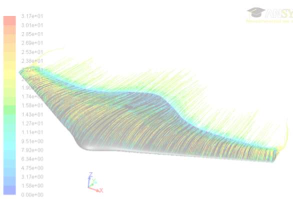
# AMRC
Design and Prototyping Group

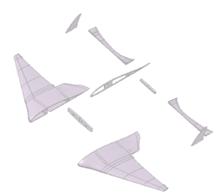
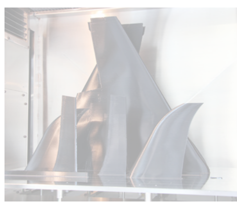
Case study

The University Of Sheffield.
Advanced Manufacturing Research Centre
BOEING

# FDM Printed Fixed Wing UAV



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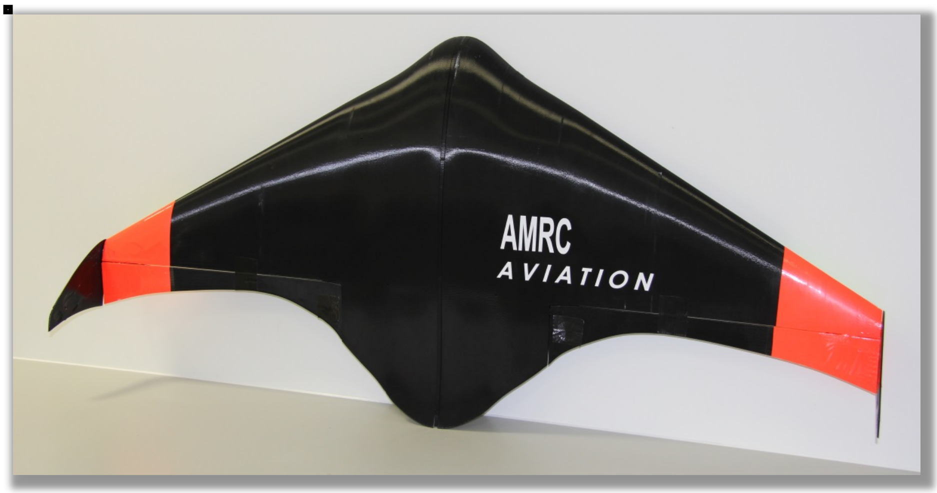
DPTC Case Study

# FDM Printed Fixed Wing UAV

AMRC Design and Prototyping Group

A team of engineers from the AMRC's new Design & Prototyping Group (DPG) have designed, manufactured and flight tested a prototype Unmanned Aerial Vehicle (UAV) airframe constructed entirely of ABS plastic, using Fused Deposition Modelling (FDM) technology.




The recent increase in the use of both additive layer manufacturing and UAVs has led to the availability of a number of 3D printed UAVs for a range of applications. Small wingspan, fixed wing aircraft are used for applications ranging from hobby flying to reconnaissance and humanitarian aid. Key drivers in the development of these vehicles are manufacturing lead time and cost, with additional focus on ease of assembly. With this in mind, the DPG undertook an internal project to design and build a low cost UAV airframe in ABS using their Stratasys Fortus 900mc FDM machine. For printing relatively large components such as a UAV airframe, FDM technology was chosen over stereo lithography and selective laser sintering for its lower initial investment, material cost and simplified process.

Ordinarily, an FDM built aircraft would require significant amounts of support material around its component parts to prevent the airframe structures from deforming during the build process. Using support material adds a direct material cost, and significantly increases build time, in some cases by an order of magnitude. This is a result of the machine having to change between build and support structure heads after each printed layer. A more efficient self-supporting design is however constrained to a maximum angle in the machines vertical orientation (layer height). This requirement places onerous geometrical constraints upon the designer, particularly for a small aircraft operating at low Reynolds numbers, where performance depends largely upon a complex combination of specific and accurately orientated geometrical forms.

The manufacturing aspects of the project were led by Additive Manufacture Development Engineer Mark Cocking:

*"By understanding the capability of the FDM process & associated software, we were able to manipulate the design to contain a number of unique features as well as preventing build deformation. All parts required for the airframe can be combined onto a single build within the DPGs Fortus 900 machine, taking less than 24 hours with ABS-M30 material. Before design for additive manufacture optimisation, this airframe would take over 120 hours to produce."*

