
Depar**t**ment of Mechanical & Aerospace Engineering

ME519: MEng Group Project

# Final Report

## Airbus – Fly Your Ideas

Group L

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## Abstract

Group L entered into the Airbus 'Fly Your Ideas' competition under the name StrathBIRDS, with Dr Matthew Stickland acting as their academic mentor. The team generated a selection of ideas which were shortlisted, using selection criteria, based on the competition requirements. The final idea chosen was 'Boundary layer control through the application of Knudsen pumps'. A feasibility study was conducted by creating a mathematical model of a flat plate with boundary layer suction. The results showed that suction could reduce the drag coefficient over the laminar part of the wing by 23%. Although the laminar part of the wing was only approximately 1.2% of the wings' average chord length without suction, the improvement was still considered to be significant when considering the scale of the Airbus A380's operations.

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# 1 Introduction

The group, formally known as group L, was randomly formed and composed of five students with four students from the University of Strathclyde and one exchange student from the Federal University of Rio Grande do Sul, Brazil. The objective of their final year Master's project was to develop and enter an idea into the Airbus 'Fly Your Ideas' (FYI) competition.

## 1.1 The Airbus FYI Competition Overview

For the competition, the group entered under the name StrathBIRDS (Building Ideas, Reaching Dreams) and their supervisor, Dr Matthew Stickland, was acting as their academic mentor. The Airbus FYI competition was designed for teams of students who aim to investigate and develop innovative solutions for the eco-efficient aviation industry. Teams had to consist of three to five members studying a Bachelors, Masters or PhD level degree in any discipline at a recognised degree-awarding institution.

The Airbus competition was aimed at recognising the team with the most innovative and sustainable idea that benefited any of the seven categories detailed in Table 1.

**Table 1 - FYI Categories**

| Category | Description |
|---|---|
| **Energy** | Ideas that are aimed at reducing energy consumption, increasing energy recovery or identifying sustainable sources of renewable energy. |
| **Efficiency** | Ideas that are aimed at improving performance or reducing environmental impact. These could include enhanced aerodynamic performance, weight reduction or improved maintainability. |
| **Affordable Growth** | Ideas that are aimed at reducing the cost of manufacturing processes, materials, equipment and operations. |
| **Traffic Growth** | Ideas that are aimed at supporting the projected increase in passenger travel by developing improvements in the management of aircraft missions, air traffic control and ground operations. |
| **Passenger Experience** | Ideas that are aimed at addressing the cabin of the future, as well as integrated transport systems and improved airport operations. |
| **Community Friendliness** | Ideas that are aimed at reducing noise levels, improving air quality and easing traffic. |

| | |
|---|---|
| **Other** | Any other Innovative ideas for an eco-efficient aviation industry of the future which are not covered by these six challenges. |

Although there were seven different categories, it was acceptable for a team to enter an idea that fell into more than one of these categories. When entering the competition, however, the team had to specify which category best described their proposed idea.

The competition was composed of three rounds each being judged by a panel of Airbus employees and industry experts. At the start of each round, a briefing pack was sent to the teams to explain the evaluation criteria and format required for that particular stage of the competition. Table 2 outlines these rounds and the start and end dates associated with them.

**Table 2 - Competition Rounds**

| Phase | Starts | Ends |
|---|---|---|
| **Registration** | 19 June 2012 | 30 November 2012 |
| **Round 1** | 3 September 2012 | 7 December 2012 |
| **Round 2** | January 2013 | April 2013 |
| **Round 3** | May 2013 | |
| **Final Presentations & Awards** | June 2013 (Single Day) | |

**Registration:** Groups nominated one group member to register an account on the Airbus FYI website and enter the names of other members of the teams (including academic mentor). The other members validated their commitment to the group via a verification e-mail.

**Round 1:** Each team submitted their proposal; this was an online questionnaire about the chosen idea, including its origin, potential benefits and development.

**Round 2:** Up to 100 teams were selected to progress into the second round of the competition depending on the assessment of the round 1 questionnaire. In this round all teams were required to develop their proposed ideas and compile a written report that details their findings. The creation of a short video about the team and proposal was also required to support the work. During this stage, an Airbus mentor was recruited to work alongside the team. The Airbus mentor's role was to support the team with the direction and structure of the project.

**Round 3:** Based on the team's success in the previous round, five finalists were selected and had to prepare a presentation to be delivered to a panel of Airbus and industry experts. This presentation was to be delivered at the live final in June 2013. A top prize of €30,000 was awarded to the winning group and runner's up are awarded €15,000.

This report outlines the team's progress and the idea chosen to enter into round 1 of the competition. The majority of the report is focused on the strategy adopted and the targets achieved in relation to the 'Statement of Purpose'. In addition there is a short technical report attached detailing the numerical results of the project.

## 2 Project Strategy – Semester 1

The main objective of this semester was to generate a comprehensive list of ideas and to submit one of these ideas into Round 1 of the Airbus FYI competition. It became clear from the first group meeting that the idea that was chosen to be investigated would effectively determine how successful the group would be in the competition.

Group meetings were held at least once a week and the actions carried out in these meetings along with the short term objectives for the next meeting were noted. The main work carried out in the first two weeks consisted of the following tasks:

- Development of 'Statement of Purpose'
- Development of Gantt chart
- Development of 'Idea Generation' strategy

The 'Statement of Purpose' formed the foundations of the teams' project organisation and strategy and the Gantt chart outlined a detailed project schedule by which to assess the group's progress and forthcoming deadlines. The 'Idea Generation' strategy laid out the process that the group would adhere to when developing an idea for the competition.

## 2.1 Idea Generation Stage

The steps involved in the idea generation stage are illustrated in the flowchart in Figure 1.

