Investigation into the Application of Winglets on Canards for Tip Vortex Position Improvement

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The canard configuration offers a number of advantages over the conventional tail aft arrangement and has been successfully used since the earliest years of aeroplane flight. The canard configuration has a significant disadvantage in that the trailing tip vortices can interfere with the wing which is the main lifting surface of the aircraft. Winglets attached to the canards are a potential means of relocating the vortex to a more desirable position. The aim of this project is to visually investigate the tip vortex position improvement the winglet will have on a canard. This achieved through the use of wind tunnel testing of the canard configuration and determining the relative change in position of the tip vortex with the addition of a winglet, supported with CFD analysis.

Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>ADFA</td>
<td>Australian Defence Force Academy</td>
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<tr>
<td>CFD</td>
<td>Computational Fluid Dynamics</td>
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<tr>
<td>QFD</td>
<td>Quality Functional Development</td>
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<td>UNSW</td>
<td>University of New South Wales</td>
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Nomenclature

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<th>Symbol</th>
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<tr>
<td>( c_t )</td>
<td>Tip chord of wing less winglet</td>
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<tr>
<td>( c_{wr} )</td>
<td>Root chord of winglet</td>
</tr>
<tr>
<td>( c_{wt} )</td>
<td>Tip chord of winglet</td>
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<tr>
<td>( h_w )</td>
<td>Height of winglet</td>
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<tr>
<td>( l_w )</td>
<td>Front-view length of winglet</td>
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<tr>
<td>( s )</td>
<td>Semi-span of wing (less any winglets)</td>
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<tr>
<td>( s_a )</td>
<td>Semi-span of wing (including winglet)</td>
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<tr>
<td>( t )</td>
<td>Distance from point on winglet to wing/winglet junction</td>
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<tr>
<td>( \phi )</td>
<td>Angle between mean plane of winglet and wing plane of symmetry</td>
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I. Introduction

The canard configuration has been utilised in aircraft design as early as the first Wright Brothers airplane took to the skies in the early 1900s with its control surfaces ahead of the main lifting surfaces to take advantage of the undisturbed flow (Raymer, 2006). The canard configuration offers other important performance advantages over the more conventional aft tail arrangements; however, it suffers from an inherent issue with the canard’s tip vortex interfering with the aerodynamics of the main wing. Significant detailed design analysis has been undertaken into the longitudinal and vertical positioning of the canard and wing surfaces to reduce the interference caused by the canard tip vortex but another unexplored improvement exists in the addition of a winglet to the canard. The incorporation of a winglet to a wing will result in a relocation of the wing tip vortex to the tip of the winglet (Barnard & Philpott, 2004). The addition of a winglet to a canard should theoretically move the canard tip vortex to the tip of the canard winglet and if the winglet is appropriately sized the vortex will be in a more aerodynamically favourable position relative to the main wing.

A. Aim and Scope

The aim of this project is to visually investigate the tip vortex position improvement of a winglet on a canard. This investigation will aid in the improvement of canard positioning on aircraft in particular their flow field interactions with the main wing. This investigation will involve construction and testing of a simple canard configured model in the outflow of the UNSW@ADFA low speed wind tunnel and visually identifying the positional control a winglet has on the canard’s tip vortex. Once the visual investigation of tip vortex position improvement is complete a CFD analysis will be conducted to complement the physical testing.

\(^1\) ZACM4049/4050 Aeronautical Engineering: Project, Thesis & Practical Engineering.
Due to the high levels of complexity possible in the design of a canard configured aircraft, the intent will be on simplifying the model design for ease of construction and testing but able to be applied to a range of canard configured aircraft design variations.

B. Limitations
The conduct of this thesis is restricted to a two-semester period in which a literature review is to be conducted, a canard with winglet and wing model designed and built and flow visualisation testing conducted in the wind tunnel. Ideally, if time allows a CFD analysis of the canard with winglet vortex flow position will be carried out after education into the conduct of CFD analysis and computer based model design is carried out. Any funding and availability of CFD training courses or facilities has not been determined as yet for the period it is planned for. Additionally, the two-semester period will be separated with a stand-down period at the end of the academic year. During this period there is potential for interruption to the progress of the project as key support staff and facilities become unavailable due to closure over the Christmas period.

