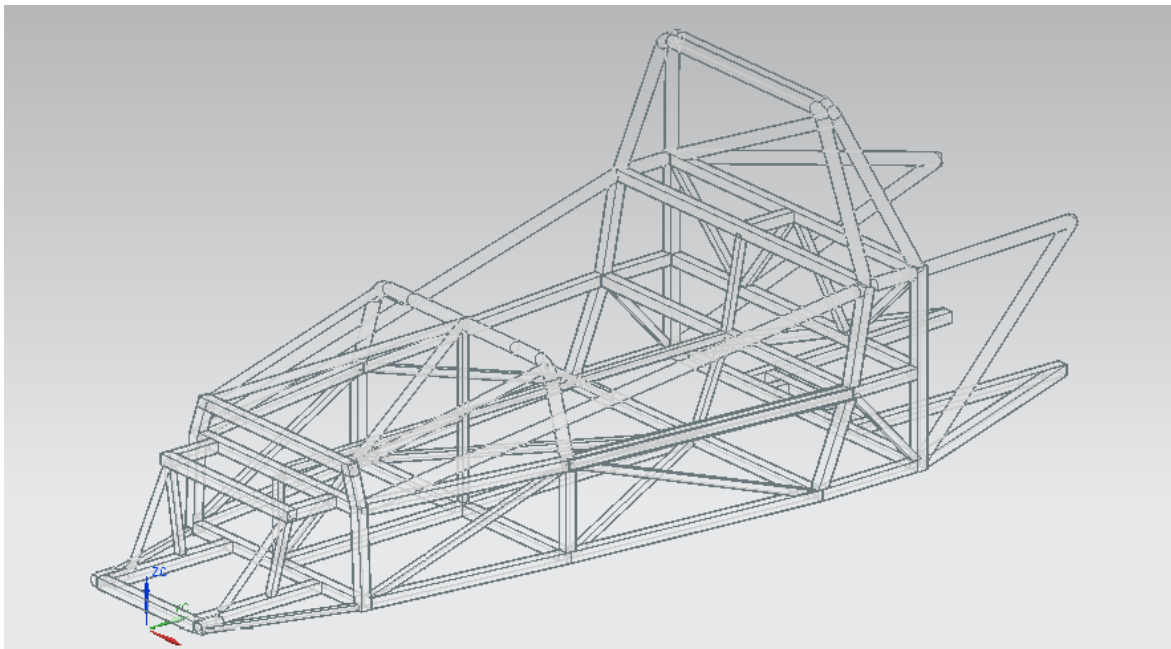


BEng Motorsport Engineering and Design



Module:
Major Project – Final Report

Title:
**Optimising the Torsional Stiffness of an MCR Sports 2000 Chassis
through the application of Finite Element Analysis**



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Nomenclature

K	Stiffness
T	Torque
L	Load
Δ	Deflection
θ	Angle of Twist (Degrees)
DOT	Design Optimisation Tool
BIGDOT	Large Scale Optimisation Software Library
SAE	Society for Automotive Engineers
CAE	Computer Aided Engineering
CDS	Cold Drawn Steel
NDT	Non Destructive Testing
FEM	Finite Element Model
CSYS	Cartesian Co-Ordinate System
1D	One Dimensional
2D	Two Dimensional
FE Model	Finite Element Model
FEA	Finite Element Analysis
RBE 2	Rigid Beam Element 2
DTI	Dial Test Indicator
DOF	Degrees of Freedom
LHS	Left Hand Side
RHS	Right Hand Side
mm	Millimetres
E	Young's Modulus
GPa	Giga Pascal
N	Newton
SSS	Simple Structural Surfaces
LT	Left Top
LB	Left Bottom
RT	Right Top
RB	Right Bottom
VRAND	Vanderplaats Research & Development
KG	Kilograms
DOE	Design of Experiments
C FEA 9	Correlation FEA 9
TT	Twist Test

1. Introduction

A race car's chassis is one of the most important areas on a vehicle. It not only has to encompass the driver and the entire driver controls it also houses the powertrain and drivetrain components as well. It must be designed with safety in mind and be able to withstand heavy structural impacts, along with providing a firm basis to ensure the vehicle dynamics and handling response is good and precise. With this the manufacturing techniques used must be within a reasonable time from initial build to vehicle factory exit and be at a justified financial position.

Over the past century the race car chassis has evolved from the simple steel ladder frame through to the complex carbon fibre monocoque. As time has moved forward the development of the chassis has continued to progress with race car manufactures evolving designs to keep their vehicles performing at the optimum level. Table 1 displays a brief overview of the evolution of the race car chassis. It has primarily kept with the basis of under floor type applications and does not include chassis types such as the ultra-light steel autobody (ULSAB) which is suited for most sedan applications.

	Evolution of the Race Car Chassis											
	Decade/Year											
	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2011/12	
Chassis Type												Vehicle
Open Section Ladder												 Alfa P2
Cruciform Underfloor Chassis												 Lagonda V12
Twin Tube Frame Chassis												 Jaguar Lister
Backbone Chassis												 Lotus Esprit GT1
Triangulated Chassis												 Caterham Super 7
Pure Monocoque												 Minardi PS01
Spaceframe Chassis												 MCR Sports 2000
Punt Chassis												 Lotus Exige GT3

Table 1: Chassis Evolution

When a vehicle is travelling on a circuit, each wheel will experience and take loads from the conditions from bumps, curbs through to debris. The force sustained moves through all the mechanical components of the suspension and steering and eventually to the chassis. The chassis must resist these loads and maintain its torsional stiffness to avoid bad dynamic feedback.

During the design and preparation of any chassis, whether for use on the road or race track the torsional stiffness plays a key factor. It becomes an even greater factor with the applications of an open cockpit such as the open ladder section through to a spaceframe; the lack of structure over the driver area reduces a large degree of torsional stiffness. It is always the goal of the engineer to compensate and therefore strengthen these areas in different ways without increasing mass and compromising overall design.

2. Purpose

MCR Race Cars Limited builds and supplies race cars to compete in the Sports 2000 championship within the United Kingdom.

The car itself is that of a steel space frame chassis with a rear mounted 2-litre Ford Duratec engine delivering 200bhp, this is mated to a 6-speed sequential gearbox feeding torque to the rear wheels. Originally designed in Brazil and built in St David's, West Wales. The car had a very short development phase from the initial design through to the manufacturing process.

On the 24th of April 2005 the MCR competed in its first Sports 2000 race at Silverstone circuit. The car had only been finished and rolled out the factory in West Wales a few days prior to the event. It competed with no testing or initial shakedown, however despite this the car went out and managed finish a very respectable 4th position. Since then the car has risen to become very competitive and pick up a range of top level podiums.

MCR Race Cars have had a good partnership with Swansea Metropolitan University since the company was founded. The Sports 2000 Race Car is a fairly new project under taken by the University to aid with its Motorsport Degree Programme. The vehicle based at the Universities workshop has been apparent since 2009 and in fact was the ninth vehicle to be manufactured.

With this there is a spare bare chassis which was one of the first to be completed over in Brazil and has taken residence as well in the Universities workshop.

There is very little understanding known about the performance and overall design of the MCR chassis, as stated it was originally designed in Brazil in a 2-D AutoCAD design package prior to commencing.

With the race car present in the workshop and along with the bare chassis, this is a unique opportunity to investigate the design characteristics and performance of the chassis along with pursuing the route of optimisation to enable to car to compete at the highest level and hence keep MCR on the forefront of the championship.

The other vehicles in which the MCR competes against all have a similar spaceframe chassis arrangement with fibre glass bodies, each of these manufacturers boast optimised chassis by use of the latest finite element packages. Some of these vehicles are displayed in table 2.

MCR Competitors			
			
Ray BR09	Loaded Gunn TS10/11	Juno CN Series	Andre Inverter

Table 2: MCR Competitors

Using the Universities facilities of both workshop and computer laboratory will enable an accurate scaled finite element model to be created in the computer aided design software package Siemens NX 7.5. This will enable the author to correlate with the actual chassis and hence investigate ways of optimising the Torsional stiffness and reducing the overall mass. The model will help predict the effect on the torsional stiffness of chassis by change of the placement of bars and the thickness of both the box sections and tubes which build up the entire structure.

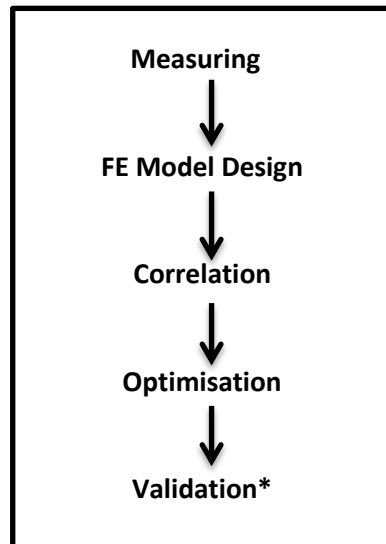
Therefore the overall purpose of this report is to outline the steps made to build up this model through from the initial measuring process through to the build and optimisation phase. Other computer based applications will inherently be used and process outlined to aid with the gateways set to ensure the project moves on the correct path.

From what is obtained in the project will hopefully be passed on to MCR to help them as a

company develop their race cars and inspire future chassis generations. This will in turn help them and the University to understand all aspects of the chassis and gain the knowledge required to keep pushing this area of the vehicle forward.

As no other accurate finite element model has been created before, it will be a learning curve for both parties involved.

The work plan for the project:



*Validation is subject to time constraints.

3. Literature Survey

As with any project suitable research had to be carried out in order to gain a good understanding of the subject in question.

Initially when the author looked into initial literature samples it became apparent that it was very difficult to find sources which related to actual 'chassis design'. Many books stated as chassis design gave more an overview of vehicle dynamics, with discussions more so towards suspension setup and behaviour. To overcome this author was able to gain articles from suitable IMechE journals and from technical papers gained from sources on the internet.

Basic overview of Stiffness and Strength

It is stated in the book Motor Vehicle Structures, concepts and Fundamentals (Brown, 2002) that the primary purpose of a vehicle chassis structure is to maintain the shape of the vehicle and support the various loads which are applied to it. This overall structure accounts for a large proportion of financial leverage when designing any sort of vehicle. As there are numerous structures types available it is important to ensure the correct one is adequate the design, therefore you wouldn't choose a spaceframe for a family saloon car. This must also be taken into account when looking at other design constraints such as cost, production volume and application. The performance of a vehicle structure is related to its **strength** and **stiffness**, to maintain the optimum these constraints are applied with the reduction to mass to not sacrifice performance.

Strength requirement implies that no part of the structure will lose its function when subjected to high road/track loads, any failure which may occur would be noted to material fatigue and extreme load cases. The stiffness (K) of a structure relates to the deflection (Δ) when load (P) is applied therefore:

$$P = K\Delta$$

(Brown, 2002)

The above equation only applies to structures in the elastic range, when plotted on a graph it is the slope of the load against the deflection.

The stiffness of a vehicle structure has important influences on its handling and vibrational behaviour. It must be ensured that deflections to extreme loads are not so great that it alters any of the steering geometry or unacceptable vibrations such as scuttle shakes.

There are two types of stiffness:

- **Bending Stiffness** – This relates to the symmetrical deflection of a point near the centre of the wheelbase to multiples of total static loads on a vehicle.
- **Torsional Stiffness** – This relates to the torsional deflection (θ) of the structure to an applied torque (T) about the longitudinal axis of the vehicle.

(Brown, 2002)

Both the above cases apply completely different local loads to individual components within a vehicle. For the setting of this report the author is focusing on the torsional stiffness, in modern structures this is given by:

Deflection across span given by:

$$\Delta_{span} = \Delta_{Positive} - \Delta_{Negative}$$

Then the angle of twist at each chassis interval:

$$\theta = \frac{\Delta_{span}}{Interval Span \times \left(\frac{180}{\pi}\right)}$$

To calculate torque:

$$T = P \times L$$

There stiffness is calculated as:

$$K = \frac{T}{\theta}$$

(Brown, 2002)

The above equations will therefore be adopted to fit into the authors report and hence calculate the torsional stiffness of each of potential amendment made.

The Motor Vehicle Structures book (Brown, 2002) helped the author understand the simple physics behind what was required when looking at the torsional stiffness of the MCR chassis.

Design of a Twist Fixture to Measure the Torsional Stiffness of a Winston Cup Chassis:

An SAE technical paper was obtained regarding the design of a twist rig in order measure the torsional stiffness of a NASCAR chassis (Thompson, 1998). The author thought this article was extremely relevant as a twist test itself would be completed in order measure the stiffness of the chassis but also for correlation and validation of the FE model.

The paper outlines the importance of a suitable twist rig as a way of validating the results gained for chassis amendments made using finite element analysis and also to have a direct experimental method rather than relying on only computer based results. A NASCAR chassis is very similar to that of the MCR as it is itself a spaceframe chassis, the constraints applied to the rig were:

- Ability to twist the chassis in both clockwise and anti-clockwise directions.
- Ability to measure torsional stiffness with a total error of less than 5%.
- Adjustable to different chassis geometries.
- Ability to gain repeatable measured data.

In order to twist the chassis, equal and opposite vertical displacements were applied to the front spring perches. In this case the load was applied using linear actuators in the form of screw jacks with reaction forces measured on a corner weight scale, deflection measured at points with DTI gauges.

The twist fixture incorporated in this design allowed load to be applied in equal and opposite vertical directions about a virtual pivot point close to the vertical chassis centre, this ensured that the chassis was twisted in pure rotation and resulting in an accurate measurement of absolute chassis stiffness. Along with this the ability to control each of the independent jacks would allow the chassis to be twisted precisely.

Prior to the build of the rig, a finite element analysis was completed testing how the chassis would behave on the rig. This was completed by adding and subtracting various fixed and user defined constraints to see which ones would be suitable for the rear, for the MCR the author will be looking at completely fixing the rear.

With the boundary conditions completed the build of the actual rig could be completed, the paper outlines the how the constraints were used in order to simplify the design for ease of construction, the rear stands were built using a triangular post as this could be attached to the chassis without the need to remove items such as the trailing arms etc. Ball joints were placed at

the attachment of the stand to the chassis so all rotational degrees of freedom could be decoupled. The stands themselves would be directly bolted to the floor so all rotations and translations required a fixed constraint. Using tension/compressive load cells in place of the scales would allow the tension to be recorded. For the authors own twist test, that type of issue would not be apparent as only the LHS would have a force applied, the RHS would be left free. Although not as accurate given the time constraints, the set-up of only one jack would be sufficient.

As the SAE paper continues it describes how the twist data did not match up to the FEA data, this is an area in which the MCR will infinitely have which will lead on to correlation exercises. In the later stages of the paper it describes how torsional stiffness was calculated by use of the same equations as stated on pages 11 & 12. The test carried out used a total of 10 DTIs, therefore it is required that a similar amount are used for the MCR test.

Development of a lightweight frame for a 40-foot flatbed trailer by using CAE-based structural optimization

This was an article taken out of the Issue 5 IMechE Automobile Engineering Journal for May 2011. Although it is regarding the development of a lightweight frame for a trailer, it still follows the same principles as the MCR chassis. The author was particularly interested in this article as it utilizes the program VRAND Genesis, this is the same software which will be eventually used for the MCR in later regions of the project.

The paper outlines the initial reasoning for the example stating that the original trailer chassis design hasn't altered from the standard ladder type application, a proportion of this is considered because a trailer frame should have sufficient bending rigidity and fatigue strength. In addition, the torsional stiffness of a frame has a considerable effect on the driving stability (Kim, 2011). The basis for the new trailer was a completely different design from the conventional ladder frame, the use of CAE and FEA had helped design the new layout to certain level to ensure that the trailer was ease to manufacture and the costs involved would not exceed the conventional trailer. In order to get the best setup with regard to material and mass the trailer was designed by using topology optimisation in GENESIS.

Because topology optimisation uses a simplified design domain for its initial design, it redistributes the material in the direction for minimising or maximising the objective function. Its converged result is free from the limitations of existing designs and can have a creative layout. After the finite element discretisation of the design domain, the material usage of every element is parameterized with its corresponding design variable (Kim, 2011). With the MCR the two objective functions will be of the mass and the overall displacement, therefore this is very similar to what is specified in this journal article although the article does include a lot more design variables in their article the overall mass of the trailer was reduced by 24.5 % with higher torsional and bending stiffness's achieved.

Metamodel-based lightweight design of an automotive frontal body structure using robust optimisation.

This article was also obtained from an IMechE Journal in Automobile Engineering, published in September 2009. This article looked at the use of algorithms for optimisation the material used to build up the frontal body of a vehicle. Both FEA and Matlab simulations were used which incorporated Design of Experiments and topology optimisation (Genesis incorporates both of these). However moving through the rest of the paper, the optimisation method chosen was robust optimisation twinned with the Monte Carlo method. This type of optimisation would not be incorporated on the MCR investigation.

(Zhu, 2009)

GENESIS Structural Optimisation

Background information regarding GENESIS.

GENESIS is a fully integrated structural analysis/design software package written by leading experts in structural optimisation. Analysis is based on finite element method for static, normal nodes, direct and modal frequency analysis, system buckling and heat transfer calculations. Design is based on advanced approximation concepts approach to find an optimum design efficiently and reliably. Approximate problem generated using analysis and sensitivity information, is used for the actual optimisation, which is performed DOT and BIGDOT optimisers. When the optimum of the approximate problem has been found a new FEA is performed and the process is repeated until the solution is converged into its true optimum. This process typically requires less than 10 detailed FEAs, even for large and complex design tasks. GENESIS performs Topology, Member Sizing and Shape optimisation as well as recent topometry and topography optimisation. Design Studio is a companion program for pre and post processing which greatly assists in creating the optimisation tasks and post-processing the optimisation results.

(Vanderplaats, 2007)

The Finite Element Method in GENESIS

The following text outlines the analytical part which GENESIS looks at when completing an FEA. Using the displacement method of analysis, the finite-element technique requires the solution of the matrix equation:

$$Ku = P$$

Where the master stiffness matrix K is the sum of the element stiffness matrices k_i

$$K = \sum_{i=1}^{NE} k_i$$

NE is the number of finite elements in the structure. The column of the P matrix contains the load vectors for each loading condition and the columns of U are the corresponding nodal displacements. The stiffness matrix is the function of the design variables defining the structure and is symmetric. The load vectors P may also be a function of the design variables if included. Assuming the proposed design has been specified, the stiffness matrix K and load vectors can be created. Therefore the displacements U must be solved:

$$u = K^{-1} P$$

In practice the K matrix is not inverted but decomposes K and solves the equations using forward and backward substitution.

The element stiffness k_i is created from the stiffness matrix k_i^0 in the elements local co-ordinate system and a geometric transformation matrix T :

$$k_i = T^T k_i^0 T$$

As the joint displacements u have been calculated, the forces on each element can be calculated, using the displacements and element stiffness matrix associated with that element associated with that element which is transformed to a local coordinate system by:

$$u^0 = Tu$$

Where u and u^0 contain only the displacements associated with the nodes of the element. The element forces are now:

$$f = k_i^0 u^0$$

From all those forces it is possible to calculate the stresses and the corresponding constraints. Having the nodal displacements enables the displacement constraints to be formed directly. In reality there are numerous other constraints such as local or system buckling. For those cases an FEA is used solving an eigenvalue problem for frequencies or system buckling. In each case the base matrix structural analysis is used.

(Vanderplaats, 2007)

4. Experimental Work

4.1 Current CAD Drawings

At the beginning of the project the original 2-D AutoCAD drawings were supplied to the author by Roger Dowden. These came direct from MCR in Brazil and contained all the chassis parameters such as tube/box materials, wall thicknesses and overall dimensions.

The author looked over the drawings and checked for suitability at whether the finite element model could be made direct from the measurements displayed.

Along with the original MCR drawings there was also a finite element model produced by a set of students from the previous 2nd year, these were also supplied by Roger Dowden and were completed at the University on its previous NX 5 software.

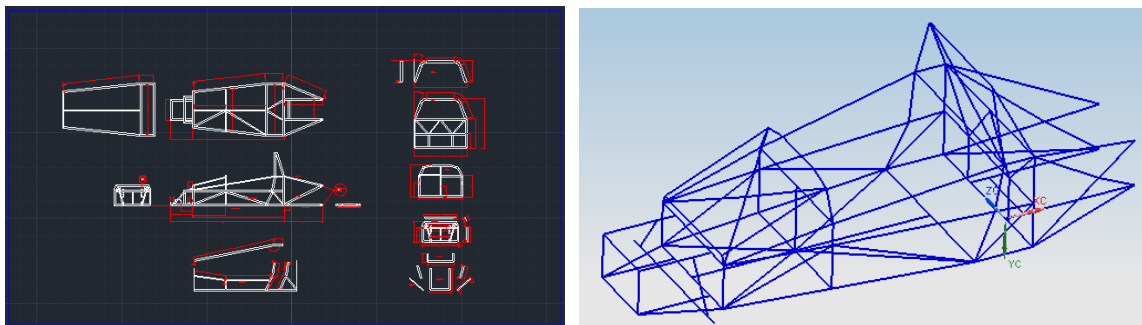


Figure 1: Initial CAD Drawings

Figure 1 on the left displays a zoomed out screen shot of the AutoCAD drawings as supplied by MCR, these drawings were ideal for gaining the box and tube dimensions. However the author deemed the drawings unsuitable for taking direct measurements off to use in NX 7.5, because of this the author would be required to take the actual measurements from the bare chassis on the flatbed housed within the Universities workshop.

Figure 1 on the right displays the NX 5 drawing produced by previous 2nd year BEng students. After viewing it became apparent that all areas of the model would have to be verified to confirm the overall dimensions were accurate and therefore correct. There were also a large degree of inconsistencies on various parts of the model where certain items either hadn't been modelled or were modelled incorrectly.

As the author had already confirmed that measuring the actual chassis was the best route to enable accurate dimensions to be obtained, it was immediately decided that rather than cross checking the 2nd year model and continually trying to make it accurate, the better option would be for the author to build their own in NX 7.5 with the dimensions gained.

4.2 Measuring Process

As it had been decided a new FE drawing was to be made this meant each co-ordinate from the chassis would have to be manually recorded.

The chassis was placed on the flatbed to ensure each of the measurements could be taken with the highest level of accuracy. The centreline was highlighted, to make it easier for the author to gain the measurements, a strip of aluminium bar was placed on the right hand side of this line with same being placed on the left hand side edge of the flatbed. This meant any measuring implement could be held flush against the aluminium and would ensure a high level of accuracy was maintained. The final area of preparation was to ensure the flatbed was still at a 100% flat level; this was achieved and confirmed by use of spirit levels.

With all the flatbed preparation completed the chassis could be manoeuvred and placed on the flatbed (Figure 2). As the aluminium strips had been placed on the centre of the bed the chassis had to be placed on four, 2 inch stands. It was then possible to mark the centre line on the chassis at various points and hence line it up with the centre line of the flatbed, to ensure the chassis would not move a ratchet strap was placed over and secured on the underside of the bed. Each of the points was then taken from the front through to the rear of the chassis using a range of set squares and steel rulers. The co-ordinates were recorded and verified, each set of points were completed in tiers starting from the bottom of the chassis through to the roll hoop, this made it easier for the author to complete the task in the shortest possible time. Only the left hand side was measured, the assumption would be taken that the chassis was symmetrical and would therefore reduce the authors measuring time.

When each point of the chassis had been measured it enabled the author to input each of the measurements into NX 7.5 and build up the wireframe model.



Figure 2: Chassis on Flatbed

4.3 MCR Race Cars Visit

As the project would be working alongside MCR Race Cars the author agreed it would be of benefit to the project to visit the factory and gain some background knowledge on the chassis and some feedback from the proprietor.

On the 10/10/2011 the author travelled to MCR, whilst there it was a good opportunity to be introduced to Clive Hayes the proprietor. The author and Clive discussed the chassis design along with amendments Clive himself had made to the 'works' car. The works car itself had been constantly adapted from the start of production with additional bars placed at rear (figure 3). Clive stated at one race weekend the car went out with 13 different modifications made to it. Also when the cars were initially built drivers couldn't feel any dynamic adjustments, however since the additions the cars have become a lot more responsive.

Although the current cars are manufactured from SAE 4130 mild steel, Clive was looking into replacing it with Cold Drawn Steel (CDS). This change wouldn't have any impact on the torsional stiffness but would come down to a financial factor.

During the closing stages of the visit, the author obtained a small piece of 'off cut' chassis tube, this was taken back and used for demonstration and ultrasonic test purposes.



Figure 3: Rear Engine Cross Members

4.4 Ultrasonic Testing

A key factor in the project was the sectional dimensions of each part of the spaceframe; the structure is up of a mixture of box sections and cylindrical tubes.

The AutoCAD drawings had been completed in Brazil where the cars were originally designed, although technical drawings displayed the characteristics for each particular part of the chassis the author wanted to be 100% certain that what was stated was correct on the Universities chassis.

All of the external box section lengths and tube diameters could be verified using a range of workshop measuring tools. In terms of the internal wall thicknesses these required a more in depth and advanced method.

Contact was made with Dr Pete Charlton who runs the 'NDT' test facilities at the University; a meeting was scheduled to discuss the needs of what was required and the best solution for it. The NDT department had a range of equipment but primarily the ultrasonic test machine was best suited for looking at the MCR's chassis wall thicknesses.

Ultrasonic Testing takes upon the use of sound waves which have a frequency higher than 20 kHz to determine the thickness of bars and tubes. The tester itself utilises a piezoelectric probe which sends a signal to a connected oscilloscope and hence provides a trace. This trace is displayed in both a graphical format and a numerical one and would confirm each of the thicknesses.

Dr Charlton confirmed that each of the box sections could be measured with ease; however there were doubts over whether the tubes could be measured, due to the shape and small diameter the probe finds it very difficult to gain a return signal as there is no flat surface for it to rebound from. The author supplied Dr Charlton with the chassis 'off cut' for testing. Initial calibration of the probe and repeated attempts provided only a much disrupted trace with the oscilloscope displaying a varied range of figures; it was agreed between the author and Dr Charlton that only the box sections would be tested. This would mean all tube sections would be to the AutoCAD drawings.

The ultrasonic testing was completed on the 29/11/11, each part of the box section was tested in various areas to check for continuity and hence give a value or the material thickness. Figure 4 displays each part of the chassis which was tested highlighted in red.

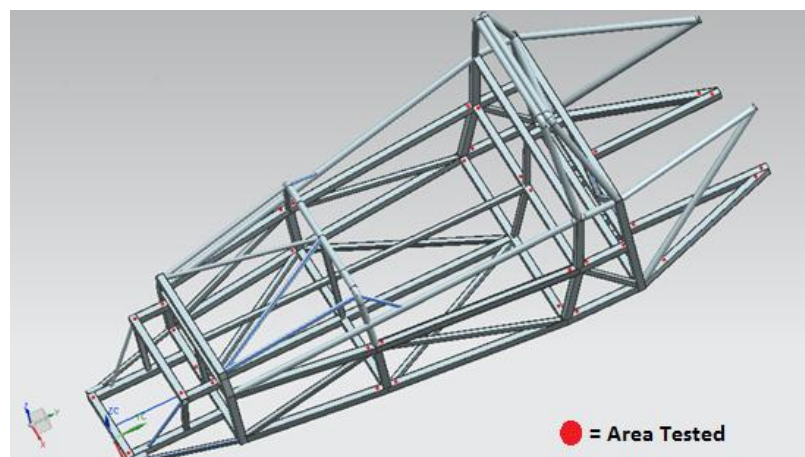


Figure 4: Ultrasonic Tested Areas

There were three types of box section on the chassis, these were:

- 15x15mm – AutoCAD Thickness: 1mm
- 20x20mm – AutoCAD Thickness: 1.2mm
- 30x30mm – AutoCAD Thickness: 1.5mm

The majority of the chassis was compiled and built up by 30x30mm sections, with the 20 and 15mm bars making up the reinforcing cross member sections on the sides, floor and on parts of the frontal crash structure.

Table 2 displays all of the results gained from the test.

Point:	Box Section:	Wall Thickness:
1	30x30	2.34mm
2	30x30	2.20mm
3	30x30	2.20mm
4	30x30	2.13mm
5	30x30	1.96mm
6	30x30	1.96mm
7	30x30	1.96mm
8	30x30	2.02mm
9	30x30	1.96mm
10	30x30	1.96mm
11	30x30	2.09mm
12	30x30	2.00mm
13	30x30	2.19mm
14	30x30	2.30mm
15	30x30	2.08mm
16	30x30	2.16mm
17	30x30	2.05mm
18	30x30	2.02mm
19	20x20	1.80mm
20	20x20	2.00mm
21	20x20	1.96mm
22	20x20	1.70mm
23	15x15	1.65mm
24	15x15	1.50mm

Table 3: Ultrasonic Test Results

It can be noticed that the 30x30 sections fluctuate around the 2mm mark with the 20x20 sections just under. Only two areas of the 15x15 were tested which display a thickness of around 1.50mm. Although these values seemed very different to what is stated in the AutoCAD drawings, it had to be taken into account that the chassis was covered with a thick layer of primer and paint. Along with this, chassis joints which had been welded would display marginally thicker as material has effectively been added to the bars. The AutoCAD drawings take into account the chassis hadn't been welded or primed/painted, therefore the author was happy that with the results obtained confirmed both the chassis and drawings matched and were suitable to be adopted on the finite element model.

5. Finite Element Model

5.1 Initial Model Build

With all the initial actions completed, construction of the finite element model (FE model) could be started; the software being used for this was Siemens NX 7.5.

The FE model would form the basis of the whole project, by use of finite element analysis it would act as a tool to manipulate bars and export into other optimisation programs.

Using the X, Y & Z co-ordinates obtained in the measuring exercise, each could be inputted into NX 7.5 as a CSYS datum point (Cartesian co-ordinate), the points would then be connected using 'point to point' lines and would therefore enable a complete wireframe model to be produced.

As stated in chapter 4.2, one technical assumption which was made took into account the chassis was 100% symmetrical. Because of this the chassis was mirrored over to provide the right hand side as displayed in figure 5.

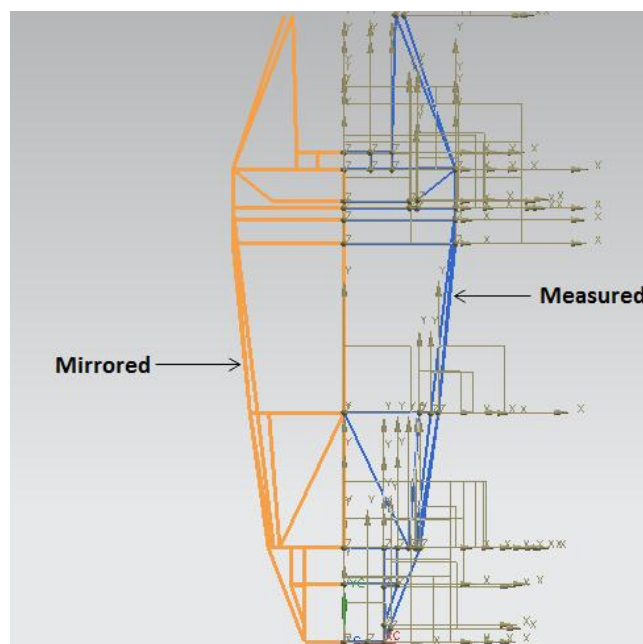


Figure 5: NX 7.5 Mirrored Wireframe Model

5.2 FEM Build

With the wireframe completed (figure 6), it enabled the author to export it into an advanced simulation and therefore build into an FE model.

As all the chassis information had been previously been obtained it enabled each physical property to be specified, these are all displayed in table 4.