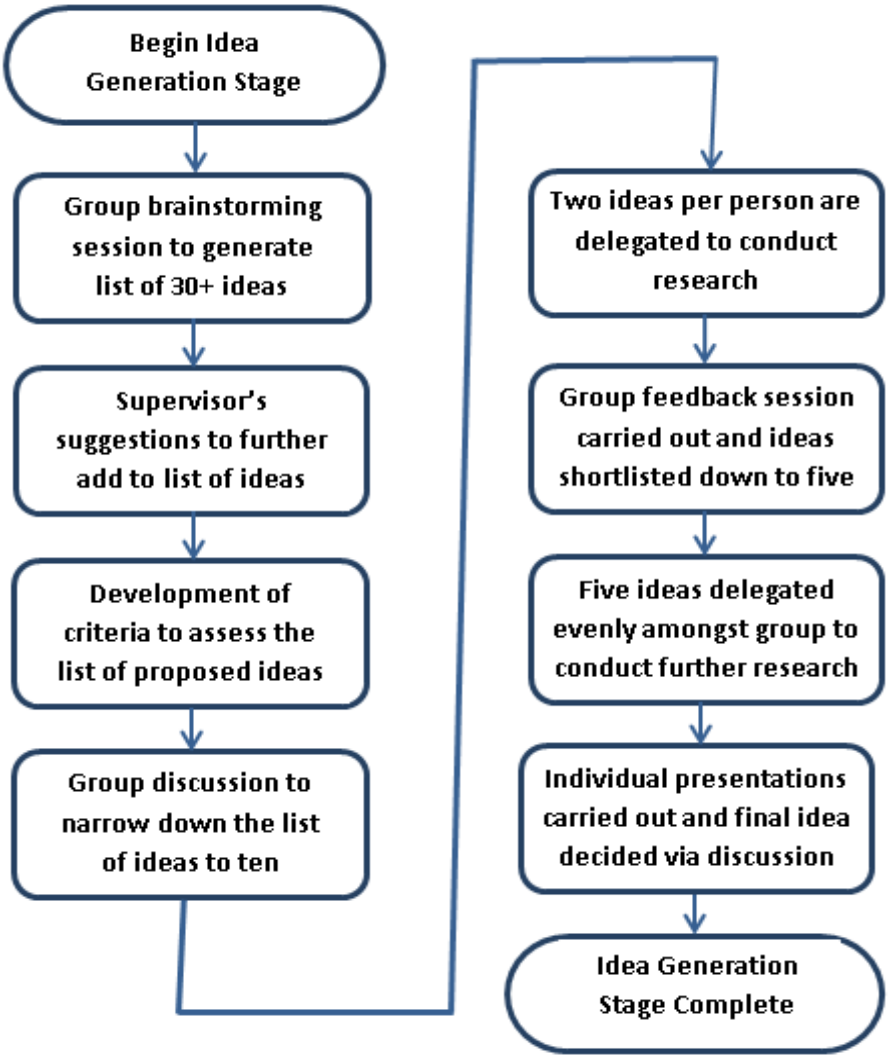



**Figure 1: Flowchart of idea generation stage**

During the first stage of the idea generation strategy, each member was required to perform a brief amount of research and generate a minimum of five potential ideas. At the following meeting, the group discussed their findings and collectively compiled a list of over thirty ideas.

Following on from this, a meeting with the project supervisor was arranged in order to gain an understanding of his hopes and ambitions for the project. The project supervisor made it clear that the direction of the project and the idea generated was ultimately down to the group however he did provide assistance and advice on possible ideas to investigate. These additional suggestions further added to the group's list of numerous ideas.

After generating a comprehensive list, a process of elimination was carried out over a number of weeks to narrow down the list until one idea was selected. In order to assess each idea's potential; a set of criteria was generated via a group discussion. The criteria were developed with a focus on the Airbus FYI competition. Table 3 explains the criteria and the questioning behind it.

**Table 3 - Criteria Explained**

| Criterion | Questioning |
|---|---|
| **Originality** | How original is the idea? Has there been any previous research similar to the idea subject field? |
| **Complexity** | How complex is the idea? Will the complexity limit the progress over the academic year? |
| **Group Subject Knowledge** | What is the level of knowledge amongst group members in relation to the idea? What degree of learning will need to be carried out? |
| **Supervisor Subject Knowledge** | What is the predicted level of knowledge of supervisor in relation to the idea subject field? Will the supervisor be able to provide significant advice and expertise on idea? |
| **Economic Benefit** | What is the potential level of economic benefit to be gained from the implementation of the idea? |
| **Environmental Benefit** | What is the potential level of environmental benefit to be gained from the implementation of the idea? |
| **Experimental Potential** | What kind of experimental analysis can be carried out on the idea? (e.g. theoretical, software, physical testing) |
| **Industry Desirability** | How desirable is the idea from the perspective of the Airbus competition? |
| **Cost of Project** | What costs are likely to be involved in the process? |

A group discussion was carried out in order to reduce the original list of ideas down to ten. During this elimination process, the criteria were considered to have the same weighting factor, with the exception of 'group subject knowledge', which was considered roughly twice as important. The ten ideas were then delegated evenly amongst the group (two per person) to research and assess their specified ideas against the criteria.

A group feedback session was then carried out whereby each member voiced their opinion on their researched ideas. The main objective of the meeting was to narrow down the ten ideas to a shortlist of five. After an intense discussion, five ideas were selected and, as before, were delegated evenly amongst the group. Each member was to conduct a significant amount of research into their specified idea and to re-assess it against the criteria. At the end of this stage each member was required to present a PowerPoint presentation on their findings and make a recommendation on the suitability of the idea for the competition.

## 2.2 The Shortlist

### 2.2.1 Boundary Layer Control

Creating a device or method to control the boundary layer would allow for an increase in aircraft performance. By preventing the separation of turbulent and laminar flow, lift could be increased and drag decreased. In doing so, the aim would be to create a more efficient aircraft. Research showed that many such methods already existed, or were currently being researched:

- **Shaping** – Designing aerofoils of certain shapes to delay the point of transition causing a reduction of the total frictional drag of the body.
- **Wall Cooling** - Decreasing the heat from the surface, resulting in an increase of the velocity gradient of the wall. This would produce a more full and stable profile.
- **Suction** – Removing the fluid particles located closest to the surface through a porous surface. This would generate a thinner boundary layer that would separate further downstream. This technique would also allow for higher angles of attack and a reduction in skin friction drag.

### 2.2.2 Aircraft Turnaround Time

Reducing aircraft turnaround time was an idea that looked into the process of aircraft when on the ground. These processes included:

- **Ground Handling** – Maintenance and safety checks by airport crew
- **Cabin Services –** Cleaning the cabin, replenishing on-board consumables, restocking catering requirements for the flight
- **Ramp Services** – Guiding aircraft in and out of parking, refuelling, luggage and cargo handling, passenger stairs.
- **Passenger Service –** Check-in, gate arrival, passenger lounge.
- **Taxiing** – Movement of the aircraft on the ground, under its own power.

Ramp services and taxiing were the two processes that were focused on for further development. Ramp services could possibly be improved by renewing the way in which loads were taken on and off the aircraft. This would involve looking at the cargo hold and trying to utilize as much space on the aircraft as possible.

A major factor in the design of current aircraft is that they generate high levels of noise and burn a high amount of fuel during taxiing and take off. One way to avert this would be to use electric taxiing, instead of using the engines to move the aircraft. This would significantly reduce noise and the emissions produced by an aircraft during taxiing.

### 2.2.3 Riblets

Riblets are micro-grooved surfaces on the surface of an aircraft in the free stream direction. They were designed to reduce skin friction drag, which can account for up to 50% of the total drag in cruise condition for commercial transport aircraft.

NASA and ONERA had already extensively researched riblets, with many flight tests having been done in the past. This did show that the idea was not new or original and that many companies in the aviation industry, including Airbus, had most likely already carried out research into riblets. Therefore the aim of this idea was to investigate the application of riblets into more complex areas of the aircraft such as the wing roots, under carriage or flaps. The possibility of merging the idea with another was also investigated.

### 2.2.4 Eco-efficient Air Conditioning

Companies such as Airbus spend a significant amount of money developing air conditioning (A/C) systems. With the A/C system being the second most power consuming aircraft device, after propulsion, a small improvement could provide a noticeable economic benefit.