C. Project Management
The client brief for this project is attacked at Appendix 1 In order to meet the aim of this project a project plan was developed utilising fundamental project management techniques. Included at Appendix 2 is the original project plan document which broadly outlines this thesis project and Appendix 3 is the Gantt chart from the project plan showing its diagrammatic representation. Contained within the project plan document is the risk analysis, milestone chart and task breakdown structure.

II. Literature Review
The scope of the literature review for this thesis project was contained to four main areas: aerodynamic benefits and design detail of winglets, design requirements and issues on canards, flow visualisation and CFD analysis.

A. Aerodynamic Benefits and Design Detail of Winglets
Winglets are most simply described to be a near vertical extension of the wingtip which has the function relocating the tip vortex of a wing above and outwards of its normal location (Aircraft Technology, 2007). However, before describing the aerodynamic benefits and design of a winglet, an introduction into vortex generation and why they should be relocated must be understood.

Lift is physically generated by the net imbalance in pressure forces from low pressure above the wing and high pressure below and acts perpendicular to the relative airflow (Anderson, 2007). At the wing tips the higher-pressure air at the bottom of the wing curls around to the top of the wing (Raymer, 2006). This results in a spanwise component of flow along the wing and a circulating flow from the wing tips downstream of the wing which is the trailing vortex. The rotation of air behind the wing produces a downward component of velocity of air behind the wing known as downwash (Anderson, 2007). The effect of downwash is that the undisturbed air is inclined downwards around the wing which in turn tilts the lift force backwards (Bertin & Cummings, 2009). The inclination of the lift force due to the downwash has a component which acts rearward called induced drag which opposes the motion of the wing in forward flight (Anderson, 2007). Thus, the production of lift generates wing tip vortices which in turn cause downwash and induced drag.

Figure 1. Wing with Upper Winglets (Freestone, 1998)
Raymer (2006) suggests that an obvious solution would be vertical plate mounted on the wing tip thus preventing the circulating flow from below to above at the wing tip; however he also acknowledges that the addition of a large vertical surface in turn produces its own drag thus reducing any potential benefit in induced drag reduction. Richard Whitcomb is attributed for the modern development of the winglet and it was his research in the 1970s that showed their aerodynamic benefits when applied to transport aircraft (Smith, Komerath, Ames, Wong, & Pearson, 2001). Whitcomb (1976) recognised the benefits of wingtip devices in reducing the drag produced by the wing and experimented with his design of a large primary surface located at the rear and above the wing tip. His research into previous wing tip devices discovered that they excluded the examination of vertical surfaces producing side forces to ‘reduce the lift-induced inflow above the wing tip’ and diffuse the strength of the vortex generated at the wing tip, thereby reducing the induced drag (Whitcomb, 1976).

A winglet in its simplest form (as shown in Figure 1) resembles an aft swept wingtip extension of smaller chord turned upward from the plane of the wing to between 15 and 45 degrees from the vertical with the trailing edges of the wing and winglet aligned at their junction (Freestone, 1998). The junction of the winglet and wing is not always sharp and can be blended to reduce the interference drag in the transition area (Aircraft Technology, 2007). Winglets have a slight ‘toe-out’ so as to have a slight angle of attack to the circulating air at the wing tip. This produces a sideward lift component on the winglet resulting in its own vortex system at the winglet tip. The winglet’s vortex acts against the vortex generated at the wing tip to partially reduce it in strength, which effectively results in the major tip vortex of the wing forming at the tip of the winglet. Now that the main tip vortex is at the winglet, it is above and outside the normal plane of the main wing consequently reducing the effects of downwash and the subsequent development of induced drag (Barnard & Philpott, Aircraft Flight, 2004). In addition to the vortex reduction and reposition, the sideward lift component, acting perpendicular to the incoming circulating flow, can produce a forward acting component of force. This effectively contributes to the thrust of the aircraft reducing the total aircraft drag (Lan & Roskam, 2003).

Complex winglets, not unlike Whitcomb’s initial design shown in Figure 2, consist of both a larger upward and smaller downward turned elements, with the smaller down turned element positioned forward of the larger upward element (Freestone, 1998). Whitcomb’s rationale for the forward placed smaller winglet below the wing tip is to compliment the reduction in induced velocity encountered by the larger winglet above the wing tip at higher coefficients of lift such as in takeoff and landing. However, they are often less than optimum in size due to ground clearance issues but Whitcomb’s experiments concluded that even a shortened winglet will improve the overall effectiveness of the winglet.

