packaging to clear the existing mounting pocket in the transmission tunnel was accomplished using full size layouts and full size metal mockups.

A series of live tests were started on 4 February 2004 to verify every electrical circuit functioned properly. The tests were conducted with the components mounted on the wooden mock up well before the wiring system was installed in the vehicle. The vehicle battery was used to supply the power to each of the circuits being tested. The tests identified a few concerns that were corrected before system was installed in the vehicle.

BODY - FITTING PANELS TO SUPPORTS

Hood & frame center lines aligned during body panel adhesive bonding process.

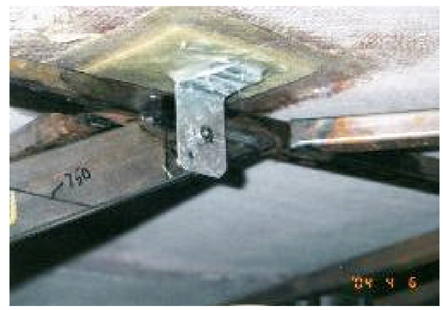
Three steel ribs for attaching door panel to structure.



Hood temporary positioning bracket mounted to "headlamp surface" which will be removed later.

Temporary bracket for locating and holding rocker panel tip during panel bonding process.

Door panel temporary positioning brackets.



Typical steel bracket for bonding fiberglass body panels to steel support structure.

Rear deck temporary positioning fixtures used to position and hold the fiberglass panel in precise alignment before final bonding to the steel support structure.

The hood, rear deck, passenger side door and rocker panel were received at the FedEx depot in Romulus on 20 February 2004. We transported them to the workshop on a trailer. Fitting the body panels required that they be accurately temporarily held in relationship to each other and the under lying support structure. This necessitated that measurements be taken between the body panels and the steel structure and the shop floor. A centerline was scribed on the shop floor by dropping perpendiculars from the front and rear cross members of the vehicle frame. Centerlines were scribed on the hood panel and the rear deck panel using a pencil and a steel flexible straight edge (100 foot steel measuring tape). The centerlines on the hood and rear deck were carefully aligned with the centerline on the shop floor using a plum bob.

The fore & aft locations and heights were established by aligning the “O-O” holes in the rocker panel mounting flanges with the “O-O” holes in the rocker panel mounting rails. The rocker panels were temporarily attached to the mounting rails using # 10 hex head sheet metal screws.

Temporary metal and wood brackets were attached to the tail lamp surfaces and the headrest surfaces on the rear deck. The tail lamp surfaces would later be cut out to make room for the actual tail lamps. The holes in the headrest surfaces would later be covered with the upholstered headrest pads. The wood and metal brackets were attached to the steel support structure. Threaded studs and nuts permitted the rear deck to be moved and then precisely held with respect to the support structure and the adjacent rocker panels. A concern was identified during the early phase of fitting the rear deck. It was found that the lower portion of the fiberglass rear deck interfered with the steel pivot ends of the rear deck support structure.

This was caused by a failure to cut sections at the pivot locations during the design phase. A centerline section indicated adequate clearance to the pivots however the lower surface curves forward at its outer ends and the actual condition was interference. Redesigning and revising the lower pivot points by moving them forward in the vehicle resolved the concern. This required cutting and welding the ends of both the rear deck support structure pivot columns and the pivot columns on the vehicle frame.

Metal brackets were temporarily attached to the headlamp surfaces in the fiberglass hood and to the steel headlamp mounting brackets in the steel hood support structure. The headlamp surfaces would later be cut out of the fiberglass hood to make room for the actual headlamps. Threaded studs and nuts permitted the hood to be adjusted in two planes (fore & aft and up & down) and then precisely held in the desired position.

The trailing edge of the hood was positioned in its design location by placing it against a wood and steel bracket attached to the steel support structure at the vehicle centerline. Out board studs and nuts were used to precisely control the heights of the two rear corners of the hood. The two studs were threaded into tapped holes in the hood support structure.