The A/C system in aircraft provides fresh air supply, cabin pressurisation, heating and cooling. Cooling is the most power consuming aspect of A/C system, and it was determined that this is where the efficiency could be improved. The group would focus on analysing the current air cycle refrigeration processes utilized by modern aircraft and determine where the process could be made more efficient.

### 2.2.5 Knudsen Pumps

A Knudsen pump utilizes the principle of thermal transpiration, where a temperature gradient causes the gas molecules to move from one side of the pump to the other, to generate suction.

Knudsen pumps benefit from having no moving parts allowing for weight reductions if they were to be used in aircraft systems. This idea also had potential to be merged with either the eco-efficient air conditioning concept or could be used as a method for boundary layer control by suction.

### 2.3 The Resulting Idea

The idea generation stage resulted in the following idea being generated.

***"Boundary layer control through the application of Knudsen pumps"***

The final idea evolved out of two separate ideas; one relating solely to investigating Knudsen pumps and one aimed at developing a boundary layer control strategy. Table 4 demonstrates how the idea fared against the criteria.

**Table 4: Idea against the selection criteria**

| Criterion | Answers |
|---|---|
| **Originality** | The idea is entirely unique. As far as the group is aware, Knudsen pumps have never been incorporated into aircraft. |
| **Complexity** | The idea is of sufficient complexity and the academic year will provide enough time to allow a significant investigation to be carried out. |
| **Group Subject Knowledge** | Knudsen pumps originally unknown to group and degree of learning required is within the groups' capabilities. |
| **Supervisor Subject Knowledge** | Investigating Knudsen pumps was a suggestion by the supervisor so he has therefore adequate knowledge in the subject. |
| **Economic Benefit** | By replacing a conventional pump with a Knudsen pump, power consumption can be reduced and hence financial savings can be made. |
| **Environmental Benefit** | Knudsen pumps have the potential of reducing carbon emissions and improving aircraft performance (fuel consumption). |
| **Experimental Potential** | Due to the nature of Knudsen pumps, physical experiments are unlikely. Project will consist of theoretical and software based simulations. |
| **Industry Desirability** | The group consider the idea to demonstrate the level of innovation expected by the Airbus competition guidelines. |
| **Cost of Project** | Costs are likely to be minimal and within the groups' budget range. |

### 2.4 Discarded Ideas

The team generated many ideas that were discarded due to their complexity, lack of available resources, time constraints and the realistic benefits they could provide to helping the aviation industry. This included:

- **Panoramic body** – Using a clear material to create the top half of the fuselage. This would allow for a better passenger experience, but the structural aspect of this idea would place severe limits on the development.
- **Windowless cabin** - Removing the row of windows on the fuselage and replacing them with a strip of clear material or having no windows at all. Whilst this could allow for improved aerodynamics, the passenger experience would be reduced. The process of manufacturing an aircraft with a strip of clear material would also cause structural concerns, which realistically would reduce the economic benefit of the idea.
- **Cabin interior redesign** – This idea would involve looking at the arrangement of the interior of the cabin. It was considered that by looking at the way seats and storage bays are positioned, and providing an alternative would allow for a better passenger experience and also decrease aircraft turnaround times by allowing ground services to be more efficient.
- **Vibration energy harvesting** – Utilizing the vibration of an aircraft to generate energy to power internal devices. Although this was considered an eco-friendly idea, the weight trade-off would negate any benefit that could be produced.
- **Dynamic stall replication** – By recreating dynamic stall a period of high lift could be generated. This required the airfoil to rapidly change its angle of attack producing a vortex. The high level of complexity and lack of resources on dynamic stall resulted in the idea being discarded.

# 3 Round 1

After being formally registered as a group with an academic supervisor in the competition, the next milestone was to complete the Round 1 Proposal. This was an online questionnaire about the chosen idea explaining how it was innovative and stating the benefits that it would generate. It also detailed how the group planned to develop the idea. The main points in the proposal included the title, a description of the idea and the work that the group intended to carry out through the competition. The Round 1 Proposal was assessed by Airbus staff and industry experts. The assessor's decision was based on the criteria set out in the briefing. Their decision on which teams should progress to next stage was final and no correspondence could be entered into on that matter. The original version of the Round 1 Proposal can be found on the group website.

## 3.1 Summary of Round 1 Proposal

The proposal was made up of five parts. Each one was accompanied by a short criterion that would be considered when assessing the answers.

### 3.1.1 Part 1 – Title

***"What is the title of your proposal?"***

The advice was to reflect the scope, goal and benefits of the idea. If desired the group could give an acronym of the title for reference. The title selected was:

*"Boundary layer control through the application of Knudsen pumps to reduce skin friction drag and increase efficiency."*

### 3.1.2 Part 2 – State of the art

***"What do you understand to be the state of the art in the area of your idea?"***

The aim was to explain the current operational practice in the subject area of the idea and what new approaches were already under development in that field. The group made the following submission:

"*Knudsen pumps themselves are state of the art considering they have no moving parts and utilise thermal transpiration to effectively control gas flow. To date there are no known applications of Knudsen pumps within aircraft. There are currently several methods of boundary layer control applied to aircraft, through aerofoil shaping, wall cooling and turbulators. Boundary layer suction is presently carried out through suction slots; however there is a limit to the volume of air that can be extracted. The addition of Knudsen pumps would allow more low energy air to be extracted from the flow."*

### 3.1.3 Part 3 – Idea explanation

***"Please explain your idea."***

It was recommended to explain the main features of the idea and what challenges would be faced in order to implement the concept. Also, what was innovative with relation to what was state of the art was required to be mentioned. The following section was submitted:

*"The basis of the idea is to utilise Knudsen pumps to provide suction of the boundary layer. In doing this low energy air is extracted from the flow, allowing it to remain laminar for longer and delaying flow separation. Knudsen pumps utilise thermal transpiration, which in simple terms involves creating a temperature gradient that causes gas molecules to move from one side of a tube to the other. Placement of Knudsen pumps within the wing should allow this methodology to be applied to the boundary layer.*

*Challenges that will arise include meeting the current aircraft design and safety standard; the location and quantity of Knudsen pumps required to extract air at the desired flow rate; the cost of implementing the pumps and maintenance of them during working life.*

*As Knudsen pumps have not been used in aircraft applications previously overcoming these challenges will be increasingly difficult due to the innovation behind the idea. The concept will be compared with the current technology available and benefits of each shall be evaluated.*

### 3.1.4 Part 4 – Benefits

***"What benefits do you expect your idea to generate?"***

The assessment was based on the explanation of the benefits of the idea with particular attention to positive environmental, economic and social impact. The answer given was:

*"Through the application of Knudsen pumps to provide boundary layer suction on the leading edge of the wing, the transition from laminar flow to turbulent flow is delayed. As a result the skin friction drag across the wing can be reduced, thus enhancing aerodynamic performance and increasing efficiency of the aircraft. Increased aircraft efficiency and reduced fuel consumption leads to a positive environmental and economic impact. Knudsen pumps also have the benefits of using no moving parts, allowing for an extended lifecycle."*

### 3.1.5 Part 5 – Further work

***"If your team progresses to Round 2, what new work do you intend to carry out to test and validate your idea?"***

A plan was to be outlined of how the team would develop the idea and how it would measure the benefits it could bring. This was:

