# BAE Systems/EPSRC integrated research programme in aeronautical engineering

**N. McDougall**
Cranfield University
Cranfield, UK

## ABSTRACT

BAE Systems and the Engineering and Physical Sciences Research Council (EPSRC) have recently formed a partnership to invest in strategic research in aerospace and defence. The framework which has been developed as part of this new alliance places a strong emphasis on collaboration. This contrasts with the conventional approach to industry led research which is normally based on the establishment of 'centres of excellence' in specific subject areas. By using a collaborative approach, the funding partners aim to benefit from inter-disciplinary collaboration which will take place during the project, giving rise to a more effective use of the invested funds.

The objective of the research programme is to develop technologies which would support the design of low cost (both to acquire and operate) flapless unmanned aerial vehicles (UAVs). This work includes fundamental aerodynamic research to provide control forces without the use of conventional flaps, coupled with developments in the areas of control systems, manufacturing engineering, structural engineering, the electromagnetic behaviour of these structures and design optimisation. The output from the research has been extended to include the design, manufacture, assembly and flight of a demonstrator vehicle, which will provide the research teams with a platform on which to evaluate the performance of their technology in a realistic flight environment. A total of fourteen research groups at ten universities are involved in the five year programme, which has a total value of £6·5M (€9·75M).

## 1.0 INTRODUCTION

This paper outlines a new approach to collaborative industry / university research which has been recently introduced by BAE Systems in partnership with the EPSRC. High quality research is vital to BAE Systems both in terms of product enhancement and new business opportunities and the Company has worked closely with the academic sector for many years to provide innovative technology solutions. The BAE Systems product applications range from component level, through entire land, sea and air vehicle systems to the integration of such assets within a system of systems capability. The research that will benefit the Company is spread over a diverse range of topics and significant impact can often only be achieved when research outputs are integrated in an inter-disciplinary sense.

The solution to this issue, which BAE Systems has adopted, is to join forces with the EPSRC and develop a model for collaborative research which focuses on a small number of strategic capabilities derived from the business needs of the company. Resources are directed at a small number of academic partners to provide research, education and training, and recruitment opportunities in strategic domains. The EPSRC and BAE Systems bring complimentary attributes to their partnership to support a large scale academic research programme with strong links to government and clear strategic direction provided by industry through managed technology pull. This helps the EPSRC achieve their goal of 'UK Limited' benefiting from the investment in research and helps BAE Systems achieve high return on investment in academic research.

**Paper No. 2933**. Manuscript received 13 October 2004, revised version received 13 March 2005 accepted 30 August 2005.

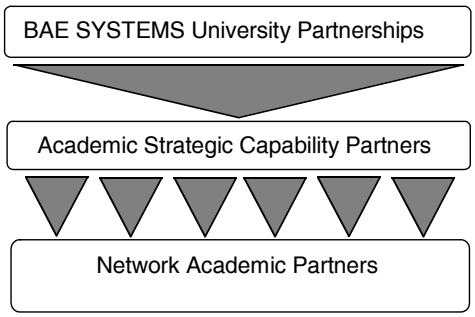


Figure 1. Schematic representation of BAE Systems University partnerships.

The first part of this paper covers the underlying structure behind this approach, followed by an overview of the integrated research programme in aeronautical engineering. This is the first project initiated under the BAE Systems /EPSRC collaboration.

## 2.0 RESEARCH STRUCTURE

BAE Systems is a 'systems integrator' which can define and execute all stages of a capability from concept through to production over a very broad product range. The company has grown and developed both organically, and through mergers and acquisitions. The diverse history and technical capabilities of the businesses that make up BAE Systems has resulted in a large number of research collaborations that were developed at a local level. Whilst these collaborations satisfied local business unit requirements, it was identified, through a review some three years ago, that greater co-ordination and strategic alignment was required to fully realise the benefit of investment in the academic sector.

The review led to a decision to modify the company's approach to working with the academic community to one driven by the goals of:

- Establishing strong BAE Systems footprints in the academic sector in areas critical to future business needs

and

- Focusing funding and synergistic requirements onto agreed academic groups

through

- A framework that addresses training, education and recruitment needs from the same academic teams within partnerships primarily supported by common funding.