The front wheel opening “tips” of the rocker panels were positioned and temporarily held in place by wood and metal brackets attached to the engine. Screws and nuts permitted adjustment to obtain and hold the precise side-to-side location of the tips.

The fiberglass door panels were temporarily attached to the steel door support structure using a system of 90 degree steel brackets and studs and nuts. This system permitted adjustment and precise holding of the fiberglass door panels with respect to the door support structures.

After the body panels were adjusted to achieve the intended alignment “target locations” were marked with a felt tip pin on the under side of the body panels for adding steel mounting brackets. The panels were then removed from their temporary mounting positions. Fiberglass pads were added to the under side of the fiberglass body

panels at each of the target locations. The fiberglass pads were needed to minimize the possibility of "bleed thru" where the steel brackets would be bonded to the panels. Bleed thru can occur when high, concentrated forces are placed on the underside of fiberglass panels resulting in cosmetic marks showing on the top surface of the panel. The fiberglass pads were approximately 152 mm (6 inches) square and were "laid up" as follows: a coating of vinyl ester resin to the target area, 1 layer of fiberglass mat, 1 layer of core mat 3 mm (.12 inches) thick, 1 layer of fiberglass mat, 1 layer of fiberglass fabric (6 oz/yd^2) with a coat of vinyl ester resin between each layer and on top of the fiberglass fabric.

The body panels were then reattached to their support structures using the temporary systems described above. Steel, 90 degree brackets, 32 mm (1.25 inches) wide x 38 mm (1.5 inches) x 38 mm (1.5 inches) x 1.6 mm (.06 inches) thick were modified by grinding the galvanized coating from one of the outer faces. Each bracket was carefully fitted to its location by drilling a 6.3 mm (1.25 inch) hole in its galvanized face. The location of the hole had to result in the bare face being approximately 1.5 mm (.06 inches) from the fiberglass pad when the bracket was bolted to the steel support structure. The steel support structure had 6.3 mm (1.25 inch) holes drilled at the target locations to receive the brackets. M6 hex head cap screws were installed in the steel support structure. The length of the exposed thread was such that a hex nut could be installed to hold the cap screw in place and there would still be enough thread for the steel mounting bracket and a hex nut to hold the bracket in place.

A layer of methacrylate adhesive was applied to the bare face of the steel bracket (the literature and our own testing verified that the methacrylate bonds well to bare steel and poorly to galvanized steel). The bracket was placed over the exposed thread on the cap screw and a hex nut was tightened to hold the bracket in place while the adhesive cured. This process was repeated at each of the four corners on the hood and at four corners on the rear deck. The temporary mounting systems were removed and the hood and rear deck body fits were verified. The fits were judged to be satisfactory so the remainder of the steel brackets were added to the hood and rear deck to fully secure them in place.

Three, steel sheet metal "ribs" were added to each door structure. The ribs served as mounting surfaces for the steel 90-degree brackets. The fiberglass door panels were bonded in place using the same process that was used on the hood and rear deck. The door panels required extensive reworking of their edges and upper surfaces to achieve the desired fit to the adjacent hood, rocker panel and rear deck panels.

The rocker panels were bolted securely to the rocker panel mounting rails using M6 cap screws. The front wheel regions of the rocker panels are attached to sheet metal structures that serve as inner fenders.