*"A detailed analysis on Knudsen pump performance will be carried out using both mathematical and computational methods. From this, the output pressure and temperatures required for effective thermal transpiration will be recorded. The performance of an Airbus wing incorporating boundary layer suction techniques will be evaluated. Upon completion of this the performance benefits of Knudsen pumps will be investigated. An analysis detailing the potential increased aircraft efficiency through the use of Knudsen pumps shall then be completed."*

### 3.2 Airbus Feedback

Unfortunately, the team did not make it through to Round 2 of the competition. The following was the notification the team received feedback from the Airbus panel:

*"Dear team StrathBIRDS:*

*Many thanks again for entering your idea into the Fly Your Ideas competition and although you were not successful in progressing to Round 2 we hope you are still supporting the other teams currently taking part.*

*As promised please see below the feedback on your Round 1 submission from the team of Assessors who reviewed your proposal.*

- *The title of your proposal clearly and accurately described your idea*
- *Your proposal accurately described the state of the art for the area your project focuses on*
- *Your idea and its features are well conceived and clearly described*
- *The idea itself is interesting and innovative – in comparison to current practice*
- *You have identified the principle challenge and barriers for implementation of your idea*
- *The potential benefits linked to your idea are clearly explained*
- *Your proposal did not clearly identify the economic benefits you expect your idea to deliver*
- *Overall you have shown a well defined plan to progress the development of your idea*
- *Your overall approach to quantitative measurements of your idea needed development*

*Notes/Areas to consider:*

- *How could temperature gradient be maintained without power? Enough suction?*

*Thank you for taking part in the Airbus Fly Your Ideas 2013 competition. We wish well with your ongoing studies and your future career."*

The feedback did not include much detail of why the team did not progress, however it encouraged the team that the idea was interesting and innovative enough to continue on with as a university project.

# 4 Project Strategy – Semester 2

## 4.1 Main Objective

The main objective of the second semester was to take the idea generated from the previous semester and conduct a detailed investigation. Through this a set of results could be obtained that highlight its benefit for the eco-efficient aviation industry.

Like in the previous semester, group meetings were held on a weekly basis, however as the project progressed, two or three members working on same task formed a sub-group and would meet separately. The weekly group meetings were a chance for each sub-group to report back on the progress and discuss the work that lay ahead. The main pieces of work that were conducted in this semester were the following:

- 'Idea Development' stage
- Development of website & video
- Development of report & presentation

From day one, it was clear that the outcome of Round 1 of the Airbus FYI competition would ultimately have an effect on the work carried out in semester two. It was therefore in the best interest of the group to consider the different scenarios and to understand the effect they would have on the project.

The first scenario considered was that of the team progressing through to Round 2 of the competition. In this case, an additional report, on-top of the university report, and a video would have to be produced in compliance with the competition guidelines. An Airbus mentor would also be assigned and would act as a consultant to the group to help develop the project. By considering this scenario, a semester two project strategy that adhered to both the university and Airbus competition deadlines was developed.

The second scenario considered was that of the team failing to pass round 1 of the competition. In this case, it was decided that the project would continue as planned with the exception of the work required by the competition round two guidelines. Although, the production of a video would not be necessary in this scenario, it was the group's decision to produce it either way and incorporate it into the website.

After considering both of these scenarios, a semester two project plan could be constructed in such a way that the outcome of Round 1 of the Airbus competition would have minimal effect of the work to be carried out. As was highlighted previously, it was the latter scenario which arose. Since careful consideration was given, the project was able to run smoothly and the project milestones and deliverables could be cemented.

### 4.2 Idea Development Stage

This stage formed the main technical aspect of this project and accumulated the most working hours out of the tasks. Moving on from the 'Idea Generation' stage, the main purpose of the 'Idea Development' stage was to conduct further research and perform analytical, computational and/or experimental testing. This stage was planned out in detail after group discussions and meetings with the project supervisor. The flowchart shown in Figure 2 summarises the main tasks carried out during this stage.

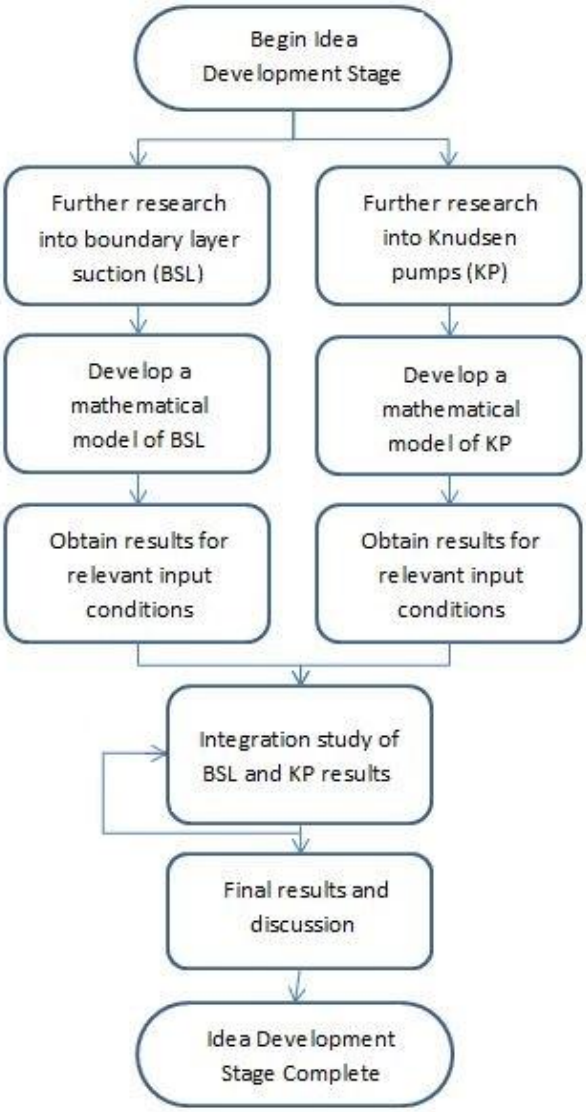



**Figure 2: Flowchart of idea development**

As the selected idea was generated by encompassing two ideas, boundary layer suction and Knudsen pumps, the initial period of work could be split between the group with three members focusing on the boundary layer suction side and a further two on the study of Knudsen pumps. Each sub-group was instructed to conduct further research into their respective subjects with the objective of developing a computer-based mathematical model. The purpose of the mathematical model was to provide a tool to

assess the performance of the aircraft by inputting various parameters. Experimental testing was considered for this stage however since Knudsen pumps require specialised machinery in order to be manufactured, it was not a feasible option and the project was kept theoretical.

In each of these sub-groups, one team member oversaw the whole process of the development of the mathematical model and became a technical specialist in the topic. The remaining members assisted in the development for the initial period but later undertook roles in other tasks such as the website design, video production and report plan.

Once both models were created, the technical specialists from each sub-group worked on integrating the two models. This stage was repeated until the results were refined to demonstrate the potential benefits a Knudsen pump can generate when employed for boundary layer suction.

