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1 Introduction

In modern automotive design, aerodynamic efficiency is essential for enhancing vehicle performance, particularly at high speeds, as seen in motorsport applications. A critical component that elevates such performance is an active rear wing, which dynamically adjusts its angle to optimize downforce and reduce drag, leading to improved stability, handling, and, in some cases, fuel efficiency.

This report presents a group project focused on designing an active rear wing specifically tailored for the Morgan Plus 4, aiming to enhance its aerodynamic profile without compromising its iconic aesthetic. The project uses advanced engineering tools and methodologies, including Computational Fluid Dynamics (CFD), lap time simulations, coding, and mechanical design. In this report, particular attention is given to the author's tasks in aerodynamic testing, which involve using CFD simulations to evaluate the wing's impact on downforce, drag, and overall vehicle handling at varying speeds. Through rigorous testing and design optimization, this project aspires to balance both performance gains and the classic aesthetic, creating a sophisticated solution for modernizing the Morgan Plus 4's aerodynamics.

2 Team Roles

2.1 Roles and Members

- **Project Manager:** Chloe Rees (2218480). In charge of organisation of meetings, Gantt charts, presentation templates, and overseeing everybody's work.
- **Mechatronics & Control Systems:** Charlie Jones (2103718) & Connor Casey (2103540). Responsible for selecting which equipment is necessary for wing control and programming this equipment.
- **Vehicle Simulation:** Munty Rahman (2112510). Responsible for data handling and lap time simulations.
- **Mechanical & Structural Design:** Tomos Cole (2205508) & Joe Howard (2100922). Responsible for Mechanical design of a wing on SolidWorks and structural testing, as well as material selection.
- **Aerodynamics:** Ryan Boardman (2203353) & Catriona Burn (2203239). Responsible for Aerodynamic testing designs to prove what wing profile would be more effective using wind tunnel and CFD.

2.2 Author's (Catriona Burn) Role

In this group project, my primary responsibility is the aerodynamic testing of the wing, working alongside Ryan Boardman (2203353). These tests will consist of both computer simulations and small scale wind tunnel testing, as well as in depth research into some high performing wing profiles that have already been studied.

To better understand our team dynamics and individual contributions, Belbin's model is referenced. Belbin's model is a behaviour based questionnaire that assists with understanding of team roles. It consists of nine characteristic roles typically found in effective teams. These roles include the Shaper, Implementer, Completer-Finisher, Coordinator, Team worker, Resource Investigator, Plant, Monitor-Evaluator, and Specialist. These roles are also grouped into 3 sections, the Thought-oriented Roles, the People-oriented Roles, and the Action-oriented Roles.

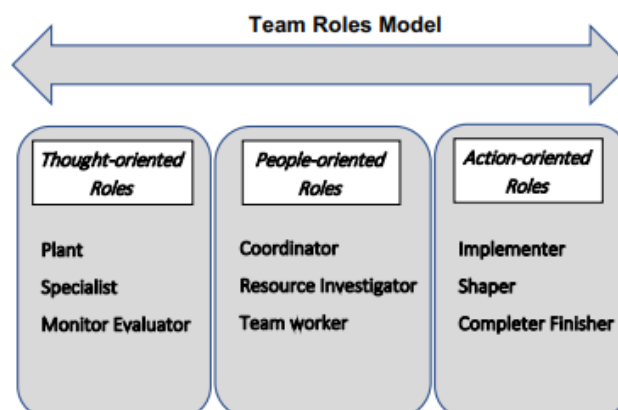


Figure 1 (Rahmani et al., 2021)

After reviewing the characteristics of each role, I identified with two in particular:

1. Completer-Finisher: This role ensures that the teams work meets a high standard of quality, often pushing the team to meet deadlines. Although it can introduce stress due to the drive for perfection, it's essential for maintaining accuracy and thoroughness.
2. Monitor-Evaluator: This role involves critically analysing the teams ideas and decisions with logic and caution. They offer balanced evaluations of the objective, though can sometimes lack motivation to inspire others.

Belbin's model is assessed through a personalized report that provides insight into an individual's behaviour in a team setting. This assessment includes questions designed to gauge how one contributes to a team, highlighting strengths and weaknesses during group work. Given the action-oriented nature of my role—comprising of research, physical experiments, and computational simulations—several roles in Belbin's model are well-suited to these tasks. These include the Shaper, Implementer, and Completer-Finisher.

After completing the Belbin assessment, I found that my strongest roles are Implementer and Completer-Finisher. These results align with the requirements of my role in this project, as both roles emphasize structured, reliable work and a commitment to high standards. As an Implementer, I am methodical and efficient, translating ideas into practical tasks. As a Completer-Finisher, I focus on thoroughness and quality control, ensuring that all work meets the high standards before completion.