When all the properties were inputted, a 1D collector mesh collector was created. This would enable the author to specify a 1D mesh on the correct area of the chassis. The size of the mesh would be of 61mm; as this would take into account the distance in-between each of the rivets fastening the shear panels, along with this a merge node tolerance of 0.001mm.

Physical Property	Material	Dimension	Wall Thickness
Box Section	Steel	30x30mm	1.5mm
Box Section	Steel	20x20mm	1.2mm
Box Section	Steel	15x15mm	1mm
Tube	Steel	28.5mm Diameter	1.5mm
Tube	Steel	16mm Diameter	1.2mm

Table 4: Chassis Physical Properties

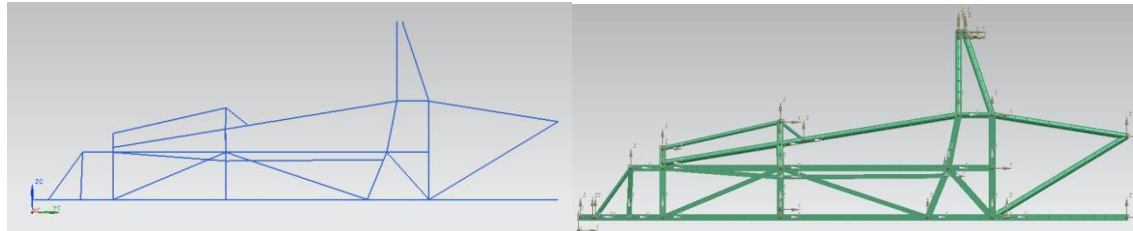


Figure 6: NX 7.5 Wireframe & FE Model

Figure 6 (left) displays the wireframe; this is only a part file which is ready to be exported into an FE model, on the right displays the FE state which is meshed accordingly.

The next stage was to ensure the model operated correctly and meant exporting from an FEM into a simulation state. The author applied 4 fixed constraints on the rear and added a force of 100N uniformly in both upwards and downwards direction on the front on the structure as displayed in figure 7, with this the model was ready to be solved.

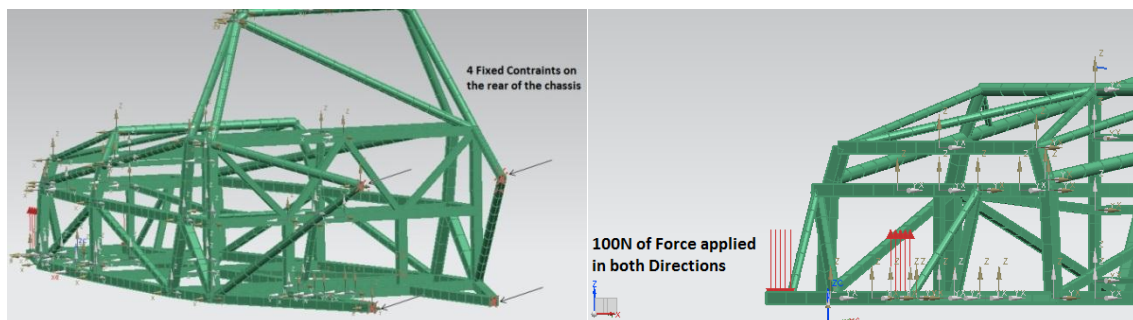


Figure 7: First FE Model Simulation Setup

5.3 First FEA Solve

With the simulation solved it became apparent there was OKB of results, this meant at some point there was a break in the chassis causing the whole simulation to fail. The option available was to specify a 'Param Bailout -1', this would force the application to solve and hence display the faulty area.

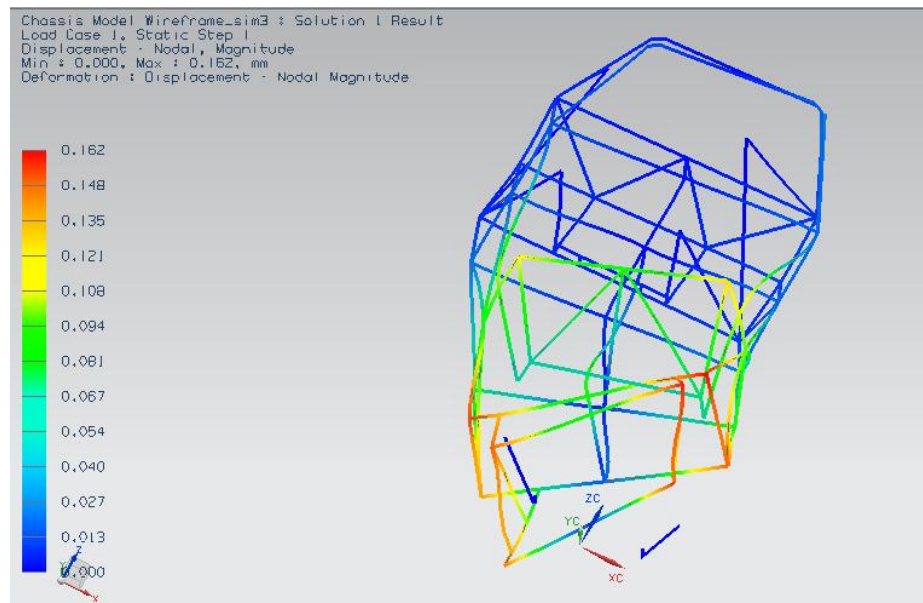


Figure 8: Initial FEA Failed Solve

Figure 8 displays the results with the bailout function specified, it can be noticed there are 4 areas in which the model is not connected.

With the non-connected members re-joined the simulation could be solved again. This was effectively was a 'shakedown' of the model to ensure functionality so the project could progress adequately.

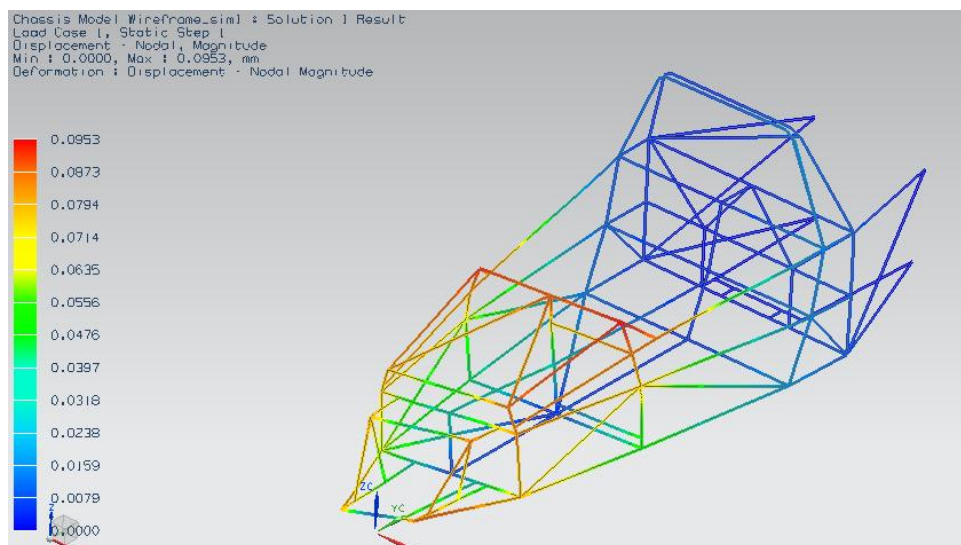


Figure 9: Initial Working Model

Figure 9 displays the result of the second simulation, as a shakedown it confirms all areas of the model are connected, and therefore can then be manipulated to 'correlate' against the actual chassis.

5.4 Shear Panel Addition

As the chassis had at one time had been part of a race car, there were still shear panels present. These were namely placed on the front bulkhead, on back and top of the fuel tank and along the central column in the driver/passenger cockpit.

Shear panels or simple structural surfaces (SSS) are predominately ideal for use where shear forces are being exerted. The panels act as a way of improving stiffness of a section by means of applying a thin layer of material to resist deflection during shear (Brown, 2002).

The MCR at some point had had more of these panels along the sides and inside of the chassis and hence where it probably gained a lot of its stiffness. This is something in which the author will experiment with later on in this report.

The panels present were added on to the FE using simple CSYS co-ordinates as per the rest of the model. The author ensured that they were drawn as an offset to accommodate the size of each bar. Therefore each panel was drawn at an offset of 15mm away and past each beam (Figure 10). For the FE model each panel was given the following properties:

Material	Thickness (mm)
Aluminium	1.1

Table 5: Shear Panel Physical Properties

When meshed accordingly, each of the shear panels was attached to the chassis using RBE 2s; these would act as the rivets. The author ensured that the total number of RBE 2s were the same as on the chassis.

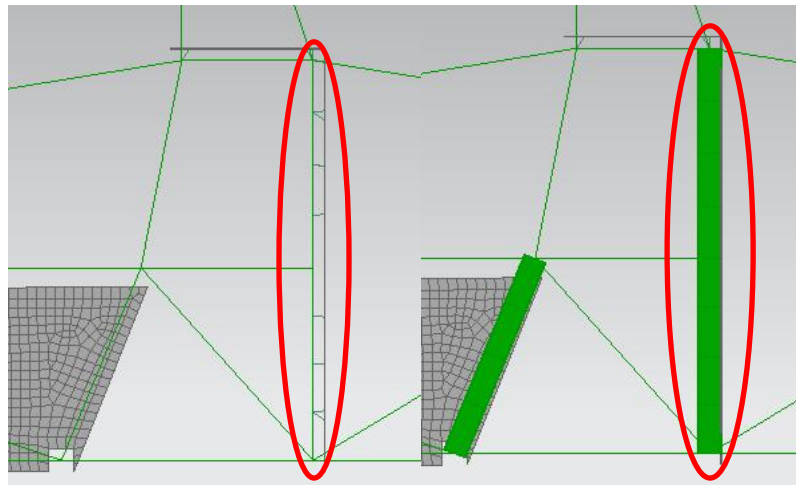


Figure 10 : Offset Shear Panels

6. Technical Assumptions

Using a 1D mesh takes into account that all the chassis parameters are at their optimum. As part of this project there were a number of key areas where technical assumptions would have to be made, these were due to the design and construction of the chassis but also the limits of creating a 1D FE model.

6.1 Welded Joints

The biggest and most prominent assumption which was made regarded how the structure of the FE model was put together.

As with all spaceframe chassis' each main structural member and cross member is jigged and cut to size, then welded to ensure a tough construction is achieved. The MCR as stated utilizes a range of box and tubular sections in varying dimensions; these are fastened by both means of MIG and TIG welding. However on an FE model each curve is joined by a pin joints which assumes optimum weld properties; this can be translated to give an overall tougher structure than what is apparent in reality.

Twinned with this, each set of curves are joined together to form one middle pin joint whereas on the actual chassis each bar is cut back to size and hence do not join in the middle, this is illustrated in figures 11 with comparison of the same area in both formats. With this assumption there is no alternative to take it into account unless a larger 2D model is built.

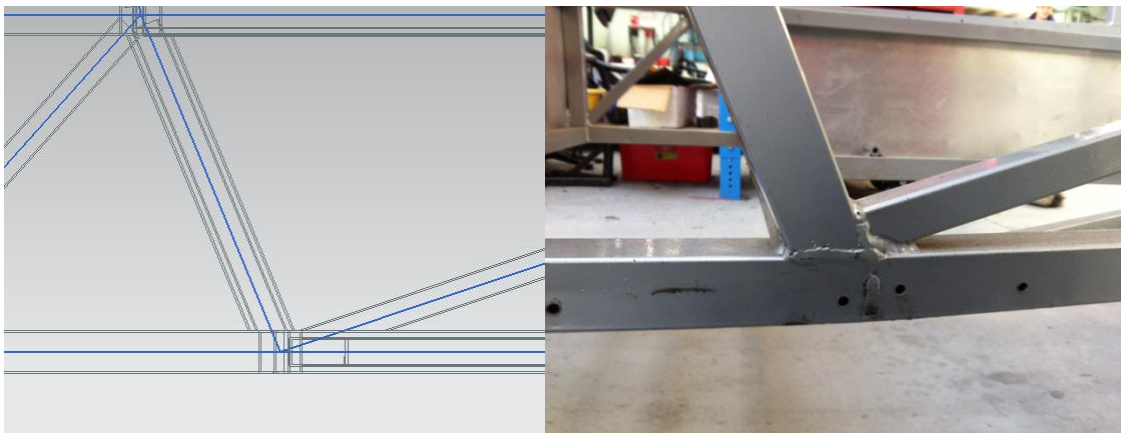


Figure 11: Welded Joint NX & Real Life Equivalents

6.2 Chassis Material Bends

Another assumption takes into account each of the manufactured bends in areas such as the dashboard and the roll hoop.

During the construction phase, each tube of material would have been mechanically bent in order to gain the correct angle. When these bends are applied the material around these areas will be subjected to a force and hence a second moment of area. This means the material will be thinner in these areas than on the rest of the tube. On a meshed 1D FE model it assumes that these bends are of constant thickness throughout as specified in the physical properties, hence resulting in a stiffer structure than reality permits.

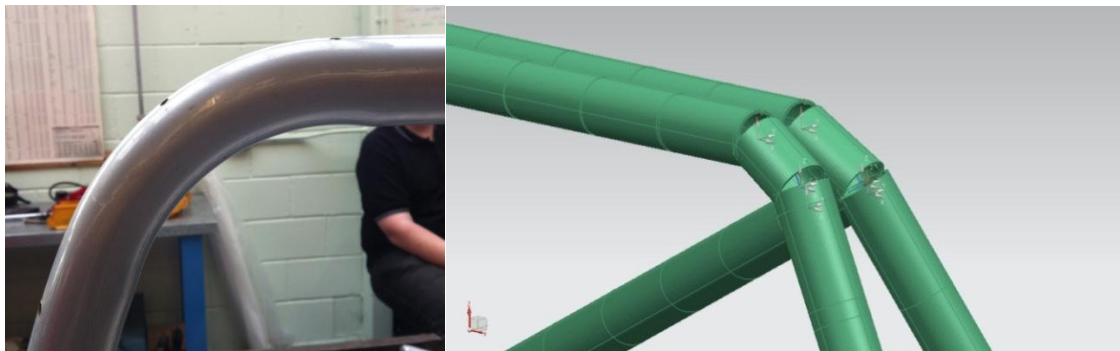


Figure 12: Roll Hoop Bends Real Life & NX Equivalents

Figure 12 (left) displays the bend in the main roll hoop of the chassis, it can be noticed the change in dimension of where the bend has been placed during the manufacturing process. This makes for comparison with figure 12 (Right) with the meshed roll hoop where the material thickness is kept constant throughout.

6.3 Roll Hoop Welds

The MCR utilizes two roll hoops of same height and physical property; one is placed directly behind the driver as per Sports 2000 regulations with the second at an angle seated on the back of the fuel tank bulkhead, both of these roll hoops meet together and are joined but a series of spot welds.

This is similar to the weld joints; however a separate property has to be specified for the FEA to take the connection of the two hoops into account.

A 'rigid beam element 2' (RBE 2) has to be applied and joined from node to node make the connection apparent. These elements have no deflection and no material properties therefore ensuring any force applied to the structure doesn't affect the rigid elements

However the welds on the actual chassis are stressed and fatigued in the same way when a load is applied, as no weld properties can be stated with the rigid links it factorises out a degree of accuracy when running through the simulation and achieving results.

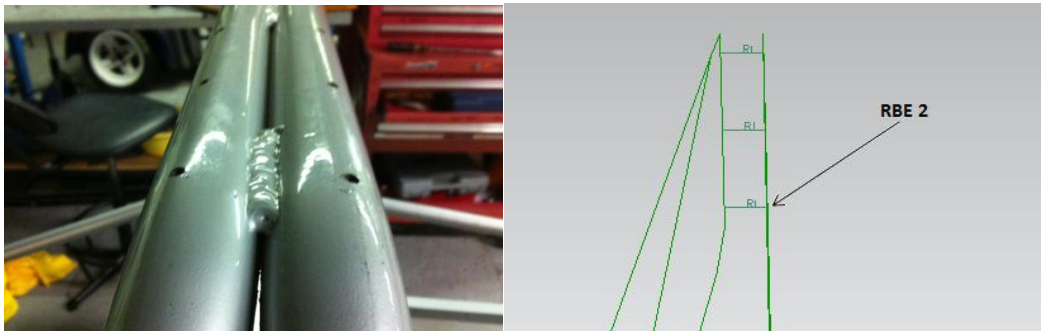


Figure 13: Spot Welds Real Life & NX Equivalents

6.4 Material Consistency

One of the final assumptions made for the FE model took into account the consistency of the material. As this chassis had once been part of a race car there were areas apparent which had been adapted to suit other purposes.

Around the spaceframe there were holes drilled where the external cladding was riveted on. Twinned with this there were also holes present on the internal cockpit area (Fig 14), all of which change the polar 2nd moment of area. Also there were parts where components such as gear linkage ducts which run through the spaceframe. These holes can only be incorporated if the model is changed to a 2D setting.



Figure 14: Spaceframe Bars

Each of the assumptions stated have a large effect on the chassis and contribute heavily to its overall stiffness. On building a 1D FE model there is no real way of factorising each of the assumptions in and hence just have to be taken into account when process results and comparison of data.

7. Twist Rig & Test

With the FE model completed the next focal point was to correlate the model. This would encompass using actual data gained from a chassis twist test and comparing against the FEA, the author would then be able to find the solutions to help match the model to real life to push the project forward and use the FE model as a tool rather than just a model. This section encompasses the twist rig along with the test prior to correlation.

7.1 Twist Rig

A suitable rig had to be manufactured to enable the chassis to be twisted; this was completed courtesy of David Campion.

As stated in the FE model, the rear of the chassis would be constrained to a fixed assembly with the front mounted so it is pivoted around a central loading bar. This main load bar was joined to a set of 'dummy dampers' in the form of steel bar located in the bottom and top suspension pickup points and connected to aluminium 'dummy rockers' as like on the race cars. The rockers were locked to the lower suspension points to avoid any major deflection occurring. The central loading bar could then be applied with load acting in the 'Z' axis to twist the chassis. The rear of the chassis was constrained by a frame directly bolted to the chassis and to the floor.

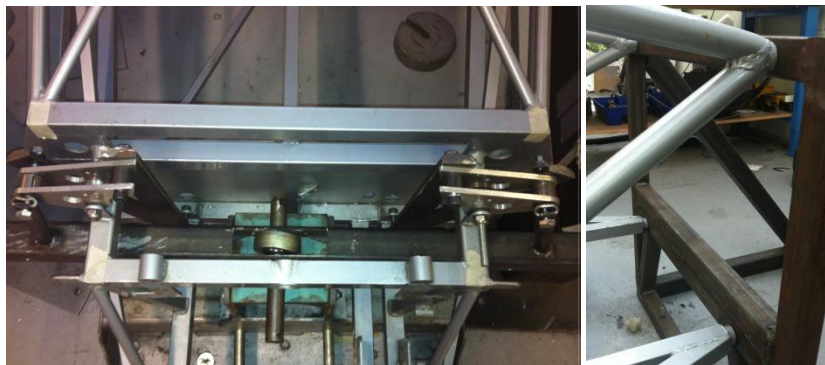


Figure 15: Front and Rear Twist Rig Mountings

7.2 Twist Test

The results gained from the twist test would be used for main correlation exercise. 9 DTI gauges would be placed on either side of the chassis and separated at intervals of 205mm from the main load bar; each of these DTIs would be placed at the intervals so they were level to each other from left to right.

A scissor jack seated on a corner weight scale was placed at the end of the twist rig bar; the jack was increased in height until in contact with the twist bar, this was continued up until a load of 1500N was applied to the rig and hence the chassis. For the authors own test the jack and scale was placed on the left hand side. Because of this all the readings on the left would be positive with the right therefore being negative.

When the required load had been achieved each DTI reading was noted, these results could then be carried forward into the correlation part of the project.

The table of results are displayed and continued in chapter 8 Correlation.

7.3 Twist Rig Incorporation on the FE Model

In order to progress to the correlation region of the project, all the parts of the twist rig had to be incorporated on to the FE model. That included all the components, constraints and loads.

To keep the FE model with minimal complexity the author continued to use CSYS co-ordinates as used throughout. Each mounting area was measured and modelled as required, to continue consistency all areas of the rig would be specified their physical property and assigned a 1D mesh. All components of the FE rig were modelled to how it was present, all except the rockers.

This was due to the author experiencing problems joining a 1D mesh to a 2D shell mesh which was apparent on the rockers as they were machined from aluminium. On running the FEA on multiple occasions both meshes broke away from each other as highlighted in red in figure 16, this meant a 'param bailout' was required for it to function and was therefore deemed unfit for purpose. Due to this the author opted to use three 6x6mm bars as shown in figure 17 which utilised 1D meshes, this therefore eliminated breakage during the FEA. However the change in design would have to be taken into account when analysing results and correlating.

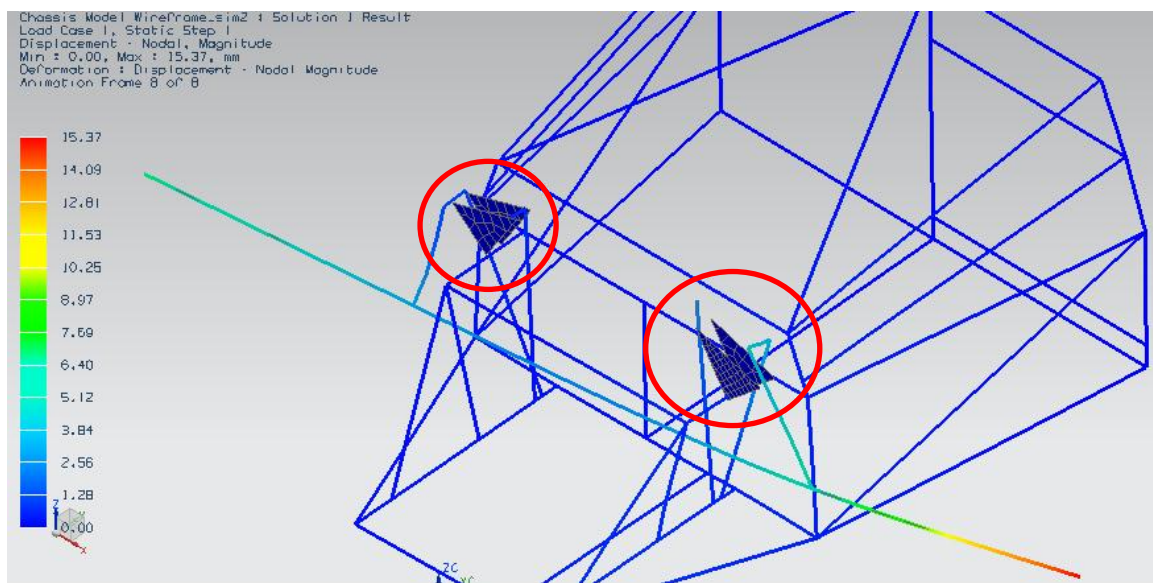


Figure 16: Initial FEA Twist Rig Application

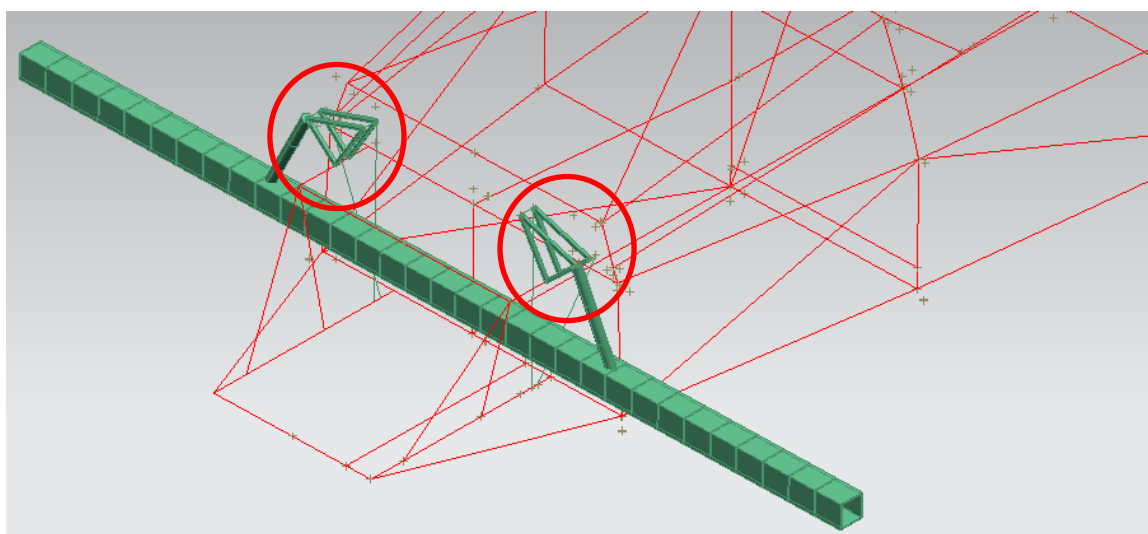


Figure 17: Comissioned FEA Twist Rig Application

The rear of the chassis was constrained using the 4 fixed constraints as used for all simulations. As a model built up of 1D mesh the ability to apply a pinned constraint was not available. This type of constraint was required to simulate the bearing on the rig which the main loading bar was connected to. To factorise this in the author used a 'user defined constraint' (Figure 18), applying such a function permitted it in the centre of the main rig bar. In turn the author fixed all 6 DOFs (Degrees of Freedom) then unapplied DOF 4 to make it rotate freely in the 'Y' axis. This therefore simulated in the same manner when a load was applied.

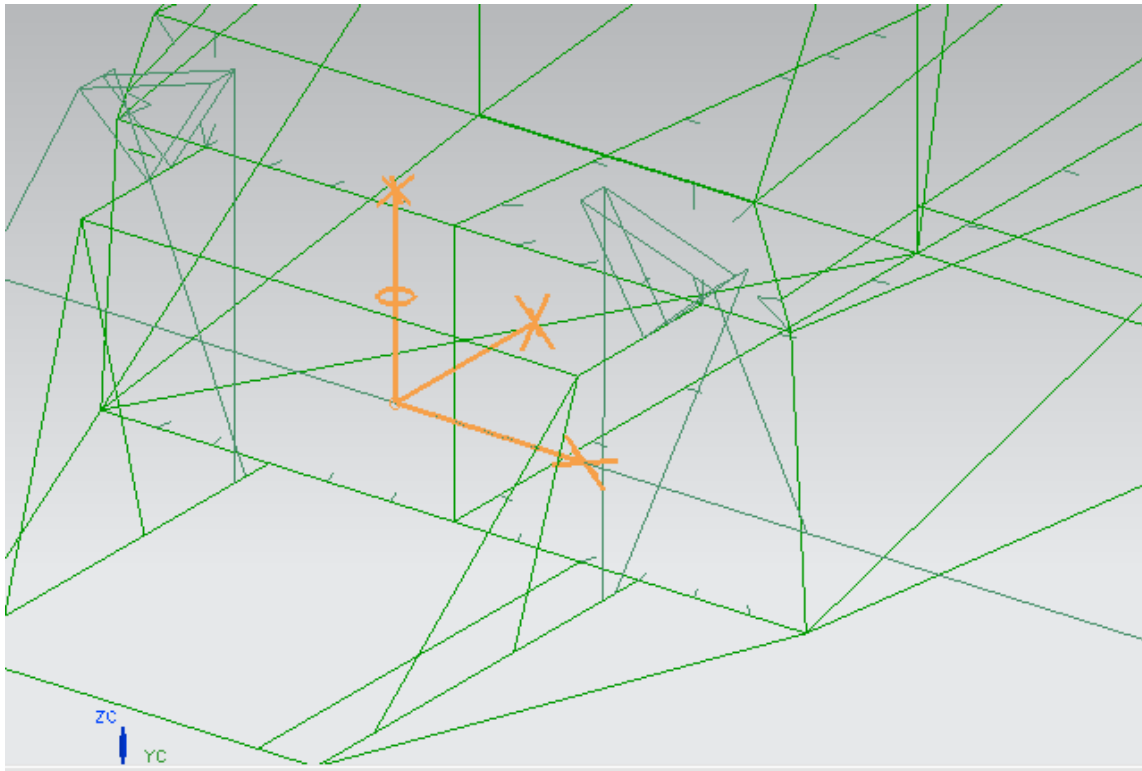


Figure 18: User Defined Constraint

As the rig was now apparent on the model, the results gained from the actual twist test could be used to validate the FE model.

8. Correlation

8.1 Initial Phase

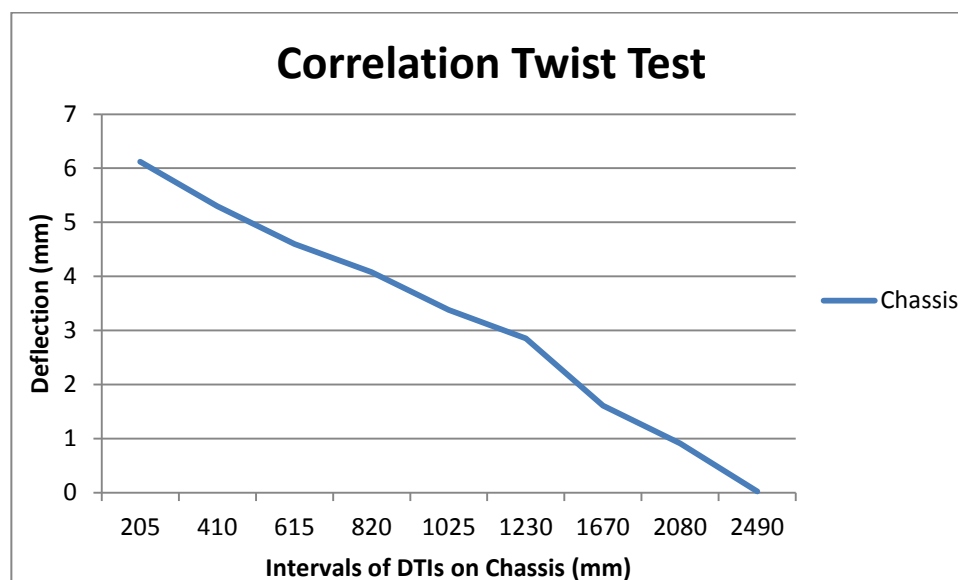
With a twist test completed and the rig layout applied to the FE model the next phase of the project was to correlate the results. This would be a transition period to help move from being a general FE model to an effective design tool to help the author determine potential amendments and their effects on torsional stiffness.

The results gained from the twist test are displayed in table 5; the load was applied to the left side of the rig:

LHS (Load Applied):				RHS:		
DTI	Length (mm)	Deflection (mm)		DTI	Length (mm)	Deflection (mm)
1	205	6.12		1	205	-2.50
2	410	5.30		2	410	-2.10
3	615	4.60		3	615	-1.90
4	820	4.08		4	820	-1.66
5	1025	3.38		5	1025	-1.25
6	1230	2.85		6	1230	-0.96
7	1670	1.61		7	1670	-0.67
8	2080	0.91		8	2080	-0.15
9	2490	0.02		9	2490	-0.01

Table 6: Twist Test Initial Results

Inputting the results displayed in table 6 into a graph would allow the author to visually correlate the model with a high level of accuracy. The graph would also be used to indicate levels poor strength and where amendments should be best suited, that phase of the project will be noted and discussed in chapter 9 Optimisation.



Graph 1: Initial Twist Rig Test

With initial results plotted the author ran the model through an FEA to gain a set of comparative data, in the same process as the actual twist test a load of 1500N was applied to the rig. Using Nastran's 'Identify' function in the simulation post view enabled the author to look at the nodes

in the exact areas where the DTIs were placed on the chassis. The results could then be plotted against the original test and therefore the correlation process could commence.