**Figure 2. Wing with Upper and Lower Winglets (Freestone, 1998)**

A canard configuration is an alternative to the more common aft mounted tail arrangement with the major difference being that having the canard mounted at the front of the aircraft places the control surfaces in undisturbed air allowing for greater controllability (Raymer, 2006). In the aft tail arrangement the aft control
surfaces will inevitably encounter disturbed air from the main wing in some if not all aircraft conditions, depending upon their arrangement and location. Additionally, in trimmed stable flight an aft tail arrangement usually produces a down force which must be countered by additional lift produced by the main wing. An aircraft with a canard configuration in trimmed stable flight produces an upload on the canard which contributes to the overall lift of the aircraft (Thompson, 1992). Since both the canard and main wing surfaces are producing positive lift, the total wing area, weight and drag of the aircraft may effectively be lower than the conventional tail aft arrangement (Barnard & Philpott, 1995). When the canard is used as a control surface, a downward elevator deflection will result in an increase in the lift to pitch the aircraft’s nose up and an upward deflection would pitch the nose down. Due to the canards relative position in undisturbed air flow, operation of the elevator control will produce an immediate response which is more favourable in pitch control (Barnard & Philpott, Aircraft Flight, 1995).

The major advantage of the canard configuration is it can be designed to have improved safety in the stall. A canard designed with a higher aspect ratio or increased angle of attack compared to the main wing will be encouraged to encounter stall before the main wing. Since the canard is designed to stall first, the centre of gravity forward of the main wing will result in a nose down pitching moment precluding main wing stall (Raymer, 2006). Another advantage in design that the canard configuration has is in pressurised passenger aircraft. The main wing spar is allowed to pass behind the pressure cabin reducing the complexity in internal structural design and strengthening such as in the Beech Starship shown in Figure 3 (Barnard & Philpott, Aircraft Flight, 1995).

The canard configuration is not faultless, as having a small wing at the front of the aircraft will inevitably result in downwash and trailing vortices which will interact with the main wing and major lifting surface of the aircraft (Tu, 1996). However, with proper positioning and sizing these interactions can be favourable by increasing the maximum lift coefficient and delaying stall (Ma, Liu, & Wei, 2004). This is most often found in highly swept canard configurations where the canard’s vortex can be made to interact with the leading edge vortex of the trailing wing to increase its overall strength and produce greater lift (Raymer, 2006). In contrast a more conventional low-to moderate sweep and higher aspect ratio wing will not receive the fore-mentioned favourable lift augmentation through vortex interaction. Tip vortices from the canard will cause downwash on the main wing inboard of the canards span, effectively decreasing the effective angle of attack and therefore the amount of lift generated (Raymer, 2006). Outboard of the canard tip vortex the main wing will receive the opposite effect in upwash, which may potentially lead to wing tip stall.

David Lacey (1979) conducted a four volume experimental study on the effects of canard geometry, position and deflection on aerodynamic loads in the subsonic to supersonic regimes. Generally, for favourable interference the canard must be within 1.5 wing-chords of the wing quarter chord, slightly above or in plane with the wing and to maximise the lift to drag ratio it must have a low sweep, high aspect ratio and a small negative deflection (Lacey, 1979). However, Lacey’s studies and the majority of canard research is mostly concerned with the improvement of close-coupled canard configurations for application on highly swept and delta wing aircraft designs with many of these aircraft operating an all moving canard and outside the scope of this project.

C. Flow Visualisation
Gerard Markham previously undertook research in 2008 into flow visualisation techniques for his thesis project utilising the UNSW@ADFA low speed wind tunnel. His thesis project involved the testing of a half scale model of an Unmanned Aerial Vehicle with a canard configuration (Markham, 2008). Due to the similar nature of the scope of testing and the research Markham conducted into alternative methods of flow visualisation, the author has decided to also utilise the wool tuft flow visualisation technique in this thesis project.
Tuft visualisation involves the attachment of an array of tufts across the surface of the tested object to observe the flow conditions across the surface. Each individual tuft is a point indicator of the local flow direction which when combined with the indications from neighbouring tufts arranged across the rest of the surface, they provide a visual indication of the flow behaviour across the entire surface (Crowder, 1989). Tufts are useful in discovering regions of backflow and strong cross-flow and whether the flow is attached or separated (Shapiro, 1963). The technique itself has the advantage of being easily implemented with readily available materials and equipment. Conventional tufts can be deceptive with their apparent simplicity, consisting of short pieces of flexible string or yarn allowed to move freely under the influence of a flow when attached to a surface. However, tufts effectiveness in indicating flow behaviour is dependent upon the material properties in response to the flow conditions (Crowder, 1989). When selecting tuft material it must have flexibility and durability to bend about its attachment point but also be large enough for the flow behaviour to be observed in the flow regimes for which it will be experimented (Shapiro, 1963).