### 4.3 Results & Future Work

The software used for the boundary layer suction and Knudsen pump modelling were MathCAD and Microsoft Excel, respectively. In these calculations, the Airbus A380 was used as a benchmark for the input parameters as it is the world's largest passenger airliner.

It is important to note that the purpose of this study was not to examine or develop work in the field of boundary layer suction or Knudsen pumps. The benefits of these technologies are well-known within each respected field. The purpose of this study was to use tested modelling techniques and demonstrate that the two technologies can be theoretically integrated to benefit the eco-efficient aviation industry.

The study focused on applying suction across a portion of the aircraft wing and also on the nacelle of the engine. The Mathcad model was primarily used for evaluating the suction pressure required to reduce the skin friction drag across the aircraft. Once the suction pressure was determined, the Excel model was utilised to determine the size and capabilities of the Knudsen pump to provide this pressure.

From a theoretical point of view, the study was particularly successful in demonstrating that a Knudsen pump can be effectively used in the operation of boundary layer suction. The results are encouraging in the sense of potential benefits and it leaves many additional possibilities for further improvement and research. As was shown in section 3, there were many positives points from the competition feedback. The main negative point was in regards to how the temperature gradient for the Knudsen pump could be maintained. The work carried out in this semester tackled this problem and proposed a solution that involves using the aircraft de-icing system. It is the group's belief that this project would provide a useful benchmark for future students to enter the competition. With that advantage of a pre-generated idea and an insight into the benefit that can be gained from its implementation, the progression into round two can be achieved next year.

# 5 Targets Achieved

As was mentioned previously, a 'Statement of Purpose' formed the basis to the team's organisation and planning strategy. This statement outlines the main targets of the project along with an important set of milestones and deliverables. By referring to this information, the group reflected on their performance throughout the project.

## 5.1 Mission Statement

Several important targets of the project were detailed in the statement of purpose. The first of these was the mission statement;

*"To generate a series of ideas that benefits the eco-efficient aviation industry and to develop one of these ideas to a level that allows the team to enter the Airbus 'fly your ideas' competition"*

As was detailed previously, the group successfully generated multiple ideas that benefited the eco-efficient aviation industry. Through the 'Idea Generation' stage, a final idea was decided upon. This final idea was developed to the level required to enter it into the Airbus FYI competition before the round 1 deadline.

## 5.2 Project Strategy

Following on from the mission statement, a project strategy was documented. Sections of this strategy that were completed in the first semester were 2.1. - Idea generation stage, 2.2. - The detailed research stage, 2.3. - Final idea selection and 2.4. - The university interim report, 2.5. Airbus FYI round 1 proposal. These sections were always planned to be completed in the first semester and the group worked hard to ensure that they were.

The sections of the project strategy that referred to semester two were 2.6. – Detailed design phase development, 2.7. Final report and video, 2.8. University presentation and website. Initially the group focused on the detailed design phase, specifically further research into Knudsen pumps and boundary layers as the combined knowledge of the group was relatively low in these areas. Following the research stage, detailed numerical calculations were carried out to further understand Knudsen pumps and boundary layers. When the results were obtained the group developed the report, video, website and prepared the university presentation.

### 5.3 Project Security & Privacy

Throughout the project all data and information were kept between the group members and project supervisor. The only exception to this was the information submitted to Airbus as part of the round 1 proposal. The team did not progress to round 2 so section 3.2 of the 'Statement of Purpose' became irrelevant. This merely stated that the Airbus mentor allocated in round 2 of the competition would also be included in project details.

### 5.4 Project Aims

The main aims of the project were collated as a series of milestones and deliverables with a proposed completion date set for each. The following piece discusses these milestones and deliverables and reflects on the group's success in achieving them.

- Concept shortlist (5 ideas)
  - This milestone refers to the generation of the list of five concept ideas. Through regular team meetings and a rigid selection criterion, the team created this shortlist and present it on time.

- Final project idea selection
  - This milestone required a decision on the final project idea and was, once again, delivered on time. The success of this task was due to the detailed discussion and presentation stage which was outlined previously.

- Supervisor meeting
  - The purpose of this meeting was to discuss the final idea and take on board any suggestions. This milestone was completed a week late due to the complexity in finding a time when the whole team and supervisor were available to meet. The lateness of this milestone had the potential to have knock-on effects if the supervisor advised against following through with the decided final idea. Had this occurred, a different competition idea would have had to be selected from the five shortlisted which would have distracted time from

| | |
|---|---|
| | other tasks such as the production of the university interim report. Fortunately, the supervisor supported the idea and gave various suggestions on how to take it forward. |
| • University Interim Report | - By compiling a detailed report plan and delegating the various sections evenly amongst the group, this report was successfully completed on time. |
| • Round 1 proposal | - The round 1 proposal was completed by two members of the group while the other three developed the semester 2 plan. Through effective team work between the pair the proposal was completed and submitted ahead of schedule. |
| • Develop semester 2 plan | - As stated the other three members of the group compiled a detailed semester 2 plan and gantt chart. This was based on the final project idea and what was required to develop it further. The plan was completed on time and ready for implementation upon the groups return from the Christmas break. |
| • Supervisor meeting | - The purpose of this meeting was to discuss the semester 2 plan with the project supervisor. Again this milestone was completed late due to availability of team members and the supervisor. As a result the team held off on beginning the semester 2 work as they felt it important to have it approved by the supervisor before progressing. This time was later recovered. |

- Detailed design phase results
  - With the team failing to progress to round 2 of the competition the need for this milestone to be fulfilled as early as planned became void. The deadlines were now driven by university requirements as opposed to Airbus requirements. As a result the team made a group decision to extend this milestone deadline by three weeks enabling more time to achieve results.

- Supervisor meeting
  - This milestone was met on time although the purpose of it changed. Originally the purpose of it was to run the results from the detailed design phase past the supervisor. As the previous milestone deadline was extended the meeting was used to detail results to date but also to discuss further results that could be acquired with the additional time.

- Supervisor meeting
  - As the majority of supervisor meeting milestones had been delayed due to the complexity of finding a time when everyone was available this meeting was merged with the previous one to ensure it was met on time. The purpose of this meeting was to discuss what content should be included in the final report, website and presentation.

- Final university report and website
  - Again the completion date for this milestone was moved once the team found they had not progressed to round 2. To ensure this was completed in time with the new date one team member was responsible for the report and one

| | |
|---|---|
| | other for the website. As per the interim report the final report was split between the full group and each member wrote a section then one member pulled it all together and formatted it. The website was worked on primarily by one team member with the support of a second member of the group. |
| • University presentation | - The group worked together to produce the final presentation and ensure that the content was appropriate to the project. Again this milestone deadline was extended when the group found the date of the presentation was later than originally planned. |
| • Detailed design phase complete | - This milestone was achieved on time and with the workload being distributed amongst the group members it was possible to successfully complete it. |
| • Video production | - The video was completed on time and produced by one of the team members. |
| • Final supervisor meeting | - The final supervisor meeting is yet to happen and will be to discuss the overall project, team achievements and fulfilment of the contract. |

### 5.5 Project objectives

Three project objectives are stated here and a reflection on whether or not they were achieved is detailed. Starting with the first objective:

*"To fully investigate and develop an idea for the eco-efficient aviation industry"*

This objective was completed successfully. The idea of utilising Knudsen pumps to aid with boundary layer control on the aircraft wing was created, investigated and developed.