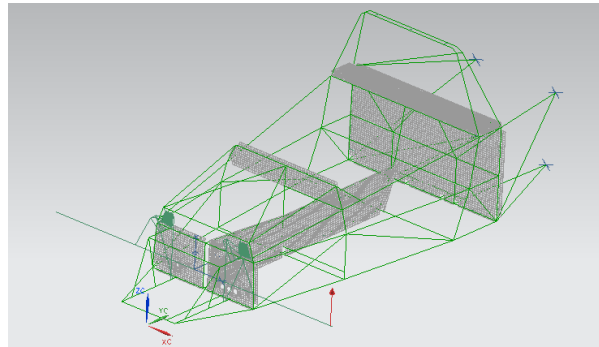
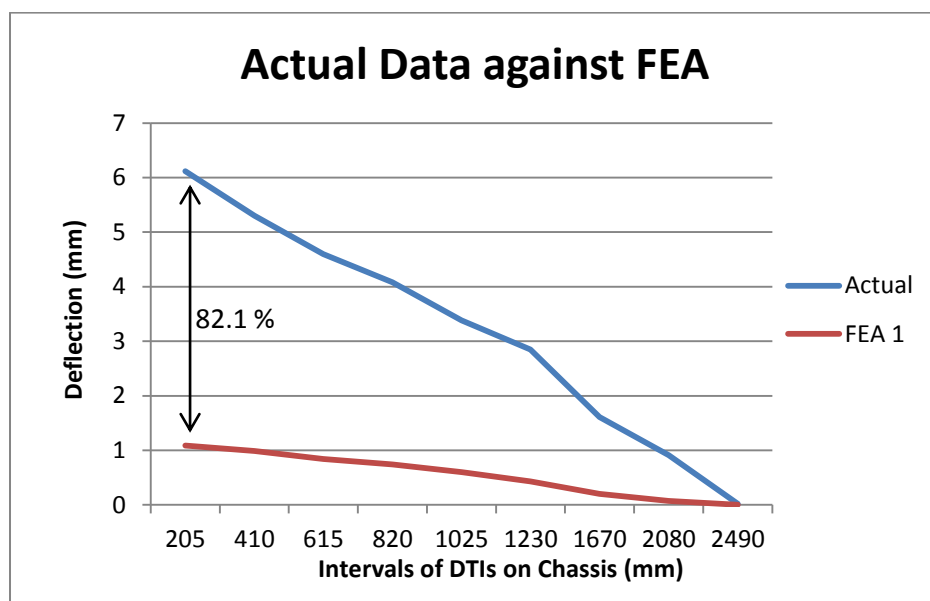


Figure 19: Initial FE Correlation

Figure 19 displays on the left the FE model prior to the simulation solve, apparent in this state are the rear fixed constraints along with the user defined constraint with the 1500N of load applied to the left of the rig bar.

LHS (Load Applied):				RHS:		
DTI	Length (mm)	Deflection (mm)		DTI	Length (mm)	Deflection (mm)
1	205	1.09		1	205	-0.48
2	410	0.99		2	410	-0.47
3	615	0.84		3	615	-0.52
4	820	0.74		4	820	-0.50
5	1025	0.60		5	1025	-0.42
6	1230	0.43		6	1230	-0.31
7	1670	0.20		7	1670	-0.15
8	2080	0.07		8	2080	-0.06
9	2490	0	9	2490	0	

Table 7: NX Correlation Results



Graph 2: Comparison of Results

Graph 2 displays a comparison of the both sets of results. On plotting the data it became apparent that the FE model was a substantially stiffer structure compared to that of the actual chassis.

Despite all the assumptions stated in chapter 6 being taken into account the FEA results should not have been as low as shown, there was in fact an 82.1% difference between the highest values of each of the tests. It was therefore apparent there were certainly errors present within the FE model and reflecting in the FEA.

8.2 FEA & Model Investigation

At a glance of the simulation postview it could be noticed that a large degree of deflection was present in the main twist bar as highlighted in figure 20, although the results displayed are exaggerated to 10% of the model it still showed most of the deformation was in this area.

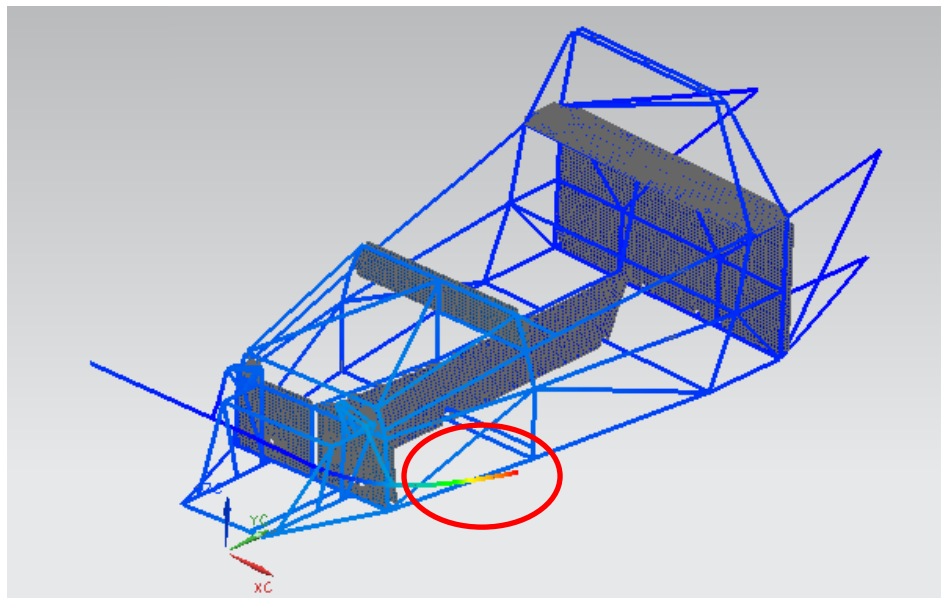


Figure 20: FE Twist Bar Deformation

Due to this the author began focusing on the twist rig in the early stages of correlation. Each individual part of the rig was taken into account with all the dimensions and lay up cross checked to ensure no careless errors had been inflicted.

With all the twist rig parameters verified the author began to look closer at the chassis itself, the points listed discuss what areas were focused on:

- **Chassis Physical Properties:** The author cross referenced each of the tubes and bars to ensure that each one was put to the correct parameters. This included verifying the dimensions had been placed into the FE correctly with regard to wall thicknesses and size. The author also verified on the actual chassis by measuring again smaller structural cross members towards the bottom and rear of the chassis.
- **FEM Physical Properties:** Not to be confused with the chassis physical properties, the author debugged the file on NX 7.5 where each of the chassis properties were created. It came to the author's attention that there were several physical properties apparent from early generations of the model; although these properties were now obsolete they could still be specified by error. Fortunately none had accidentally been specified however to

keep the model tidy for ease of viewing and accuracy the author removed all of the redundant physical properties.

- **RBE 2s:** Each shear panel was cross referenced to ensure the correct amount of RBE 2s were present. As these RBE 2s are rigid links to simulate welds and rivets they have no deflection values, therefore an extra amount could increase the stiffness of the chassis in these particular areas.
- **Shear Panels:** On inspecting each of the shear panels on the actual chassis, it became apparent there were various holes present on the front bulkhead and on the central driver/passenger shear panel. It was possible for the author to implement these on the FEM by applying simple sketch and subtract methods on the 'N-Sided' mesh panels. The changes can be viewed by means of figure 21.

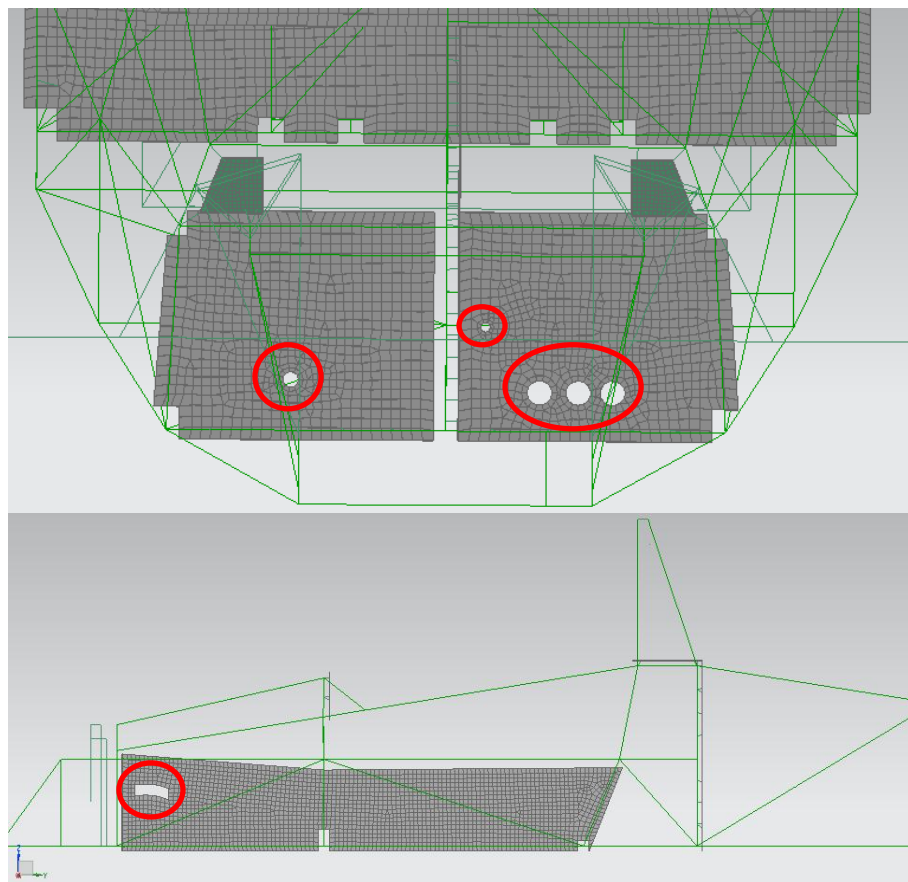


Figure 21: Shear Panel Amendments

8.3 Twist Rig Stiffness

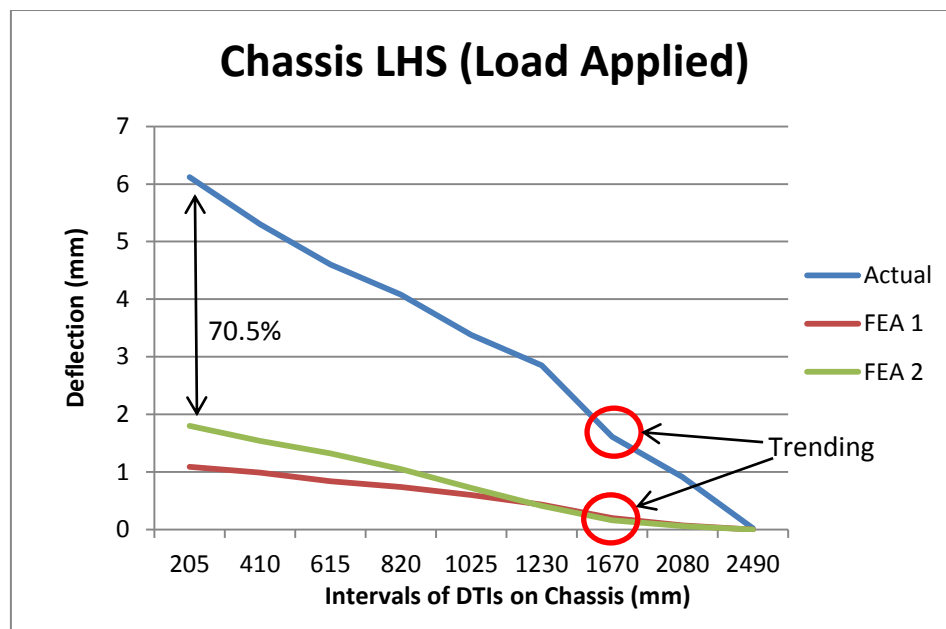
With each of the noted areas confirmed, the author returned to the front twist rig bar and rig. Due to the vast deflection portrayed by the FEA the author re-focused attention on this and looked for suitable alternatives to work around it. Initially it was thought the reasoning behind the vast difference was due to the rig sustaining most of the deflection, because of this the author chose to increase the grade and therefore the stiffness of the twist rigs material.

It was assumed the material of all the rig components was steel. Looking at the steel properties within the NX 7.5 material library, steel is given the known Young's Modulus (E) of 206GPa. NX gives the user the ability to copy any material present within the library; on completion the user has the opportunity to modify any of the material parameters. In order to aid the correlation

phase the author increased the young's modulus to higher level but stayed within respectable limits, the FEA was solved and the results are displayed in table 8.

LHS (Load Applied):				RHS:		
DTI	Length (mm)	Deflection (mm)		DTI	Length (mm)	Deflection (mm)
1	205	1.8		1	205	-1.8
2	410	1.54		2	410	-1.59
3	615	1.32		3	615	-1.29
4	820	1.05		4	820	-1.04
5	1025	0.72		5	1025	-0.7
6	1230	0.41		6	1230	-0.39
7	1670	0.16		7	1670	-0.14
8	2080	0.06		8	2080	-0.05
9	2490	0		9	2490	0

Table 8: 2nd FEA Correlation Results



Graph 3: 2nd FEAComparison Results

Graph 3 displays the plotted results from the second FEA simulation, also present on the graph is the initial FEA and real chassis data. As stated the simulation had increased material properties to try and enable for the deflection in the twist rig to be eliminated and transferred into the chassis. With the second simulation the results had increased to a slightly to a first point percentage difference of 70.5%. Although the results were still very far from correlating it could be noticed that the results had started to tend similarly to the chassis namely at DTI 7 located 1670mm from the twist rig.

Despite this a further in depth look was required to debug the model so the results could become more closely matched, it was now apparent the middle to the rear of the chassis was where the issues were present.

To eliminate all other factors the author investigated the following:

- **Duplicate Nodes:** This means that if two nodes are present in the same area, it would lead to that area being twice as stiff. A finite element check proved there were some present within the shear panels, these were removed with immediate effect however there were none on any part of the chassis structure.

8.4 Rear Twist Rig Investigation

Turning attention back to the rear of the structure and looking at figure 22, it showed there was a large degree of stiffness at the rear of the structure than present on the front.

As all debugging exercises had been completed regarding the structure and front twist rig, the only possible reasoning to why the chassis was delivering such stiff results had to be linked to the way the rear of the chassis was constrained.

As with all the previous simulations the rear bars were constrained with 4 fixed constraints, using this type of constraint assumes the bars are fixed at their optimum and therefore any sort of deflection is ruled out.

Comparing this to the rear fixing points of the twist rig, the chassis is fastened with 4 bolts the rear of the rig structure which is built from steel box section and mechanically fastened to the floor. It therefore became apparent that potentially deflection was occurring in the rear rig structure influencing the results. To confirm this, the author completed another twist test with 4 DTIs placed on the rear of the rig.



Figure 22: Rear Twist Rig Test

The results:

Rear Twist Rig Deflection (Actual)		
DTI	Area	Deflection
1	LT	0.82
2	LB	0.18
3	RT	0.55
4	RB	0.13

Table 9: Rear Twist Rig Test Results

Originally the author completed a test to ensure the bolts fastening the chassis were not rotating, once this was ruled out another set of results were obtained as shown in table 9. These were taken in the Z axis at a load of 1500N. This therefore confirmed there was deflection present and

that the rear assembly must be incorporated onto the FE model.

As with all areas on the model CSYS Co-ordinate systems were used to incorporate the rear rig, the assembly was given the physical properties:

Section	Dimension (mm)	Wall Thickness (mm)	Material
Box	40x40	3	Steel

Table 10: Rear Twist Rig Physical Properties

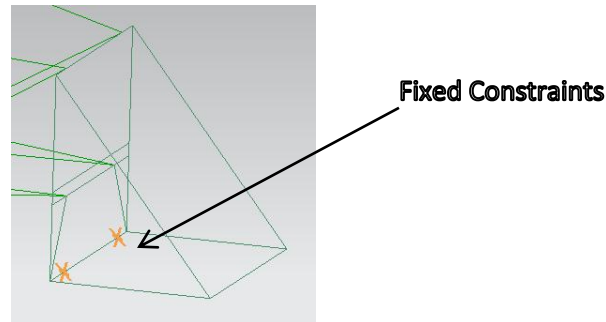


Figure 23: FE Model Rear Constraints

As with the actual chassis rig, the FE model was constrained in the same way using two fixed constraints to simulate the bolts fastening the rig to the floor. The results from the FEA with the rear assembly present are displayed in table 11.

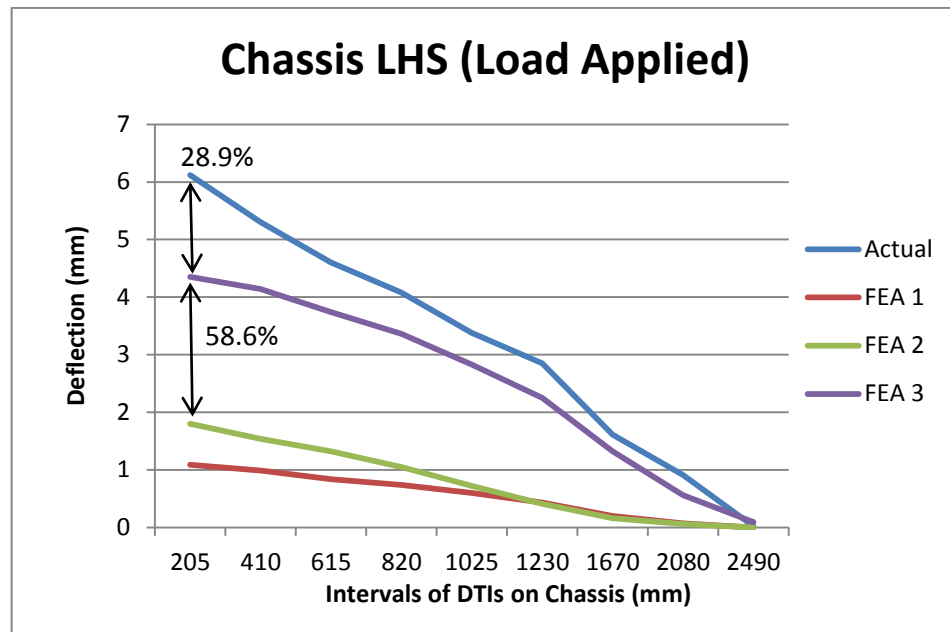
Rear Twist Rig Deflection (FEA)		
DTI	Area	Deflection
1	LT	0.97
2	LB	0.13
3	RT	0.67
4	RB	0.11

Table 11: Rear Twist Rig FEA Results

Comparing table 10 and 11 definitely confirmed that the rear twist rig had a large effect on the overall results when trying to correlate, through this addition the results gained for the overall chassis are displayed in table 12 and graph 4.

LHS (Load Applied):			RHS:		
DTI	Length (mm)	Deflection (mm)	DTI	Length (mm)	Deflection (mm)
1	205	4.35	1	205	-2.92
2	410	4.14	2	410	-2.86
3	615	3.74	3	615	-2.66
4	820	3.36	4	820	-2.4
5	1025	2.83	5	1025	-2.03
6	1230	2.25	6	1230	-1.66
7	1670	1.32	7	1670	-0.98
8	2080	0.56	8	2080	-0.4
9	2490	0.09	9	2490	-0.01

Table 12: 3rd FEA Correlation Twist Test Results



Graph 4: 3rd Correlation Comparison

Looking at the results twinned with the comparison graph, it is clear to see that the addition of the twist rig on to the model has had a large effect. The difference between the highest values of FEA 2 to FEA 3 is that of 58.6%, it could also be noticed that the results were also beginning to trend a lot closer than the previous simulations.

That said focusing on the mid-point through to the front of the chassis on FEA 3 shows that part is a fair degree stiffer with a difference of higher values of 28.9%.

8.5 Effect of Material Subtraction on Bars

Mentioned in chapter 6.4, a technical assumption which had been taken was regarding the overall material consistency of the spaceframe bars. Due to the chassis at some point being part of a full race car there were holes present along either side where cladding was riveted on, however there were holes present on the bars facing into the cockpit. Because a 1D mesh was being used for all areas of the model any holes present in the tubes or bars could not be factored in. This would only be apparent if the mesh was changed to a 2D situation, this would however mean a complete overhaul of the FE model to change each of the physical properties which in return would require a vast amount of time which was not available to the author.

Therefore for author chose to investigate by applying a torque to a simple 2D bar mesh. One would have holes present with the other remaining intact.

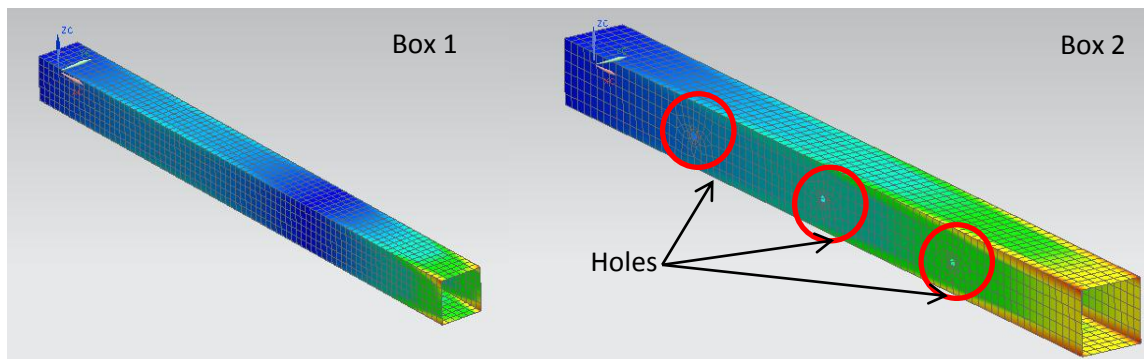


Figure 24: 2D Bar Element Comparison

Each of the tubes displayed was applied with a torque of 200N/m; the results gained for their displacement are shown in table 13.

Tube	Displacement (mm)
1	0.228
2	0.818
% Difference	72.1%

Table 13: % Difference of Results

It can be noticed there is a considerable difference between either of the sections and that holes present towards the front are a causing a large effect on the FEA and potentially explain why the front of the model is stiffer than in reality. The final area for the author to look at was comparing the displacement of these 2D elements to a 1D element with the same torque applied.

In the 1D simulation a moment was applied to the same value of 200N/m, due to this being a moment the result would be displayed in degrees of rotation.

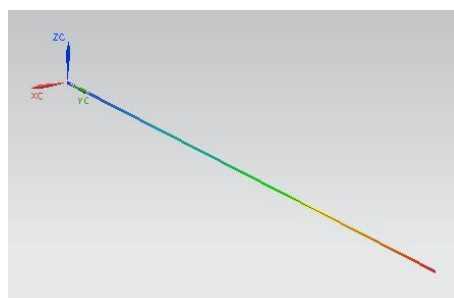


Figure 25: 1D Beam Element FEA

The result gained showed a maximum rotation of **1.599°**, using simple trigonometry this could be converted to see the deflection in millimetres.

$$\tan\theta = \frac{x}{15}$$

Where:

15 = Half Box width

$\theta = 1.599^\circ$

x = Opposite

Therefore

$$15\tan 1.599^\circ$$

$$= 0.418\text{mm}$$

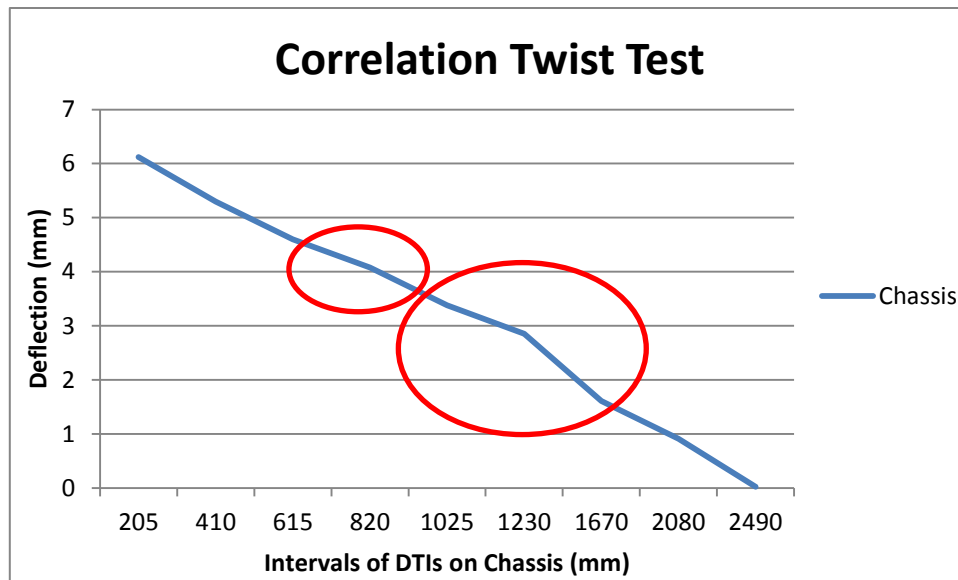
Comparing this to the 2D mesh, there calculates to be a 48% difference between the sections with holes present and the 1D beam element mesh. This would therefore represent the change in deflection between FEA 3 and the actual chassis. Ideally the author would have liked to have manipulated the physical properties to allow for the difference to be noted however given the time constraints this was not possible. Therefore this will remain as a technical assumption but with a better understanding gained.

9. Optimisation

As the chassis was correlated to a level at which the author thought was suitable, the main outcome of the project could be addressed.

The optimisation process would entail continuation use of NX 7.5 as a design and FEA tool with the process then moving on an optimisation package VRAND Genesis.

To begin with the author referred back to the initial twist rig test:



Graph 5: Correlation Twist Test, Areas of Investigation

Although graph 5 has primarily been used for correlation exercises, the graph can be used in order to highlight areas of focus. The parts where the results lead to a sharp gradient represents where the chassis is weak, this exercise therefore acts as a way of scaling down the authors work to ensure that the optimisation is carried out in the most prominent areas.

Both of the areas displayed in red are where the MCR has the poor strength and where the author could improve, this area starts from the middle through to the rear of the chassis. Fortunately all the areas which required attention had the same trend in the FE model and therefore the author had confidence that what was being experimented could make a difference in reality.

9.1 Movement of Bars & Bracing – NX 7.5

The initial wireframe model produced was no longer required as any addition of bars or bracing could be applied whilst the model was in the FEM deck. Providing the additional areas were meshed appropriately then their influence could be noted in the overall result, when no longer required the mesh could simply be removed and curves hidden for the next amendment.

This section will display the FEA results gained from each of the different chassis amendments. The exact figures will be noted in the appendix A and stiffness calculations of each amendment will be displayed and discussed in **chapter 10 Results & Analysis**, each of the graphs displayed are taken from the **Left Hand Side** of the model where a load of **1500N** was applied.

9.1.1 Engine Side Cross Brace

This was an amendment currently in use by MCR; it consists of two 28.5mm tubes running diagonal from the top of the fuel tank frame to the bottom tier bars which fasten to the gearbox plate.

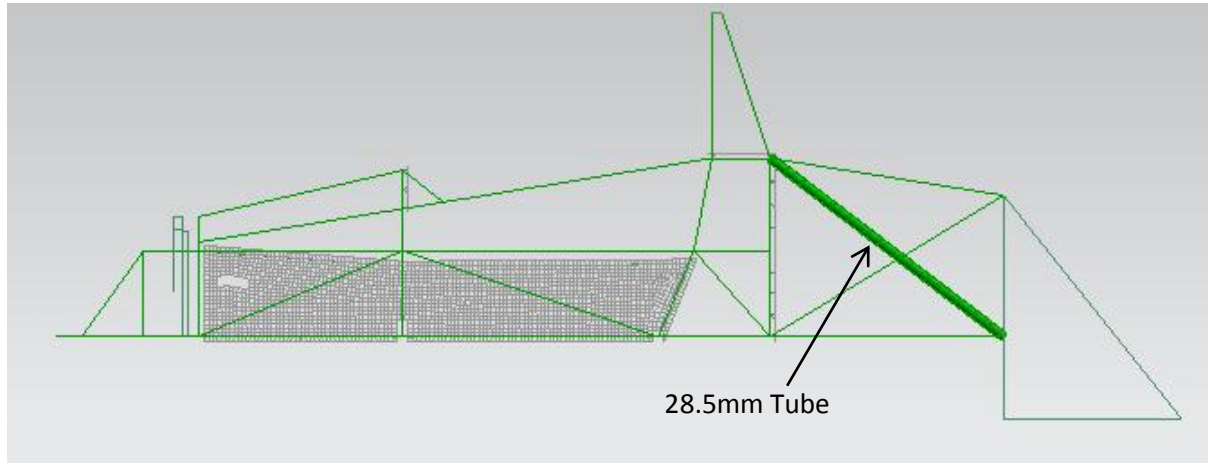
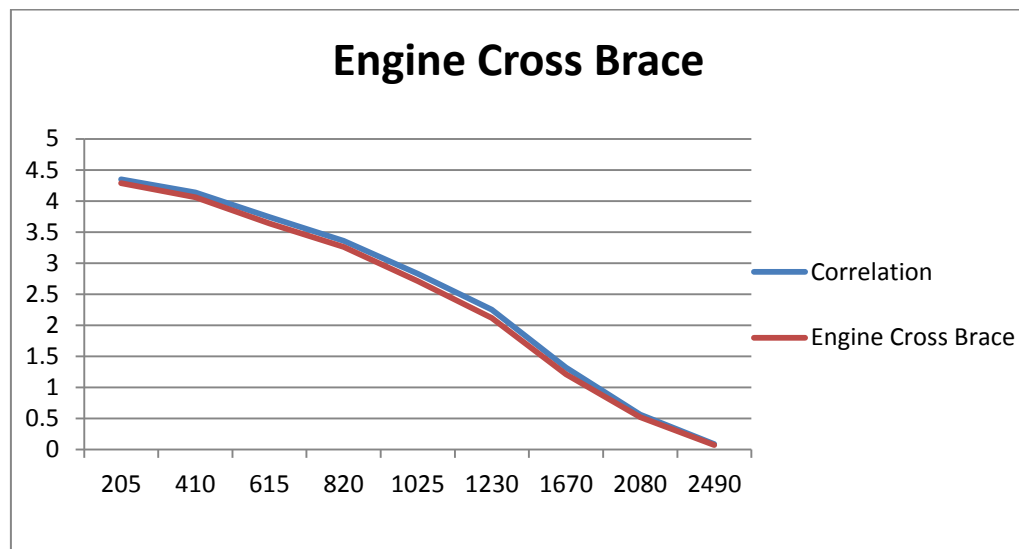


Figure 26: Rear Engine Brace

FEA results plotted against correlation results.



Graph 6: Rear Engine Brace Deflection

The graph displays that there has been a minor decrease in the deflection at the rear of the chassis. The main steep gradient between 1025 & 1670mm has become a slightly smoother. The total weight of the chassis in this state is 60kg.

9.1.2 Roll Hoop Struts

Adding a 28.5mm tube from each side of the roll hoop to the dashboard, this amendment is currently in use by an MCR team. This also includes the rear engine struts.