RIDE HEIGHT

After the body panels were fitted a ride height study was conducted. The ride height of the vehicle -that is the distance between the vehicle frame and the ground-was intended to be the same as the 1994 Corvette. This height also controls the clearance between the tires and the wheel well flanges. In order to achieve the height objective it was planned to have the same weight as the 1994 Corvette so that the springs would deflect the same amount. The weight of the completed vehicle was projected based upon the known weight of many of the components. Every component except the engine and transmission had been weighed before it was assembled onto the vehicle. The weights of the engine and transmission were found in the book “Cor-vette Specs” by Mike Antonick, published by Michael Bruce Associates, Inc., Powell, Ohio. The weight of each component not yet completed was estimated based upon similar parts or engineering calculations. The projections indicated the vehicle would weigh approximately 1350 kg (3000 lb) versus the target weight of 1507 kg (3350 lb). A study was conducted to project the final ride height of the vehicle versus weight. The height of the partially completed vehicle was measured at each of the four corners of the frame (between the frame and the floor). A series of sand bags and iron lifting weights were placed in the cockpit in increments of approximately 22 kg (50 lb). After each weight increment was added the heights were measured. The heights were again measured as each increment of weight was removed. The height measurements were averaged and plotted against the weight increments. The results indicated the target height would be met if approximately 135 kg (300 lb) of ballast were added to the vehicle. Research was conducted on several alternative ways of adding ballast to the vehicle including lead shot, lead ingots, iron lifting weights and steel shot. Steel shot was selected because the cost per unit volume was the lowest and the shot could be placed “out of sight” in the frame rails. Steel shot was purchased from Metaltec Steel Abrasive Co. in Canton, Michigan and approximately 135 kg (300 lb) was added to the frame rails by drilling 25 mm (1 inch) diameter holes in the tops of the rails. The holes were covered with sheet metal squares and painted after the shot was added.
After the vehicle was complete except for upholstery it was weighed at a commercial scale. The weight was 1503 kg (3340 lb).

It was found that driving the vehicle caused it to settle on its suspension system by a few millimeters. The actual vehicle height was found to be approximately 10 mm (.39 inch) lower than the target. This resulted in tire rub against the front and rear wheel well flanges under extreme wheel jounce conditions. It was necessary to remove all of the ballast from the frame in order to achieve adequate clearance between the front tires and the front wheel well flanges. In the rear, spring bolts 25 mm (1 inch) longer than standard were used to obtain the desired ride height.

UPHOLSTERY SUBSTRATES

Door trim panel substrate prior to adding polystyrene foam.

Steel bracket ties door arm rest to door structure.

Lauan door trim panel substrates with steel mounting brackets.

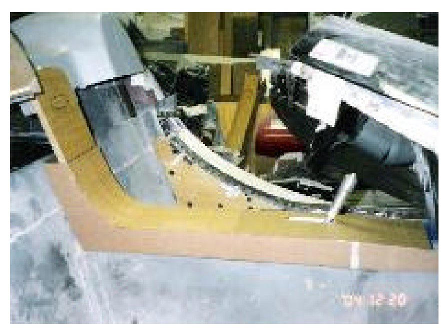
Forming upper door trim panel substrate to curved door flange using "partial kerfs" and epoxy putty to "freeze" the shape.

Five steel spring finger tabs hold the upper trim panel against the door flange.

Door trim panel substrates with polystyrene foam adhesively bonded in place prior to shaping and smoothing.

"Pocket & flange" for mounting door handle trim bezel.

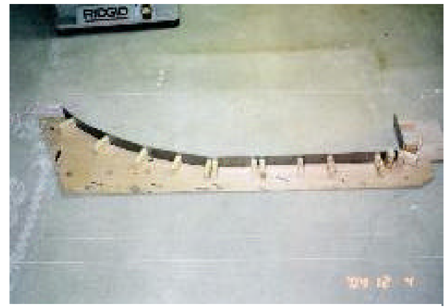
Upholstery substrate for rear deck lower edge.



Console mocked up in corrugated paper board.

Console mock up in shifter region to develop precise location of opening.

Final console substrate fabricated in plywood.



Door sill upholstery substrate weld fixture.

Door sill upholstery substrate with flange skip welded in place.

The upholstery trim panel substrates were fabricated from 5 mm (.20 inches) Lauan, 12 mm (.50 inch) plywood, vinyl ester resin / fiberglass cloth and sheet metal. The armrests were the first substrates to be designed. They were designed on a full size layout. They were developed by setting in the vehicle on a mock up seat and trying several shapes, sizes and locations. The armrests were intended to provide a resting perch for the occupant's arm, to provide ready access to the door handle and to provide a door pull for closing the door. After the basic size and location were developed, Craig Sandvig prepared sketches of the styling features for the armrests. Each armrest was fabricated beginning with a 5 mm (.20 inch) Lauan back plate. Two top plates were cut from 12 mm (.50 inch) plywood. The lower of the two top plates was bonded to the back plate using hot melt adhesive and wood screws.