The concentration of research means that the company will invest more significantly, with a longer term commitment, in those areas of strategic importance.

The new structure of the university partnerships is shown schematically in Fig. 1. The intent is that relationships between universities and BAE Systems should be managed centrally through a small number of strategic capability partners, each responsible for a multi-disciplinary strategic domain defined by the needs of the business. The bulk of the work will be executed through a network of academic partners who collaborate together to form the project team to deliver the research. The structure of these relationships follows a similar approach to that used to reduce the number of commodity suppliers in manufacturing through rationalisation of the supply base into 'tiers', where only the 'first tier' or prime contractor has a direct business relationship with the ultimate customer. It should be noted, however, that for specific discipline-based research, outside of the integrated programme described below, BAE Systems would deal directly with the academic group identified as the specialist supplier in that field.

- Market drive towards Unmanned Combat Airborne Vehicles (UCAV).
- Customer demands lower cost of acquisition.
- Customer demands reduced through-life costs.
- Technology to provide competitive advantage in the marketplace.
- Maximise return on investment in research.

Figure 2. BAE Systems business drivers for aeronautical engineering research.

### 2.1 Strategic capabilities

key to the success of this approach is the definition of the strategic capabilities which will form the core business of BAE Systems in the future. The following strategic domains have been identified:

- aeronautical engineering
- systems engineering
- signal and information systems
- support solutions
- decentralised data & information systems

In each so called 'strategic domain', the company will work with the selected strategic partner (Cranfield University in the case of aeronautical engineering) to develop a collaborative research proposal that addresses 'grand challenges'. The challenges are constructed to support the high level business needs of the company, and an academic team is drawn from the network of (pre-selected) academic partners to execute the research. During the planning stage both BAE Systems and the EPSRC work to promote collaboration within the network, brokering 'marriages' between groups of researchers whose work is seen to be complimentary. These 'marriages' extend across institutional divides and should also cross disciplinary boundaries. It is intended that projects will be initiated in each strategic domain over the next five years or so, giving a rolling programme of work which will develop over time. Once the programme is fully underway with projects in multiple strategic domains, BAE Systems and the EPSRC will encourage cross-domain working where appropriate.

## 3.0 INTEGRATED PROGRAMME IN AERONAUTICAL ENGINEERING

The first project resulting from this new strategy is the programme in aeronautical engineering, coordinated by Cranfield University as the strategic capability partner. The programme is jointly funded by BAE Systems and the EPSRC with a value of at least £6·5M and duration of five years.

Key business drivers for aeronautical engineering within the Company were defined at the outset, and these have been listed in Fig. 2. These business drivers were then developed into two 'Grand Challenges' for the research team forming the high level objectives for the project as follows:

*Grand Challenge #1:* "A maintenance-free UCAV without conventional control surfaces and no cost or performance penalties."

*Grand Challenge #2:* "Significant research impact through effective academic/industry management and exploitation of large scale, integrated academic research."

The first grand challenge results from a drive to reduce the acquisition and operation costs of UAV's whilst retaining capability. The advantages of unmanned systems must be demonstrated in terms of performance ('effectiveness' is often used as a measure for military aircraft) but it

https://doi.org/10.1017/S000192400000107X Published online by Cambridge University Press

should also be recognised that this effectiveness is quickly eroded if the costs of acquisition or operation are too high. As an example, the current rate of loss of the Predator UAV of 32 per 100,000 flying hours is an order of magnitude higher than the more capable F-16 (Ref. 1). This diminishes the usefulness of the unmanned system and makes it less attractive to the end customer.

The integrated research programme will attempt to reduce the costs of potential future UAVs by simplifying the airframe with the elimination of conventional control surfaces and replacing them with different aerodynamic control effectors. This work is coupled with a significant study into the production of low-cost composite structures, together with the tools required to predict through thickness stresses and the electromagnetic performance of the structure. Given this simplified structure and the control forces that can be produced with 'flapless' devices, the challenge for the control system designers and aerodynamicists is to extract the maximum performance from the aircraft.