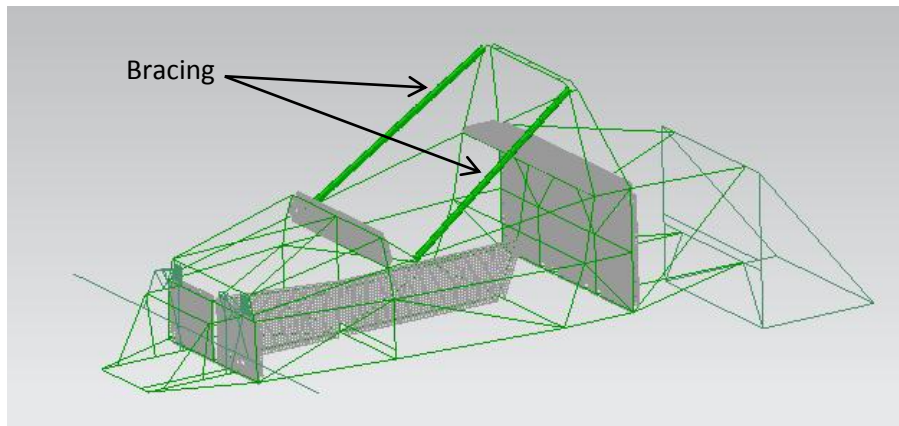
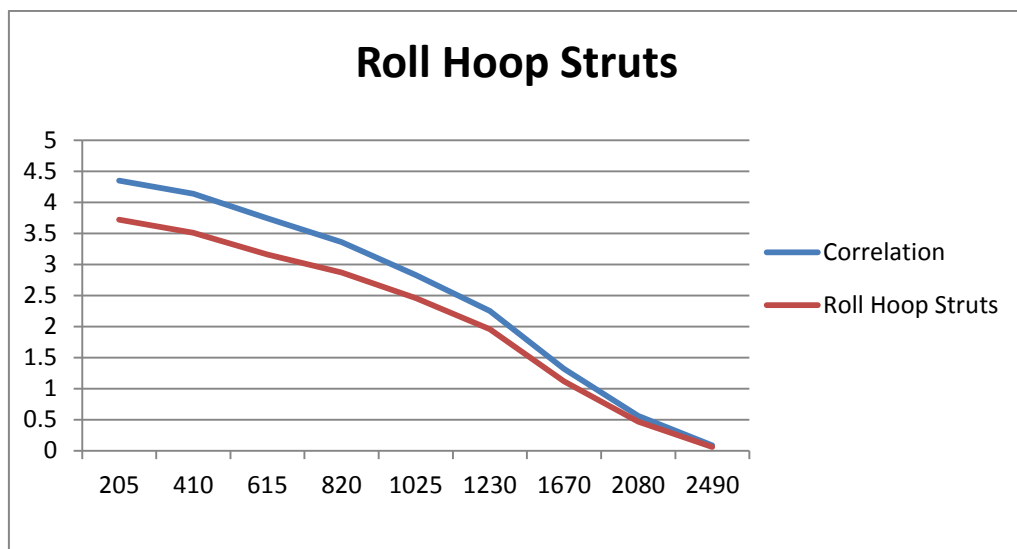


Figure 27: Roll Hoop Bracing

The FEA results plotted against the correlation results.



Graph 7: Roll Hoop Bracing Deflection

The graph displays there has been a large decrease in the overall deflection, this amendment has had a positive impact on both the front and rear of the chassis despite being located in the middle. The chassis in this state weighs 62kg.

9.1.3 2nd Tier Fuel Bracing

20x20mm box bracing added to either side of the fuel tank frame. This is located in the area where chassis is deemed to be weakest. All other chassis parameters are normal.

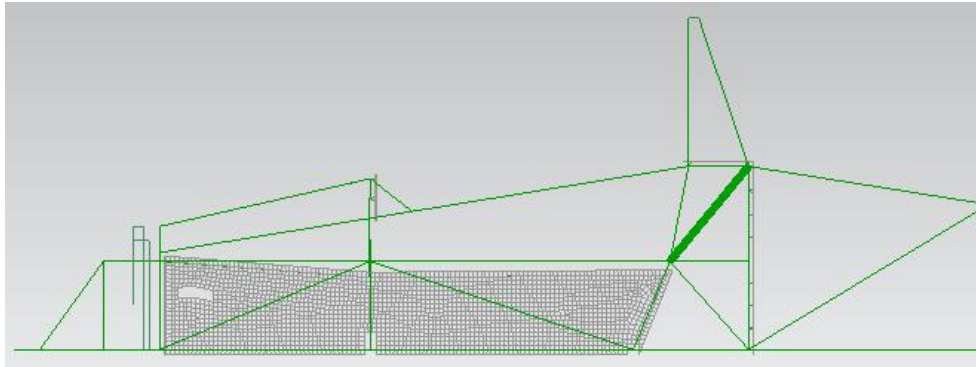
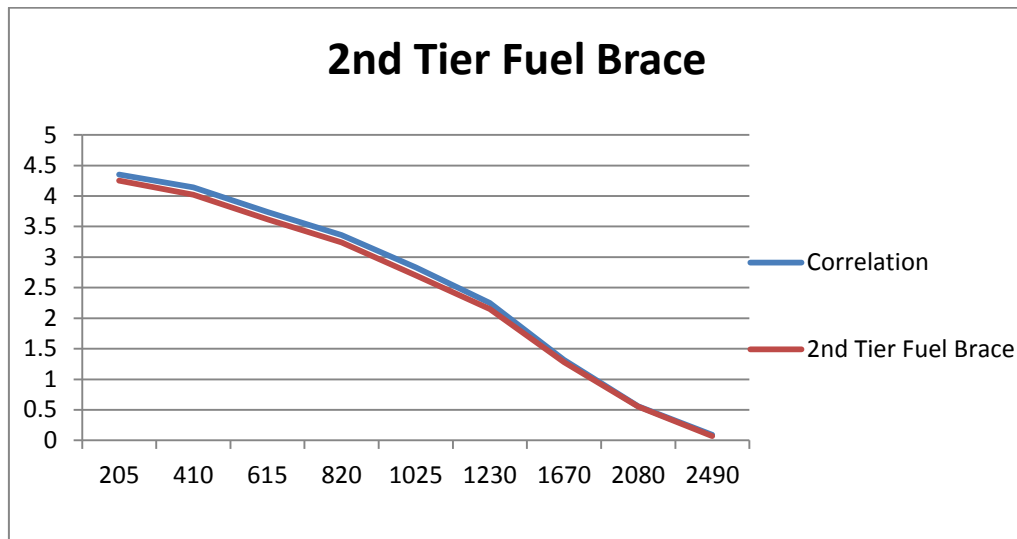


Figure 28: 2nd Tier Fuel Bracing

The FEA results plotted against the correlation results:



Graph 8: 2nd Tier Fuel Bracing Deflection

The graph shows there has been a minor increase in decreasing deflection up until the point where this cross member is located, however the result trend after this nearly identical. The chassis in this state weighs 59.1kg.

9.1.4 1st Tier Double Brace

A double brace was added underneath the fuel tank, as at present it has remained with a rectangular frame. The brace is 30x30mm box. This FEA also includes the 2nd tier fuel brace.

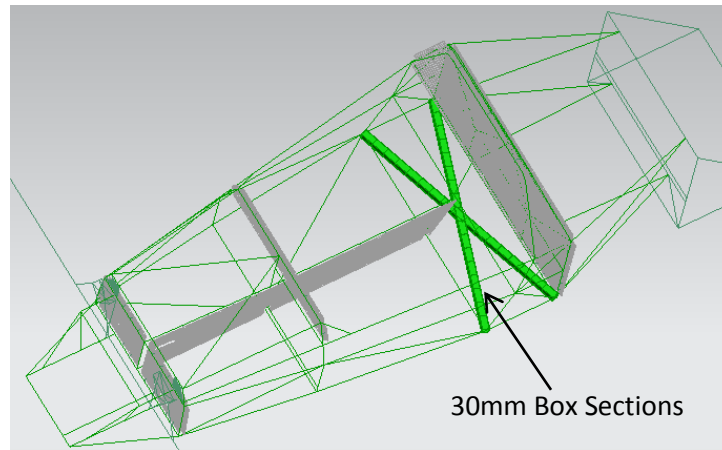
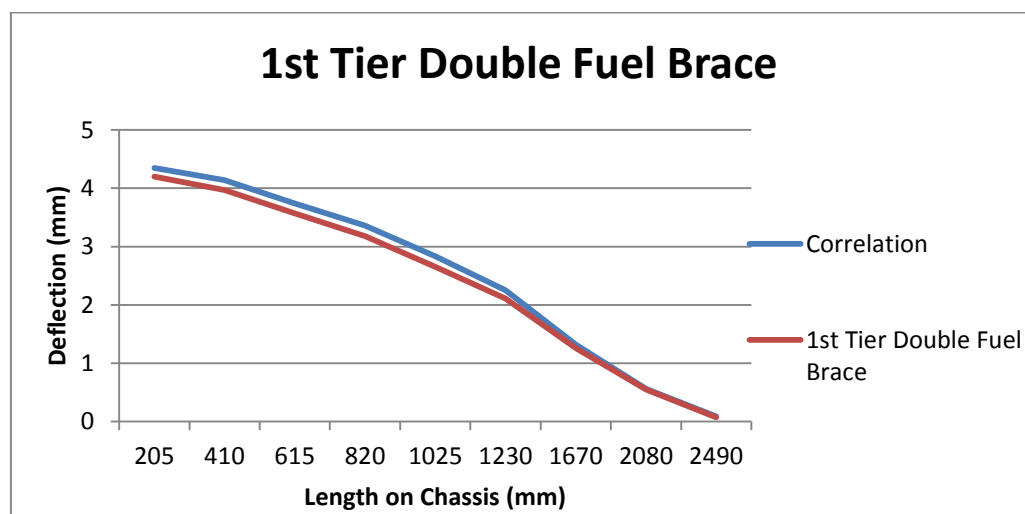


Figure 29: 1st Tier Double Bracing

The FEA results plotted against the correlation results:



Graph 9: 1st Tier Double Bracing Deflection

The results show once again an overall decrease in deflection from the front to the section where these bars are present, the highest fall in deflection 0.20mm. The chassis in this state weighs 61.9kg.

9.1.5 2nd Tier Middle Brace

A cross member bar was added to either side of the chassis cockpit in between the 2nd and 3rd tier bars. These bars were 30x30mm box sections. The 2nd tier fuel and 1st tier double braces were also present.

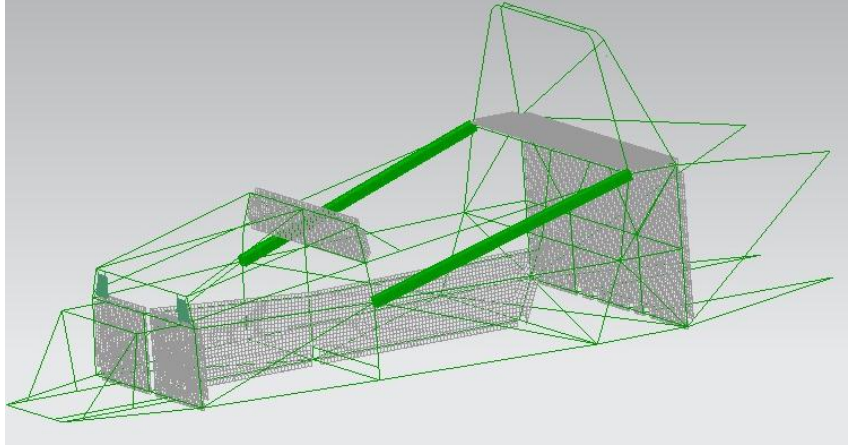
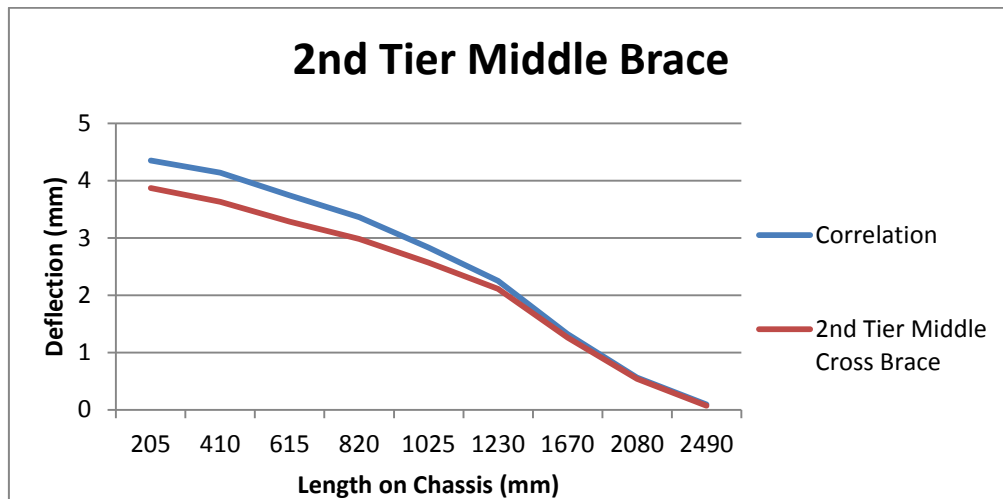


Figure 30: 2nd Tier Middle Brace

The FEA results plotted against the correlation:



Graph 10: 2nd Tier Middle Brace Deflection

Adding the mid cross brace has made a positive effect on the overall deflection of chassis, however at 1230mm the chassis is still has a sharp point and steep curve which continues to the rear of the chassis. The weight of the chassis in this state is 64.4kg.

9.1.6 Floor Cross Sections

The passenger floor cross brace sections were increased in size from 15mm to 30mm, this is an amendment which MCR currently have in place. Cross members were also placed on the driver's side. This FEA also included both types of fuel brace and 2nd tier middle brace.

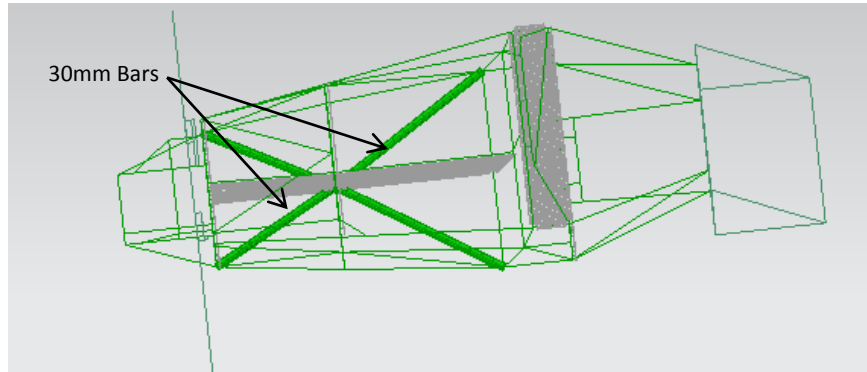
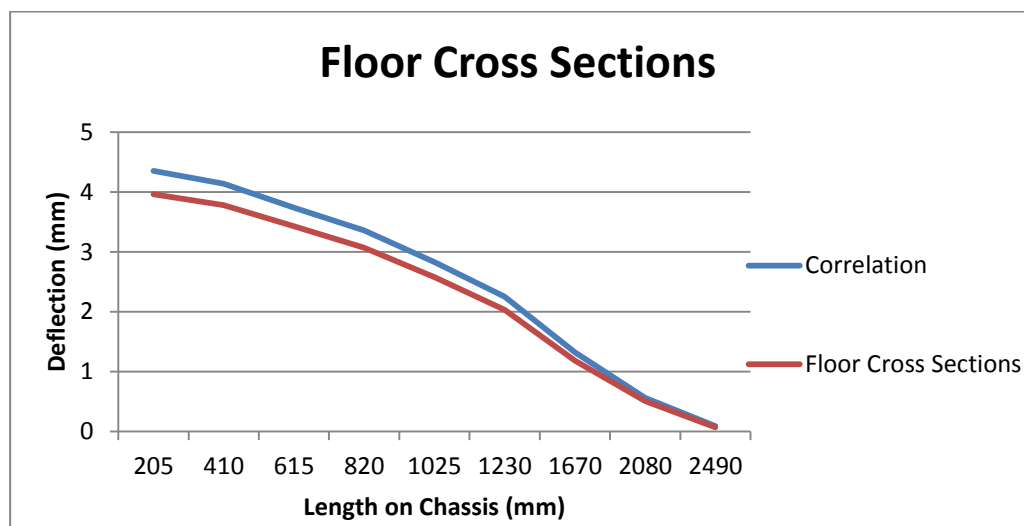


Figure 31: Floor Cross Sections

The FEA results plotted against the correlation results:



Graph 11: Floor Cross Section Deflection

This amendment has certainly smoothed out the spike at 1230mm; everything onwards becomes closer to the initial correlation result. With all amendments the chassis comes to a weight of 68kg.

9.1.7 30mm Cross Members

This is another amendment completed by MCR with all their new chassis. The side structural cross members were increased from 20mm to 30mm. For this FEA all other Parameters were put to original.

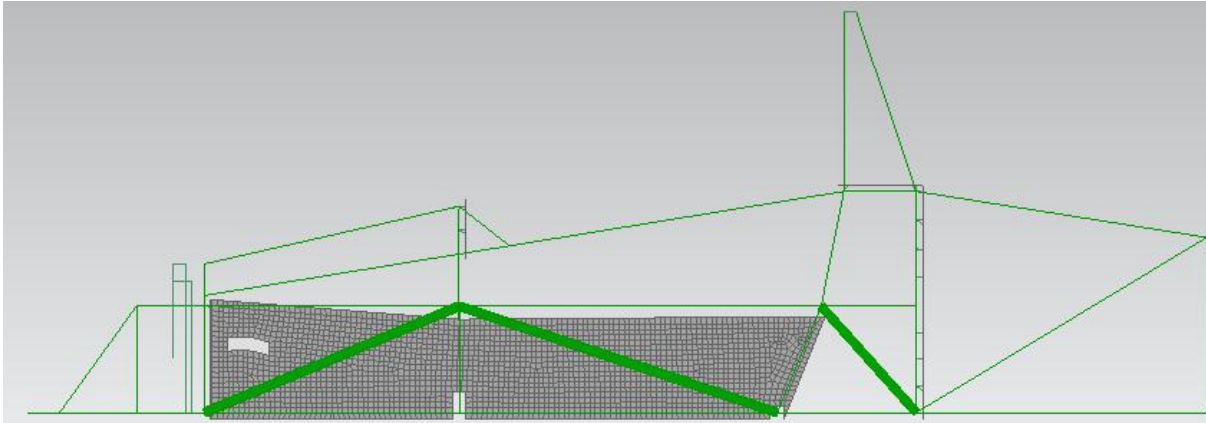
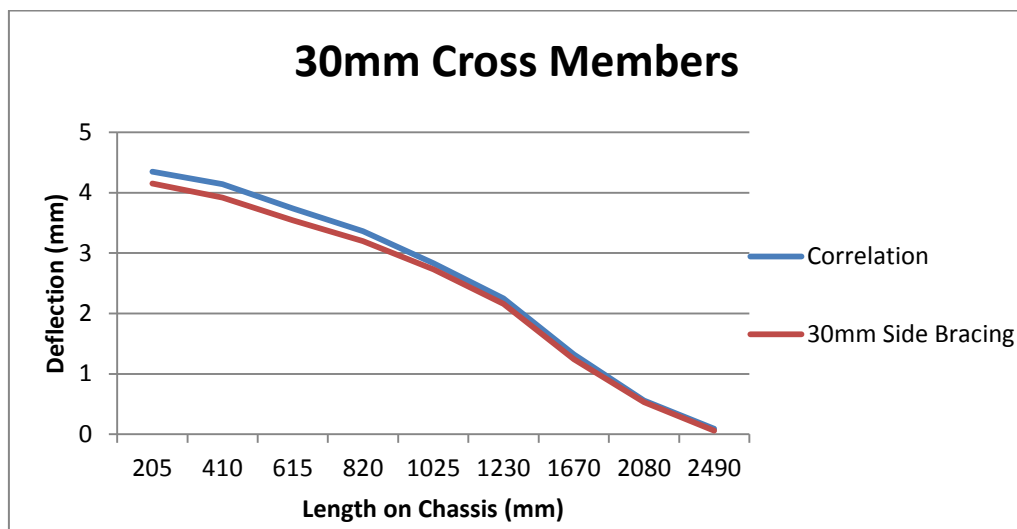


Figure 32: 30mm Cross Members

The results plotted against the correlation results:



Graph 12: 30mm Cross Member Deflection

The amendment has certainly made a small improvement however the results still follow very closely to the correlated results. The weight in this state is 60.9kg.

9.1.8 Front Fuel Cross Brace

Located behind the driver the structure layout was added with a single 20mm box diagonal cross member in each quarter. All other parameters remained normal.

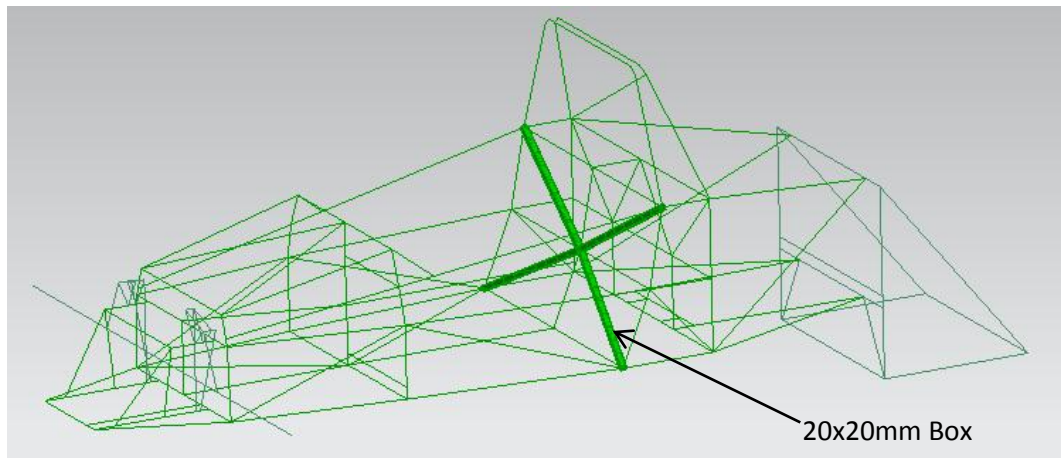
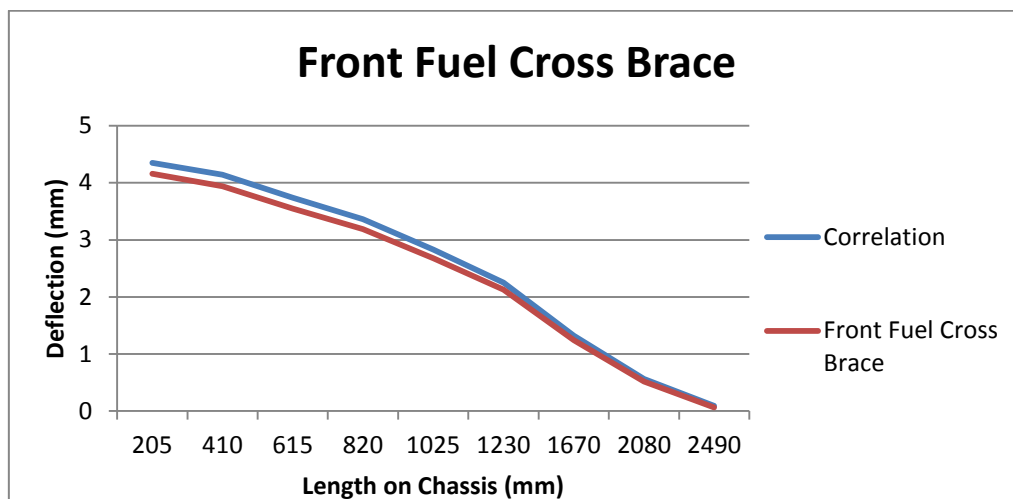


Figure 33: Front Fuel Cross Brace

The results are plotted against the correlation results:



Graph 13: Fron Fuel Cross Brace Deflection

The results show a minor decrease in deflection, however is not of a sizable advantage. The weight of the chassis in this state is 60.9kg.

9.1.9 Lower Fuel Tank Bracing

At the rear of where the fuel tank is situated there are three square sections, a 20mm box section was added diagonally into each of these sections. All other chassis parameters remain in a normal state.

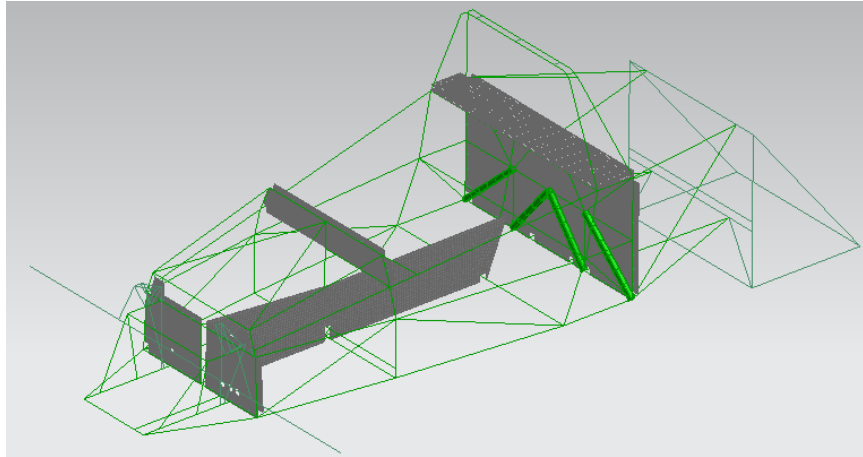
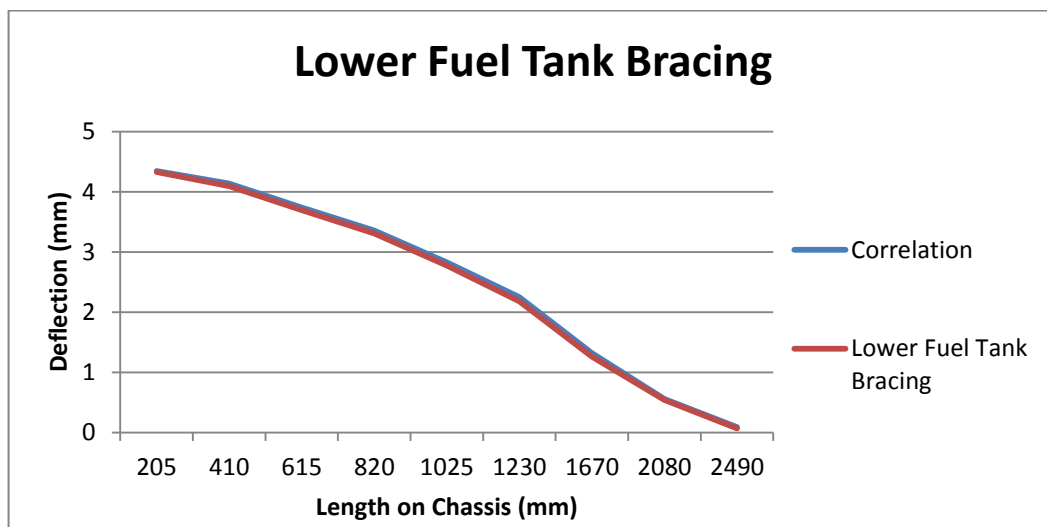


Figure 34: Lower Fuel Tank Bracing

The results plotted against the correlation results:



Graph 14: Lower Fuel Tank Bracing Deflection

Although this isn't a major amendment made to the structure along with not a major change in results, the area in which the author is focusing on is considerably smoother and is fairly consistent compared to the correlation. The weight of the chassis in this state is 59.6kg.

9.1.10 Bracing Under Engine

Looking to the rear of the chassis where the engine is seated, a set of 30mm box sections were applied diagonally. All the other parameters on the chassis were normal.

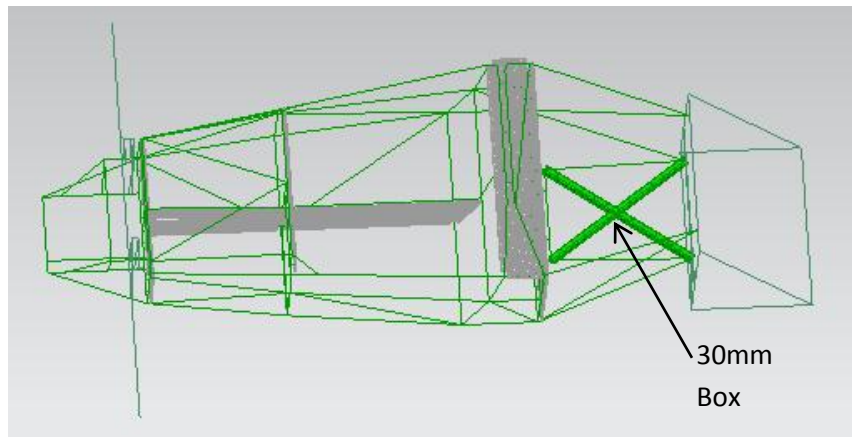
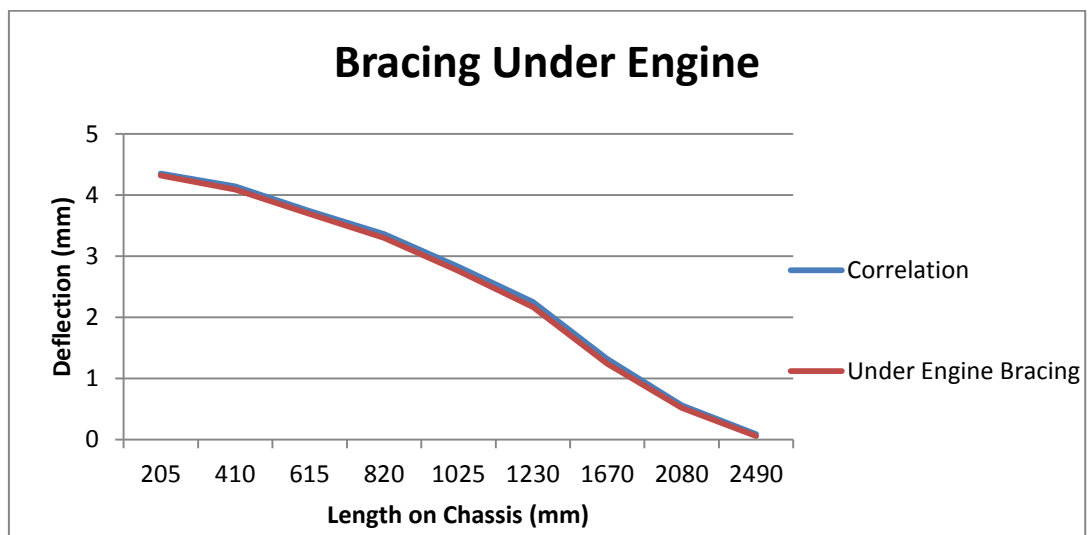


Figure 35: Bracing Under Engine

The FEA results plotted against the correlation results:



Graph 15: Bracing Under Engine Deflection

Looking at the rear regions of the graph it can be noticed that these bars have smoothed out the authors focal area to a reasonable level. As the rear of the chassis is weakest this could be a well-supported amendment. In this state the chassis weighs 60kg.

9.1.11 Roll Hoop Gusset

As there are two roll hoops present, the author experimented by inserting a 3mm steel gusset plate in between the two of them. In the model the plate is attached by means of RBE 2s, all other parameters of the chassis are normal.