*"To enter into round 1 of the Airbus 'fly your ideas' competition"*

The round one proposal for the Airbus competition was submitted ahead of schedule as a result of effective team work leading up to the deadline.

*"To work effectively as a team"*

Throughout the project, effective teamwork was applied through excellent communication, accountability and planning. As a result the team were able to achieve the milestones and objectives they set out at the beginning of the project. The majority of these were finished on time and for the few that were not the team worked together to find a solution and get the project back on track.

### 5.6 Risk management

It was important for the team to consider risk management in the initial planning stages as it prepared the team for any possible project risks and allowed a pre-planned recovery strategy to be implemented. Section 7.2 of the 'Statement of Purpose' states the following:

*"Possible absence of team members will be reviewed at weekly team meetings. This will allow workload to be redistributed and prevent delaying project deadline"*

At one of the weekly meetings a team member notified the team of his projected absence during the final idea selection stage. To counteract this, the team member prepared his research presentation a week in advance and presented it to the team. The following week, the remainder of the teams' research presentations were completed and the absentee's presentation was reviewed by the other members before a final idea was decided upon. Through risk management implementation the project was kept on time and the final idea selection milestone was accomplished as planned.

Section 7.4 of the risk management came into play as the team did not progress to Round 2. Nevertheless the project continued and necessary milestones and deliverables were met. Section 7.4 stated:

*"If progression to round 2 is not achieved the project shall continue in line with airbus competition guidelines and relevant milestones and deliverables will be met"*

### 5.7 Project Management

Throughout the first semester the team was led by one project manager who was selected during the initial planning stage. The project manager was responsible for arranging the weekly team meetings. A timetable was created that complied of each team member's availability to assist with team meeting organisation. The project manager had to ensure that the team stuck to targets and time deadlines in order to achieve the desired milestones on time and to present the deliverables to a high standard. Further to this, the manager has provided a central point of communication for the team for both internal and external communications and contacts. It is a role that has been vital to the project to ensure effective progress throughout. A different project manager was selected for the second semester to distribute the load whilst continuing to guarantee the team's aims and objectives were reached on time.

### 5.8 Planning & Control

Throughout the project an online storage utility named Dropbox has been utilised to aid with document control. This provides a secure location for team members to view, edit and upload any relevant project documentation. It ensures that only the most up to date revision of a document can be seen at any one time. It has been an effective way of allowing the whole team access to any required documentation, whilst keeping it secure and up to date.

### 5.9 Budget

As a result of the project becoming heavily research based, the resources were sourced through the university. This included software, books and research papers. A free web hosting domain was utilised and the method of video production selected resulted in no further cost. Due to this combination of factors the budget was not actually tapped into and the entire project was conducted making use of resources readily available in the university.

### 5.10 Additional Details

Further to the statement of purpose, a Gantt chart was employed to help keep the project running on time. This allowed every action to be noted and assigned an estimated length of time for completion. The Gantt chart enables the team to clearly view their progress at any point during the project.

Weekly team meetings were scheduled as a minimum and often further meetings were arranged. These were an effective method of ensuring the team was on track and each team member was suitably contributing to the progress of the project.

### 5.11 Task Allocation

Throughout the majority of the first semester each team member carried out the same tasks. Initially each member came up with five possible ideas. Following this each member took one idea, researched it further and generated a presentation on it. This was then presented to the rest of the group to enable the discussion of which one should be selected as the 'final idea'.

The round 1 proposal was written by Adnan and Jonathan as it was decided that only two group needed to work on this. In the meantime the other three team members, David, Matt and Rob prepared the second semester plan.

As the second semester work was more substantial than the first semester it had to be distributed sensibly between the team. David and Jonathan researched Knudsen pumps and then generated a calculations document on them. At the same time Adnan, Matt and Rob were researching boundary layer control. This proved to be somewhat more challenging and as a result they enlisted the help of the project supervisor Dr Stickland.

When the research was complete David and Rob produced a MathCAD sheet to generate some numerical results for the boundary layer. Adnan developed the website with some support from Matt, although Matt's main focus was the team video. Jonathan was responsible for planning the final report and pulling together the sections and suitably formatting. The team worked together on the final presentation to ensure every aspect of the project was covered and set it up so every member would be involved during presenting.

# 6 Project Summary & Concluding Remarks

## 6.1 Group Dynamic

The working dynamic of the group was good, with the division of labour evolving fluidly with the changing parameters of the project over time.

During the initial idea generation stage, the roles of each member were roughly similar, as the primary objective of finding and assessing concepts for further research required all members to participate. This meant that any aims and deadlines set by the project manager were common to each group member, and ensured that all were working at a similar pace. Furthermore, the elimination of ideas to form a shortlist and the subsequent selection of the chosen concept required cooperation between all members, as opposed to distinct sub-teams working separately. This phase could therefore be considered fairly safe in management terms, due to the common deadlines.

The following stage of the project required the completion of research on fairly separate topics, as well as several distinct deliverables and objectives, and the interaction between members was therefore slightly more independent. This change in the overall group dynamic was also taken as an opportunity to switch to a second project manager, to alleviate the extra effort required in such a role. The group was divided into sub-teams as detailed previously, and their progress was reported and displayed to the project manager, rather than being directly observed throughout.

## 6.2 Successful Outcomes

The project, viewed as a feasibility study, was considered a success. Despite not progressing through the competition, the concept was researched and proved to have the potential to increase the fuel efficiency of aircraft, and given further study, to be installed successfully. Especially given the originality and unique nature of the idea, this project has provided a sound platform for further investigation into the application of Knudsen pumps for boundary layer suction.

During the research stage of the project, distinct areas of the project (particularly those relating to boundary layer control) were found to contain complications which slowed the progress of the sub-team, threatening deadlines which had been set. Similarly, the team's progress was occasionally slowed by the unforeseen absence or unavailability of some group members. At such times, the teams were redistributed in order to speed up the lagging sections, such that all objectives could still be met.

The research style selected required negligible financial input, due to its focus on computational modelling and mathematics rather than physical testing or manufacture. In addition to the obvious monetary savings,

this also allowed for factors such as budgeting to be disregarded, allowing the team to concentrate more thoroughly on the project's objectives.

### 6.3 Reflection & Possible Improvements

The primary mode of research during both stages of the project was initially journal articles and technical papers. This approach was chosen with the aim of finding and using the applied methodology of the relevant theory and mathematical modelling techniques. However, it was later found that more helpful, basic material could be found in broader resources such as textbooks. This slower approach of building a model and an understanding from the basic principles may have proved more efficient overall.

During the idea generation stage, in order to prevent the later complications mentioned in the previous section, it may have been more effective to shorten the time over which ideas were generated, and therefore to allow more time to do preliminary research on each assessed concept. This way, the solutions to such complications could be researched early. Furthermore, an idea containing material, theory or otherwise which was likely to cause problems could be taken into account when selecting the final idea.