In summary the research themes are as follows:

| | |
|---|---|
| Aerodynamics | Cranfield University<br>Imperial College of Science, Technology & Medicine<br>University of Manchester |
| Control Systems | University of Leicester<br>Imperial College of Science, Technology & Medicine |
| Electromagnetics | University of Nottingham<br>University of Wales, Swansea<br>University of York |
| Materials & Structures | Imperial College of Science, Technology & Medicine |
| Manufacturing | Cranfield University<br>University of Liverpool<br>University of Warwick |
| Numerical Simulation | University of Southampton |
| Integration | Cranfield University |

Figure 3. Research Responsibilities and Teams within the Collaborative Research Programme.

### *Aerodynamics*

A broad range of work covering fundamental investigations of miniature flow control devices to the use of Coanda jets to provide control forces and perhaps eliminate moving control surfaces.

### *Control Systems*

The development of robust control systems for control of individual aircraft and groups of aircraft forming a system of systems. This involves multi-sensor and multi actuator systems such as the flow control devices being developed by the aerodynamicists.

### *Electromagnetics*

Advanced modelling techniques for efficient and accurate prediction of the response of UAV-type structures to naturally occurring and man-made electromagnetic threats.

### *Materials & Structures*

The development of techniques for the prediction of through thickness stresses in complex composite geometries.

### *Manufacturing*

The development of low-cost manufacturing techniques (including tooling and fixtures) which support low volume manufacture of UAVs.

### *Numerical Simulation*

The development of multi-disciplinary optimisation tools the assist in the concept development of UAVs for a range of different operational roles. This work includes the development of approximate cost models to support the manufacturing theme.

### *Integration*

The integration and demonstration of the technologies developed during the programme in a flying demonstrator. This is a significant part of the project and is discussed in more detail below.

So far, what has been described could be seen as a confederation of conventional research programmes. The responsibilities within the programme are shown in Fig. 3, illustrating the 'teaming' approach to research with multiple research groups collaborating on research in a given theme. The collaborative integration theme is one of the unusual features of the project. This area, although the responsibility of Cranfield, will be delivered by all of the themes working together, resulting in a flying technology demonstrator.

### *Flying Demonstrator*

The inclusion of the technology demonstrator in the programme is an important feature which warrants further discussion. Interestingly, the report from the Aerospace Innovation and Growth Team (AeIGT) on the future of the UK aerospace industry (Ref. 2) highlighted the historical success of demonstrator programmes within the aerospace sector and recommended their adoption to improve the UK's competitive situation for the future.

Cranfield University has some experience in the design and manufacture of UAV demonstrators, such as the 'Eclipse' shown in Fig. 4. These vehicles have been produced as design exercises to explore the technical challenges which UAVs provide at this small scale. This work is being extended in the current programme such that the design of the demonstrator will include new technologies developed by the programme team. This will provide a 'fast track' route to demonstration of the 'readiness level' of technologies developed during the programme. The demonstrator will therefore drive the academic community to develop their ideas a little further than is commonplace in conventional academic research, and it is intended that this will help in the transfer of technology to industry. The challenges imposed on the team by the requirement to support the demonstrator will also help to retain the 'research adventure' envisaged by BAE Systems when the project was conceived. 'Research adventure' is a phrase that has been coined to try to capture the idea that this project should not be afraid to take risks, and that failure can often prove positive results. At one of the early review meetings it was even suggested that a measure of the risks taken by the project team might be made if the demonstrator crashed during flight testing! (We have no plans for this to happen!!)

Clearly, not all of the technologies developed during the project will reach a suitable level of maturity in time to be incorporated into the design of the demonstrator. One of the early tasks for the project team has been to establish a vision for the demonstrator and outlining those technologies which we have high confidence will be sufficiently well defined by 2006 when the demonstrator design activities commence. In cases where the technology will not be ready in time, or the scale of the demonstrator prohibits its inclusion, a series of parallel demonstrations are planned. These demonstrations are required to prove the (lower) level of technology readiness and to form the foundations for future work.

