



INTEGRATED PROGRAMME
IN AERONAUTICAL ENGINEERING

THE FLAVIIR PROJECT TEAM IS:

Cranfield University

Imperial College of Science,
Technology and Medicine

The University of Leicester

The University of Liverpool

The University of Manchester

The University of Nottingham

The University of Southampton

The University of Wales Swansea

Warwick University,
Warwick Manufacturing Group

The University of York



The **FLAVIIR** project is a 5 year research programme looking at technologies for a future Unmanned Air Vehicles (UAV) funded jointly by **BAE Systems** and **EPSRC**.

Managed from Cranfield University and including 9 other university partners, the programme covers all the key aspects of the next generation UAV from an aeronautical point of view. The focus for the research is the "Grand Challenge" laid down by BAE Systems:

To develop technologies for a maintenance free, low cost UAV without conventional control surfaces and without performance penalty over conventional craft

Alongside the research into individual technologies themselves, the FLAVIIR project will also deliver a flying demonstrator vehicle for these new advances, thus applying the research methodology to the integration phase and providing direct experience and evidence of real performance benefit.

The £6.2M funding has been nominally split into a 3 year research phase followed by a 2 year demonstration phase, although with technology integration being treated as a research topic in its own right this boundary is necessarily blurred.

The technical research has been split into 7 themed areas; Aerodynamics, Control systems, Electromagnetics, Manufacturing, Materials/Structures, Numerical simulation and Integration.

WHY ARE BAE SYSTEMS INVOLVED?

The FLAVIIR project forms part of the BAE Systems strategy to concentrate its funding on a few selected universities, to increase company involvement in these university programmes, to facilitate a greater degree of cooperation between university partners and to include system integration into the research agenda. Future UAVs will be necessarily cheaper, more modular and will rely on designs that consider many cross-discipline interactions and trade-offs. The FLAVIIR programme, and others like it, is therefore necessary to ensure that BAE Systems understands both the emerging technologies and how they can fit together to deliver suitable systems in the future.

The FLAVIIR project direction is overseen by an Independent Steering Group (consisting of members from the MoD, European Industry, Academics and senior BAE Systems staff). Technical Audit is provided by a Technical Committee (consisting of key academics from the project and selected BAE Systems staff).

Day to day running of the project is undertaken by the Project Director (a Cranfield Professor) and a Project Manager (from BAE Systems).

This level of management allows flexibility for BAE Systems to change the project direction as company needs dictate, whilst providing a level of audit to ensure that novelty and research elements remain a high priority.

THOSE MAKING UP THE CONSORTIUM AND WHAT THEY BRING INTO THE PARTNERSHIP

The university partners are Cranfield University, Imperial College of Science, Technology and Medicine, The University of Leicester, The University of Liverpool, The University of Manchester, The University of Nottingham, The University of Southampton, The University of Wales Swansea, Warwick University, Warwick Manufacturing Group, and The University of York.

WHY THIS PROJECT IS DIFFERENT AND EXCITING

The focus on building and flying a demonstration vehicle ensures that not only are the various technologies developed further than would be considered normal at a university, but also that the inter disciplinary interaction between different universities (and single university departments too) is enhanced. Both of these provide great benefit to the overall outcome.

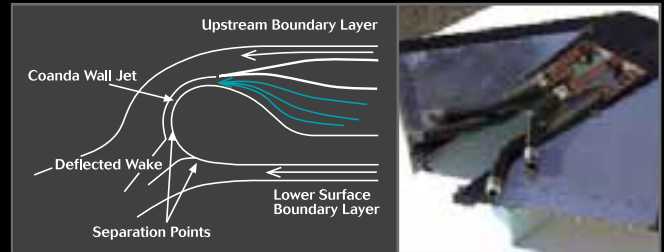
Furthermore, in order to build in added flexibility to the programme £0.5M has been reserved for topics not considered at the outset - so called 'seedcorn' projects. Such projects will kick off at various stages during the FLAVIIR programme at wherever the most innovative and relevant ideas stem from within the partnership.

This unusual addition to the project at the outset is designed to increase the innovation and hence the success of the project overall.

THE 7 THEMES

Aerodynamics

Here the research focus is on novel means of flow control for improved manoeuvrability, stealth, robustness and simplicity.



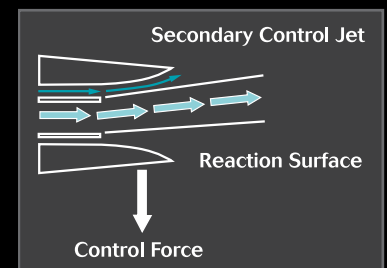
Control using blown air from the wing trailing edge is being investigated by Manchester. The basic principle is that blown air entrains the upper surface flow thus giving rise to an increase in lift.