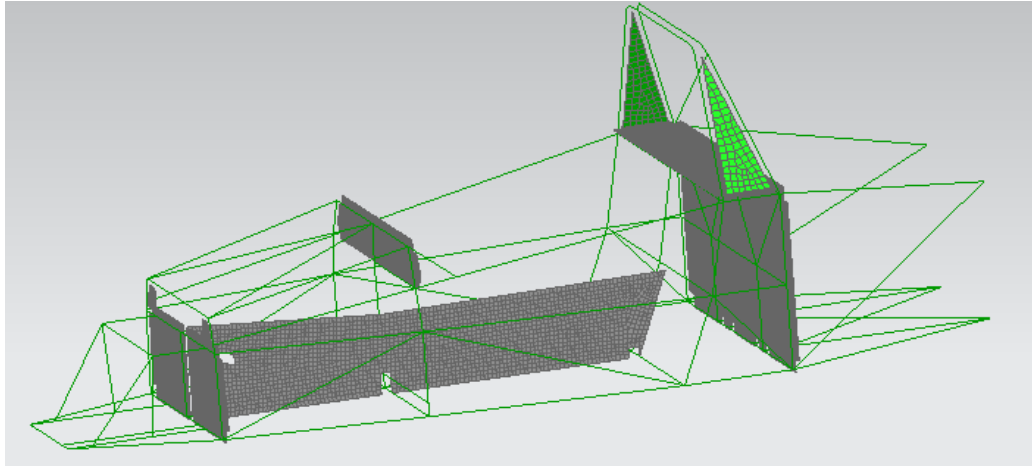
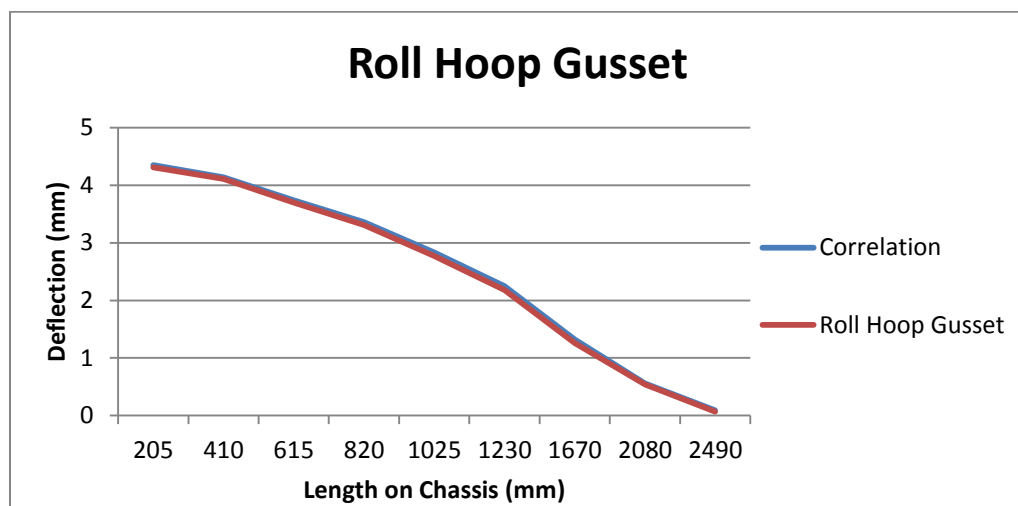


Figure 36: Roll Hoop Gusset

The results plotted against the correlation results:



Graph 16: Roll Hoop Gusset Deflection

Looking at the results, the addition of the roll hoop gusset however has smoothed the result at 1230mm slightly, although this addition could work well alongside other amendments it could not be applied as the body fastens around both of the roll hoops. The chassis in this state weights 59kg.

9.1.12 Multi Braced Chassis

Looking over all the amendments and tests which were completed in the various configurations, the author decided to pick the main ones which had the biggest effect on the deflection.

These were:

- Rear Diagonal Engine Bars
- Roll Hoop Struts
- Lower Fuel Tank Bracing
- Under Engine Bracing

In the area which the author was focusing on these had the greatest effect in the author's opinion. As the roll hoop struts were apparent in the middle they completed the front regions of the chassis.

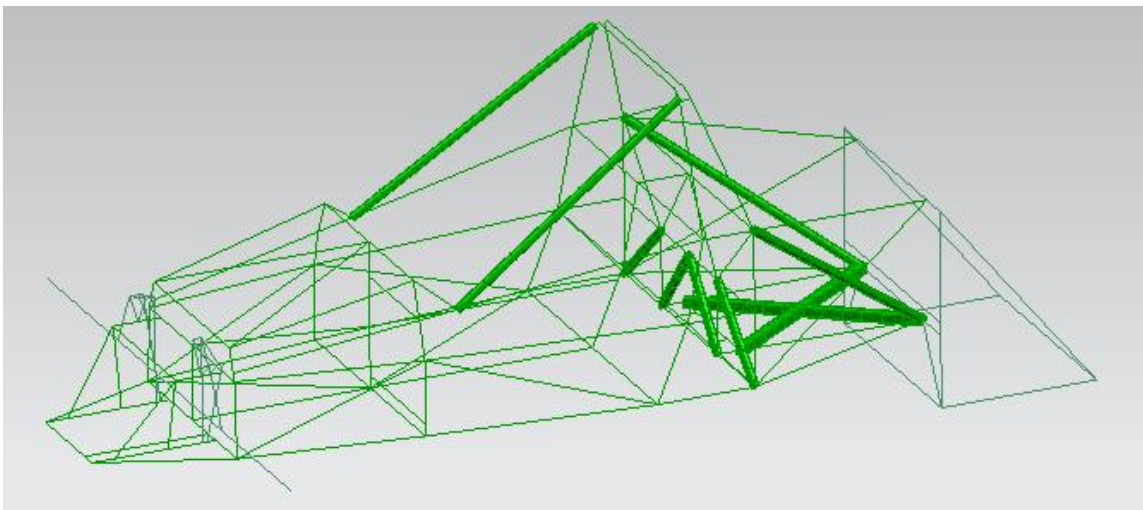
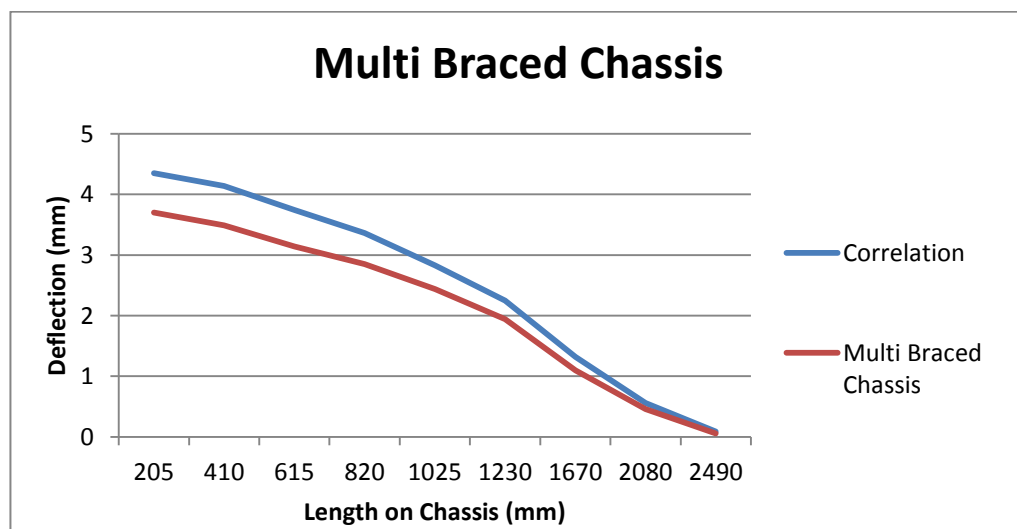


Figure 37: Multi Braced Chassis

The FEA results compared to the correlation results:



Graph 17: Multi Braced Chassis Deflection

The effect of the extra braces has influenced the deflection heavily, it also smoothed out the mid to rear of the chassis meaning although still not great it is marginally stiffer than previous set ups. In this state is 61kg.

9.1.13 Single Roll Hoop

Although the MCR has two roll hoops, the author experimented with removing the roll hoop nearest the driver and keeping the rear one. In order for this to work efficient similar bracing as in 9.1.2 had to be used in order maintain structural integrity.

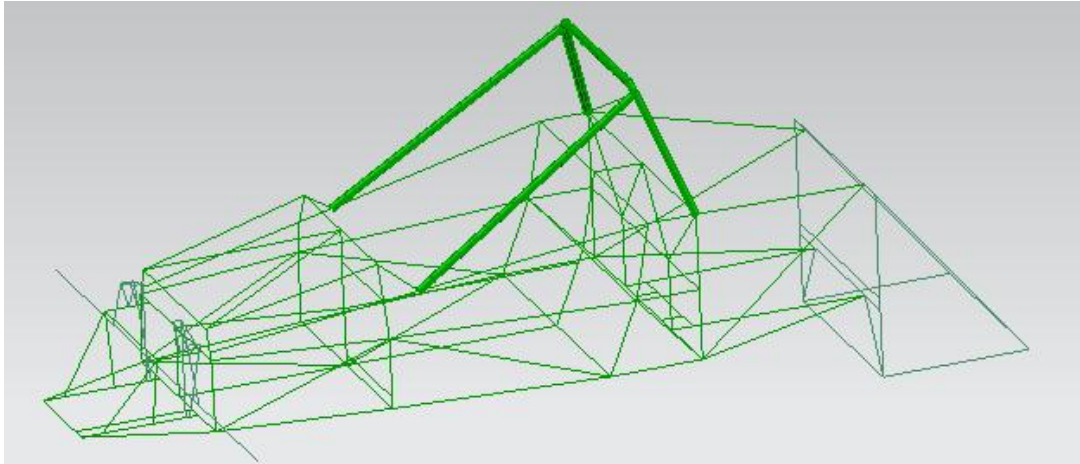
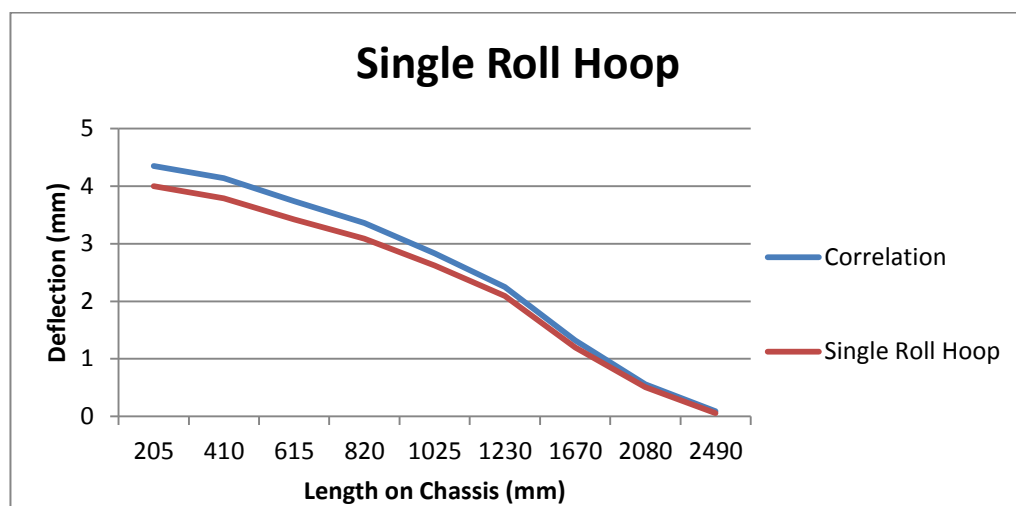


Figure 38: Single Roll Hoop

FEA results plotted against the correlation results:



Graph 18: Single Roll Hoop Deflection

Although the chassis has decreased in deflection the results don't display a heavy significant change. The author suspects that a lot of the structural integrity of this layout has come from the two circular struts placed on either side of the hoop. The weight of the chassis in this format is 69.1kg.

9.1.14 Single Roll Hoop with Items with 9.1.12

In This setting the chassis still had the single roll hoop and side bracing bars; however the items in 9.1.12 were also added to look at effect.

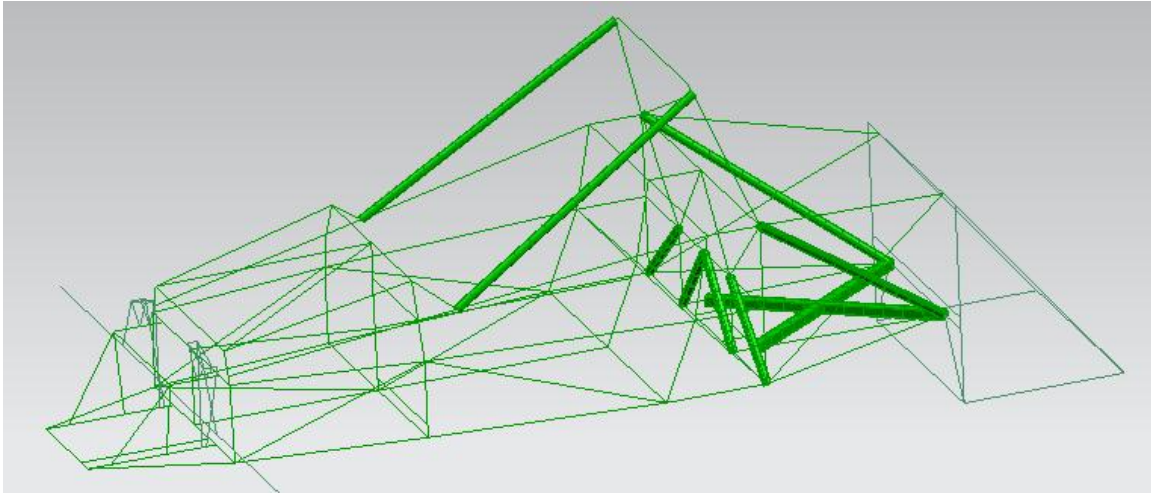
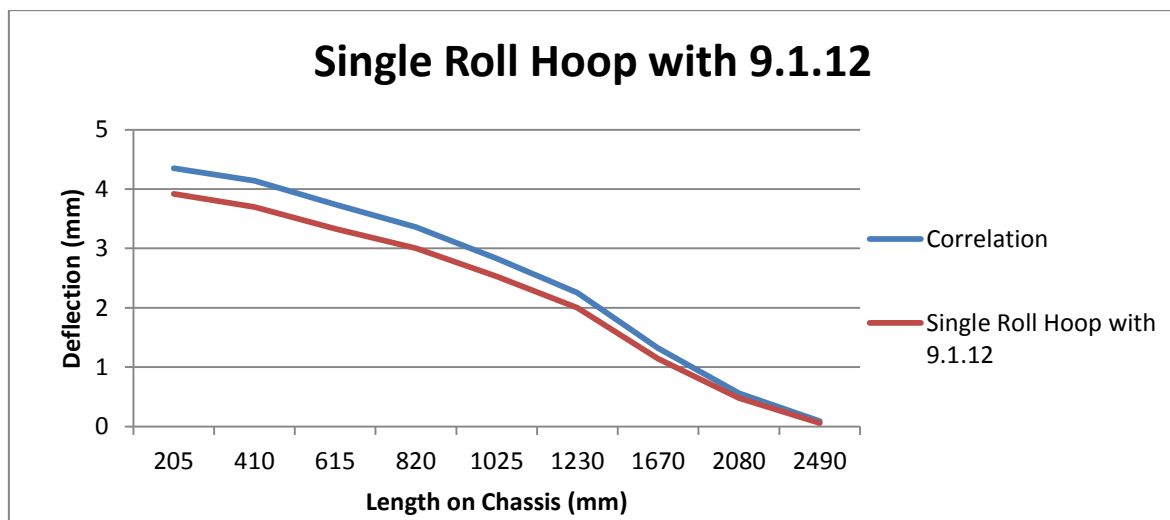


Figure 39: Single Roll Hoop Multi Braced

The FEA results compared to the correlation results:



Graph 19: Single Roll Hoop Multi Braced Deflection

The addition of the bars in 9.1.12 has had a positive effect on the single hoop construction; however the author deems this amendment unsuitable for the fact this is a major structural change and for it to be put forward would require a closer correlated FE model. The weight of this set up is 72.7kg.

9.2 Cladding – NX 7.5

With a large amount of amendments and experiments completed with the movement/position of spaceframe bars, attention was turned to applying side cladding on to the model.

MCR currently use side and floor cladding on their race cars, therefore this makes it a hybrid chassis. The cladding itself is that of aluminium which is 1.1mm thick, a large proportion of the vehicles torsional stiffness could be achieved by the application of these panels. Because of this the author it would be suitable to apply these onto the model.

9.2.1 Side & Bottom Cladding

All areas of the chassis were returned to their original state; cladding was added to the sides and fastened with RBE 2s.

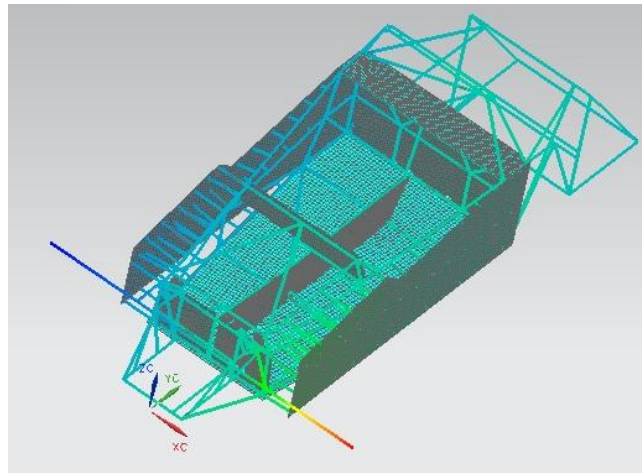
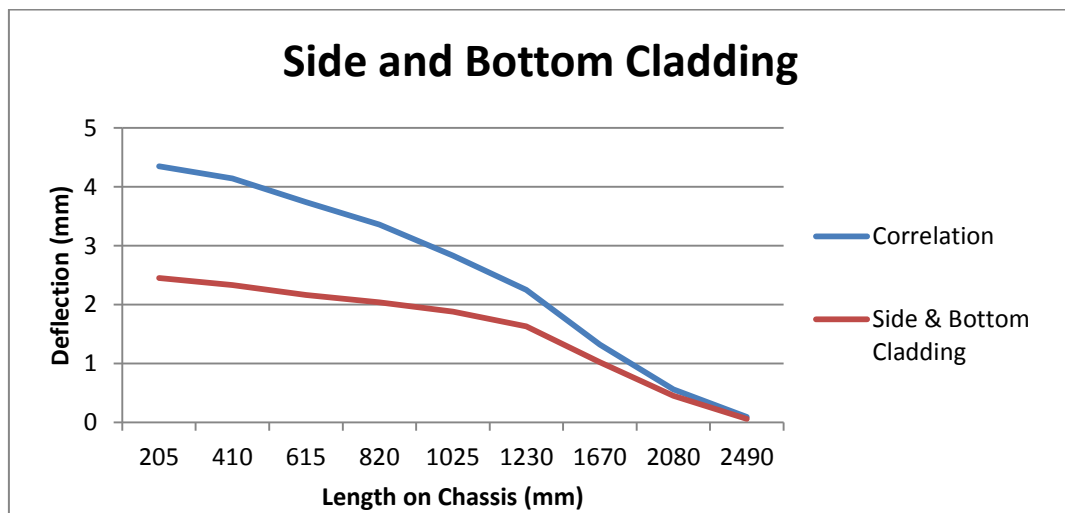


Figure 40: Side & Bottom Cladding

As per the previous FEAs the results were plotted against the correlated results:



Graph 20: Side & Bottom Cladding Deflection

Weight: 79.8kg

9.2.2 Engine Cladding

Cladding was placed underneath the engine area, all the other remained at regular parameters.

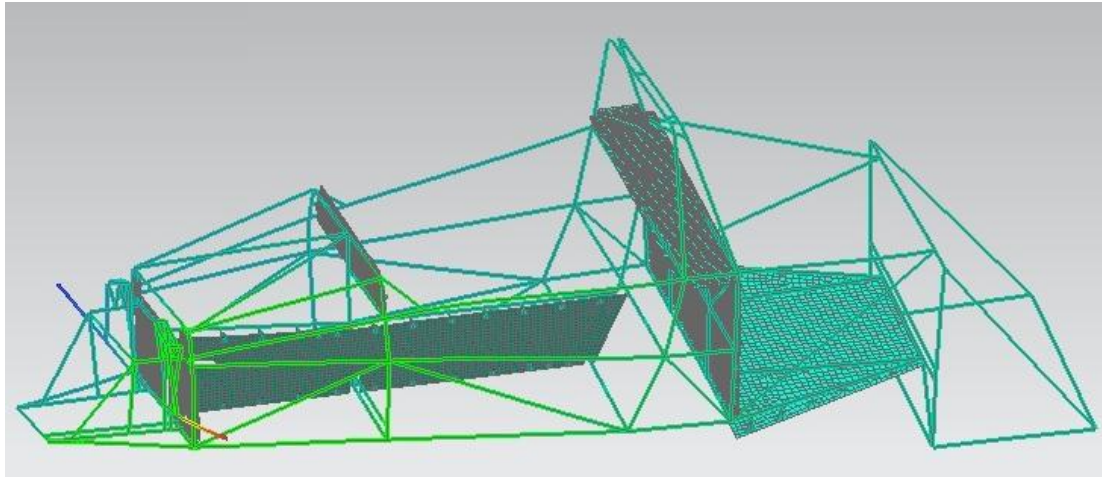
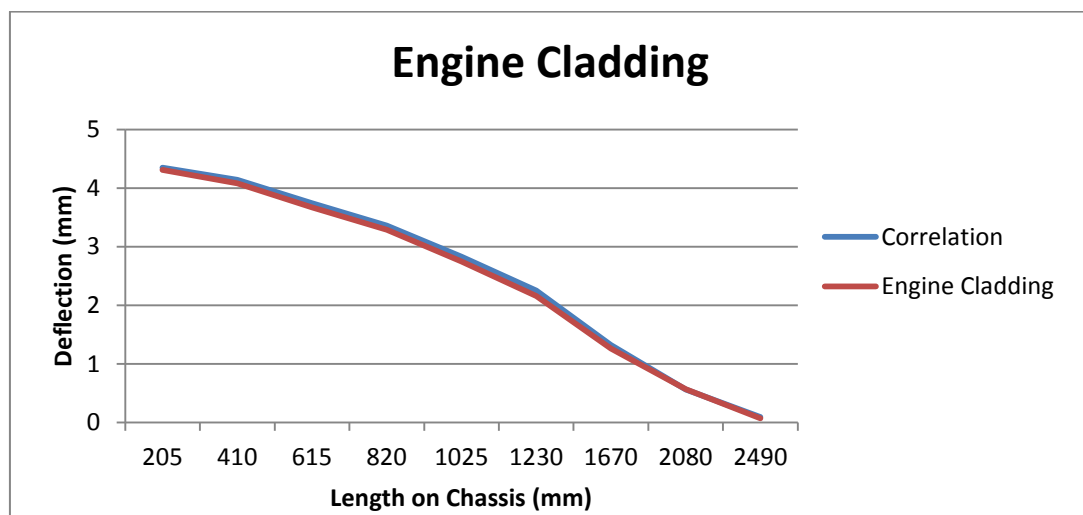


Figure 41: Engine Cladding

The results plotted against the correlation results:



Graph 21: Engine Cladding Deflection

Weight: 60.7kg

9.2.3 Side Cladding with 9.1.12 & 9.2.2

For this simulation the side cladding was returned along with all the bracing amendments applied in 9.1.12, also present was the cladding underneath the engine.

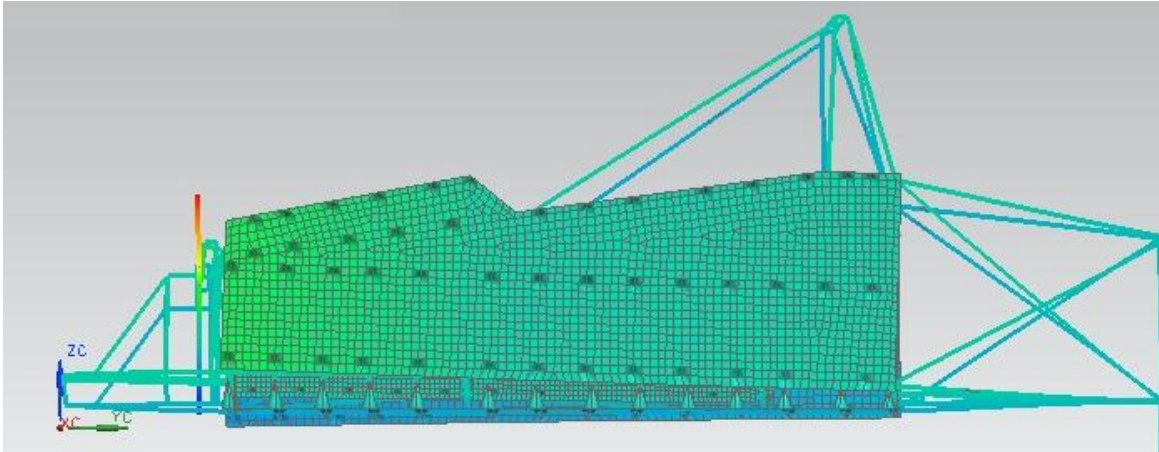
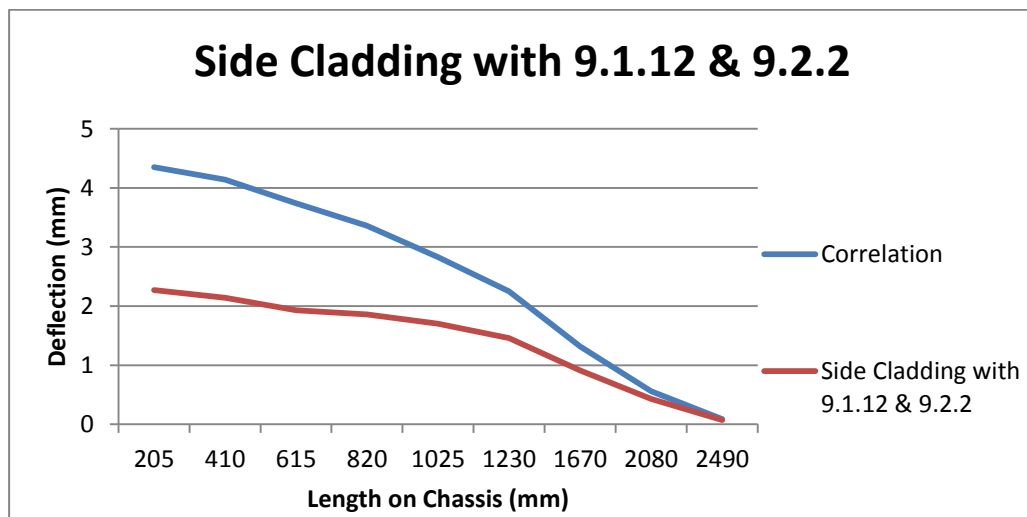


Figure 42: Side Cladding with 9.1.12 & 9.2.2

The results plotted against the correlation results:



Graph 22: Side Cladding with 9.1.12 & 9.2.2 Deflection

Weight: 84.7kg

9.2.4 Side Engine Cladding with 9.2.3

With this simulation the author kept the model in the state from the last run but added cladding to the sides of the engine.

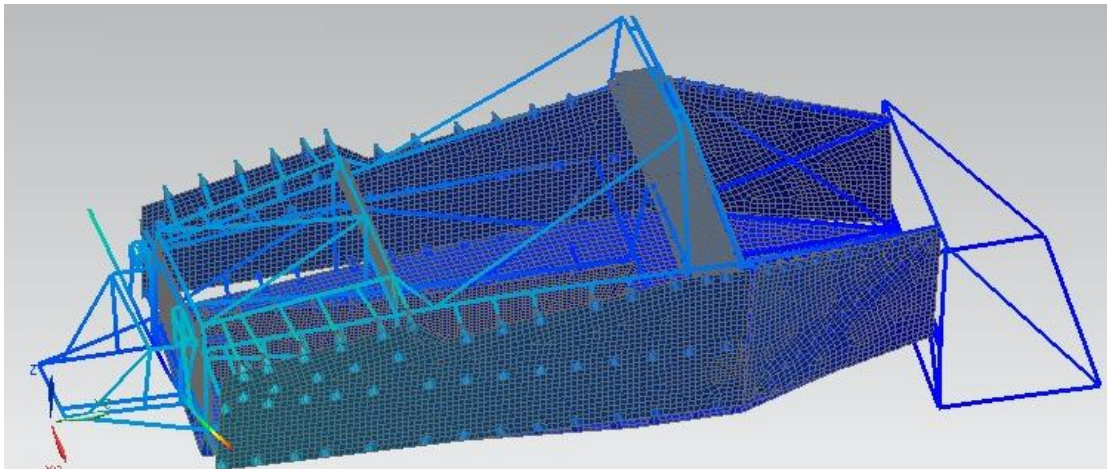
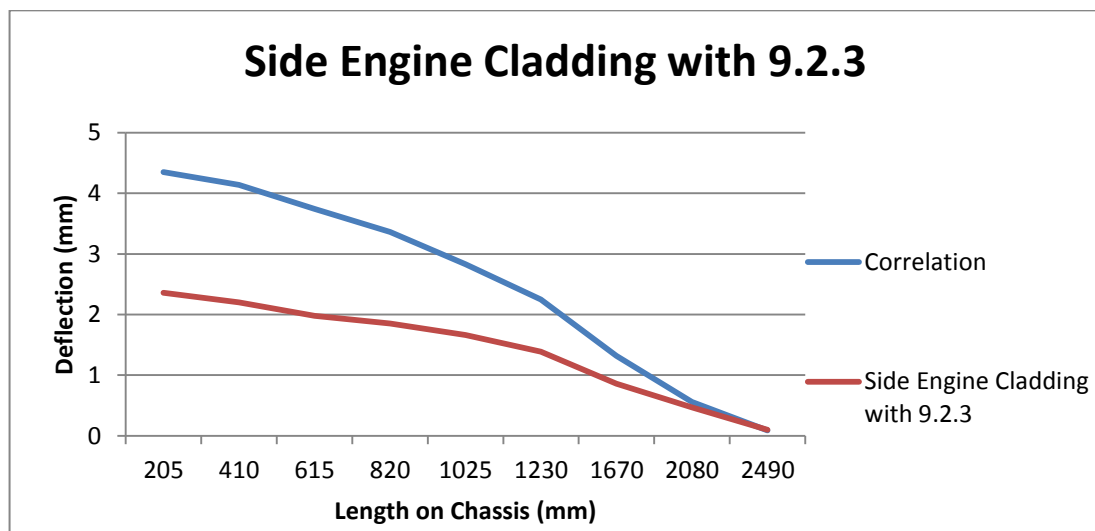


Figure 43: Side Engine Cladding with 9.2.3



Graph 23: Side Engine Cladding with 9.2.3 Deflection

Weight: 86kg

9.2.5 Single Roll Hoop with Side & Engine Cladding

For continuity purposes, it was decided to run a simulation with side and engine cladding on with the single roll hoop setup.