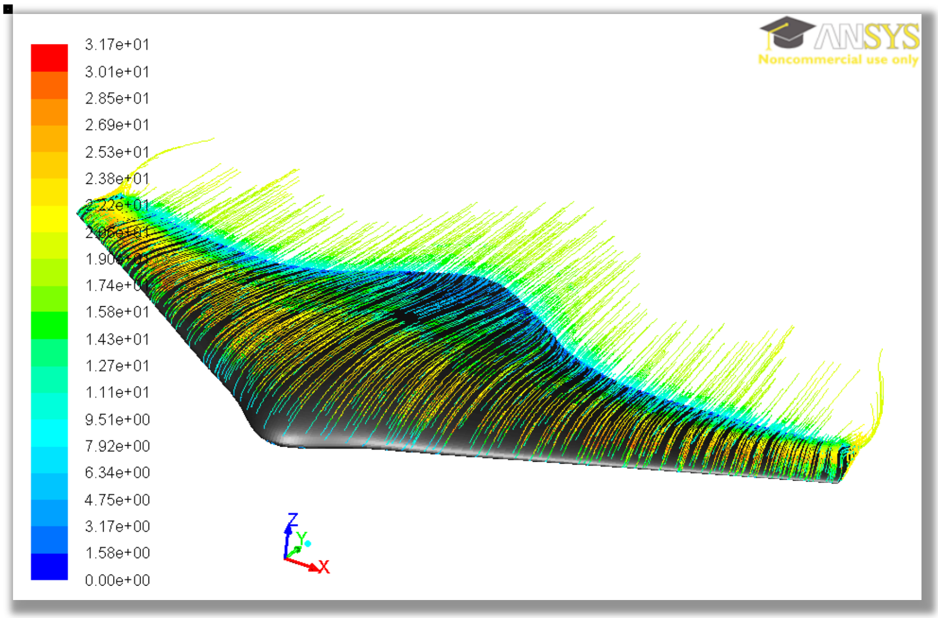

With these constraints in mind, a number of conceptual CAD models were created for evaluation. A range of configurations, sweep angles, chord lengths, taper ratios and aerofoil sections were considered. Development Engineer John Mann was responsible for detail design and CAD modelling of the aircraft:

*"The whole airframe was designed specifically for additive manufacture. The optimum configuration for the diverse requirements of aerodynamic performance and FDM manufacture appeared to be the blended-wing-body. This type of design has a number of advantages: Primarily for this project, it lends itself to FDM technology due to the smooth leading and trailing edges over each half-span. "*

This configuration allowed all geometry to remain below the critical angles beyond which support material would be required. In addition, the aerodynamic advantages over conventional fuselage and wing designs, and its potential as a testing platform for a range of new technologies were considerations during the down selection process.

Computational Fluid Dynamics (CFD) was used to optimise the chosen design and to assess the lift, drag, pitching moment and other characteristics over a range of angles of incidence. Sam Bull, Development Engineer, conducted these analyses:

*"The final configuration comprised two aerofoil sections blending from a thick, reflexed section in the body to a thinner, conventional section on the outer wing. The trailing edge was extended aft near the centre, where the reflexed aerofoil aids the longitudinal stability of the tailless design."*




The FDM process also allowed the design to incorporate swept wings with straight leading edges, suited to the low Mach number flight regime the UAV would operate in.

The airframe comprises just nine parts, all of which are built using the FDM process: Two wings, two elevons, two spars, two wing end fences and a central spine. None of these components require support material during build. The aircraft was designed to split into two halves about the central spine. This configuration allowed a larger wingspan to be built within the FDM machines build envelope, and made transportation easier. A pair of short spars (front and rear) clip into sockets formed within each wing half, giving a rapid set-up time for flight. The low part count contributes to the rapid manufacturing time for the airframe. The airframe has a wingspan of 1.5 metres, and weighs under 2kg.

The internal structure of the wings is a semi-monocoque which has to serve a number of purposes:

- The unsupported thin walled structures have to withstand becoming distorted as the build height increases during manufacture.

- Aerodynamic loads around the aerofoil in flight act to distort the skin and create bending moments, especially in manoeuvres. The wing structure has to withstand these loads.

- Due to the requirement to minimise fixings and reduce part count, the structure has to incorporate a solution for ease of assembly of the two wing halves. In this case, two locating spars are used to snap the wings together without any additional fixings, while adding rigidity and strength to counteract launch and flight loads.

The control surfaces, in this case trailing edge elevons, were designed to snap fit onto two hinges that protruded from the outer wing section. Elevon control is by means of a direct acting servo in each wing. The servos are fixed onto mounting spigots housed within the aft section of the body. The wing tips are capped by flat end fences which clip into the ends of the aerofoil sections, closing them to span wise airflow and helping to reduce induced drag. The wing end fences also provide a degree of yaw stability, and serve as a retaining structure for the elevons.

In order to prove the design, the UAV was flight tested as a radio controlled slope soaring glider.

The aircraft showed good stability, and low aerodynamic noise at speed indicated an efficient wing design.

Senior Design Engineer Dr. Garth Nicholson oversaw the project:

*"Following successful flight testing, the airframe is currently being optimised further to incorporate blended winglets and twin ducted fan propulsion, to facilitate the target flight envelope. Future planned developments include full on-board data logging of flight parameters, autonomous operation by GPS, and control by surface morphing technology. Concepts for novel ducted fan designs are also being investigated".*

Through this project, the AMRC's Design and Prototyping Group have demonstrated that design for manufacture of relatively large, thin walled parts can be optimised for the FDM process such that only build material is required without any support structure, thus giving considerable manufacturing time and cost savings.

- For detailed information about the development of the FDM Printed ABS Fixed Wing UAV, contact Dr Garth Nicholson, Senior Design Engineer:
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- For more information on the AMRC's Design and Prototyping Group, contact Craig Roberts, Head of Design:
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