3 Group Tasks

Below is a table of all the tasks we need to complete as a group, with hours spent, and start and finish dates.

Table 1: Group tasks.

Task	Hours	Start	Finish
Organising into roles: who is taking which role for the project.	6hr	07/10/24	09/10/24
Identifying project risks: what may require more attention/time.	16hr	08/10/24	11/11/24
Initial design: rough idea of wing profile(s) to get started on a CAD model.	56hr	14/10/24	11/11/24
Aerodynamic research: to help decide which wing profile(s) is best.	84hr	14/10/24	25/11/24
Study of regulations: to decide what we can/can't do with the design.	14hr	07/10/24	14/10/24
Materials research: weighing up costs and benefits of materials.	2hr	24/10/24	25/10/24
CAD Design of wing: drawing a few wing designs on SolidWorks to CFD and stress test to decide what design is best.	42hr	11/11/24	02/12/24
Stress analysis of wing: using ANSYS to stress test the supports and wing, deciding if a more structural design is necessary.	76hr	03/12/24	10/02/25
CFD testing: to determine how aerodynamic our wing design is.	28hr	10/02/25	24/02/25
Prototype Production: laser-cutting or 3d printing our model.	12hr	25/02/25	03/03/25
Prototype assembly: assembling of our model if it has been manufactured in pieces.	12hr	25/02/25	03/03/25
Wind tunnel: test and receive wind tunnel data to back up the CFD testing.	14hr	03/03/25	10/03/25
Equipment selection: choosing what equipment is necessary for the control systems part of our active wing.	82hr	21/10/24	01/12/24
Design of System control: designing how the wing will move.	84hr	24/02/25	10/03/25
Generating control algorithms: producing the a code that will control the wing.	34hr	02/12/24	13/01/24
Testing software code: testing that the code works.	8hr	10/03/25	14/03/25
Testing of control systems: testing that the control systems move how we want.	6hr	10/03/25	14/03/25
Tuning: changing the systems until they work how we designed them to.	6hr	14/03/25	17/03/24
Vehicle simulation testing: lap simulations of the Morgan with and without a wing.	222hr	03/12/24	24/03/25
Evaluation of prototype: evaluating how effective the wing is.	20hr	18/03/25	28/03/25
Total hours:	818hr		

4 Personal Tasks

Below is a table with a list of personal tasks, with dates of when each task will occur, as well as hours, and start and finish dates.

Table 2: Personal tasks.

Tasks	Dates of tasks occurring	Hours	Start	Finish
Aerodynamic Research	Monday Aero lectures plus minimum 6-7 hrs a week of research focused time.	42hr	14/10/24	25/11/24
Study of regulations	7 th , 8 th , 9 th , and 14 th October 2024.	10hr	07/10/24	14/10/24
CFD of wing designs	CFD lectures occurring 18 th and 25 th November, plus previous personal learning time occurring 5 th , 6 th , 12 th , and 13 th November.	40hr	10/02/25	24/02/25
Wind tunnel testing	21 st and 28 th October. 11 th November. Practice tests. Actual wing design tests in the new year.	30hr	03/03/25	10/03/25
Presentation prep	A few hours a day for 2 weeks leading up to presentation.	20hr	25/11/24	09/12/24
Group report	17 th , 18 th , 19 th , 24 th , 25 th , 26 th February. 3 rd , 4 th , 10 th , 11 th , 17 th , 18 th , 24 th , 25 th March.	34hr	17/02/25	30/03/25
Final presentation prep	18 th , 19 th , 25 th , 26 th February. 5 th , 11 th , 12 th , 18 th , 19 th , 25 th , 26 th March.	23hr	24/02/25	30/03/25

5 Bill of materials

Below is a list of material options for our rear wing design. Lead times are a minimum of 2 weeks, the purchase should be made 3-4 weeks prior to start of 'use' in Gantt chart.

Table 3: Bill of Materials.

Material	Cost (per kg)	Lead time
Carbon fibre	*£599 ²	2-3 weeks
Titanium	£161 ³	2 weeks
Aluminium 7075	£25 ⁴	2 weeks

2- (CT Carbon, 2015)
3-(eBay, no date)
4-(eBay, no date)

*unable to find cost of carbon per kg, so a carbon wing similar to our design was used as reference.

6 Equipment list

Below is a list of equipment the aerodynamics team will need in order to complete efficient testing, including their uses and availability.

Table 4: Equipment list.

Equipment	Use	Availability
CFD software	Aerodynamic testing of the wing and morgan. Will give downforce and drag values to measure how effective the wing is.	Any computer in room 006
Wind tunnel	Pressure readings across the wing to back up any simulation data received from CFD.	Very often available.
Laser cutter	To manufacture the model if it needs to be made in parts.	Will have to be requested and scheduled. Could take 2-3 weeks
3d printer	To print the model for wind tunnel testing if not laser cut.	Requested and scheduled. 1-2 weeks.