A pocket was formed under the lower top plate to receive a steel-mounting bracket. A lower edge was fabricated using 5 mm (.20 inch) Lauan with saw kerfs partially cut to permit bending. The lower edges were attached the back plate using hot melt adhesive. Three 1/4- 20-cleat nuts were attached to the back plate and held in place with hot melt adhesive. The back plate was "loaded" with slabs of polystyrene foam held in place with hot melt adhesive. The foam was shaped using a Sureform tool. The foam was smoothed using dry wall compound. Latex primer was applied to the foam. Two layers of vinyl ester resin and fiberglass cloth were applied and sanded to complete the armrest substrates. Each armrest is attached to its respective door trim panel with three flat head 1/4 – 20 machine screws driven into the cleat nuts. In addition each armrest is supported with a steel bracket that projects from the door steel structure. The steel bracket has two 1/4-20 J nuts that receive screws passing thru two counter sunk holes in the plywood lower plate. A door pull trim cup is attached to the lower plate using two wood screws.

The door trim panels were fabricated beginning with a 5 mm (.20 inch) Lauan back plate. Each back plate is flat and covers the lower portion of the door structure. Each is held in place with steel tabs, pop rivets and sheet metal screws. Each upper door trim panel is curved to match the inner flange of the fiberglass door trim panel. Each upper trim panel substrate was cut from 5 mm (.20 inch) Lauan. It was then "notched" with partial saw kerfs to permit it to easily bend. A 1.2 mm (.048 inch) thick chipboard spacer was temporarily attached to the fiberglass door flange using double face tape. The spacer represented the room needed for the leather that would later be added to the substrate. A sheet of wax paper was placed over the chipboard spacer and held in place with masking tape.

A layer of epoxy putty was applied to each substrate and held in place against the wax paper using C clamps. After the epoxy putty cured the clamps, wax paper and spacer were removed. Each substrate then had the curved shape of the fiberglass flange. A 1/4-20-cleat nut was added to the front and rear of each upper substrate at the corresponding location of the two holes that had been drilled in the fiberglass door flanges. Two 1/4- 20 hex head cap screws are used to attach the upper trim panels to the fiberglass flanges. In addition five steel "finger tabs" press the upper trim panel against the fiberglass flange. The finger tabs are attached to the lower substrates using pop rivets.

A "pocket and flange" was fabricated in each of the lower trim panels to receive the door handle trim bezels. The pockets were fabricated from 5 mm (.20 inch) Lauan and 3 mm (.125) thick pressed board. They are attached to each back plate using hot melt adhesive. A flange was added to the lower edge of the lower trim panels using the partial kerfs technique described earlier.

Flanges were added to lower edge of the upper substrates using 5 mm (.20 inch) Lauan. Matching flanges were added to the upper edge of the lower trim panels using 5 mm (.20 inch) Lauan. The two flanges were off set by 2 mm (.08 inches) to provide room for the two layers of leather that would be added. The upper and lower substrates were then "loaded" with polystyrene foam and shaped and finished the same as the arm rests discussed above.

The substrates for the lower edge of the rear deck were fabricated using the "splash" technique. Sheet wax 1 mm (.04 inches) thick was applied to the areas to be covered. The sheet wax served as a spacer for the leather that would be applied to the substrate. Six layers of vinyl ester resin and fiberglass cloth were applied to the sheet wax. After the resin cured the substrates were removed and trimmed to size. End "transition" pieces were formed using 12 mm (.50 inch) plywood, 5 mm (.20 inch) Lauan and polystyrene foam. They are attached to the vinyl ester resin substrates using methacrylate adhesive. The complete substrates are attached to the rear deck fiberglass panels using 1/4- 20 hex head screws and cleat nuts at their outer ends. They are tucked under the headrest substrates at their inner ends.

The instrument panel top substrate was fabricated using the splash technique described above, i.e. sheet wax, 5 layers of vinyl ester resin and fiberglass, smoothed.