The trailing edge has to be modified to become rounded, but in general the thickness of a typical trailing edge does not have to be altered.



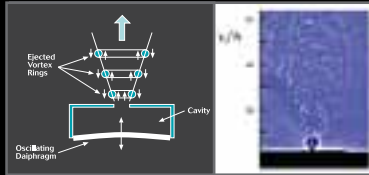
Thrust vectoring utilising secondary coanda jets to enable deflection of the primary jet is also being investigated by Manchester. The principle is that deflection of the main jet can be achieved by switching on a higher pressure secondary wall jet which sticks to the geometry and bends the main jet with it.

Basic demonstrations have taken place on laboratory equipment and the research will focus on achieving an optimal design and build for a real aircraft.



Synthetic jets, or zero mass jet actuators are a novel means of controlling flow separation and hence can be used to augment lift and control an air vehicle. These jets are typically around half the boundary layer height (approximately 5mm diameter) in size and it is envisaged that many hundreds of such devices would be enabled on a flying surface to affect control. In order to understand the fundamental principals

in using such devices and explore how to use and design with them Imperial College are looking at



computational modelling using large eddy simulation (LES). The end goal is to achieve sufficient understanding to enable simpler and faster computational models to be built such that they can be used within the design cycle.

Another form of synthetic jet using small-scale surface deformations is also being investigated experimentally by Imperial College. Here the benefits of such devices over cavity oscillators are being studied.

The bridge between developing novel flow control mechanisms and actually utilising such devices in an aircraft is in the flight dynamics and control required. Hence research is being undertaken both at Cranfield and at Manchester in developing suitable experimental techniques to both develop and test control system software.

Control Systems

The overall aim is to provide technologies that will support high levels of autonomy, increasingly complex systems made up of many cheap components, the ability to reconfigure to react to a changing environment and the integration into a distributed control network.

Novel flow control mechanisms naturally require new control laws, but in addition further advances are being sought in this area covering:

- Coordinated control, integrated control (multi-platforms) and condition monitoring
- Non-linear and adaptive control
- Distributed aerodynamic control

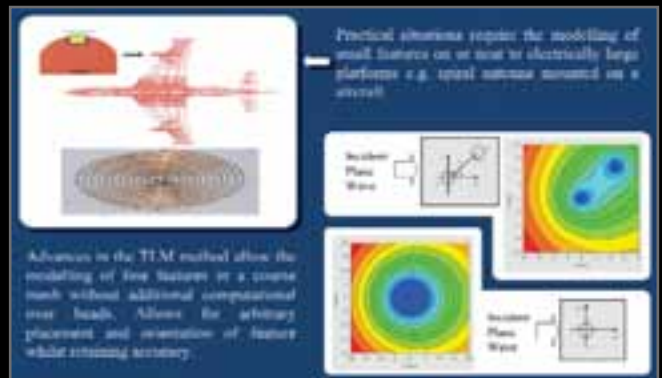
Leicester are focusing on coordinated, integrated and distributed control. In particular coordinated dynamic programming methods for multiple UAVs and condition monitoring based on engine data will be studied.

Non-linear modelling of dynamic response to improve on linear models and allow some modelling of component ageing will also be researched. The practicality of utilising large arrays of micro-sensors and micro-actuators (as envisaged with sets of synthetic jets for example) requires the development of appropriate coordination approaches that will open up the possibilities of radically new control methods. Imperial College and Leicester will investigate methods to compose such arrays into robust and dynamically configurable virtual entities. The intention is to design systems where the control can take advantage of the nonlinearities thus reducing the need for conservative design.

Imperial College are studying adaptive and non-linear control strategies for aerospace systems. This will be focused on devising new generic adaptive and non-linear control algorithms suited to aerospace applications and the provision of robust but non-conservative implementations of these algorithms. The end goal is improved performance and reliability for the control software.

Electromagnetics

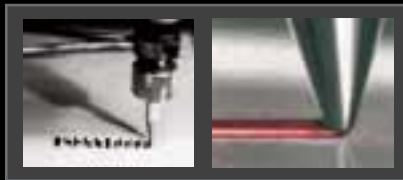
The sole thrust of the electromagnetic theme is to be able to predict and find novel ways of reducing susceptibility to RF threat and lightning strike. A single predictive code will be produced collaboratively by 3 Universities (Swansea, Nottingham and York). Swansea will apply novel numerical analysis techniques utilising fast hybrid mesh methods. Nottingham are researching ways to model small scale electrical devices within a large scale environment in an efficient manner. The aim is to be able to efficiently and accurately design with small gaps, slots, cables and wires. Such a tool will allow more detail and novel ideas to be explored at the concept stage. York are concentrating on material models - how to model carbon fibre structures, honeycombs etc. and on determining the effects of manufacturing irregularities on EM fields during pulsed RF threat and lightning strike.