For low-speed wind tunnel testing under white light the recommended tuft length is around 2 to 3 centimetres and spaced evenly in an array across the surface no closer than the tuft length to avoid tangling and interference between tufts (Crowder, 1989). Attachment is commonly achieved with adhesive tape or glue and requires considerable time and effort to attach each tuft to a surface individually (Lanser, Botha, & Crowder, 1995). As this flow visualisation method has been applied many times in the past several time saving methods have been developed. Amongst these is the tuft board method produced by Crowder (Tufts, 1989) which is used to make lengths of adhesive tape with the tufts already attached for ease of application to a surface.

In addition to the surface visualisation method, visualisation of the flow field at positions around a surface, such as tip vortex generation and downwash, can be achieved through the application of a tuft grid. The tuft grid consists of tufts attached to the intersections of a wire grid and mounted cross-plane and perpendicular to the flow. When the tuft grid is set up downwind of a surface such as a model wing they will indicate the flow direction in the flow field off the model as seen in Figure 4 (Crowder, 1989). Streamers, which are essentially just longer tufts, may also be applied singularly at key locations such as at wing tips to potentially indicate the flow of a vortex. Figure 5 shows how streamers can be attached to the leading edge of a surface to indicate the surface flow angle. Crowder (1989) warns that when using streamers they can develop the tendency for dynamic instabilities resulting in a whipping motion at the tip which may provide false visualisations of the flow, not to mention the potential for tangling with any adjacent tufts or surface features.

Figure 4. Tuft grid in wind tunnel (Crowder, 1989)

Figure 5. Leading edge surface streamers on wind tunnel model (Crowder, 1989)

D. CFD analysis

CFD has had a relatively short history which started in the early 1970’s as a means of simulating transonic fluid flows. As computer technology advanced the applications of CFD also improved with solutions to the two-dimensional and three dimensional Euler equations becoming feasible in the 1980’s. Further advances in computer speeds and numerical acceleration techniques in the mid 1980’s encouraged the simulation of viscous flows governed by the Navier-Stokes equations and the computation of fluid flows past complete aircraft configurations (Blazek, 2005). CFD involves replacing the partial differential equations that govern the means of solving fluid problems, with discretized algebraic equations, and then numerically solving them to find the properties of the flow at any point in space and time (Munson, Young, & Okiishi, 2006).

The major formulations used in simulating flows in CFD are the Navier-Stokes and Euler equations. The Navier-Stokes equations are based on the principles of conservation of mass, momentum and energy and are assumed to describe all significant aspects of incompressible and compressible viscous flows (Cebeci, Shao, Kafyeke, & Laurendeau, 2005). The Euler equations are a more simplified form of the governing equations that make up Navier-Stokes, and describe the flow of inviscid fluids. Generally, most CFD is conducted with the
Navier-Stokes equations as they provide a higher quality simulation of flow computations but Euler may be utilised as an alternative depending upon the complexity and nature of the problem (Blazek, 2005).

The increased use of CFD has now meant that it has become one of the principle means of determining the aerodynamic qualities of a design, alongside wind tunnel and flight testing (Bertin & Cummings, 2009). In aircraft applications CFD is not used as a replacement of wind tunnel and flight testing but rather to compliment it, as it allows a designer to determine the entire flow field behaviour around an aircraft which is difficult to fully obtain in wind tunnel analysis and through flight testing. Designers often conduct CFD analysis of a computerised design prior to wind tunnel testing and make refinements within the computer based models to attain the desired characteristics. A CFD tested model is only an estimate of its real characteristics and must be confirmed with physical testing to gain an appreciation of its actual characteristics. CFD estimates are commonly only within a small percentage of error of those obtained in physical testing and often only minor adjustments are required on a test item to meet desired design characteristics, thereby reducing the design costs associated with trial and error methods conducted before CFD was possible (Raymer, 2006).