The console was developed on full size layouts and using mock ups in the vehicle. The first mock up was fabricated using corrugated paperboard. After reviewing the first mock up it was decided to revise the cross section of the console. A second paperboard mock was fabricated and it was agreed that it would be the final design. Fitting the console to the transmission shifter required a careful, detailed design. The console lower surface had to be above the shifter mechanism, the opening had to be precisely located fore and aft and side-to-side and the upper surface of the console had to be as close as possible to the shifter mechanism to maximize the space for the leather shifter boot. A partial mock up of the console in the immediate area of the shifter lever was fabricated using 12 mm (.50 inch) plywood. The partial mock up verified the functional conditions were met. The precise location of the opening was then determined by measuring the distance from the opening to the intersection of the rear bulkhead and the transmission tunnel top. The console was then fabricated from 12mm (.50 inch) plywood. The curved face at the upper rear of the console was accomplished using the partial kerfs technique. The partial kerfs were filled with polyurethane adhesive after the top panel was attached to the side panels using dry wall screws. The console substrate was then smoothed using polyester body filler.

The substrates for the doorsill trim covers were fabricated from sheet metal. The curved panels were formed and clamped in a weld fixture. The flat side panels were then skip welded to the curved panels.

The substrates for the moldings that trim the door striker covers were fabricated from sheet metal using a technique similar to the one used for the doorsill trim covers.

INTERIOR - SEATS & SHIFTER KNOB

Seat mounting bracket with built in 8.5 degree tilt.

Transmission shifter and PRNDL gauge.

View of seats in finished vehicle interior.

Several seat alternatives were evaluated for appearance, size and seating comfort. The Cerullo Performance Seating model SC seat was selected for the vehicle. It was evaluated initially with an unupholstered sample seat sent by the Cerullo people. The evaluation included placing the seat in the vehicle and confirming it would fit between the transmission tunnel and the frame rails. The SC model is one of the few aftermarket seats fabricated 495 mm (19.5 inches) wide. Most seats available are wider and would not package in the vehicle. The team judged the sample seat to be comfortable to set in and its appearance was well liked. Adapter brackets were fabricated to mount the Cerullo seats at the desired angle of 8.5 degrees from the horizontal and to position the seats as close as possible to the floor in order to achieve the desired H point. Two leather hides and four yards of vinyl in Light Oak color were shipped to Cerullo in Pomona, California for fabricating the seats for the vehicle.

The transmission shifter knob was styled by Craig Sandvig. The components were designed on a full size layout and CAD details were prepared. The details were sent to several firms to quote. A.S.A.P. Machine Co. of Canton, Michigan was selected to machine the parts in aluminum. The knob components are adhesively bonded to an aluminum tube. The aluminum tube slides onto the Corvette shifter lever and is held in place with a setscrew. John Loudermilk at Laird's Glass & Upholstery wrapped the conical part of the knob in leather. John also provided several helpful suggestions related to the upholstery substrates.

FUEL FILLER DOOR

Barbara Dickirson verifying fuel filler door location ergonomics with corrugated paper board mock ups.

Chuck Carlson (L) and Craig Sandvig routing fuel door hole using fixture.

It was decided to add a fuel filler door to the rear deck after evaluating the ergonomics of filling the fuel tank by having to open the rear deck. The aluminum door selected is the type used on the Mustang Bullitt. It has been modified by polishing it and laser etching the team logo on its top surface. The door cross sections are essentially a perfect match to the surface of the rear deck. A full size design layout was prepared to determine the optimum location of the door opening with respect to the fuel tank filler neck. The outline of a filling station fuel filler nozzle was traced on to a sheet of corrugated paperboard and cut out. The paperboard nozzle was used to identify the target “pierce point” in the rear deck. A mock up of the rear deck surface was fabricated in corrugated paperboard and placed in design position on the fuel tank. The opening diameter and location was then evaluated and judged to be excellent.