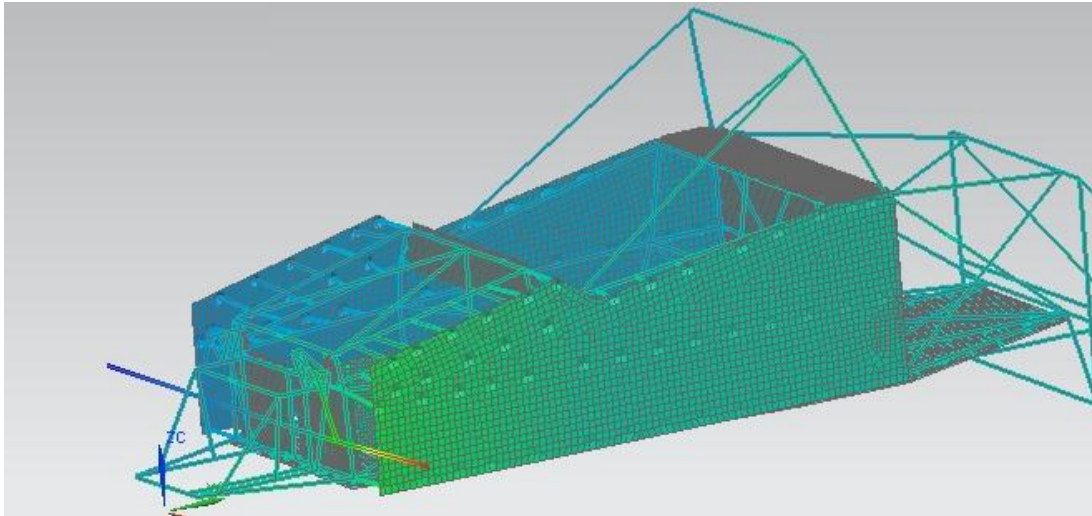
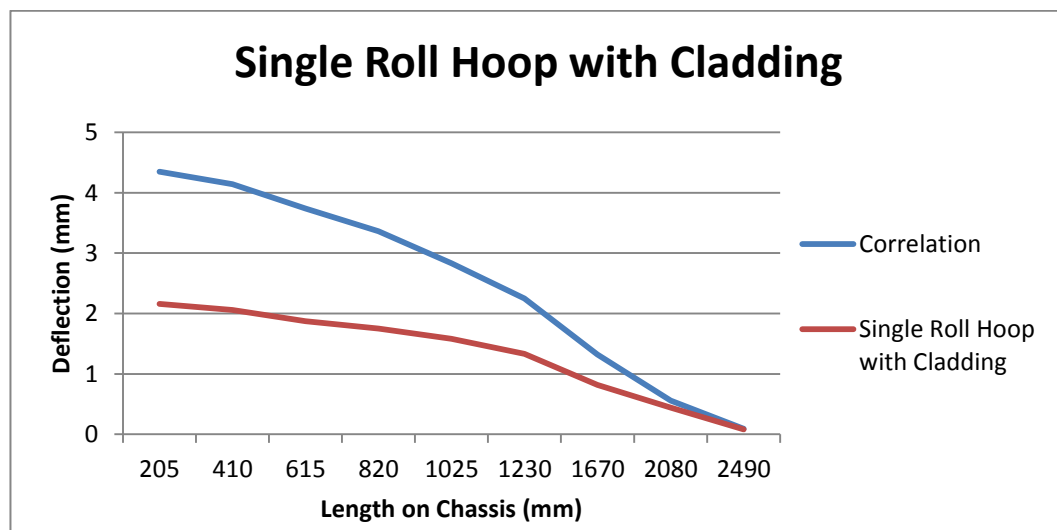


Figure 44: Single Roll Hoop with Side & Engine Cladding

The FEA results plotted against the correlation results:



Graph 24: Single Roll Hoop with Side & Engine Cladding Deflection

Weight: 72.4kg

Looking over at all the cladding setup shows the can almost reduce the deflection by 50%. That said it does come at a weight addition of nearly 14kg.

9.4 Chassis Optimisation – Design Studio for GENESIS

After investigating the application of different bars and their placement on the chassis, attention was turned to looking at gaining one of these designs for ‘Optimising’.

FEA 9.1.12 had been put together after a range of the amendments had been experimented with individually; the decrease in deflection gained from these applications led the author to implement them as a whole. Other items were deemed inappropriate with regard to the weight gain compared to overall result.

To move forward into the optimisation process the author moved way from using NX 7.5 and move towards VRAND GENESIS. This is multi-discipline optimisation software which would enable the author to export the simulation from the Nastran deck into GENESIS, and then look at each of the bars individually to determine a DOE type setting to find the optimum wall thickness and dimensions; this would be gained by specifying the maximum deflection possible for each bar.

As the chassis predominantly made up of 30mm box sections and 28.5mm tube sections the author chose to concentrate on these areas.

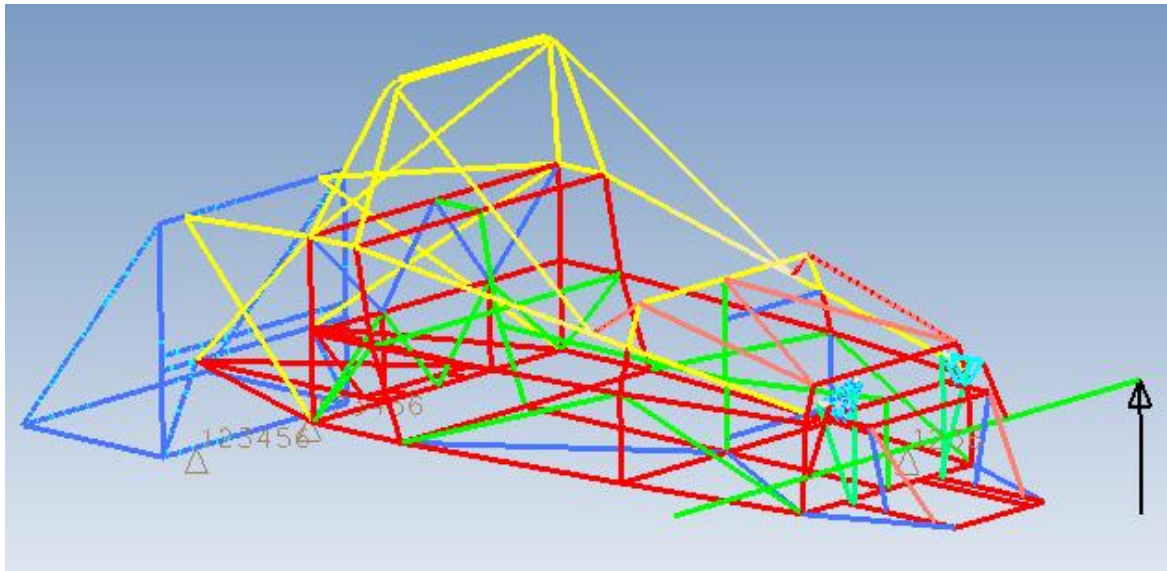


Figure 45: Design Studio For Genesis

Figure 45 displays the model successfully set up in GENESISs after being exported from NX 7.5. Each of the constraints and loads were also carried over ensure the FEA could be completed in GENESIS.

Looking at the main optimising region, Genesis looks at each tube differently than that of NX. Rather than specifying the external diameter and wall thickness it looks at the internal diameter and wall thickness. The 2 bars in their original state were:

Type:	Internal Dimensions:	Wall Thickness:
30x30mm Box	27mm	1.5mm
28.5mm Tube	25.5mm (Diameter)	1.5mm

Table 14: Physical Properties for Potential Optimisation

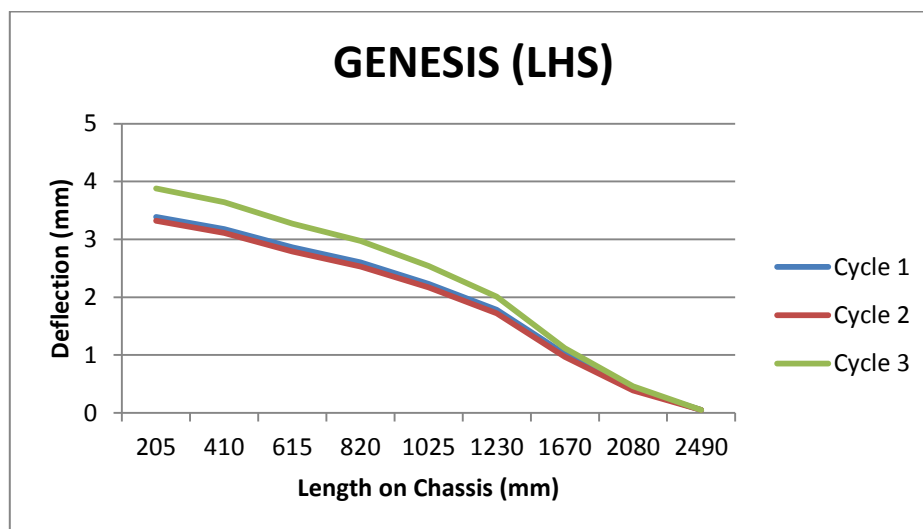
The main part of the package is to specify exactly what is required to be optimised, in this setting it was 'mass' and 'displacement'. The simulation would be run to try and save the most mass without sacrificing the stiffness, the maximum displacement was set at 5mm as this is what highest deflection achieved for both of the types of bar on the middle tier of the chassis.

The final parts which must be inputted were the design variables. This is a higher, lower and middle value of which the user wants the dimensions to fall into, the middle variable is always the current specified size therefore what is displayed on table 14. Table 15 has the author's inputted variables:

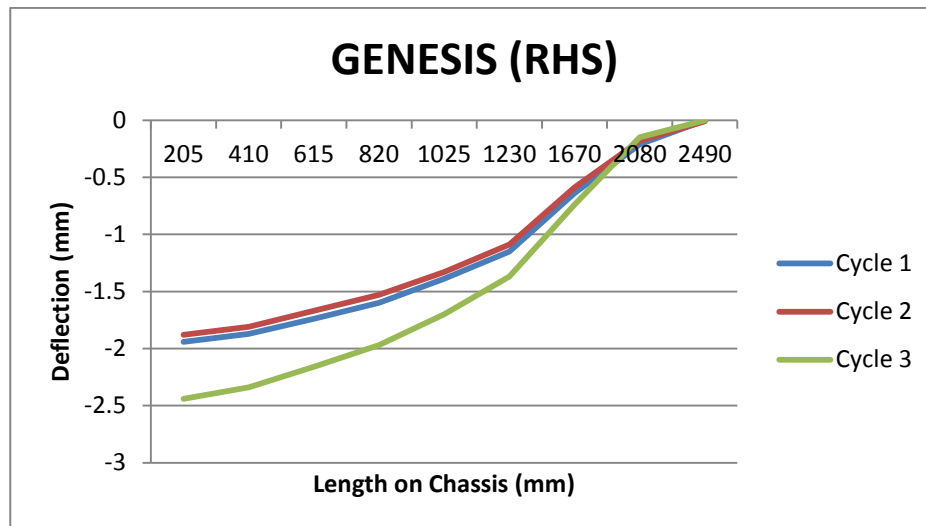
Type	Lower Variable (mm)	Current Variable (mm)	Upper Variable (mm)
Box Inner Dimension	24	27	30
Box Wall Thickness	1	1.5	3
Tube Inner Diameter	25.5	25.5	30.5
Tube Wall Thickness	1	1.5	3

Table 15: Design Studio for Genesis Variables

When the simulation was run it went through each of the design variables to find the best suited, there were in fact 3 sets of results which were obtained using the variables stated in table 14. The results gained will be discussed in chapter 10 'Results & Analysis', however graphs 25 and 26 display a comparison of the results for both the left and right.



Graph 25: Optimisation Cycle Comparison Deflection Left



Graph 26: Optimisation Cycle Comparison Deflection Left

10. Results & Analysis

With the main part of experimental work completed with respect to changing and modifying bars the results could be looked at with a more analytical sense.

In chapter 9, the author displayed the graph of results from only one side of the chassis. In this section both left and right results have been used to calculate the stiffness's for each measured interval on the chassis and argue the reasons for why the chosen amendments were used for the final optimised chassis. The intervals span of each of the points of the DTIs measured are given by table 16.

Interval/Length on Chassis	Interval Span (mm)
1/205mm	716
2/410mm	781
3/615mm	855
4/820mm	892
5/1025mm	942
6/1230mm	980
7/1670mm	848
8/2080mm	672
9/2490mm	496

Table 16: Chassis interval Span

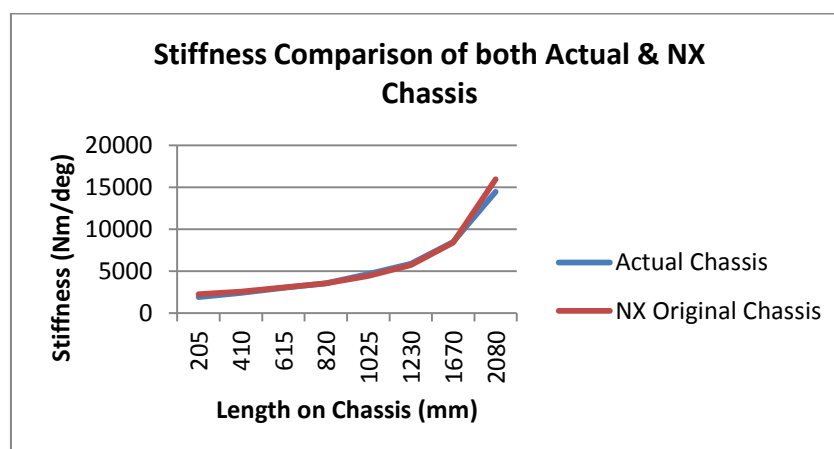
10.1 Stiffness Results – Actual Chassis

Before any of the other torsional stiffness's were calculated the results from the actual results were completed along with the NX correlated chassis for comparison.

Actual Chassis			Torque Nm	Stiffness at each Chassis Interval								
FEA	Chassis	Load (N)		Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
TT	Actual Chassis	1500	1305	1891.88022	2403.8491	2995.992	3539.4912	4634.0188	5858.534	8471.277	14439.471	376572.239
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03

Table 17: Torsional Stiffness Results Initial Chassis

Although the table 17 displays 2 chassis which are physically identical there are differences in the stiffness's. This is because the NX chassis wasn't 100% correlated against the actual chassis due to the time constraints present. Looking over the 2 results however, displays although the NX model is marginally stiffer than the actual chassis towards the front as the results move towards the middle the actual chassis then becomes stiffer than the NX model. This therefore represents the difference between the FE and reality and without a matched correlated model the results have to be treated with an element of caution.



Graph 27: Initial Stiffness Comparison

10.2 Stiffness Results – Spaceframe Bars

Chassis Parameters			Torque	Stiffness at each Chassis Interval									
FEA	Chassis	Load (N)		Nm	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03	
1	Rear Engine Struts	1500	1305	2287.24	2608.28	3156.23	3680.56	4674.40	6183.11	9467.90	18665.66	161388.10	
2	Roll Hoop Struts	1500	1305	2722.54	3115.32	3709.32	4286.22	5258.70	6805.19	10384.15	20966.90	188286.12	
3	2nd Tier Fuel Brace	1500	1305	2313.19	2639.24	3140.96	3707.42	4705.16	6082.02	8859.87	17197.57	161388.10	
4	1st Tier Fuel Brace	1500	1305	2336.39	2666.94	3218.83	3769.33	4789.18	6200.28	9067.85	17197.57	141214.59	
5	1st Tier Fuel Double Brace	1500	1305	2343.10	2678.99	3229.51	3790.43	4821.46	6217.55	8983.49	17197.57	141214.59	
6	Mid 2nd Tier Cross Brace	1500	1305	2584.47	2989.66	3573.20	4087.86	4989.65	6234.92	8941.90	17393.00	141214.59	
7	Floor Coss Sections	1500	1305	2524.46	2841.61	3386.77	3937.34	4943.67	6451.16	9467.90	18665.66	141214.59	
8	30mm Side Cross Brace	1500	1305	2387.70	2719.95	3261.97	3755.39	4634.02	6049.06	9197.39	15779.22	188286.12	
9	Fuel Tank 'V' Struts	1500	1305	2258.73	2570.59	3096.02	3608.65	4565.00	6032.71	9110.62	17797.49	161388.10	
10	Front Fuel Cross Brace	1500	1305	2370.35	2699.31	3245.66	3769.33	4746.79	6149.04	9854.34	18440.77	188286.12	
11	Lower Fuel Tank Bracing 1	1500	1305	2261.86	2578.04	3096.02	3608.65	4555.31	5984.19	9025.47	17797.49	161388.10	
12	Lower Fuel Tank Bracing 2	1500	1305	2268.15	2585.54	3105.89	3621.51	4565.00	6016.45	9025.47	17592.92	161388.10	
13	Under Engine Bracing 1	1500	1305	2258.73	2570.59	3096.02	3608.65	4555.31	5984.19	9110.62	18440.77	188286.12	
14	Under Engine Bracing 2	1500	1305	2268.15	2581.78	3105.89	3621.51	4584.51	6082.02	9197.39	18440.77	188286.12	
15	Gusset Roll Hoop	1500	1305	2265.00	2570.59	3096.02	3608.65	4644.05	5984.19	9025.47	17797.49	161388.10	
16	Single Roll Hoop	1500	1305	2489.77	2837.08	3404.54	3929.73	4876.25	6305.37	9561.64	18896.10	188286.12	

Table 18: Spaceframe Amendment Results

Table 18 displays each of the amendments made with each of the calculated stiffness's. The row highlighted in blue is the chassis in the current unmodified state.

Looking at over the results it is apparent to see all of the amendments all have a decent and positive effect on the chassis; the author used this in order to look over each of the intervals with each change to pick out the most suitable ones in order to improve the current design. From the simple outlay it became apparent that the that the roll hoop struts provided a high degree of stiffness from the interval 6 to the rear of the chassis shows nearly s 24% increase in stiffness. Along with this, the rear engine struts which are currently in use by MCR also represent a marginally higher stiffer rear end, with just over a 14% increase in stiffness.

Looking over the rest of the table FEA 9 the front fuel tank cross brace does show signs of potential however cannot be used as that area is main access route to the fuel tank.

The single roll hoop design does appear feasible however although the stiffness has decreased, without a closer correlated model for author isn't happy pursuing this route. That said. a large proportion of the strength is suspected from the bracing required on either side.

The items carried over:

- Rear Engine Struts
- Roll Hoop Struts
- Under Engine Bracing
- Lower Fuel Tank Bracing

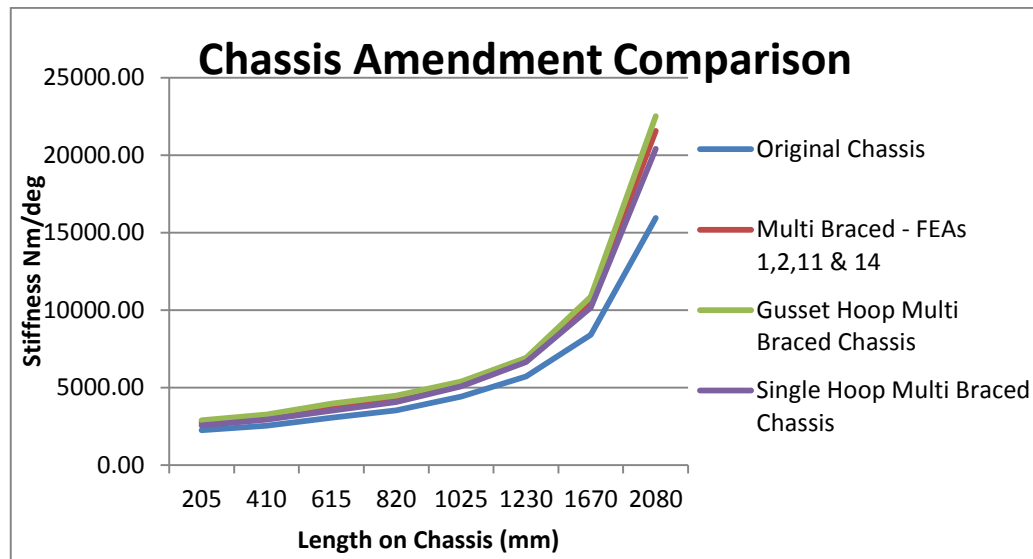
All of the items except the rear engine struts are not currently in use by MCR.

Table 19 displays effect of the extra bars on the stiffness:

Chassis Parameters			Torque Nm	Stiffness at each Chassis Interval								
FEA	Chassis	Load (N)		Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03
1	FEAs 1, 2, 11 & 14	1500	1305	2740.84	3137.30	3766.72	4322.70	5310.77	6868.00	10554.38	21557.52	188286.12
2	Gusset Roll Hoop with FEA 15	1500	1305	2886.37	3257.96	3958.12	4484.92	5390.83	6910.53	10850.85	22508.59	225943.34
3	Single Roll Hoop & FEA 15	1500	1305	2552.11	2916.14	3508.82	4063.34	5084.24	6643.16	10165.53	20407.79	188286.12

Table 19: Stiffness Results for Multi Braced Chassis

Also present on table 19 is the additions with the gusset plate on the roll hoop and the single roll hoop design.



Graph 28: Chassis Aemdment Stiffness Comparison

Graph 28 shows the compassion of stiffness's of all the values taken from table 18. Although the gusset hoop chassis is marginally stiffer than the multi braced chassis, the author chose to stay with multi brace. It could be argued that numerous bars and gussets could be added to make the structure as stiff as it could physically be, however this comes at a price of weight, performance, cost and manufacturing time.

10.3 Stiffness Results - Cladding

Cladded Chassis Parameters			Torque	Stiffness at each Chassis Interval								
FEA	Chassis	Load (N)	Nm	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03
1	Side Cladding	1500	1305	4740.70	5294.19	6066.65	6553.77	7297.79	8423.02	11496.73	21865.48	188286.12
2	Engine Cladding	1500	1305	2271.31	2589.30	3120.82	3634.47	4536.05	6065.49	8983.494	16457.89	141214.59

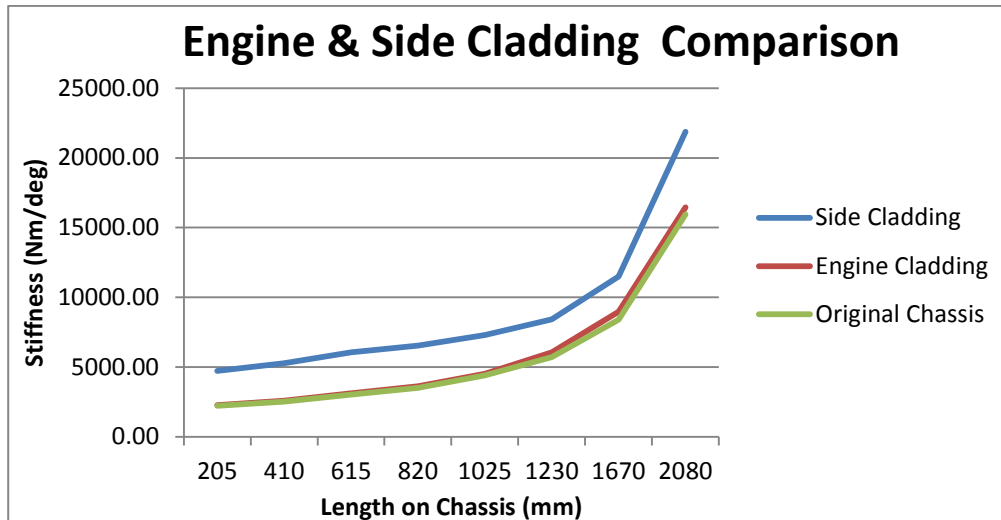
Table 20: Cladding Stiffness Resultts

Table 20 displays the stiffness results for the side cladding, apparent are the results for the single roll hoop as well. The addition of cladding on both sides and bottom of the chassis, influence the stiffness heavily. It can be noticed at interval 1 (205mm on chassis) the stiffness more than doubles on the addition of the panels compared to the bare chassis, there is a drop off with the engine cladding as that simulation was only run with that panel on only.

Cladded Chassis Parameters			Torque	Stiffness at each Chassis Interval								
FEA	Chassis	Load (N)	Nm	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03
3	Cladding with FEAs 1, 2, 11 & 14	1500	1305	5260.65	5890.23	6809.07	7361.12	8220.50	9579.84	13412.86	25509.73	188286.12
4	Engine Side Clad with 1,2,11&14	1500	1305	4593.80	5341.89	6405.90	7103.73	8220.50	9920.45	13601.77	19132.30	1129716.72
5	Single Roll Hoop with FEA 19	1500	1305	5642.91	6307.97	7376.50	8062.17	9169.02	12469.84	15089.46	22844.54	112971.672

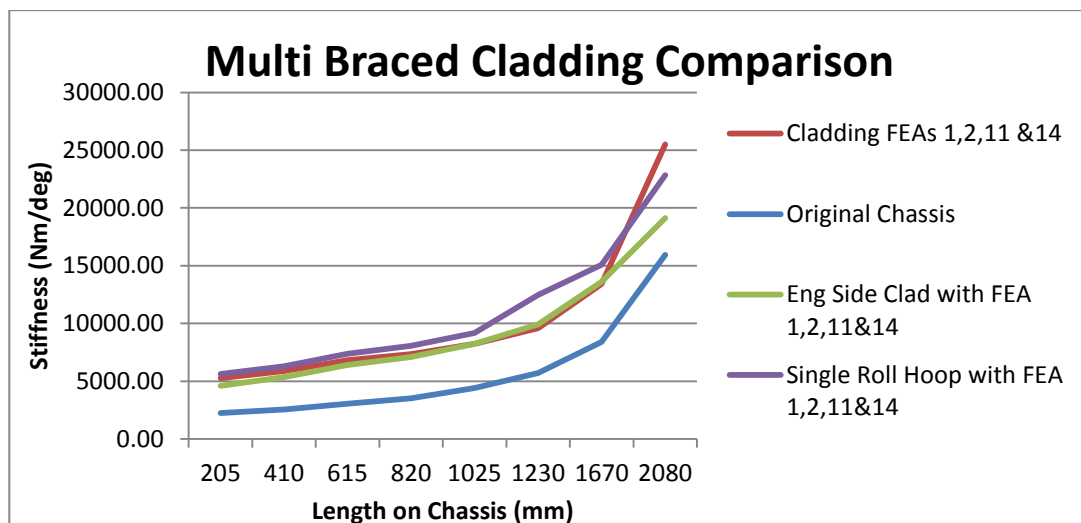
Table 21: Multi Braced Stiffness Cladding Results

Table 21 displays the results for the simulations with the multi bracing included and also for the single roll hoop. With the extra bracing the interval 1 result has more than doubled compared to the original chassis with just cladding added, on this simulation was that of cladding on the side of the engine. Although cladding on the side of the engine does give extra stiffness it is not suitable as does not allow access for the engine ancillaries which are apparent. Although the single roll hoop has higher front end stiffness compared to FEA 3, it becomes apparent at the rear that FEA 13 is in fact 10% stiffer.



Graph 29: Engine & Side Cladding Stiffness Comparison

Graph 29 is a visual comparison of the results in table 21, the large effect of the cladding can be significantly noticed when compared to the original chassis. Comparing this to graph 26 there steepness in gradient towards the rear of the chassis is less steep with the cladding applied compared to the bare spaceframe.



Graph 30: Multi Braced Cladding Stiffness Comparison

Graph 30 displays the multi braced cladding comparison, it can be noticed visually the stiffness's vary in pitch with the different set ups. However cladding FEAs 1,2,11 & 14 give to highest stiffness with the single roll hoop layout giving a slightly higher result in the middle areas of the chassis but comparatively drop towards the rear.

10.4 Stiffness Results - Genesis

The GENESIS simulation completed 3 design cycles giving different dimensions for the 30x30mm box section and the 28.5 Tubes. Table 22 demonstrates.

Cycle 1	30 Box (mm)	28 Tube (mm)
Inner Dimension	30	30.5
Wall Thickness	1.3	1

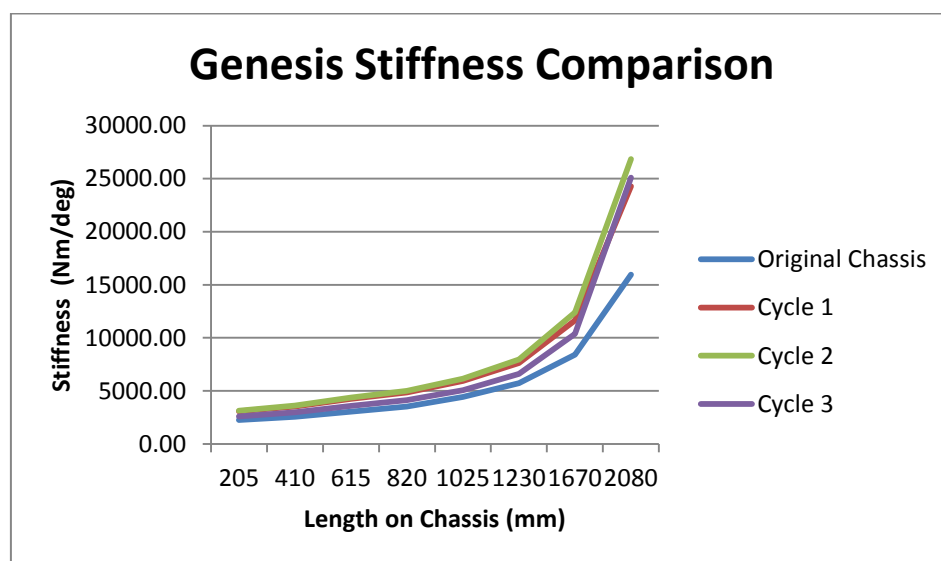
Cycle 2		
Inner Dimension	30	30.5
Wall Thickness	1	1.3
Cycle 3		
Inner Dimension	29	30.4
Wall Thickness	1	1.2

Table 22: Design Studio for Genesis Cycle Results

Using each of the variables stated in table 22, the author inputted each of the variables into the physical properties in NX 7.5 to ensure the results matched up. Also this would enable the author to gain each of the DTI/node point results as well. Each result was gained and stiffness's were calculated for each of the cycles as displayed in table 23.

Genesis Chassis Parameters			Torque Nm	Stiffness at each Chassis Interval								
Cycle	Chassis	Load (N)		Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03
1	FEAs 1, 2, 11 & 14	1500	1305	3059.66	3522.47	4233.47	4837.30	5926.94	7618.09	11635.25	24294.98	225943.34
2	FEAs 1, 2, 11 & 14	1500	1305	3136.16	3615.55	4366.36	5004.11	6130.14	7943.42	12381.10	26852.35	188286.12
3	FEAs 1, 2, 11 & 14	1500	1305	2580.38	2974.66	3586.36	4112.69	5060.26	6603.85	10384.15	25091.54	225943.34

Table 23 - Design Studio for Genesis Cycle Stiffness Results



Graph 31: Design Studio for Genesis Cycle Stiffness Comparison

Looking at graph 28 it is apparent that cycle 2 is the optimum layout for the optimised sections. By increasing the second moment of area of both the tube and box has rapidly increased the stiffness compared to the original chassis.

Mass Reduction (Spaceframe Only) using NX 7.5 solid properties check:

Chassis :	Mass (kg):
Pre optimised	61.1
Cycle 1	45.5
Cycle 2	49.9
Cycle 3	46.5

Table 24: Mass Reduction

As GENESIS ran through the cycles each one GENESIS withdrew mass from each of the bars. Table 24 displays the results. As cycle 2 is the stiffest out of the 3 cycles the mass reduction for this is 11.2KG which therefore means GENESIS has reduced the mass by a respectable 18%.

10.5 Optimisation Results

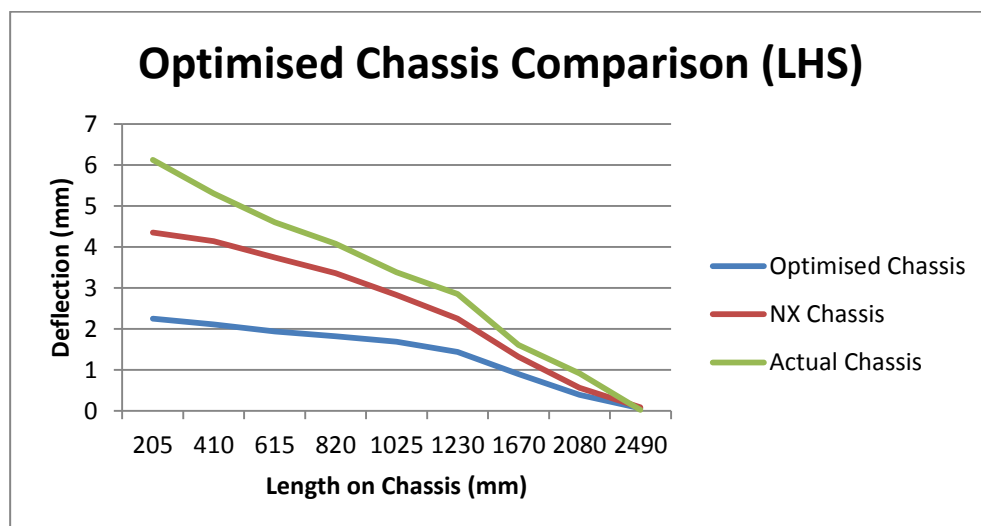
Taking into account all the results gained from the experimental work of the extra bracing through to the investigation into the effect of the cladding on various parts of the outer structure. The author then moved forward from NX 7.5 to the more advanced package of VRAND Genesis Putting together all the optimum results gathered from each of the experiments and placed into the last model and tested.