### *Flexibility*

Inherent to any large programme is the ability of the programme management team to accommodate the unforeseen or unexpected. In this case the need for flexibility arises for two main reasons. Firstly, the

https://doi.org/10.1017/S000192400000107X Published online by Cambridge University Press

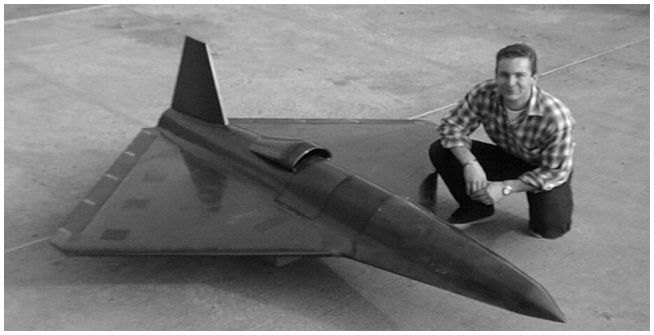

Figure 4. UAV Demonstrator – BAE Systems and Cranfield University.

programme has taken two years to develop from the initial meetings to discuss the concept to the approval of the funds. In this time science has moved forwards, and there is a need to adjust some of the research objectives to reflect this. Secondly, the construction of the project has inevitably left gaps in the research where work will have to be completed to achieve the project objectives. Flexibility is achieved both from the attitude of the research teams working on the project, and through the provision of limited funding within the programme budget to facilitate additional work. Seed corn funding has been set aside to allow new ideas to be explored as they arise during the programme. A further flexible element in the project is in the development of inter-disciplinary 'theme teams'. These teams are assembled from the network universities to address specific issues facing the project and can be short-lived or last the full duration of the project, as required.

### 3.1 Programme management

A consequence of the networked structure of the project is the requirement for an additional management overhead to ensure the delivery of the project. At the highest level, an independent steering group (ISG) has been established, chaired by Mr Mike Markin, Science and Technology Director for the Ministry of Defence. The purpose of the ISG is to provide a strategic level of guidance for the project on technical issues, and to provide the normal checks and balances for publicly funded research. As this project is the first one under the joint EPSRC/BAE Systems partnership, the steering group has also been requested to provide feedback on issues that arise due to the framework for the research. The intention is that work in the other strategic domains will benefit from the experiences gained in the aeronautical engineering project.

## 4.0 CURRENT STATUS AND CONCLUSIONS

At the time of writing the project is in its infancy. The network partners are all planning to start work between June and September 2004, and the programme team is reviewing the scope and deliverables from the project during this period. Two theme teams have been established to formulate the outline specification for the demonstrator. This will include gateways and milestones for the delivery of technical information to the integration team based on the revised scope of work from each technical theme.

The second grand challenge recognises the risk associated with breaking the mould for industry-academia interaction. This project represents a new approach to the management of industry led academic research, being highly integrated in both the cross-disciplinary sense, but also in terms of delivering research, training and recruitment opportunities. As the vanguard of the new partnership between BAE Systems and the EPSRC there are a number of open questions regarding the project at this point in time. The initial signs, however, are good. The project team is already working together and individuals are collaborating outside their own disciplines. The demonstrator is providing a central focus for the project, with all of the network partners showing considerable enthusiasm for having their technologies in a suitable state to fly on the vehicle in 2009. A challenge for the project team over the coming months will be to develop contacts within BAE Systems to ensure close collaboration and promote transfer of the technology into the company. Where possible some of the research posts within the programme will be filled with seconded staff from BAE Systems, and work is going on within the company to define suitable parallel internal research programmes to help facilitate technology transfer.

It is the hope of the author that members of the project team attending this year's Aerodynamics Research Conference will return in future years to present the research outcomes from the project.

## ACKNOWLEDGEMENTS

The author acknowledges the technical and financial support for the project from BAE Systems and the EPSRC (Grant Number GR/S71552/01).

## REFERENCES

1. SWEETMAN, B, UCAVs grow fat on requirements, *Jane's International Defence Review*, April 2003.
2. An independent report on the future of the UK aerospace industry Volume B Overview, The Aerospace innovation and growth team, published by the DTI, London, 2003.