Before the hole and counter bore were routed the under side of the rear deck had to be thickened to provide sufficient material for mounting the door. The target area was thickened by adhesively bonding a 250 mm (10 inch) diameter x 5 mm (.19 inch) thick pre molded vinyl ester/fiberglass “plate” to the under side of the deck. It was necessary to design and fabricate a fixture to route the hole and counter bore in the fiberglass rear deck. The fixture was fabricated out of plywood and temporarily attached to the rear deck using screws. The hole and counter bore were routed then the fixture was removed. Holes for the attaching screws were then drilled in the flange formed by the counter bore.

LICENSE PLATE BRACKET ASSEMBLY

License plate mounting bracket with integral electrical contacts is easy to remove and install with two knurled studs.

The license plate/ frame assembly is attached to the lower side of the rear deck using two knobs with 1/4-20 studs on them. The assembly is easily removable by unscrewing the knobs. The electrical connectors for the illumination lamp are integrated into the assembly and do not require any extra steps to connect/disconnect the circuit. The assembly is easy to remove and reinstall for displaying the vehicle at car shows. The assembly also incorporates a metal tab covered with felt that serves to dampen vibration. The felt protects the paint from being scratched.

AIR CONDITIONER

A/C duct fabricated from vinyl ester resin and fiberglass cloth over corrugated paper board.

Heater and A/C center distribution chamber.

A/C INSTRUMENT PANEL DUCT

The instrument panel A/C duct was designed using full size layouts. The duct had to provide a nearly constant cross sectional area its entire length and it had to have 5 mm (.20 inch) clearance to the gauges, windshield support structure and the steering column. The duct is fabricated using pressed fiberboard, corrugated paperboard, hot melt adhesive, polyurethane adhesive and covered with vinyl ester resin and fiberglass fabric. The duct has a compression seal to the heater and A/C center distribution chamber. The duct ends slip over the outboard instrument panel registers. The center flange is located and supported with steel brackets and threaded studs attached to the fiberglass instrument panel.

A/C & HEATER DISTRIBUTION CHAMBER

The heater and A/C center distribution chamber is a highly modified unit like the type used on the donor vehicle. The openings for the center floor out let and the defroster outlet have been covered with sheet aluminum panels pop riveted to the plastic housing. New floor out lets have been fabricated using pressed fiberboard and polyurethane adhesive. They are pop riveted to the plastic housing. The floor outlets were designed to clear the transmission tunnel and direct appropriate size streams of air to the occupants' feet. The chamber is attached to the heater core case using a foam seal. The chamber is attached to the cross car beam using M6 hex head cap screws.

A/C REFRIGERNAT HIGH PRESSURE CUT OUT

The A/C refrigerant system is protected with a high pressure cut out switch. Should the refrigerant system pressure exceed 3100 kPa (450 psi) the electrical circuit to the A/C clutch will open and thus relieve the over pressure condition until repairs can be completed.

GRILL

Grill components in weld fixture.

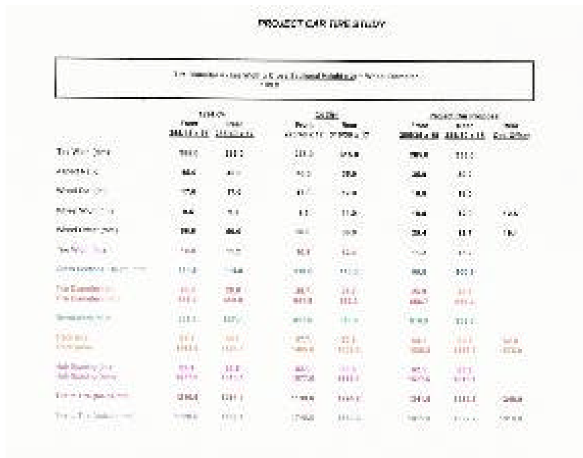
The grille was styled by Craig Sandvig. It was designed on a full size layout and CAD details were drawn. The grill follows the contour of the opening in the fiberglass hood in the side view. Each bar of the grill is located 1 mm (.04 inches) rearward of the one below it. The grill was mocked up using black tape 3.1 mm (.125 inch) wide over a sheet of pressed paperboard that had been painted silver. The first mock up was reviewed in the vehicle and the spacing between the bars was judged to be too large. A second paperboard mock up was fabricated showing the bars closer together and reviewed in the vehicle. The new bar spacing was judged to be excellent. A mock up was fabricated using aluminum bars held in place with all threaded rods and screws. The “fabrication” holes in the mock up could be seen and were visually objectionable. The final grill is fabricated from aluminum flat stock components welded together. A fixture was fabricated to hold the bars in their design position during the welding process. The grill is attached to the steel hood support structure on the top and to the fiberglass hood on the bottom. Two steel brackets are adhesively bonded to the fiberglass hood panel for the lower mounts. Nuts and bolts are use to fasten it at its four corners.