III. Anticipated Progress of Project

The following is an expansion on key tasks within the initial project plan document formulated at the beginning of this project (Appendix 2).

A. Literature Review

In the initial project plan the literature review was originally contained within the task titled Model Construction, but has been separated into its own distinct task so as to encompass a wider body of research topics not restricted to that effecting model design and construction.

In these initial stages of the project a detailed literature review is to be conducted on canards, winglets, flow visualisation and the basis behind CFD analysis. The aim of this review is to determine the respective design requirements and aerodynamic behaviours of the canard configuration and winglets and determine how they can be combined for vortex positional control. In addition to vortex position control the physical characteristics of the canard configuration are researched for development of a functional test model for wind tunnel testing. Once research on the design aspects of a canard configured model is complete a review of winglet geometry must be carried out for attachment to the canard tip.

Research into flow visualisation will also be conducted in the literature review to determine a visualisation technique that will allow the determination of vortex positional control on a model that can be easily applied to a model for wind tunnel testing which is simple and repeatable. Also included in the literature review are studies into the conduct of QFD analysis to aid in the successful design and development of a model that meets the aim and scope of the project as well as assist in the conduct of other stages of the project.

B. Model Construction

The model design process will undergo a basic QFD analysis used to ensure that the ultimate design of an item reflects the requirements of the customer. The purpose of undertaking a QFD for the model in this project is to ensure that the projects necessary requirements are established and translated into technical solutions (Blanchard, 2004). A part of the QFD and model design phase is a wind tunnel analysis is carried out to ensure adequate scaling and aerodynamic qualities are identified and the model is appropriately built.

The model design will incorporate canard and wing surfaces with the ability to add a winglet to the canard and be sized accordingly to be accommodated on a test bench for use in the outflow of the UNSW@ADFA wind tunnel. Additional model requirements may evolve from the literature review and will be analysed appropriately during the QFD process, however, fundamentally the design will be of a simple nature to allow for ease in construction and testing. Due to the symmetrical nature of aircraft about the

The final phases in this stage will involve purchasing materials and construction of the models. Funding for the purchase of materials may be sort, however, this may prove to delay the project unnecessarily and it may simply be at the project manager’s expense to avoid any inconveniences. The types of material used will be determined in the design process, but for simplicity, it should be of a type readily available and easy to work with.

C. Testing

The constructed models will undergo testing in this phase to investigate the effect of winglets on the canard and their effect on the position of the wing tip vortex. A setup and adjustment phase will be conducted to allow
for any changes to be incorporated and to ensure proper positioning and visualisation of the model during wind tunnel testing. A series of tests will be conducted to ensure consistent and definitive results are established and that they conform to the aim and scope of the project. The major focus of the testing will be on the effects of adding a winglet to the canard and its resultant effects on the position of the trailing tip vortex. Therefore, the model will first undergo testing with just the canard and wing and the position of the canard’s trailing tip vortex in this configuration will be determined. Determination of the canard’s trailing tip vortex may require several tests in the wind tunnel to optimise the conditions for visualisation. Once testing in the canard and wing configuration is completed the addition of the winglet to the canard will be tested and the relative change in location of the trailing tip vortex determined. Finally a comparison and analysis of the results will be conducted with the potential determination of whether or not additional variation or testing is required. If the project allows time for the conduct of additional testing of variation, potential feature of examination can include variation in the winglets geometry in height, inclination or size or the overall position of the wing and canard.

D. CFD Analysis

CFD analysis is the final stage of this project and will require additional literature review on the application and use of CFD for this project. In addition to the literature review is tuition and studies on the use of CFD and the design and modelling of computer based drawings of the canard and wing configuration with the integration of the winglet. The aim of this stage is to initially develop the necessary skills and knowledge to conduct a basic CFD analysis of flow field behaviours. Once the necessary skills have been developed and honed a two dimensional canard and wing aerofoil cross-section analysis will be undertaken as a first step. Once the criteria for two-dimensional flow analysis are completed the canard and wing sections are developed into a threedimensional representation and the tip vortex generated by the canard will be analysed. The final stage will be the incorporation of the winglet to the canard tip and analysis of the change in position of the tip vortex.