When selecting the idea to be taken forward for research, and to submit to Airbus for the 'Fly Your Ideas' competition, it was gradually decided that a major priority was the knowledge of the group members, all of whom were aero-mechanical engineering students. This led to the selection of an idea which was fairly in depth and aerodynamics-based. However, the ideas that were selected by Airbus to progress to the second round concerned primarily passenger experience or environmental impact. On reflection, a more universally interesting idea may have helped the team to be selected by Airbus for the second round.

Another potential reason for the group not progressing to the second round was the first round 'Proposal'. The team's focus was on the selection of a suitable and ideal concept to present to Airbus, so much so that the first round proposal was done quite swiftly assuming the idea would impress by its merit. However, a shift in the priority towards the actual presentation of the idea to Airbus, rather than the optimisation of the idea itself, may have been more successful.

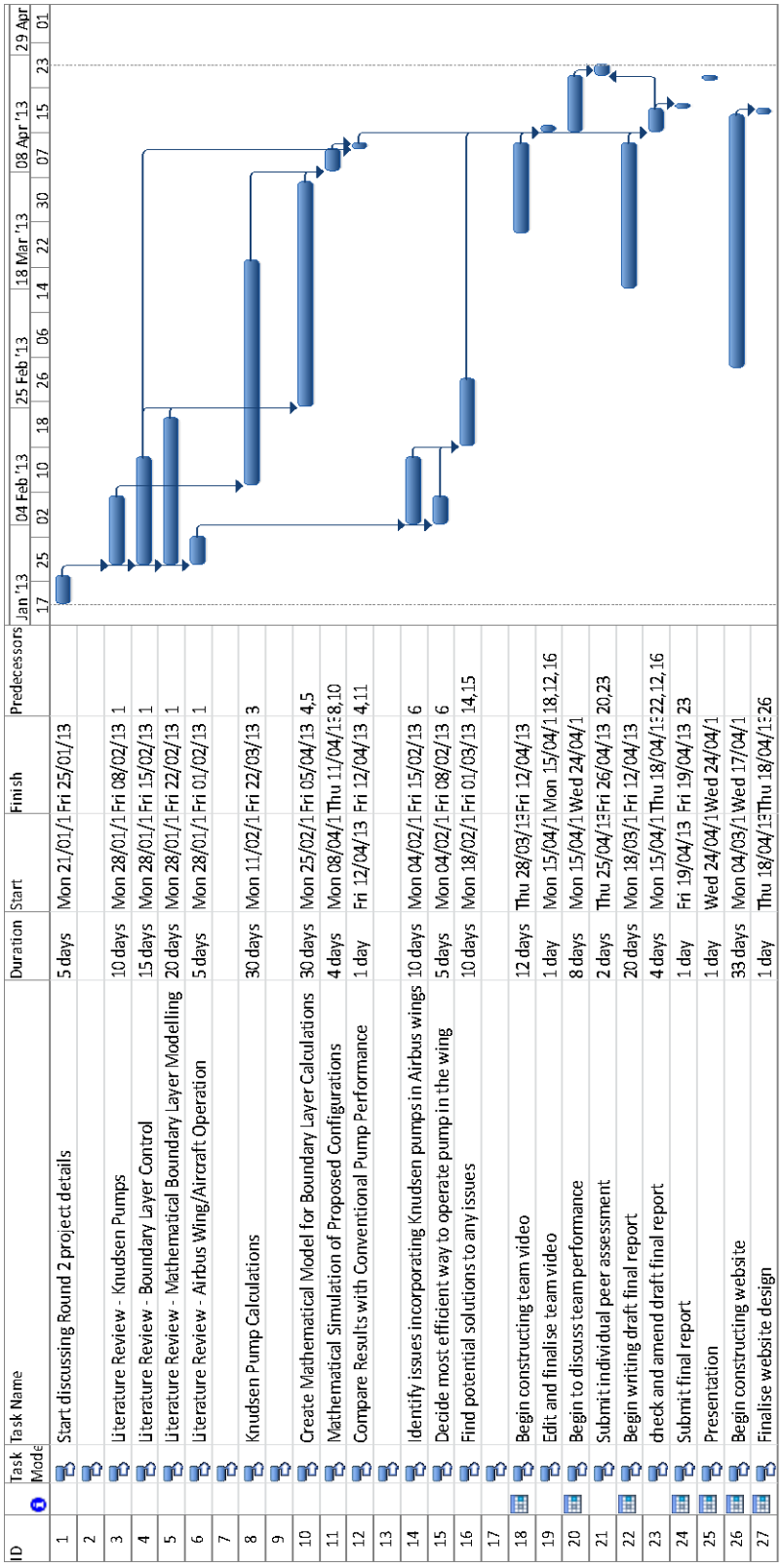
### 6.4 Concluding Remarks

In conclusion the group worked effectively together throughout the project to fulfil the objectives and milestones set out in the 'Statement of Purpose'. Formal project management tools were utilised to ensure all project goals, milestones and deliverables were met within the defined project duration. Through application of their mechanical engineering knowledge, a high level of communication and strong team work the group successfully achieved all they set out to do.

# 7 Appendices

## Appendix A

### Concept Development Gantt Chart



| ID | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 1 | | Start discussing Round 2 project details | 5 days | Mon 21/01/13 | Fri 25/01/13 | |
| 2 | | | | | | |
| 3 | | Literature Review - Knudsen Pumps | 10 days | Mon 28/01/13 | Fri 08/02/13 | 1 |
| 4 | | Literature Review - Boundary Layer Control | 15 days | Mon 28/01/13 | Fri 15/02/13 | 1 |
| 5 | | Literature Review - Mathematical Boundary Layer Modelling | 20 days | Mon 28/01/13 | Fri 22/02/13 | 1 |
| 6 | | Literature Review - Airbus Wing/Aircraft Operation | 5 days | Mon 28/01/13 | Fri 01/02/13 | 1 |
| 7 | | | | | | |
| 8 | | Knudsen Pump Calculations | 30 days | Mon 11/02/13 | Fri 22/03/13 | 3 |
| 9 | | | | | | |
| 10 | | Create Mathematical Model for Boundary Layer Calculations | 30 days | Mon 25/02/13 | Fri 05/04/13 | 4,5 |
| 11 | | Mathematical Simulation of Proposed Configurations | 4 days | Mon 08/04/13 | Thu 11/04/13 | 8,10 |
| 12 | | Compare Results with Conventional Pump Performance | 1 day | Fri 12/04/13 | Fri 12/04/13 | 4,11 |
| 13 | | | | | | |
| 14 | | Identify issues incorporating Knudsen pumps in Airbus wings | 10 days | Mon 04/02/13 | Fri 15/02/13 | 6 |
| 15 | | Decide most efficient way to operate pump in the wing | 5 days | Mon 04/02/13 | Fri 08/02/13 | 6 |
| 16 | | Find potential solutions to any issues | 10 days | Mon 18/02/13 | Fri 01/03/13 | 14,15 |
| 17 | | | | | | |
| 18 | | Begin constructing team video | 12 days | Thu 28/03/13 | Fri 12/04/13 | |
| 19 | | Edit and finalise team video | 1 day | Mon 15/04/13 | Mon 15/04/13 | 18,12,16 |
| 20 | | Begin to discuss team performance | 8 days | Mon 15/04/13 | Wed 24/04/13 | |
| 21 | | Submit individual peer assessment | 2 days | Thu 25/04/13 | Fri 26/04/13 | 20,23 |
| 22 | | Begin writing draft final report | 20 days | Mon 18/03/13 | Fri 12/04/13 | |
| 23 | | check and amend draft final report | 4 days | Mon 15/04/13 | Thu 18/04/13 | 22,12,16 |
| 24 | | Submit final report | 1 day | Fri 19/04/13 | Fri 19/04/13 | 23 |
| 25 | | Presentation | 1 day | Wed 24/04/13 | Wed 24/04/13 | |
| 26 | | Begin constructing website | 33 days | Mon 04/03/13 | Wed 17/04/13 | |
| 27 | | Finalise website design | 1 day | Thu 18/04/13 | Thu 18/04/13 | 26 |