The 28.5mm tube sections have been increased to 31.8mm with a wall thickness of 1.3mm twinned with this the 30x30mm box sections were increased to 31mm with a wall thickness taken from 1.5mm to 1mm.

Bracing was added from the roll hoop to the dashboard mountings, with extra diagonal cross members both under and on the sides of the engine.

The final amendments added were aluminium cladding on both sides of the chassis and also present underneath with a thickness of 1.1mm.

The results:



Graph 32: Optimised Chassis Deflection Comparison

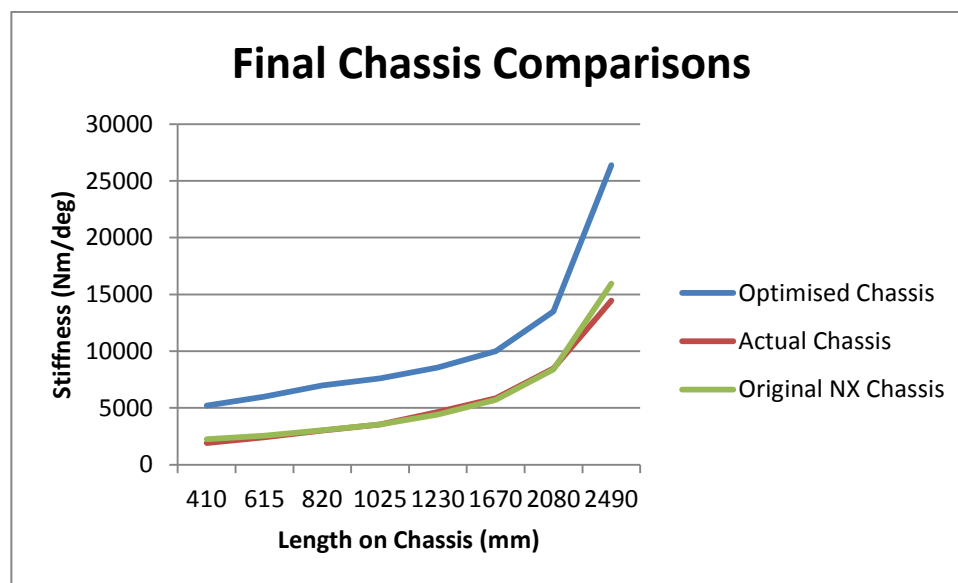
The initial deflection taken on the LHS and compared shows the vast difference between the NX chassis and the optimised one, the overall deflection has been heavily reduced at the front by over 48%. The rear regions of the chassis still show a slight kink however the overall stiffness in that area has been increased and improved by 42%.

By increasing the 2nd moment of area on the two types of bars and reducing the wall thicknesses, GENESIS has managed to reduce the weight from 74.9kg to a fantastic 63.8kg a total saving of 11.1KG, a 14% reduction respectively.

Optimised Chassis			Torque	Stiffness at each Chassis Interval								
FEA	Chassis	Load (N)		Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
1	Gen Cycle 2 & FEA 17	1500	1305	5210.226	5989.3882	6979.909	7609.2433	8548.0108	10009.42	13506.65	26389.378	188286.12
TT	Actual Chassis	1500	1305	1891.88022	2403.8491	2995.992	3539.4912	4634.0188	5858.534	8471.277	14439.471	376572.239
C FEA 9	Original NX Chassis	1500	1305	2243.19	2541.21	3042.80	3527.20	4414.71	5708.70	8397.61	15943.58	53796.03

Table 25: Optimised Chassis Stiffness Comparison

Table 24 displays the torsional stiffness results of the optimised chassis against the actual and NX chassis. The structure compared at the front is immediately noticeable in the fact it is over 50% stiffer than the original NX model, compared to that of the actual chassis the optimised one is over 60% stiffer. A visual representation of this is displayed in graph 32.



Graph 33: Final Chassis Stiffness Comparison

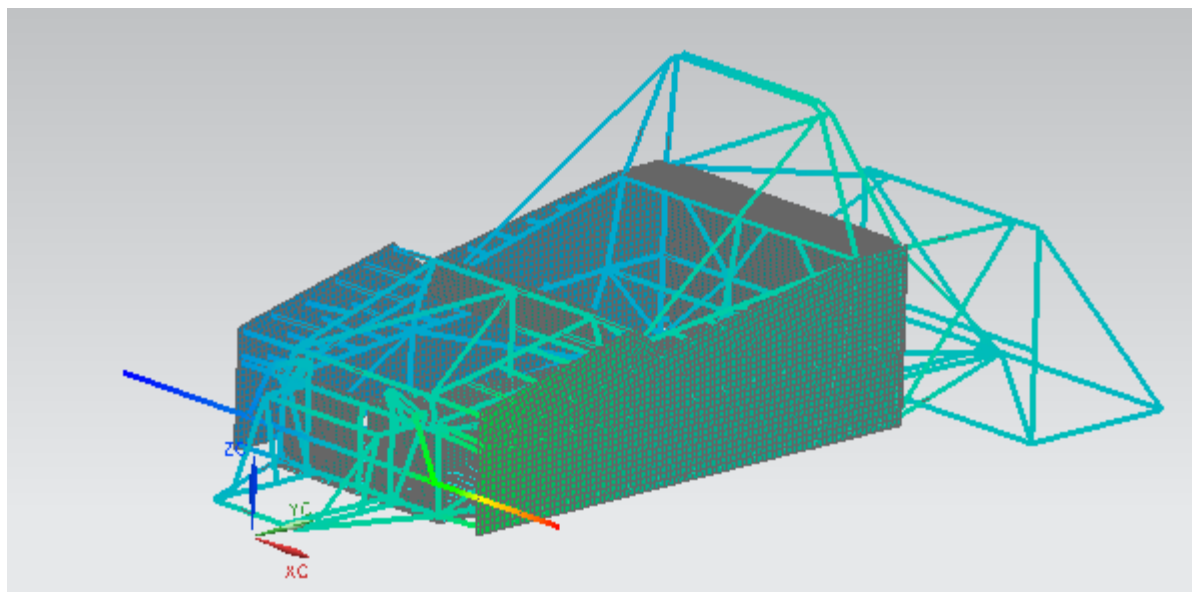


Figure 46: Optimised Chassis FEA Screen Shot

11. Conclusion

With a final optimised design the author has been able to complete what the initial project proposal outlined.

The author has been able to take the initial chassis and place into a finite element program to build a model which has been used as a tool to predict potential amendments that could be adopted on to future generations of the MCR Sports 2000 race car.

However as stated in the results part of this report the figures and amendments must be taken with an element of assumption and caution. This is due to the chassis not being correlated as accurate to the real chassis on present, although the FE model began to trend in a similar fashion it would have been more suitable if it was a lot closer matched up.

Initial issues grew with deflection arising from the twist rig itself and the complexity of drawing the frontal area of the rig which setback time schedules of the overall goals of the project.

That said with a working model now completed further analysis work can be passed on to another student who wishes to take the project further and gain some more accurate results.

Further work could also be a form of validation; initially the work plan set out that potentially some of the amendments could be added and tested. With more time spent perfecting the model validation could definitely be incorporated to help back up the FEA results and see the sensitivity of the model.

For the author completing this project it has definitely portrayed a better and broader understanding of the use of finite element analysis.

It has built an appreciation for how powerful such a tool is and that optimisation region takes into account so many different design factors and variables. The input work required is vast and that the attention to detail required to physically analyse how a structure is behaving demands a lot of time and investigation.

The level of accuracy required to complete this project has needed to be very high, with so many different technical assumptions present each phase has had to be repeatedly checked and verified to ensure the results are match accordingly.

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13. Appendix A

Tables of results from FEA Simulations for chassis amendments.

RHS										
FEA 1	Rear Engine Bars			FEA 2	Roll Hoop Struts			FEA 3	2nd Tier Fuel Brace	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-2.84		1	205	-2.27		1	205	-2.8
2	410	-2.76		2	410	-2.2		2	410	-2.72
3	615	-2.53		3	615	-2.04		3	615	-2.58
4	820	-2.26		4	820	-1.87		4	820	-2.24
5	1025	-1.88		5	1025	-1.62		5	1025	-1.86
6	1230	-1.49		6	1230	-1.32		6	1230	-1.52
7	1670	-0.83		7	1670	-0.74		7	1670	-0.9
8	2080	-0.3		8	2080	-0.26		8	2080	-0.34
9	2490	0		9	2490	0		9	2490	0

LHS										
FEA 1	Rear Engine Bars			FEA 2	Roll Hoop Struts			FEA 3	2nd Tier Fuel Brace	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	4.29		1	205	3.72		1	205	4.25
2	410	4.06		2	410	3.51		2	410	4.02
3	615	3.64		3	615	3.16		3	615	3.62
4	820	3.26		4	820	2.87		4	820	3.24
5	1025	2.71		5	1025	2.46		5	1025	2.7
6	1230	2.12		6	1230	1.96		6	1230	2.15
7	1670	1.21		7	1670	1.12		7	1670	1.28
8	2080	0.52		8	2080	0.47		8	2080	0.55
9	2490	0.07		9	2490	0.06		9	2490	0.07

RHS										
FEA 4	1st Tier Fuel Brace			FEA 5	1st Tier Fuel Double Brace			FEA 6	Mid 2nd Tier Cross brace	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-2.77		1	205	-2.76		1	205	-2.44
2	410	-2.68		2	410	-2.67		2	410	-2.32
3	615	-2.47		3	615	-2.46		3	615	-2.17
4	820	-2.2		4	820	-2.18		4	820	-1.99
5	1025	-1.82		5	1025	-1.8		5	1025	-1.73
6	1230	-1.48		6	1230	-1.48		6	1230	-1.47
7	1670	-0.87		7	1670	-0.89		7	1670	-0.9
8	2080	-0.34		8	2080	-0.34		8	2080	-0.34
9	2490	-0.01		9	2490	-0.01		9	2490	-0.01

LHS										
FEA 4	1st Tier Fuel Brace			FEA 5	1st Tier Fuel Double Brace			FEA 6	Mid 2nd Tier Cross brace	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	4.21		1	205	4.2		1	205	3.87
2	410	3.99		2	410	3.97		2	410	3.63
3	615	3.58		3	615	3.57		3	615	3.28
4	820	3.19		4	820	3.18		4	820	2.98
5	1025	2.66		5	1025	2.65		5	1025	2.57
6	1230	2.12		6	1230	2.11		6	1230	2.11
7	1670	1.26		7	1670	1.26		7	1670	1.26
8	2080	0.55		8	2080	0.55		8	2080	0.54
9	2490	0.07		9	2490	0.07		9	2490	0.07

RHS										
FEA 7	Floor Cross Sections			FEA 8	30mm Side Cross Brace			FEA 9	Fuel Tank 'V' Struts	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-2.5		1	205	-2.68		1	205	-2.89
2	410	-2.48		2	410	-2.62		2	410	-2.81
3	615	-2.32		3	615	-2.43		3	615	-2.59
4	820	-2.09		4	820	-2.21		4	820	-2.32
5	1025	-1.76		5	1025	-1.9		5	1025	-1.93
6	1230	-1.43		6	1230	-1.53		6	1230	-1.52
7	1670	-0.86		7	1670	-0.86		7	1670	-0.87
8	2080	-0.31		8	2080	-0.44		8	2080	-0.32
9	2490	-0.01		9	2490	0		9	2490	0

LHS										
FEA 7	Floor Cross Sections			FEA 8	30mm Side Cross Brace			FEA 9	Fuel Tank 'V' Struts	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	3.96		1	205	4.15		1	205	4.33
2	410	3.78		2	410	3.92		2	410	4.11
3	615	3.43		3	615	3.54		3	615	3.7
4	820	3.07		4	820	3.2		4	820	3.31
5	1025	2.58		5	1025	2.73		5	1025	2.77
6	1230	2.03		6	1230	2.16		6	1230	2.18
7	1670	1.18		7	1670	1.24		7	1670	1.25
8	2080	0.51		8	2080	0.53		8	2080	0.54
9	2490	0.07		9	2490	0.06		9	2490	0.07

RHS										
FEA 10	Front Fuel Cross Brace			FEA 11	Lower Fuel Tank Bracing			FEA 12	Lower Fuel Tank Bracing	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-2.72		1	205	-2.88		1	205	-2.87
2	410	-2.65		2	410	-2.8		2	410	-2.79
3	615	-2.45		3	615	-2.59		3	615	-2.58
4	820	-2.2		4	820	-2.32		4	820	-2.31
5	1025	-1.84		5	1025	-1.93		5	1025	-1.93
6	1230	-1.5		6	1230	-1.55		6	1230	-1.54
7	1670	-0.72		7	1670	-0.88		7	1670	-0.88
8	2080	-0.31		8	2080	-0.32		8	2080	-0.33
9	2490	0		9	2490	0		9	2490	0

LHS										
FEA 10	Front Fuel Cross Brace			FEA 11	Lower Fuel Tank Bracing			FEA 12	Lower Fuel Tank Bracing	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	4.16		1	205	4.33		1	205	4.32
2	410	3.94		2	410	4.1		2	410	4.09
3	615	3.55		3	615	3.7		3	615	3.69
4	820	3.19		4	820	3.31		4	820	3.3
5	1025	2.68		5	1025	2.78		5	1025	2.77
6	1230	2.13		6	1230	2.18		6	1230	2.17
7	1670	1.24		7	1670	1.26		7	1670	1.26
8	2080	0.52		8	2080	0.54		8	2080	0.54
9	2490	0.06		9	2490	0.07		9	2490	0.07

RHS									
FEA 15	FEAs 1, 2, 11 & 14			FEA 16	Cladding			FEA 17	Cladding and FEAs
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length Deflection
1	205	-2.25		1	205	-1.06		1	205 -0.9
2	410	-2.18		2	410	-1.06		2	410 -0.89
3	615	-2.03		3	615	-1.05		3	615 -0.88
4	820	-1.85		4	820	-1.03		4	820 -0.88
5	1025	-1.6		5	1025	-1.02		5	1025 -0.88
6	1230	-1.31		6	1230	-0.99		6	1230 -0.82
7	1670	-0.73		7	1670	-0.66		7	1670 -0.54
8	2080	-0.25		8	2080	-0.25		8	2080 -0.2
9	2490	0		9	2490	0		9	2490 0
LHS									
FEA 15	FEAs 1, 2, 11 & 14			FEA 16	Cladding			FEA 17	Cladding and FEAs
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length Deflection
1	205	3.7		1	205	2.45		1	205 2.28
2	410	3.49		2	410	2.33		2	410 2.16
3	615	3.14		3	615	2.16		3	615 1.98
4	820	2.85		4	820	2.04		4	820 1.87
5	1025	2.44		5	1025	1.88		5	1025 1.71
6	1230	1.94		6	1230	1.63		6	1230 1.47
7	1670	1.1		7	1670	1.02		7	1670 0.9
8	2080	0.46		8	2080	0.45		8	2080 0.4
9	2490	0.06		9	2490	0.06		9	2490 0.06

RHS									
FEA 18	Engine Cladding			FEA 19	Engine Clad & FEA			FEA 20	Side Engine Cladding
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length Deflection
1	205	-2.87		1	205	-0.88		1	205 -1.19
2	410	-2.79		2	410	-0.88		2	410 -1.13
3	615	-2.57		3	615	-0.88		3	615 -1.06
4	820	-2.3		4	820	-0.87		4	820 -1.01
5	1025	-1.98		5	1025	-0.85		5	1025 -0.95
6	1230	-1.52		6	1230	-0.84		6	1230 -0.86
7	1670	-0.89		7	1670	-0.53		7	1670 -0.56
8	2080	-0.36		8	2080	-0.22		8	2080 -0.33
9	2490	0.01		9	2490	0		9	2490 -0.15
LHS									
FEA 18	Engine Cladding			FEA 19	Engine Clad & FEA			FEA 20	Side Engine Cladding
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length Deflection
1	205	4.31		1	205	2.27		1	205 2.36
2	410	4.08		2	410	2.14		2	410 2.2
3	615	3.67		3	615	1.93		3	615 1.98
4	820	3.29		4	820	1.86		4	820 1.85
5	1025	2.75		5	1025	1.7		5	1025 1.66
6	1230	2.16		6	1230	1.46		6	1230 1.39
7	1670	1.26		7	1670	0.91		7	1670 0.86
8	2080	0.57		8	2080	0.43		8	2080 0.47
9	2490	0.07		9	2490	0.07		9	2490 0.1

RHS										
FEA 21	Gusset Plate Roll Hoop			FEA 22	Gusset Plate Roll Hoop			23	Gusset Plate Roll Hoop	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-0.87		1	205	-2.89		1	205	-2.1
2	410	-0.87		2	410	-2.81		2	410	-2.03
3	615	-0.85		3	615	-2.59		3	615	-1.9
4	820	-0.85		4	820	-2.32		4	820	-1.76
5	1025	-0.84		5	1025	-1.85		5	1025	-1.57
6	1230	-0.76		6	1230	-1.55		6	1230	-1.3
7	1670	-0.54		7	1670	-0.88		7	1670	-0.7
8	2080	-0.22		8	2080	-0.32		8	2080	-0.23
9	2490	0		9	2490	0		9	2490	0

LHS										
FEA 21	Gusset Plate Roll Hoop			FEA 22	Gusset Plate Roll Hoop			23	Gusset Plate Roll Hoop	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	2.23		1	205	4.31		1	205	3.55
2	410	2.1		2	410	4.11		2	410	3.43
3	615	1.94		3	615	3.7		3	615	3.02
4	820	1.83		4	820	3.31		4	820	2.77
5	1025	1.68		5	1025	2.77		5	1025	2.41
6	1230	1.45		6	1230	2.18		6	1230	1.93
7	1670	0.9		7	1670	1.26		7	1670	1.08
8	2080	0.42		8	2080	0.54		8	2080	0.45
9	2490	0.07		9	2490	0.07		9	2490	0.05

RHS										
FEA 24				FEA 25				FEA 26		
Single Roll Hoop				Single Roll Hoop				Single Roll Hoop		
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-2.55		1	205	-0.77		1	205	-2.47
2	410	-2.48		2	410	-0.77		2	410	-2.4
3	615	-2.3		3	615	-0.77		3	615	-2.22
4	820	-2.08		4	820	-0.76		4	820	-2
5	1025	-1.78		5	1025	-0.73		5	1025	-1.69
6	1230	-1.45		6	1230	-0.72		6	1230	-1.36
7	1670	-0.82		7	1670	-0.46		7	1670	-0.76
8	2080	-0.3		8	2080	-0.23		8	2080	-0.27
9	2490	0		9	2490	-0.02		9	2490	0

LHS										
FEA 24				FEA 25				FEA 26		
Single Roll Hoop				Single Roll Hoop				Single Roll Hoop		
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	4		1	205	2.16		1	205	3.92
2	410	3.79		2	410	2.06		2	410	3.7
3	615	3.42		3	615	1.87		3	615	3.33
4	820	3.09		4	820	1.75		4	820	3
5	1025	2.62		5	1025	1.58		5	1025	2.53
6	1230	2.09		6	1230	1.33		6	1230	2
7	1670	1.2		7	1670	0.82		7	1670	1.14
8	2080	0.51		8	2080	0.44		8	2080	0.48
9	2490	0.06		9	2490	0.08		9	2490	0.06

RHS										
Cycle 1	Genesis			Cycle 2	Genesis			Cycle 3	Genesis	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	-1.94		1	205	-1.88		1	205	-2.44
2	410	-1.87		2	410	-1.81		2	410	-2.34
3	615	-1.74		3	615	-1.67		3	615	-2.16
4	820	-1.6		4	820	-1.53		4	820	-1.97
5	1025	-1.39		5	1025	-1.33		5	1025	-1.7
6	1230	-1.15		6	1230	-1.09		6	1230	-1.37
7	1670	-0.64		7	1670	-0.59		7	1670	-0.74
8	2080	-0.21		8	2080	-0.18		8	2080	-0.15
9	2490	0		9	2490	-0.01		9	2490	0

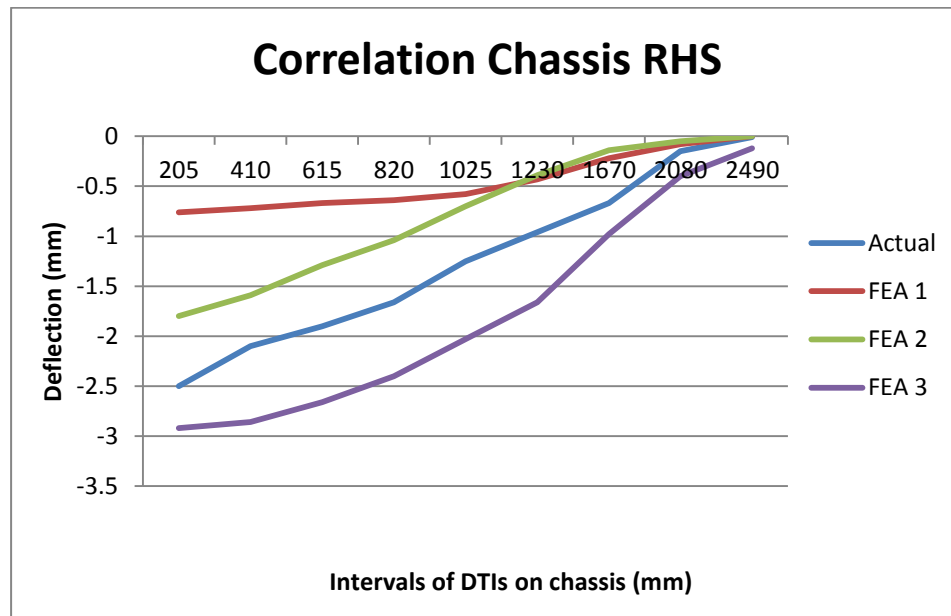
LHS										
Cycle 1	Genesis			Cycle 2	Genesis			Cycle 3	Genesis	
DTI	Length	Deflection		DTI	Length	Deflection		DTI	Length	Deflection
1	205	3.39		1	205	3.32		1	205	3.88
2	410	3.18		2	410	3.11		2	410	3.64
3	615	2.86		3	615	2.79		3	615	3.27
4	820	2.6		4	820	2.53		4	820	2.97
5	1025	2.23		5	1025	2.17		5	1025	2.54
6	1230	1.78		6	1230	1.72		6	1230	2.01
7	1670	1.02		7	1670	0.97		7	1670	1.12
8	2080	0.42		8	2080	0.39		8	2080	0.46
9	2490	0.05		9	2490	0.05		9	2490	0.05

1	Optimised Chassis (RHS)	
DTI	Length	Deflection
1	205	-0.88
2	410	-0.86
3	615	-0.85
4	820	-0.85
5	1025	-0.82
6	1230	-0.79
7	1670	-0.53
8	2080	-0.19
9	2490	0

1	Optimised Chassis (LHS)	
DTI	Length	Deflection
1	205	2.25
2	410	2.11
3	615	1.94
4	820	1.82
5	1025	1.69
6	1230	1.44
7	1670	0.9
8	2080	0.39
9	2490	0.06

14. Appendix B

Correlation FEAs for right hand side



15. Appendix C

Project Diary

6th October 2011

- 10.00am meeting with Project Supervisor as agreed on 29/9/2011.
- Overview of major project requirements. Brief discussion of MCR and chassis, looking ahead to project proposal due on the 24/10/2011.
- Title to be finalised 'Optimising the Torsional Stiffness of the MCR Chassis Whilst Incorporating Mass Reduction Techniques'.
- Meetings to be moved from Thursdays to Tuesdays at 11.00am.
- Gantt chart to be produced, highlighting specific milestones and goals – To be reviews at next meeting 11/10/2011.
- Meeting Concluded with work set out – Next meeting 11/10/2011 at 11.00am
- Pictures obtained of chassis in workshop. Printed off for measuring purposes and future reference.

7th October 2011

- Obtained from Roger Dowden previous 2nd year BEng student NX5 chassis drawings.
- To be looked at in depth to clarify the models are accurate to actual chassis.
- Original 2D AutoCAD drawings of the chassis from MCR also obtained from Roger Dowden, these will require Student download of AutoCAD via their website.
- Spoken to Dave Campion with regard to moving the chassis onto the flatbed. Will be completed 10/11 October – Need to confirm with Bradley Cox he has finished with the flatbed.

10th October 2011

- Overall basis measuring has been suspended as the MCR has been moved onto the flatbed.
- The full measuring process now is commissioned in order to gain co-ordinates for FE model in NX 7.5.
- Only potential issue is that the flatbed isn't long enough to account for the whole chassis. Providing the chassis centre line is accurate then shouldn't be a large compromise.
- Gantt chart has been completed and shall be reviewed with Project Supervisor at next meeting (11/10/11). Final clarification of dates e.g. Viva and Dissertation to be finalised.

11th October 2011

- Weekly meeting with project supervisor 11.00am
- Outcome Minutes:
 - Gantt chart to be sent via email to KL.
 - Project diary to be brought to next meeting for review.
 - Discussion of project goals and objectives along with current focus discussed.
- Discussion with Huw Jones in workshop regarding the measuring of the chassis. Date agreed for his attendance – 13/10/2011.
- Centreline on flatbed is marked along with various centre points on the chassis itself – Full measuring exercise to be worked through over week – PRIORITY
- Brief discussion with RD regarding 'Design of Experiments'. However already integrated within Genesis software.
- Brackets to be manufactured to secure chassis onto flatbed.

12th October 2011

- Was unable to carry on with any further measuring/preparation. This was due to authors own time constraints and the overall workshop availability.
- Will continue on the 13/10/11 as required.

13th October 2011

- Aluminium bars for X and Y planes have been epoxied onto the flatbed.
- Centreline marked on flatbed with aluminium bar 770mm taken from the Y axis.
- Chassis to be kept jacked up on blocks for the measuring process to accommodate centre line bar.
- HJ was present throughout the day.
- Centreline on the rear of the chassis to be extended for ease of lining up.

14th October 2011

- Continuation of measuring process.
- Chassis centre point lines up accurately and verified.
- Bottom left hand bars starting from the bulkhead were measured; clear hard copy of measurements to be made electronically as well. To be completed by w/c 17/11/2011.
- HJ present during the day, aided with measuring. Drawings of both NX and AutoCAD to be sent over to him. Email address obtained.
- 2nd year BEng students introduced, potential help to which can be sourced and can work in conjunction.
- Was unable to complete as much as author required, this was due to HND measuring classes clashing and hence limited equipment between the two exercises – Author will stay late on Tuesdays to compensate as HND classes won't be apparent.

17th October 2011

- Chassis secured to flatbed at the request of RD.
- Brackets – Too time consuming to manufacture, therefore ratchet straps have been utilised and clarified as suitable alternative.
- Measurements must be completed as of the 21/10/11, in order to keep a decent schedule for the duration of the project.

18th October 2011

- Meeting with project Supervisor 11.00am.
- Outcome minutes:
 - Gantt chart complete KL happy with overall content. However need to change weeks over to dates.
 - Clive Hayes to be contacted from MCR to chassis 'offcut' for test purposes.
 - Material properties of chassis required – Clive Hayes.
 - Weld properties required – Clive Hayes.
 - Internal/external tube and box diameters required – Clive Hayes.
 - Proposal due – 24/10/11.
 - Measuring to be completed week close – 17/10/11.
- Lower half of the chassis measured with the aid of 2nd year students.
- Email sent off to Clive Hayes from MCR – 16.20. RD copied in.

19th October 2011

- Chassis tiers 1, 2 and 3 measured and verified.
- Tube external diameters to be measured and noted.
- Rear of the chassis to be spun around and final stages of measuring too be taken d=from a suitable datum point.
- HJ present and aided with measuring.
- Still awaiting reply from MCR race cars.

20th October 2011

- Front measurements complete along with angles on 2nd and 3rd tiers.
- Front box section/front suspension points measured.
- Chassis turned around and author working through final measuring process – To be completed 21/10/11.
- HJ present during the whole day.
- Conversation with RD regarding MCR Race Cars visit. Author to be present in meeting tomorrow with 2nd year students, RD's office at 1.30pm.
- Potential MCR visit 22/10/11 – TBC.

21st October 2011

- Due to the chassis being moved around for the rear, an extra 20mm has to be added on to compensate for the aluminium centre bar on the X axis.
- Some of the lower tier bars on the Y axis require an extra 11mm added to compensate for an error made on the Y axis set square.
- At close of workshop all measuring verified and completed in X and Y axis.
- Final Z co-ordinates to be completed on the 22/10/2011.

22nd October 2011

- Final Z co-ordinates at the rear of the chassis completed.
- Verification was made with the diameters and dimensions of the tube and box sections.
- Although measurements have been completed the MCR will stay on the flatbed for cross reference purposes.

24th October 2011

- Project proposal handed in via University office at 3.25pm.
- Handed in via Tunitin 6.28pm.
- No work completed on chassis at present time in NX. All co-ordinates require tidying for ease of viewing.
- Will have completed for aim of 27/10/11.
- AutoCAD drawings maybe sent out externally for print off – TBC.
- Will begin work on NX FE model – 25/10/11.

25th October 2011

- Meeting with Project Supervisor 11.00am.
- Outcome minutes:
 - Continue to put FE model together try and complete for next meeting.
 - Continue to try and obtain chassis 'offcut' from MCR.
- Cleaned up current X, Y and Z co-ordinates for ease of viewing. Work started on building FE model in NX.
- AutoCAD download to view MCR original build drawings.

26th October 2011

- AutoCAD drawings have all tube/box thicknesses dimensions along with material properties.
- Only thing outstanding are weld properties, these will hopefully be obtained when MCR visit has taken place.
- Continuation of FE model, lower and 2nd tier bars have been completed. 3rd tier is half way through completion. Front assembly and rear bars to be completed in the later stages.

27th October 2011

- Top tier of chassis in current work in progress.
- Drawing currently started on NX 7.5 but is not changeable or viewable on NX 7. Therefore all work will be completed using NX 7.5.

28th October 2011

- Continuation of model, no updates applicable.

31st October 2011

- Issues surrounding bars which are at obscure angles. Trouble joining up with rest of the spaceframe – Potentially could be a set back if not sorted soon.
- Model will not be completed by tomorrow as agreed with KL.
- Rear bars also to be completed.

1st November 2011

- Meeting with Project Supervisor 11.00am.
- Outcome minutes:
 - Model not completed – Needs to be completed by next meeting.
 - No other work/calculations can be completed until the model is complete as this is the basis for the whole project.
 - However still on schedule according to Gantt chart – Will be good to say ahead of schedule.
- As no correspondence has been obtained from MCR regarding visit, Clive Hayes's number was obtained from RD to speak directly to organise a suitable date/time.
- Suspension rockers to be fabricated for chassis in time for twist rig test/correlation.
- Start of rear bars on FE model.

2nd November 2011

- Start of rear bars on the model assembly, clarification sort of some bars was required.
- All of the previous sketches were removed for ease of putting the model together and also to only have one line set involved. However because of this some of the 'point to point' lines were also removed.
- Continuations of FE model build up.

