National Advisory Committees Defence, Aerospace and Systems Panel

Report of the Research and Technology Task Force 2001

Foresight

Making the future work for you

Contents

The views expressed in this report are the personal opinions of the Panel and Task Force members and do not represent the official views of the organisations they represent. This report is intended to spark discussion and debate and readers should not rely on the information reported to make investment decisions.

Introduction

The National Advisory Committees (NACs) have been created to act as the national fora for defence and aerospace research and technology (R&T) development within their respective areas. In some areas, it was possible to build upon and expand the function of a previous body, such as the Aerospace Advisory Group of the Innovative Manufacturing Initiative,the Synthetic Environments Management Board and the previous Consultative Committees or Research Advisory Councils, but in many cases a completely new body had to be formed.

Nine NACs have so far been established.

- Aerodynamics
- Aerospace Manufacturing
- Avionics & Flight Systems
- Electronic Materials & Devices
- Human Factors
- Materials & Structures
- Mechanical Systems
- Synthetic Environments
- Systems Engineering

Each NAC has a specific remit to develop and communicate a shared understanding of priorities for research and technology development between all stakeholders; to maintainan overview of UK competitiveness; and to advise the Defence, Aerospace and Systems Panel of key issues relevant to the national effort in R&T.

The NACs have been very successful in bringing together representatives of industry, academia, government laboratories and funding bodies to share information on aims and programmes, and to develop a shared vision within their respective areas. The NACs have also been successful in establishing priorities for research and technology development, or for improvements to processes, and have assessed the UK's competitive position in the world market in their respective areas.

Priorities and issues for individual NACs are addressed in their individual reports.

However, a number of themes interweave the individual reports and hence have a much wider relevance to the defence and aerospace sector as a whole. Underlying themes of a more strategic nature are discussed below, whilst examples of more specific technical themes are addressed in Annex A.

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Underlying themes

The Need to Identify and Sustain Key Capabilities

First is the recognition that the defence and aerospace industry has become international. Information technology and new business processes will further facilitate geographical dispersion and the introduction of new entrants into the market place. The UK can no longer expect to maintain world-class capabilities in every area of manufacturing and technology. Against this background, it is important for the UK to identify and maintain a strong presence in those aspects of the business that drive international competitiveness and provide the market discriminators. These key capabilities include both core competencies in the business, manufacturing or design process, and key technologies that are critical to maintaining the competitive advantage. Only in this way will the UK be able to play a leading role in the concept phase of any new project, and hence influence its direction, whilst retaining the high added-value work.

The need to identify and sustain key capabilities poses a number of challenges.

Core Competencies and Key Technologies

Individual companies will, of course, wish to identify capabilities that are specific to their own business and may be reluctant to share company-sensitive information with competitors. However, the aim must be to establish key capabilities for the UK as a whole that reflect the aspirations and objectives of all stakeholders, be they in industry, academia or government.

The process of identifying key capabilities must take account of requirements across the total system in terms of position within both the product chain and the product cycle.

- In the product chain, from materials and components, through sub-systems to system integration within the aircraft, ship or vehicle, and the environment and infrastructure within which it operates.
- In the product cycle, from research and technology development, through system concept, design, manufacture, through-life support and disposal.

Some technologies will pervade the whole sector whilst others will be focused within a relatively narrow field. For example, modelling and simulation, including synthetic environments, have applications within all aspects of system design, understanding and integration, as well as business process modelling. Cost modelling is also highly important and pervasive. In contrast, there are aspects of materials technology which are specific to a single application, such as high performance combat aircraft, but are nonetheless key within that field.

The process should also identify where potential failures in technology acquisition might occur. For example, in the field of electronic materials, the UK has significant strength in high-added value operations in designing solutions that use a range of silicon processes. However, the design capability is largely reliant on limited Far Eastern silicon foundry capacity. More generally within the electronic materials and devices area, there is a problem of obtaining access to advanced technologies specific to defence and aerospace applications because of the very small volume requirements relative to the computer and communications markets.