UNDER BODY SEAT SUPPORT STRAPS

The underbody seat support straps minimize floor panel flexure.

The seats are supported with underbody straps that are attached to the rocker panel mounting rails. The straps are intended to distribute the seat loads to the frame rails. The straps are fabricated from 3.1 x 50.8 mm (.125 x 2 inch) steel. Each strap has three segments with bolted joints near the center of the vehicle to permit service to the exhaust system without the need to loosen the seat mounting nuts.

WHEEL & TIRE SIZE DEVELOPMENT



Project Car Tire Study developed by Chuck Carlson.

A study was conducted to determine the optimum sizes for the tires and wheels. The objective of the tires and wheels was to maximize tire width for appearance, use 18-inch diameter wheels for appearance and maintain the same normal tire diameter as the 1994 Corvette to minimize speedometer calibration issues. Chuck prepared a spreadsheet listing the wheel and tire sizes used on the 1994 Corvette. Both standard and optional sizes were listed. With the tire sizes known the outside diameters and widths were calculated. The static loaded radius of the tires was determined by measuring several production C4 Corvettes on used car lots. The static loaded radius is the dimension from the center of the wheel to the ground and it is smaller than the normal radius of the tire because the tire bulges slightly where it sits on the ground. Another objective was to maintain the same clearance between the inside faces of the tires and the suspension components/frame rails as the donor vehicle. Corvette track widths and wheel off sets were determined thru published data. The spacing between hubs was determined by subtracting the track widths from the wheel off sets. Revolutions per mile were also calculated for every study alternative. Thru research of tire sizes available with high-speed ratings several alternative tires were evaluated. The tires selected based upon the study were Michelin Pilot Sport, 285/ 35 ZR 18 front and 335/30 ZR 18 rear.

The three-piece wheels selected were fabricated by Fikse U.S.A. using off the shelf components with the off set and widths we specified. The polished forged aluminum wheels feature the Fikse Mach V spider and center caps laser etched with the team logo.

ENGINE

ENGINE COOLANT SURGE TANK

The engine coolant surge tank is fabricated from 5052 H aluminum sheets 2.29 mm (.09 inch) thick. The filler neck is a machined aluminum component supplied by Speedway Motors. The assembly is welded together. It attaches to the A/C evaporator assembly with screws.

ENGINE AIR INLET DUCT

The engine air inlet duct was designed on a full size layout then a CAD solid model was prepared. The CAD database was sent to Method Industries where it was fabricated using the same techniques as the body panels and the instrument panel. The duct is attached to the throttle body and air cleaner out let using stainless steel worm gear clamps and custom flex couplings fabricated from sheet rubber. The duct also houses the engine air inlet temperature sensor.

ENGINE FUEL INJECTOR COVERS

The engine fuel injector covers have been modified by filling all of the graphics and slots. They were sprayed with molten aluminium by the Flame Spray Coating Co. in Fraser, Michigan. They were then smoothed and painted.

ENGINE - FIRST START

L to R Chuck Carlson, Craig Sandvig and Gene Dickirson
immediately after the engine first started.