3rd November 2011

- Final amendments made to the rear assembly, author has now fully completed the left hand side profile of the chassis. All datum CSYS points have been hidden for ease of viewing.
- Will stay in wireframe mode until later stages.
- Will make full model – 4/11/11.

4th November 2011

- Model completed by use of the 'mirror curve' tool.
- This has allowed all the datum points with joined lines to display a full chassis model.

7th November 2011

- Use of the tube function on NX to wrap up the wireframe.
- Model to be clarified with KL in tomorrow's project meeting.
- Some arcs/radiuses will be required to 100% finish off the model.
- Author spoke to Clive from MCR. At 3.54pm clarified that Thursday will be an appropriate day to visit workshop at any time. Will need to sort out insurances with RD.

8th November 2011

- Meeting with Project Supervisor 11.00am
- Outcome minutes:
 - Looked over wireframe model, discussed spaceframe strength, beginning and end points.
 - Discussed top roll hoop bars and spot welds. RBE 2 function will be used for FEM simulation.
 - Make model into full built model with all sections, tube/bars. Datum points will have to be used to extrude box sections out.
 - Tube function will suffice for the tube sections of the chassis.
 - Speak to Dr Pete Charlton on the 4th floor with regard to Ultrasonic testing.
- Began extrude and sweep of box sections. A few datum points extended to accommodate box sections.

9th November 2011

- Had to remove some extrudes as some of the datum points became out of sync.
- Must find a solution with regard to joining each of the tube/bars. To be discussed with KL or CW on Friday potentially.

10th November 2011

- Visit to MCR Race Cars Ltd – St. David's.
- Obtained piece of SAE 4130 space frame off cut, will be used to testing purposes.
- All welds on the chassis are a mixture of MIG and TIG.
- Clive himself has already added extra bars to the rear of the work race car chassis. He and the team are constantly making amendments and evolving the vehicle. One vehicle went out on track with 13 individual modifications in various parameters.
- See photo on phone.
- All box sections are made from mild steel.
- Clive is currently looking at using cold drawn steel rather than 4130. This will make a good financial comparison.

11th November 2011

- Continue to build up model and connect bars.
- A few modifications have been made to keep full accuracy of model.

14th November 2011

- FE Model –On going.
- Off cut obtained to be brought to meeting 15/11/11.

- Need to ensure Z co-ordinate bars are at 90° angles before extrusion.

15th November 2011

- Project Meeting 11.00am.
- Outcome minutes:
 - Gain material properties for SAE 4130 off internet.
 - Speak to Gareth Stadden in machine shop regarding material test machines and suitability.
 - Calculate fatigue.
 - Look into whether both Denisson and Hansfield machine can be used.
 - Complete by next week to stay on schedule.
- Author spoke to GS; Denisson should be fixed by Monday at the latest. Cut off part of tube to see if possible to test by Thursday/Friday.
- All bars except for front are now on model – All need connecting to finish off.

16th November 2011

- All front bars on model still require connecting to deem the model completed.
- All bars which are intersecting need to be trimmed on the inside.
- Horizontal bars are drawn using a face rather than a fixed datum.
- Modifications to front left and right datum's to allow for circular areas below wishbone mounts.
- Make 2nd copy of model and backup.

17th November 2011

- Meeting with Dr Pete Charlton with regard to ultrasonic testing.
 - Difficulties to gain readings off any of the tubular bars however can be completed on all box sections. Will be completed on the 23/11/11 or soon after.
- Piece of offcut chassis cut off to be given to GS in machine shop.
- Continuation of finishing off solid model – Made points on each bar and used trim body function to cut down and avoid bars intersecting.

18th November 2011

- Finished off connecting bars and kept bars as close as possible.
- Completed arcs in various parts of the chassis along with diagonal sections in the driver and passenger floor pans.

21st November 2011

- Checked Over solid model, any suitable adjustments were made as required.

22nd November 2011

- Project meeting 11.00am.
- Outcome minutes:
 - Solid model is not required for FEA, however is good for report and presentation purposes.
 - Complete FE model with global co-ordinate system in place.
 - Mesh accordingly ASAP – Required to stay on schedule with Gantt chart.
 - Try to complete all for 23/11/11.
- Aerocom Materials – To email for material specification sheet.
- Contact SMART Swansea with regard to tensile testing.

- Added global co-ordinates and meshed accordingly. Will continue to model changeover on 23/11/11.

23rd November 2011

- FE model built in NX 7.5.
- FE model has utilised CW tutorials.

24th November 2011

- FE model completed.
- For the time being the model is built in steel rather than 4130 steel, can input all of the material characteristics at a later point into Nastran.
- If possible complete ultrasonic testing 25/11/11 – TBC

25th November 2011

- SMART Swansea emailed regarding material testing. Will hopefully receive soon as would also benefit Formula Student projects as well.
- Date agreed with Dr Pete Charlton for NDT testing – 3.00pm on the 29/11/11.
- Rest of day taken up with talk of the project for University open day.

28th November 2011

- Research on RBE 3 and 2 meshing, obtained a few online journals regarding the functions.
- IMechE journal article obtained via Owen Library.
 - Optimisation and weight reduction on a 40 foot trailer using a CAE based software programme. Issue 5 – May 2011.
 - Optimisation of the frontal area of a vehicle. Issue 4 – April 2010.

29th November 2011

- Project Meeting 11.00am.
- Outcome minutes:
 - Review of FE model and ran through simulation.
 - Model produced no results. On deeper inspection of simulation solution file it concluded there were multiple pivot ratios and therefore a gap in the nodes.
 - To overcome the issue the simulation had to have a specified 'param bailout, -1', this would force the model to solve and hence find the broken node.
 - Look on NX 7.5 help function to found out where the function is located.
 - Run model through multiple FEAs until it works and hence can be used for further analysis.
- Ultrasonic testing completed at 3.00pm with Dr Pete Charlton and Steve Mosey.
- Work on viva presentation – Time and date to be confirmed.

30th November 2011

- No applicable project work completed due to preparation of the MCR for Pembrey track testing.

1st December 2011

- No applicable updates due as day spent at Pembrey for vehicle dynamics review with MCR.

2nd December 2011

- Ran model through multiple simulations and still errors being produced with 'results in wrong format'.
- Checked over all beam elements and replaced a few around the front crash structure. Still showing multiple pivot ratios in f06 file.
- Used university computers to try and find 'param bailout' function but only found an overview of the function.
- Function found under 'solver parameters'. Specified the function to -1 as stated in f06 file. With the FEA solved. The results have shown both the front right and left bulkhead 30x30 box sections are not connected. Along with this the front diagonal members going from the main chassis structure to the front of crash structure are not connected on the left or right.
- Re-connected beams and meshed, ran through simulation and confirmed model was now working properly. Simulation was run with bailout function removed.
- Interim viva confirmed as 12/12/11 – 2.00pm.

3rd December 2011

- Journal articles obtained from library from IMechE collection. Due to being reference copies only, relevant articles photocopied and brought back for review.
- Material books loaned out until after Christmas period. Included in this are E.J Hearn's Mechanics of Materials 1. Also IMechE seminar papers on Design Techniques.

4th December 2011

- Review of all journals – All of which are regarding optimization and CAE packages. All have relevance and are suitable for project.
- Genesis software mentioned on multiple occasions in the various articles.
- FEA run through 2 more simulations.
- Email sent off to VRAND on Genesis 30 day trial software.

5th December 2011

- Rockers made for twist rig. Utilised old aluminium plates from Formula Ford, cut down and holes drilled to 10mm diameter. Led by Dave Campion.
- Still awaiting welding gas to finish off rear twist rig assembly.
- Simulation ran a further 3 times, to ensure functionality. Made a separate file to accommodate only the working files so not confused with previous FE models and simulations. Review with KL on 6/12/11.
- Need to speak to GS on 6/12/11.

6th December 2011

- Project Meeting 11.00am.
- Outcome minutes:
 - KL looked over FE model and simulation results. All is working correctly; therefore next step is to be correlated.
 - Discussion on viva and technical content required. Talk about 2nd moment of area and what has been discussed in materials lectures.
 - Add into viva about competitors and maybe information about the evolution of the race car chassis.
 - Include all information from October to present. Concentrate on an impressive viva and hence use PowerPoint as a tool other than relying on it.

- Don't rush to get twist test done as poor results won't benefit the grade outcome.
- Viva time stated on Moodle has changed to Thursday 15th December at 9.00am. Email sent to RD for confirmation.
- Email correspondence received from Gary Quinn of VRAND, instructions given of how to download software from their website along with licences.

7th December 2011

- Initial ideas put together, reading and review of extra technical papers sourced from both library and via the internet. Gain more background information on this subject area.
- Start of viva outlay.

8th December 2011

- Project viva now confirmed viva now stands at 11.00am on the 15/12/11.
- First set of slides added into presentation. Research on current competitors in the Sports 2000 championship and MCR history within the championship. All boast the use of optimized chassis using the latest FE software.
- Focus to be continued on technical content.

9th December 2011

- Continuation of viva construction.

10th December 2011

- Continuation of viva construction.
- Rear diagonal cross member bars for rear of the twist rig cut out and ready for welding onto main frame. Due to be welded by DC on the morning of 12/12/11.
- Author is to build a 2nd model of the full race car chassis. Template can be copied from current wireframe and X section added at the front.

11th December 2011

- Continuation of viva construction, therefore no major updates applicable. 23 slides in total all with relevant information. Tried to keep slides as clear and concise as possible.
- Requires fine tuning.

12th December 2011

- Viva construction continuing.
- Full viva handbook completed, however full ultrasonic to be added into body of text. Will be printed out evening of the 13/12/11.
- Aim to have viva presentation completed day close of 13/12/11.

13th December 2011

- Viva completed day close of 13/12/11.
- Booklets printed off and placed in project folders, slides also printed off and added into project pack.
- Organisation of Technical publications required.
- Email sent to Aerocom materials regarding material quotation.

14th December 2011

- Viva completed.
- 2 demo practice runs completed.
- X frame chassis completed.
- Viva 11.00am 15/12/11.
- Viva completed certain outcomes to be addressed along with project re-structuring.

15th December 2011

- Genesis tutorial sent over from KL on optimising beams. Will sort out licences for Genesis trial copy and work through over Christmas period.
- Twist rig still requires completion as issues are still apparent with the loading bar. When load is applied the bar is slipping around its pivot point. DC added extra aluminium bars around the front which has reduced the issue slightly but is still a large degree of movement.
- Author to work with DC after Christmas to find a suitable alternative and reassess set up.

19th December 2011

- Unable to get Genesis licences to work on trial copy obtained from VRAND. Tried server and normal licencing options but still receiving error messages.

9th January 2012

- Continue to use genesis tutorial, licence on trial copy has now surpassed the 30 days and hence cannot be used. Any Genesis work will now be completed on the Universities computers.
- Multidiscipline Optimization book ordered from VRAND and will take a minimum of 10 days to arrive from the US. Book contains all the trial versions of the software on CD format.

10th January 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Discussion on current status of the project.
 - Correlation is the next step, the twig rig is nearly completed and test can be undertaken during the week at some point. Rig completed courtesy of DC.
 - Continuation of Genesis, as stated will use the university computers to carry on with the optimization part of the project.
 - Start to write up parts of the project, from 1/1/12 to Easter Sunday is exactly 14 weeks.
 - Continue working through project.

11th January 2012

- Continuation of Genesis tutorial.
- Twist rig in final stages of completion. DTIs will have to be obtained from Leighton Morgan and John Kinsella.
- Suitable stands will need to be sourced in order keep DTIs in a steady state. Unfortunately there is nothing immediately suitable for the task in hand therefore items will have to be adapted to suit.
- All parts of the twist rig will have to be drawn onto the model.

12th January 2012

- Twist test completed, 6 DTIs in total used, 3 on either side of chassis.

- Chassis taken up in 100N increments. Highest taken up to 3700N. Used a scissor jack along with a corner weight scale to keep track of load applied to rig.
- Results to be put in an excel format, for ease of viewing. Will be reviewed at next project meeting.

13th January 2012

- Continuation of project beam tutorial.
- Start of building result of twist rig onto model. Using CSYS co-ordinates will be the best route to apply rig in beam element format.

16th January 2012

- Results have been placed in Excel format.
- Need to pass on to HJ as he was present during the test.
- It has been noticed there are some inconsistencies in the results. This is probably due to when DTIs slipped off or ran out of preload. Because of this another test will have to be completed.
- Will confirm with KL in project meeting on 17/1/12.
- Genesis work on hold at present time.

17th January 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Overall a very short meeting.
 - Author is going to complete another twist test to have a better solid set of data to use for correlation. This will be completed in the afternoon/evening time of the 17/1/12.
 - On the Genesis tutorial it requests the use of 'mesh points' on the beam. However as the FE model is already using beam elements, these parts are not required.
 - KL will try and come to workshop when completing test time permitting.
 - Continue with correlation work and tutorials etc.
- Twist test completed in evening of 17/1/12. Load only taken up to 1500N in 100N increments.
- 6 DTIs used in total 3 on either side of chassis. Load fed through the right hand side of chassis.

18th January 2012

- Results compiled and sent on to HJ. If suitable number is gained for deflection, results to be sent over to TT.

19th January 2012

- No applicable updates available for the project.

20th January 2012

- No applicable updates available for the project.

23rd January 2012

- Analysis of results will be reviewed with KL in project meeting on the 24/1/12.
- A small amount of free air has been gained therefore a larger amount of time can be put towards working on the project.

24th January 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Review with KL over twist rig results. Would be better to complete a test doing only up to 1500N in one hit and add more DTIs. 3 on either side are not of benefit.
 - Using more DTIs plot the deflection against the distance of the DTIs on the chassis. The steeper the intervals, the weaker the chassis area.
 - Put a DTI on the rig itself to see whether the bar is deflecting. If so this would have to be modelled in the drawing.
 - All of the loading on the twist rig must be incorporated on to model.
- 3rd twist rig test to be completed on the evening of the 24/1/12.

25th January 2012

- Analysis of results, looking over the data it suggests that the front of the chassis is weakest. However giving the loading is in this particular area the deflection will be higher. The steeper the line, the weaker the chassis.
- A total of 10 DTIs were used with 5 on either side.
- Continuation of building up the FE model with the twist rig.

26th January 2012

- Continuation of twist rig incorporation on the FE model.
- Concerns over whether to use 3D solid bodies or use point to point lines with CSYS co-ordinates. Email sent to KL on evening of 26/1/12.

27th January 2012

- Continuation of twist rig incorporation. It has been decided point to point lines will be used. Overview of rig on FE model will be discussed in next project meeting.

30th January 2012

- Twist rig is now drawn and completed on model. However a param bailout is required in order to make it work.
- Welded bars from twist bar to the dummy dampers are what are failing. Also the 2D rocker meshes are not joining to the 1D beam elements.
- Will review in next meeting 31/1/12.

31st January 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Look over twist results, would be better to have 10 DTIs on the side for the test and then swap over to the other side. Although not the best scenario will be best to gain the results.
 - KL and author looked over rig. Ideally twist rig bar should be bolted to the bottom of the chassis for ease of modelling and risk of deflection in twist rig components. The way it is currently set up means there is deflection and pivoting in the rig and makes the model become very complicated.
 - Adding a further bar on either side of the rig means pivoting from the rockers through to the lower suspension pivot points will be eliminated.
 - Will be working on adding these bars over 31/1/12 to 1/2/12.

- Rest of day taken up with cutting and drilling extra bars for the twist rig.

1st February 2012

- Bars are cut out for both sides of the rig.
- Both bars will need material to be cut out/filed out to avoid contact with the top the box crash structure.
- University does not have any M10 100mm bolts, therefore the author purchased some from Homebase to make the rig complete and hence save time on ordering.
- Modifications completed evening of 1/2/12.

2nd February 2012

- Extra DTIs obtained from LM and JK.
- 10 DTIs placed on RHS, load applied to the same side up to 1500N.
- Load though was taken up in 500N intervals so the author could keep a track on DTI gauge movements as author is working alone.
- DTIs swapped to LHS and preloaded. Also taken up in 500N intervals to 1500N.
- Results to be used and discussed at next meeting.

3rd February 2012

- Results placed in graph for ease of viewing. Can run FEA through a simulation and plot deflection as the same points as the DTIs. This can then be used for comparison.
- Add on extra rig bars made earlier in week into FE model.

6th February 2012

- Twist rig complete on drawing, however parts are breaking off and are requiring bailout to function. As previously shown the rig is breaking off where the dummy dampers meet the rockers.
- 2D mesh changed on the rockers, 'n sided' panels replaced the current area extrudes. The p shell as are set at a thickness of 6mm as are on the twist rig.
- Shear panel outlines have been started on the model using CSYS co-ordinates.

7th February 2012

- Project meeting 11.00am.
- Outcome minutes:
 - KL looked over model, tried to find way to get around breaking elements. Still working on perfecting 2D meshes.
 - Shear panels still WIP and will be completed latest by next meeting 14/2/12.
 - Review of results from twist test. Need to plot chassis DTI intervals on the spreadsheet/graph to highlight areas of base load.
 - Will look overall in next week's project meeting.
- Rest of day spent working on shear panels and trying to get 2D meshes to operate correctly on FE model.

8th February 2012

- Rear shear panels drawn on chassis. Located top of fuel tank and back of fuel tank bulkhead.
- Panels are drawn at an offset of 15mm; this is to allow for the specified dimensions of the spaceframe bar from the beam element in the middle. Also this will allow for the rivets used in the FEA also drawn at an offset but on the panel itself.

- Chris Wyatt tutorial used to help with starting and completing shear panel.
- Will promote all surfaces to draw offsets when all panels have been drawn.

9th February 2012

- Panel located in the centre of the chassis in-between driver and passenger cockpits.

This panel stretches from front bulkhead to fuel tank completed. Some co-ordinates initially were quite difficult to line up on rear of the panel.

- Although on actual chassis top box section is 20x20mm which is offset to line up with 30x30mm so the panel is flush when riveted on. However on FE model top box section is not offset therefore RBE 2s will have to compensate.
- Both front bulkhead panels completed, RBE 2s still to be added.

10th February 2012

- All shear panels have been completed. RBE 2 connectors all specified and joined on to relevant beam elements.
- 2D meshes placed on dummy rockers and nodes joined. Will run through FEA to confirm functionality.

12th February 2012

- Unable to get FEA to solve without using the param bailout function.
- Problems are arising from the twist rig assembly still. Author has tried to use RBE 2s to join dampers and rockers but are breaking off or stretching.
- Looking to find other alternatives as even if model can run the overall operation looks extremely messy.

13th February 2012

- Ran chassis through a couple of simulations – unable to get a working simulation without any bridge factors involved in the parameters.
- Will review in project meeting to see whether there is another alternative which can be inputted/best course of action.

14th February 2012

- Project meeting 11.00am
- Outcome minutes:
 - KL looked over model. Problem is still arising from a node perspective. Nodes were merges however bailout function is suspected as still being in use. Model still looks a fair degree cluttered with all RBE 2 elements present on the rig.
 - Looked over results from twist rig test, it is actually apparent that the rear of the chassis is weaker as the graph is steeper in these areas.
 - With correlation as next step, plot another graph of FE results. Author has found a way of identifying points on each part of the FE results.
- Continue with cleaning up model and carry on with correlation.

15th February 2012

- Continuation of working on model to get bailout function removed.
- Still 1D and 2D mesh areas.

16th February 2012

- No applicable updates with regard to project.

17th February 2012

- No applicable updates with regard to project.

20th February 2012

- Change of overall layout of the twist rig on the model.
- Changed layout of rockers. Rather than utilising the flat 2D meshes on n sided panels, with the issue of mounting the twist tubes. Layout changed to 3 box bar sections with dimensions of 6x6mm. Although not as accurate as what is currently on the rig, it is providing decent results and excludes any use of items such as RBE 2s on various parts of the rig.
- With confer with KL in tomorrow's project meeting 21/2/12.

21st February 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Reviewed the updated design. Author had only meshed from area of chassis just for viewing purposes.
 - As stated in previous week's meeting a graph can now be produced on the FE side and compared to actual test results.
- All can be reviewed in next meeting.
- Day spent finishing off meshing on rest of chassis and running through simulation to ensure functionality without bailout functions.

22nd February 2012

- Chassis is all meshed. Simulations run without bailout and function correctly.
- Most deflection is occurring through the main twist bar, with no apparent deflection travelling through the chassis.
- Addition of adding extra shear panels to the exterior of the chassis.

23rd February 2012

- Start of adding side shear panels into drawing in preparation for the addition on to the twist rig.
- As with current sets of panels, they have been placed at an offset of 15mm from each beam element.
- The use of n sided panels as standard mesh surfaces.
- Will continue to draw separate panels on either side of chassis rather than mirroring.

24th February 2012

- Panels completed on model and will be meshed to same tolerances as the current shear panels.
- Will FEA on the commencement of the 25/2/12.

27th February 2012

- Found suitable way of scaling down results on FEA to see deflection on actual chassis.
- When in simulation results file view, post view icon in left hand corner. Function allows user to scale down results.

- Scaled down results to look at deflection, however still showing large proportion of deflection is in the twist rig.
- Meshed panels and ran through FEA, required use once again of bailout function in order to get it to work. Problem down to a non-connected RBE 2.
- Ran through a finite element check and merged nodes. However still an apparent issue which will require further investigation.

28th February 2012

- Project meeting 11.00am.
- Outcome minutes:
 - Looked over at model
 - Next step would be effectively modifying some of the parameters in order to get the model to work and hence correlate.
 - At this present time there is about a 5/6mm difference between actual twist and FEA result.
 - Once the results roughly match up and trend in a similar fashion, the model can be used as a tool rather than just a model.
 - Author will look at modifying twist rig parameters e.g. wall thicknesses, grade of material to try and strengthen up.
- Ran through FEA, applying different parameter constraints to different parts of the model. This included applying forces on both side and applying a force through the twist rig bar.
- 600N of forced put through the bar, this made the model results be to within 0.5mm of actual results. Will have to confirm with project supervisor to see whether this is correct and can be given.

29th February 2012

- Results on right hand side are a fair degree lower than 1mm.
- Will review with project supervisor in next meeting 6/3/12.
- When model will move onto Genesis applications.

1st March 2012

- HJ is currently completing another twist test. Author is giving him a hand setting up and completing.
- Using 9 DTIs at the bottom tier of the twist rig.
- Each DTI is spaced out at 205mm intervals. As like other twist tests, DTIs are placed on one side then moved over.
- DTIs borrowed from LM and JK.
- Main issues arising from trying to find stands for each of the DTIs and decent mounting plates to put on the chassis.

2nd March 2012

- Twist Test completed with results obtained. These are more robust and consistent with what was obtained in previous test.
- Using the correlation techniques as before has meant the results are very closely matched. However will require confirmation of model layout first.
- Graphs built in both Excel & NX 7.5 environment.

5th March 2012

- Looked over model to ensure it was working adequately.
- Looked over results to confirm and ensure correct results displayed.

6th March 2012

- Meeting with project supervisor cancelled. Email sent, met with supervisor briefly who confirmed will re-schedule for later in week. Friday potential a suitable day.
- Although author is collecting items from Prodrive on Friday, author should be back in time for meeting at 2.00pm.

7th March 2012

- No applicable project updates.

8th March 2012

- No applicable project updates.

9th March 2012

- Late arriving back from Prodrive. Therefore author was unable to attend project meeting. Project supervisor notified via email.
- Confirmed with project supervisor that normal meeting time will be resumed following week. 13/3/12.

12th March 2012

- Looked over model and results. No project updates applicable.

13th March 2012

- Project Meeting 11.00am.
- Outcome minutes:
 - The way in which the twist bar is loaded with the force going through, is pushing the chassis across rather than twisting. Probably coincidental that the results nearly match up with LHS.
 - Best often is to modify E properties of the bar.
 - Will meet later in the week to review in order to push project forward and stay on track.
- Looked in to modifying E. Have to copy over material in library and rename. This gives access to material modification.

14th March 2012

- E modified and has got E results to work adequately.
- Will need minor modifications on RHS to bring results up.

15th March 2012

- Material parameters inputted so the model is working a lot closer and accurately.

16th March 2012

- Meeting with project supervisor 3.00pm.
- Outcome minutes:
 - Looked over model, front user defined constraint missing. This would simulate the twist rig bar moving about the bearing it is located on.

- There has been a bit of confusion over units from the FE model and simulation which require smoothing out.
- Author will cross check over all areas of the chassis and physical properties to ensure the units are correct along with ensuring all dimensions of bars and tubes are correct.

19th March 2012

- Author is certain that all areas of the chassis are correct and all units match up.
- As a precaution author has cross referenced all dimensions with actual chassis.
- There were some areas on the FE model where bars were specified as a larger than actual.

20th March 2011

- Project meeting 11.00am.
- Outcome minutes:
 - Scaled to model to just FE meshes. All are connected and joined.
 - Investigation into why the roll hoop is not being stressed which in reality is.
 - Author took photos of rear of chassis as the rear on the FE model is a lot stiffer than actual chassis.
 - Carried out a finite element check and highlighted some duplicate nodes. These would potentially lead the model to behave the way it is. Therefore they need to be removed.
- Continuation of debugging of model.

21st March 2011

- Investigating into the removal the duplicate nodes.
- A lot were apparent on the central shear panel and also in the roll hoop.
- All removed and FEA completed. Results marginally better but still off actual chassis.
- Rear of chassis is still stiff.

22nd March 2012

- Author looked over model – continuation of debugging. Still apparent there are duplicate nodes in other areas of the chassis.

23rd March 2012

- No applicable project updates.

26th March 2012

- Meeting with CW. Author enquired about duplicate nodes.
- Check was completed to 'merge tolerance' parameters as specified in each of the meshes. This resulted in no duplicate nodes being apparent.

27th March 2012

- Project Meeting 11.00am
- Outcome minutes:
 - Still rear of chassis too stiff, all other areas of investigation have been looked into but still results are a fair degree off correlation.
 - However one parameter has been cross referenced in the wrong area and will need to be amended. This is down to the simulation saving but not amendments

made in the FE model.

- Author will amend and meet with project supervisor later in week.
- Amendments completed and scheduled meeting for 29/3/12.

28th March 2012

- Write up of initial procedures completed for final report, this outlines the ultrasonic testing, measuring and visit to MCR.
- Also Introduction completed along with chassis evolution and purpose of the project.
- Start of project diary write up completed.

29th March 2012

- Meeting with project supervisor 3.00pm.
- Outcome minutes:
 - Went to workshop to look at twist rig. On the FE model the rear of the chassis is constrained with 4 fixed constraints. On actual rig, it is mounted on rear brace which is double bolted on to the floor. The back end on the brace is off the ground by about 5mm and would suggest the rear of the rig is deflecting as load is applied to the chassis.
 - As a test it would be suitable to place 4 DTIs on the rear brace assembly and load chassis to see if there is any deflection present.
 - Draw on the rear of model and see if this makes an impact on the results.
- Basic rear twist rig model drawn on FE model with 2 fixed constraints simulating the bolts. When run, rear rig is deflecting and hence is stressing the roll hoop. Results are alloy closer than previous simulations.
- Author to finish off drawing remainder of the rig.

30th April 2012

- Rear of twist rig drawn on FE model and displays a significant increase in the deflection of the chassis.
- Twist test completed on the rear of the actual rig. FE results are to within 0.01mm of the actual results gained.
- Results to be sent off to HJ.

2nd April 2012

- No project meeting scheduled.
- Continuation of write of the final report.
- Looked at Genesis on university computers, licence appears to have expired.
- Email sent to project supervisor requesting meeting.

3rd April 2012

- Project meeting scheduled for 3.00pm 4/4/12.
- Email sent to VRAND regarding licences. Email received from Gary Quinn with confirmation that licences can be acquired. Form sent off and licences sent through.
- Continuation of project write up.

4th April 2012

- Project Meeting 3.00pm.
- Outcome minutes:
 - Looked over model, results are trending in a similar fashion to that of the actual chassis.
 - Front of chassis is now stiffer as rear results are correlating well.
 - Looked at chassis in workshop. A lot of holes are present for the rivets of the internal and external cladding. This is probably the reason for why the chassis at the front is stiffer.
 - Author to complete two 2D mesh box sections one with holes and one without and compare deflection.

5th April 2012

- 2D meshes drawn and shows there is a large difference with the holes apparent.
- Continuation of final report write up.

10th April 2012

- Project Meeting 11.00am.
- Outcome minutes:
 - Review of 2D meshes. Large difference between results. Author can calculate Polar 2nd Moment of area of both of the box sections.
 - Next part will be to apply a 1D mesh with the same load to see and compare deflection.

11th April 2012

- Issue applying force on to 1D mesh so it twists, therefore a moment was applied.
- Continuation of project write up and correlation.

12th April 2012

- Author has decided enough has been done with the correlation as time is now becoming leaner.
- As FE model is trending to a similar fashion of the twist rig any amendments made would be of significance.
- Beginning of moving bars around to see effect.

13th April 2012

- Continuation of moving bars around and gaining results.
- Beginning of drawing side cladding and meshing.

14th April 2012

- Cladding applied to each side and bottom all is meshed and deflection results have been gained.
- Obtained results for different bar amendments on the model with cladding applied.
- All calculations will be completed next week.

15th April 2012

- NX 7.5 models have been collated; screen shots have been taken of each of the models displaying the amendments these will be placed into the write up.
- Write has been continued, correlation part now in current commencement.

16th April 2012

- Continuation of write up, still on area of correlation. This will form a large proportion of the text.
- Author has completed a two FEA models for Genesis deck input, one is of the multi braced chassis and one of original state.

17th April 2012

- Models were tried in Genesis; however none of the physical properties are displayed. Tried on university computers however still showing the same issue.
- A second model has been built, in order to get it to work in Genesis a 1D connection model had to be made. This has all the physical properties of the original FE model but does have a mesh stated. This was put through Genesis trials and appears to work sufficiently.
- No project meeting scheduled as Supervisor is away on holiday.

18th April 2012

- Model run through Genesis with results obtained. Unfortunately cannot seem to gain any mass saving from the program however can achieve an increased stiffness by modifying the 2nd moment of area on each of the bars.
- Author has decided to only look at the 28.5mm tubes and the 30x300mm box sections as they form the main basis of the chassis.
- Need to ask Project Supervisor regarding deflection node selected in Genesis cycle, will be asked on his return and during project meeting on the 24/4/12.
- Both multi braced chassis and original run through an optimisation cycle.
- Continuation of write up.

19th April 2012

- Completion of all torsional stiffness calculations for each of the spaceframe and cladding amendments. Cross checked with RD over calculations and equations.
- Continuation of write up.

20th April 2012

- Continuation of write up.

21st April 2012

- Continuation of write up.

22nd April 2012

- Continuation of write up.

23rd April 2012

- Continuation of write up, correlation part finished author has moved on to the optimisation/results.

24th April 2012

- Continuation of write up.
- Project meeting 11.00am, outcome minutes:
 - Asked Project Supervisor about max deflection node, confirmed only the highest point of deflection needs to be selected and only the one node

- Continuation of write up

25th April 2012

- Continuation of write up

26th April 2012

- Continuation of write up – Results are nearly completed a few extra torsional stiffness calculations have to be complete.

27th April 2012

- Continuation of write up – Results are completed, literature survey completed as well as conclusion. Will be proof read on the 28/4/12.
- Summary to be completed on the 28/4/12.

28th April 2012

- Summary completed
- Proof reading commenced, will import into pdf for printing purposes.

29th April 2012

- Final report & Summary now completed, everything including diary has been imported into the final report and is ready to be printed.
- Will be printed at 8am & handed in time for 11.30am hand in slot.
- ***Thank you to everyone for their help and support.***