The process must also take account of the evolving nature of the market, products and technology. Thus, a key technology of today may cease to be so in the future due to developments in other technological areas which change the system concept and design, or vice versa. For example, nanotechnology is an emerging "enabling technology" which can be spread across a huge range of applications, in some of which the UK has a lead, and which may result in changes to manufacturing processes or component design. On the other hand, mechanical systems such as transmissions and gearboxes, tend to be regarded as mature technology, attracting little R&D investment in the UK, since designers are able to work satisfactorily with available components. However, changes in power systems, such as a greater use of electric power in ships and aircraft, may change the requirement for power transmission and hence the mechanical system requirements.

Some technologies may not be key, in the sense that they are not critical to maintaining a competitive advantage, but are nonetheless important to the system as a whole. In such cases, although it may not be necessary to maintain a world-class capability, it may still be necessary to maintain a good understanding of the technology in order to ensure that the issues of design and integration are properly addressed, i.e. to be an intelligent customer.

It is important to note that systems include not only the technology of the physical sciences and engineering, but also human factors. There is a need to understand the manner in which humans interact with technology and their environment, and to recognise that advances in technology do not necessarily overcome weaknesses in human factors.

For example, automation may reduce the scope for human error in the aircraft cockpit, but introduce scope for human error in software system design and compilation.

Much work has already been done to identify key capabilities in earlier activities of the DASP, for example in the National Defence Industry Technology Strategy, and the recent work of the NACs has taken the process forward by identifying priorities in their respective fields. Work has also been underway under the auspices of the National Defence Industries Council to bring together the NDITS and the MOD Technology Strategy in order to identify possible Towers of Excellence, and the DASP R&T Task Force has identified priorities in civil aeronautics.

ndeed, aeronautics provides an excellent example of the importance of identifying core competencies and key technologies. Expertise in aerodynamics allows the UK to play a leading role in wing, engine, weapon and rotor design within international consortia.

This in turn enables the UK to influence collaborative projects at the concept phase, which determines the majority of the programme cost and hence affordability, and leads to the UK retaining the high-value work within the subsequent project programme, though there are challengers who wish to supplant the UK in this role.

Nevertheless, despite such successes, more work remains to be done if the objective of developing a shared understanding of priorities and strategy for research and technology development between all stakeholders is to be fully achieved across the defence and aerospace field.

Improved Coordination

Once key technologies have been established, they need to be sustained and developed. One vital ingredient is funding, which comes from a variety of sources in industry, the Research Councils, DTI and MOD. (It may also come from Europe under the Framework Programme). Not unnaturally, the processes by which the different bodies assess proposals for research funding place particular emphasis on the benefit to the individual funding body concerned. Furthermore, these processes can sometimes be slow and unresponsive, whereas industry often needs to react rapidly, both to technological change and market trends. In consequence, the scope for collaboration between industry, academia and Government laboratories has not been exploited to the full.

It is unrealistic to expect a major increase in national R&T funding. However, better integration between the industry, academia and Government funding bodies would ensure that best value is obtained from the national investment in R&T development, including the provision of expensive facilities. It is accepted that each organisation and funding body will necessarily have its own objectives, but nevertheless, there is scope for a more coordinated approach which takes into account the potential for greater collective benefit. This will be greatly facilitated by the development of the shared vision, referred to above, and will be achieved by seeking strategic commitment at DASP level, but based on themes emerging from the NACs. The NACs should become the accepted hub of national research activity in each technology area and it is important to ensure that they are kept informed of developments in the national scene in defence and aerospace, of the driving and constraining factors within the funding bodies, and of changing market opportunities.

The approach adopted by the MOD and its allies to stimulate international research collaboration illustrates a possible model for national collaboration. Scientists involved in a particular field of technology meet regularly in Research Collaboration Committees to exchange information on research objectives, compare programme plans and aspirations, and seek to identify areas of common interest where programme and cost sharing can be achieved to mutual advantage. The recent changes to the process for DARPs (Defence and Aerospace Research Partnerships) funding and assessment are a welcome development in this context. The NACs should continue to be proactive and the natural forum for this activity.