The entire conduct of the CFD testing is based upon the successful accomplishment of some form of training in the use of CFD and even then, the ultimate aim of determining the simulation of a canard with winglet flow field analysis may not be possible. To ensure that the CFD portion of the project is carried out a substantial portion of the project timeline has been allocated with the potential for increase as required.

IV. Progress to Date

At the time of writing this report, the planning associated with the project had been completed and project plan documentation compiled and submitted. A comprehensive literature review has been conducted on the canard configuration, winglets and flow visualisation techniques and the benefits and applications of CFD as an analysis tool have been investigated for the later stages of the project. The next stage in the project is the design and development of the model for flow visualisation testing. Preliminary planning using the QFD process has determined the major customers and their requirements. Preliminary model designs to meet the requirements established in the QFD process are based around a test bench positioned in the outflow of the UNSW@ADFA low speed wind tunnel. Aircraft symmetry about the centreline has resulted in the decision to only model one half of an aircraft’s canard and wing surfaces, which will be orientated and mounted with their spans vertically so as to allow ease of viewing of both sides of the model’s surfaces and to simplify the test bench.

Simplification of the model’s design is paramount with early designs of the canard and wing surfaces having no camber but allowed to be repositioned in the relative longitudinal and vertical planes and able to pivot to various deflections so as to optimise tip vortex development and interference characteristics of the canard on to the main wing. Design of the canard will incorporate a squared off wingtip to further encourage vortex development and also provide a good surface in which to mount a winglet. An additional canard design feature which encourages vortex development is a low aspect ratio which with the restrictive size of the UNSW@ADFA wind tunnel outflow may prove beneficial in terms of geometric sizing. Simplicity of the design can be achieved by having both surfaces with no taper or sweep, however, this may not be representative of the majority of canard configured aircraft designs and may be adapted following conclusion of the QFD process.

The nature of the winglets in the models design is still in development, but central to their design is simplicity and the ability to relocate the position of the tip vortex. Design features of the winglet for consideration in the QFD process include the options of a blended or straight junction, variations in height and inclination angle from the wing plane. The possibility exists for multiple winglet designs that can be interchanged and compared if time and resources permit.

The materials used in the construction of the wing, canard and winglet will consist of a foam core solid structure, strengthened with wooden skewers or rod covered in shrink wrap to simulate the surface of an
aircrafts skin. Wing, canard and winglet sections will be shaped using the method utilised by Markham (2008) in his thesis project with balsa wood end pieces cut to shape to provide a guide for the shaping of the foam core solid structure. The existence of a model fuselage is not critical to the scope of this experiment and will more than likely consist of a structure made from whatever materials are left available shaped into a rough representation of a fuselage with no significant details.

The visualisation technique selected will be the wool tuft technique with the tuft material characteristics such as type, length, spacing and arrangement dictated by a wind tunnel analysis and the QFD process. The canard, wing and winglet devices will have an array of tufts on both the top and bottom surfaces to visualise their respective flow field effects. A tuft grid will be used in conjunction with streamers attached to the trailing edge of the canard and winglet tips so as to gather a visualisation of the trailing vortex generated from these surfaces.

Upon completion of the QFD the design specifications of the model will be complete and material purchasing and construction can begin, paving the way for the testing stage of the project.

**VIII. Summary**

Initial research has determined the aerodynamic advantages and design of the winglets for integration to a lift producing surface such as a wing or canard so as to reposition the tip vortex of the surface to which it is incorporated. In addition to this a review of the design requirements and issues associated with the canard configuration has been carried out and the nature of the canard tip vortex and the interference effects it has on the main wing determined. Flow visualisation has been researched in particularly the wool tuft method for use on testing of models in wind tunnel analysis. A brief study on the use of QFD in flow field simulation affirmed this technique as an excellent means of confirming physical experiments in the wind tunnel. The next stage in the project is to finalise the QFD process used in aid of the model design and development so as to move to the next stage, which is the wind tunnel testing of the model and visualisation of canard tip vortex position control through the addition of a winglet.

**References**


**Appendices**

Appendix 1: Client Brief
Appendix 2: Project Plan Documentation
Appendix 3: Project Timeline