7 Milestones

Designing an active rear wing that performs effectively during braking and acceleration involves a series of complex tasks, each representing a gateway in the project. These key tasks are categorized as milestones, marking significant stages in the project's development. The major milestones for this project are as follows:

- Management assessment due (17/11/24): By this date the team is required to have a completed Gantt chart, providing an overall project plan and timeline. This milestone will ensure that the team has a structured plan for each gateway early on into the project.
- Completion of Research and Design work (25/11/24): This milestone signifies completion of preliminary research and design work. At the point of this stages completion, the team can proceed with a more detailed design and testing.
- Project Interim Viva (week commencing: 09/12/24): The team will present all research and progress completed by this date in this viva. This checkpoint will encourage any slow progress to speed up and allow for the team to consolidate data in order to showcase it in the presentation.
- Wing Testing (CFD complete by 02/12/24; Wind Tunnel testing by 10/03/25): Testing of the wing is a critical milestone of this project that determines whether it meets performance criteria. Having CFD completed for the viva will allow deeper analysis of the data before a small scale model is manufactured and wind tunnel tested by March.
- Control systems complete (17/03/25): This marks the finalisation of the wings control systems. Once this is complete it can be tested and assessed to determine whether the wing performs how we had discussed.
- Vehicle simulations complete (24/03/25): By this date all vehicle simulations must be finalised to enable assessment of the wings impact on performance. This can then be showcased in the final viva as proof of performance metrics and that the objective has or hasn't been met.
- Final viva (01/05/25): This is the concluding milestone of the project. It involves a presentation of all the research and testing, design work and performance analysis that has taken place throughout this project. The final viva will mark the project's completion, providing an opportunity to review achievements and discuss the overall impact of the active rear wing design.

7.1 Gateway objective

SMART is an acronym in project planning used to help set clear and achievable goals that guide the project towards its objectives. It stands for; Specific, Measurable, Achievable, Realistic, and Time-bound. Unlike milestones which are progress markers; gateways are decision points to stop and assess if the project should proceed, back track or discontinue.

A key gateway objective in this project is to perform aerodynamic testing on the different wing designs. This is essential for evaluating how effective each design is at meeting set performance goals for the Morgan Plus 4's active rear wing. The result of this testing will determine if any of the wings should advance to further stages or if certain components need to be adjusted or redesigned.

Listed below is how this gateway can be related to each SMART objective:

Specific

A specific goal must be set to assess whether this gateway has been met and the project can proceed to the next task. For aerodynamic testing a specific percentage of downforce increase must be met without increasing the drag by a specific percentage. For example, a 10% increase of downforce must be met at a speed of 90mph (roughly 40m/s), and an increase of no more than 5% drag.

Measurable

In order to measure this, CFD will be used on the Morgan with the wing attached as well as the wing not attached. This will produce data before and after the wing and produce evidence as to whether the wing has met the criteria. Another way of testing is to create a small scale model of the wing and test it with pressure sensors in the wind tunnel. This may not be 100% accurate as small scale because the aerodynamic forces are lower on smaller objects, but it will back up the CFD data.

Achievable

The measured data will provide insight into whether the criteria is achievable or if the goals need to be changed in order to be met.

Realistic

The measured data as well as research will also contribute to whether the performance goals we have provided are realistic or if they need to be adjusted.

Time-bound

In order to ensure the testing is complete in time for the next task to initiate, there is specific time tabling of the aerodynamic tasks. The CFD must be started after the stress analysis on or before 10/02/2025 and complete on or before 25/02/2025 (subject to change depending on previous task completion). The wind tunnel testing must be started on or before 03/03/2025 and completed by 10/03/2025.

8.2 Personal Gantt Chart

Below is a personal Gantt chart for all of the individual tasks that must be completed. These also include a start and finish marker of each week over the total 24 weeks, showing planned start weeks and durations in comparison to the actual start and duration of each task completed so far.