Manufacturing

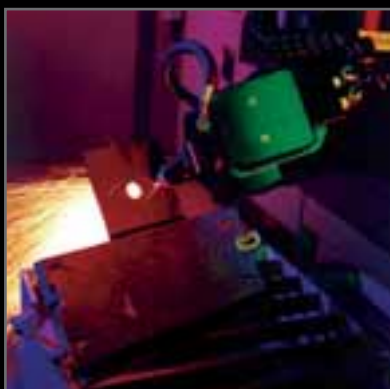
The focus of the manufacturing research is on reducing cost - not only in the production but also in reducing maintenance and increasing reliability. Cranfield are studying new low cost reinforcement fabrics to determine the relationship between laminate properties, impregnation techniques and construction. Additionally, development of other promising methods will be pursued such as dry fabric laminating, trans-laminar reinforcement, single sided stitching and tufting.

A major part of the manufacturing cost stems from the tooling required for the job. This is



particularly important for low volume production UAVs and for UAVs which are expected to be heavily modified for different missions. Warwick are thus developing new tooling techniques and processes to reduce costs and provide increased flexibility.

Modern structures are expected to have integrated components embedded within the structure itself. Liverpool are researching Direct Laser Fabrication (DLF) methods for creating these so called SMART structures and aim to take their current methods into the micro regime.



Materials and Structures

Here the focus is on developing predictive methods to model delamination in composite materials. An accurate numerical method has the potential to provide substantial cost savings by a simple reduction in the number of component tests that currently have to be completed. Imperial College have demonstrated the potential of a novel 'interface element' method that allows easy and accurate modelling of such failure mechanisms and these will be further developed and tested to a suitable standard on this project.

Numerical Simulation

Numerical simulation is concerned with numerical design and hence optimisation. Southampton are putting together a concept design framework and will focus research on modelling of complexity and cost within a concept design. These designs will be geometry based (using CAD descriptions) and will be coupled to various optimisation strategies to allow 'what-if' studies to be undertaken. Cost modelling in particular is a difficult area to get an accurate understanding and thus research will be undertaken not only to obtain the cost of parts but also in obtaining the cost of integration based on part complexity, function and mission importance.

Integration

This theme is the bringing together of all the other research areas into a single flying demonstrator. This is not simply a bolting together of each individual technology but a continuous

collaboration during the research phases of the FLAVIIR programme in order to ensure that each technology integrates and works together in a sensible fashion



to meet the overall vehicle objectives. Cranfield will be building a flying demonstrator vehicle showcasing the various technologies developed over the project, providing valuable information on the performance of the novel ideas and allowing subsequent UAV designs to take account of integration issues.

LINKS TO OTHER PROGRAMMES

The FLAVIIR programme is not designed to be isolated and fits in well with other on going collaborative research programmes in particular:

- MSTAR DARP - looking at fundamental issues of turbulence and transition modelling
- PUMA DARP - looking at unsteady aerodynamics and aero-elastics

In addition a number of other programmes funded by the MoD Joint Grant Scheme and/or EPSRC have or are being pursued to link in closely with FLAVIIR.

OTHER STRATEGIC DOMAINS

The FLAVIIR programme falls within the BAE Systems Aeronautics Strategic Domain. Other currently active strategic domains are Systems Engineering, Support Solutions, Signal and Information Systems and Distributed Data Systems and similar programmes are planned for many of these areas.

For more details on these and other forthcoming domains contact John Murphy, Head of University Partnerships, BAE Systems (john.murphy@baesystems.com).

CONTACTS AND MORE INFORMATION

Further information on the web site: www.flaviir.com or from contacting:

Professor Neil McDougall
Technical Director, FLAVIIR
School of Engineering
Cranfield University
Bedfordshire MK43 0AL
Tel: 01234 754706
Email: neil.mcdougall@cranfield.ac.uk

Philip Woods
Project Manager, FLAVIIR
BAE Systems, Advanced Technology Centre
Filton
Bristol, BS34 7QW
Tel: 0117 302 8255
Email: philip.woods@baesystems.com



Project Director's Office,
Cranfield University, Cranfield, Bedford,
England MK43 0AL
Telephone: +44 (0) 1234 754706 Fax: +44(0)1234 758203
www.flaviir.com