The first attempt to start the vehicle on 13 May 2005 was unsuccessful and the cause was found to be a faulty fuel pump. The second attempt on 20 May was successful in that the engine started however a concern was identified. The concern was related to one of the wires being connected to the incorrect fuse block. The wire was connected to the proper fuse block and the engine started as intended. The first test drive was conducted on 24 May 2005. The vehicle was driven to Belle Tire in Canton, MI on 31 May 2005 and the wheels were aligned to 1994 Corvette specifications. A series of road test drives then began and stretched out over several weeks and approximately 500 miles. A few small concerns were identified and corrected.

INTERIOR - UPHOLSTERY

Upholstery strategy discussion with
Mark Bowden (L) & Chuck Carlson.

Leather has been applied to most of the
interior trim substrates.

Aluminized felt heat shielding applied to the transmission tunnel walls.

Mark Bowden fitting carpets. Note that the seats can be removed for service without unbonding the surrounding carpet.

The first phase of the upholstery application (leather less carpet) began on 18 July 2005. Mark Bowden at Mobil Trim in Garden City, Michigan developed the patterns for covering each component in vinyl or scrap leather before he cut, sewed and fitted the finish leather. Upholstery foam at various thick nesses was used between the substrate and the leather. The leather is sewn with polyester thread. Polyester thread was selected because it is more resistant to degradation due to the sun versus nylon thread. The leather is attached to the substrates with adhesives and or stainless steel staples. The team logo had been previously embroidered on the piece of leather that was used to cover the console “waterfall”.

American Silkscreen and Embrodiery did the embroidery. Mark completed the first phase on 26 August 2005.

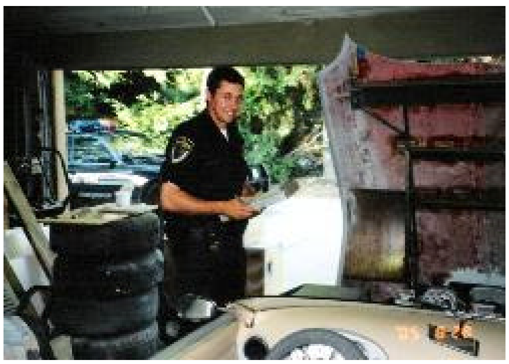
The vehicle was then returned to the upholstery shop for fitting of the carpet and the trim covers for the windshield “A Pillars” on 2 November 2005. Mark Bowden completed the carpet portion of the upholstery project on 18 November 2005.

PAINT

Chuck Carlson (L) and Swane Clayton reviewing the rocker panels prior to Swane spraying them red.

The upholstery, steering column and instrument panel were removed from the vehicle in preparation for paint. A temporary panel was installed on the transmission tunnel to support the ignition ON/OFF switch and the START switch. The steering column and steering wheel from the donor vehicle was installed in the vehicle. Temporary wiring was installed for the ignition circuit and brake lights. The vehicle was driven to Biggs Auto Renovation in Westland, Michigan on 6 September 2005 (approximately 5 miles in LOW gear all the way because we had removed the speedometer electronic module for service and thus inadvertently broke the communication link between the PCM and the electronically controlled transmission). Swane Clayton began the painting process on 7 September 2005 and completed his work on 17 October 2005.

INSPECTION AND VIN TAG



Plymouth Township Police Officer Steve Coffell inspecting the engine VIN for verifying title match.

Michigan Secretary of State officer Richard Zavitz applying the replacement VIN tag.

The GDT Speedster is titled by the State of Michigan as a 1994 Corvette. It carries the same vehicle Identification Number (VIN) as the donor vehicle. The vehicle was inspected by Plymouth Township police officer Steve Coffell on 28 August 2005 who verified the engine VIN matched the VIN listed on the title. Michigan Secretary of State officer Richard Zavitz installed a Replacement VIN tag on 20 October 2005.

PHOTOS

Nathan and Mike taking photos at Acme Photo Works.

Nathan going up to crow's nest to take the plan view photos.

The studio photos were taken by Nathan Garcia assisted by Mike Merill at the Acme Photo Works studio in Highland Park, Michigan on 22 and 23 December 2005.

If you would like more information about the GDT Speedster or have any questions you would like answered - please contact us using the following information:

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