Project Planner

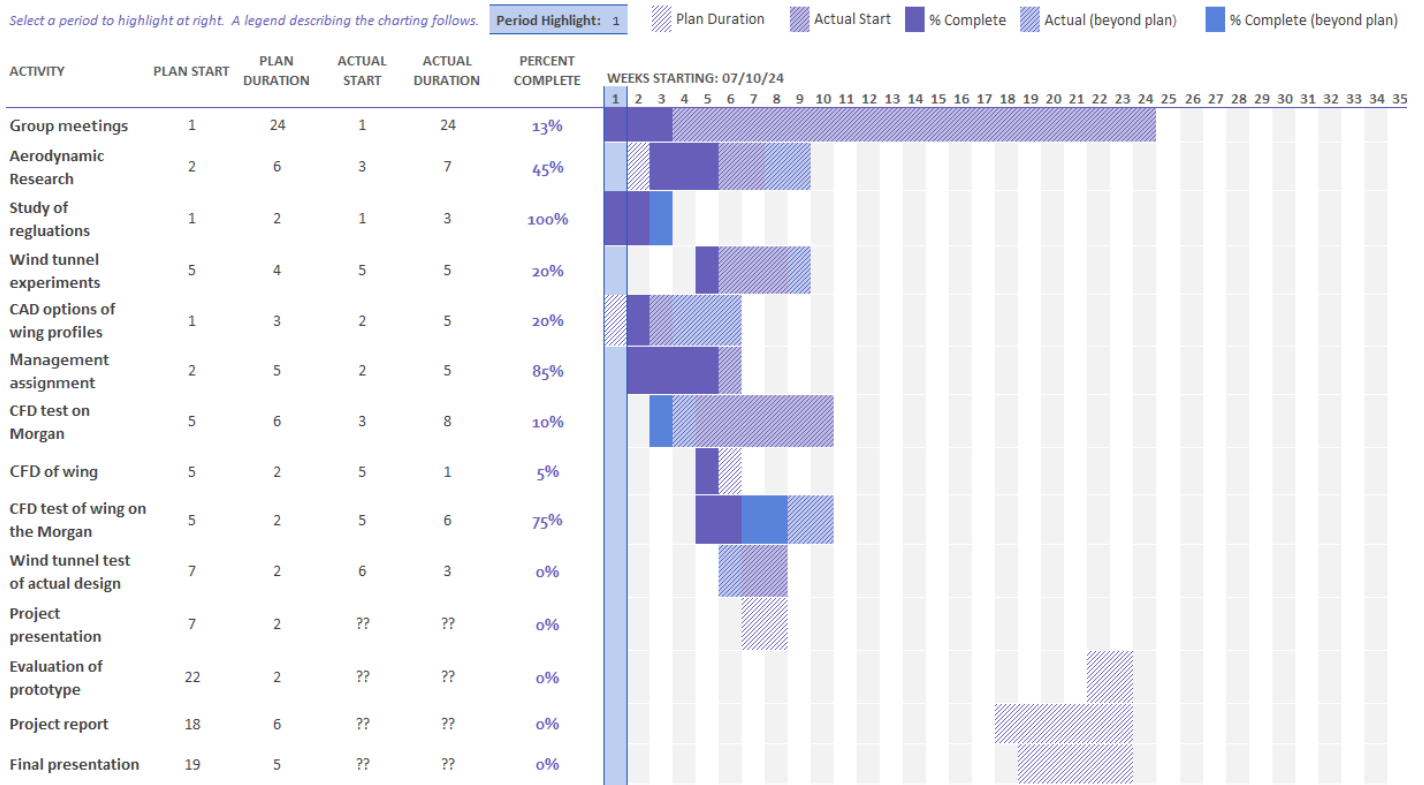


Figure 3: Personal Gantt chart.

9 Areas of Concern

When completing any project, there will always be certain areas of concern involved. This could be issues with time management, project progress or .

I have selected two main areas of concern to focus on, which are as follows:

1. Lack of trust in other members: As I have high expectations for myself, it can be difficult to trust other members to complete their tasks to this standard. This may cause a need to personally complete these tasks, producing a longer list of personal tasks. To mitigate this, group meetings are held a minimum of weekly to discuss ideas and help push each other continue successfully towards their objective.
2. Meeting the timeline: as a 2nd year student of a BEng degree, and completing multiple assignments a term (plus extracurricular responsibilities), it can be difficult to juggle all the tasks at once. This may mean some tasks are behind schedule, causing delays in other phases of this project. To account for this, the group meetings are also helpful to see where each task is at in the progress. If one is falling behind, support from others can be offered and likely encouraged.

10 Conclusion

In conclusion, this report has highlighted the importance of effective planning and evaluation to assist in successful development of an active rear wing for a Morgan Plus 4. Through the application of computational fluid dynamics and simulations, we will be able to optimise the design to enhance aerodynamic efficiency and performance. The integration of coding and SolidWorks has streamlined the mechanical design process, allowing for precise adjustments based on simulation data. By having a flexible approach to project concerns, we are able to remain on track with the rough plan and adapt for requirements from data findings.

This project has offered valuable insights into the design of an aerodynamic active wing, highlighting the importance of collaboration and communication within a team to successfully develop such product. It emphasises the necessity for innovation through in depth analysis and continuous improvement towards high performance vehicle design. Additionally, the experiences gained from this assignment will serve as a solid foundation for future projects.

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