**Appendix B**

**Statement of Purpose**


Department of Mechanical & Aerospace Engineering

ME519: MEng Group Project

# Statement of Purpose

## Airbus – Fly Your Ideas

Group L

Adnan Mahmood

David Dunsmore

Jonathan Strachan

Matheus Moschetta

Robert Adam

Supervisor: Dr Matthew Stickland

# Statement of Purpose

**It is agreed as follows:**

## 1. Mission Statement

1.1. To generate a series of ideas that benefits the eco-efficient aviation industry.

1.2. To develop one of these ideas to a level that allows the team to enter the Airbus 'fly your ideas' competition.

## 2. Introduction to Project Strategy

2.1. An idea generation stage will be completed where a selection of eco-efficient aviation concepts will be produced.

2.2. Five concepts will be carried into the detailed research stage.

2.3. A final idea will be agreed from the five shortlisted ideas.

2.4. A university interim report will be produced based on the work carried out in semester 1.

2.5. Airbus 'fly your ideas' competition round 1 proposal shall be entered based on the final idea.

2.6. During semester 2, a detailed design phase development involving further research, experimental testing and analysis will be carried out.

2.7. A final detailed report and team video will be produced in correspondence with the Airbus 'fly your ideas' competition round 2 guidelines.

2.8. A university final report and presentation will be produced along with a website design based on the work carried out in both semester 1 and semester 2.

## 3. Project Security and Privacy

3.1. All project data and information shall be kept between the group and project supervisor.

3.2. In the event of the team qualifying for round 2, the assigned Airbus mentor shall also be included in project details.

## 4. Project Aims

**The main project aims and objectives are as follows:**

| Milestones and deliverables | Date completed |
|---|---|
| Concept shortlist (5 ideas) | 24/10/12 |
| Final project idea selection | 09/11/12 |
| Supervisor meeting | 12/11/12 |
| Interim university report | 23/11/12 |
| Round 1 proposal | 07/12/12 |
| Develop semester 2 plan | 14/12/12 |
| Supervisor meeting | 21/01/13 |
| Detailed design phase results | 01/03/13 |

| | |
|---|---|
| Supervisor meeting | 04/03/13 |
| Supervisor meeting | 18/03/13 |
| Final university report and website | 22/03/13 |
| University presentation | 25/03/13 |
| Detailed design phase complete | 12/04/13 |
| Video production | 26/04/13 |
| Final supervisor meeting | 30/04/13 |

## 5. Project Objectives

5.1. To fully investigate and develop an idea for the eco-efficient aviation industry.

5.2. To enter into round 1 of the Airbus 'fly your ideas' competition.

5.3. To work effectively as a team.

## 6. Project Organisation and Implementation Strategy

6.1. Each team member will generate at least five possible ideas during the idea generation stage.

6.2. The concept shortlist shall be created via a group discussion.

6.3. Each team member will carry out further research on one idea from the concept shortlist and present their findings to the team at final project idea selection meeting.

6.4. Sections of the project interim report will be assigned to each team member with two team members compiling and formatting the final draft. The other three team members shall focus on the round 1 proposal.

6.5. A plan outlining budget, resources, testing and development shall be constructed before the end of semester 1.

6.6. The sections of the detailed design phase will be split between group members. These sections will be decided during the planning stage at the end of semester 1.

6.7. The final project report will be written using a similar structure to the interim report. The three team members not editing the final project report will focus on creating the project presentation.

6.8. One team member will take charge of video production and one team member will be responsible for the project website.

## 7. Risk Management

7.1. If specialised equipment is required during the project, it may need to be sourced externally and could be late or unavailable. In order to combat this, action will be taken to reserve/locate this equipment at least a week in advance of the requirement. Furthermore, where applicable, an alternative source will be researched for any equipment.

7.2. Possible absence of team members will be reviewed at weekly team meetings. This will allow workload to be redistributed and prevent delaying project deadlines.

7.3. As a standard risk management measure, any required health and safety regulations will be adhered to throughout the course of the project.

7.4. If progression to round 2 is not achieved the project shall continue in line with airbus competition guidelines and relevant milestones and deliverables will be met.

**8. Project Management**

8.1. The team will be coordinated by 2 project managers over the course of the project.

8.2. Manager 1 will lead the project during semester 1.

8.3. Manager 2 will lead the project during semester 2.

**9. Planning and Control**

9.1. Over semester 1, the project manager will be responsible for all planning and control.

9.2. At the end of semester 1 a detailed planning phase will be constructed for semester 2.

9.3. Over semester 2 the project manager will be responsible for ensuring project milestones are met on time.

9.4. A weekly team meeting will be held every Monday to review project progress.

9.5. At major milestones a meeting with Dr Stickland will be arranged.

**10. Document Control**

10.1. All documents will be stored and accessed on dropbox, an online storage utility. This will ensure that there are no multiple versions of any collaborative document, and provide constant secure access for all team members.

**11. Budget**

11.1. The team budget will be managed by one group member. Possible expenditures may include the following:

- Website hosting
- Video production (camera rental, software acquisition)
- Travel expenses (site visits)
- Equipment
- Software
- Printing
- Materials
- Relevant Literature

11.2. Should the team win any prize money the initial budget provided by the university shall be returned. The remainder of the winnings shall be shared equally amongst the team members.

**All agreements between the team and supervisor related to the specified work are included in this contract.**

**The names listed below agree to meet the terms of this contract.**

| **Team Members** | | | **Supervisor** | | |
|---|---|---|---|---|---|
| **Name** | **Signature** | **Date** | **Name** | **Signature** | **Date** |
| **Adnan Mahmood** | **:_____** | **____** | **Dr Matthew Stickland** | **:_____** | **____** |
| **David Dunsmore** | **:_____** | **____** | | | |
| **Jonathan Strachan** | **:_____** | **____** | | | |
| **Matheus Moschetta** | **:_____** | **____** | | | |
| **Robert Adam** | **:_____** | **____** | | | |