Human Resources

The second vital ingredient in capability sustainment is people. In many areas industry faces difficulties in recruiting and retaining enough suitably qualified and trained staff. In some cases, appropriate training is not available, in others the lack of leading edge facilities in universities inhibits training, in others the subject is perceived to be unglamorous and does not attract undergraduates, whilst in others suitably qualified people are available, but their highly marketable skills lead them to more attractive job opportunities in other sectors.

The problem of lack of suitable training tends to be more acute with the more applied subject matter and relates not only to initial training, but also to continued professional development programmes.

It seems likely that, in the quest to retain the high ground, UK defence and aerospace industry will increasingly move away from reliance on traditional manual skills to a more knowledge-based design and manufacturing process. This implies an increasing need for high level skills centred round information technology, but also with the skills needed to operate in a fast moving, flexible, complex and integrated environment for design, manufacturing and support. Needless to say, these skills will be in great demand in other sectors and the problems of recruiting and retaining enough skilled people will be exacerbated.

Centres of Excellence

Centres of Excellence can provide a focus for research and training, and bring together academic institutions, industry and government laboratories. As such they can provide the means of meeting demands for both trained personnel and technology development, at least in part, whilst facilitating programme integration. In some cases, Virtual Centres might suffice, but in others the need for facilities demands real laboratories. Such Centres could be realised through Towers of Excellence, Defence Technology Centres, Faraday partnerships, DARPs, or through partnership with other European Centres.

Many such Centres already exist, in practice if not in name, but there is considerable scope to expand the concept in a more formal way that recognises their role within the UK.

For example, a Centre for Semiconductor Technology would guarantee access within the UK to state-of-the-art Silicon and III-V technology for training, design and small-volume applications.

Clearly, if a Centre is to be a meaningful concept, it must have some durability, which implies a degree of consistency in funding. This in turn implies that there may need to be some form of competition in creating a Centre, with periodic but infrequent reviews.

Having formulated priorities within its area of interest, it would be entirely appropriate for a NAC to consider setting and promoting national challenges, either individually or jointly with other NACs, to promote Centres of Excellence and stimulate partnerships. For example, topics might include a significant reduction in noise pollution from aircraft, or radical improvements in reliability.

DARPS

Defence and Aerospace Research Partnerships (DARPS) play an important role by providing a focus for specific research programmes, again bringing together industry and the science base, and leading to practical demonstrations of technology. DARPs may act as the catalyst to create a new Centre of Excellence, may exploit the capability of an existing one, or may be single free-standing programmes. The recent launch of DARPs 2002 should ensure a vibrant set of well-designed and funded programmes of work delivering vital defence and aerospace technology in a co-ordinated way.

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The way ahead

In the previous sections NACs have identified a number of priorities relating to research and technology within the defence and aerospace sector:

- The need to identify core competencies and key technologies, and to adopt common priorities for R&T development between all stakeholders.
- The need to further improve coordination and integration of research efforts between industry, academia and Government, thereby facilitating the creation of jointly-funded programmes. A fast-track process might be adopted for research proposals which satisfy agreed criteria.
- The need to ensure a continuing supply of suitably trained personnel.
- The potential role of Centres of Excellence in contributing towards programme integration and training.
- The role of DARPs as a focus for specific research programmes and their potential linkage to Centres of Excellence.

There are many ways in which these priorities could be addressed. At the top level, buy-in and commitment should be sought from all stakeholders to a UK defence and aerospace strategy, to match that in some other countries. The Panel is keen to see the NACs take a more prominent role and that others should look to the NACs as the authoritative national bodies.

Hence, the following specific recommendations are made.

The NACs should be recognised, established and operate as the authority for defence and aerospace in their particular areas of expertise.

The Panel should take steps to help the NACs to establish themselves in this role. As well as promulgating their output, the NACs should receive inputs from others and be a source of advice to stakeholders. Such a more extensive role is likely to demand more resources than have so far been deployed. Some support is therefore likely to be required and this will inevitably need to be sought from the funding bodies.

The NACs should take on a more pro-active role in stimulating new research proposals.

The NACs could build on their work in having identified priorities by proposing national challenges in key areas. They could promote these challenges and seek to stimulate partnerships to take them forward as jointly funded programmes between industry, academia and Government, including DARPs. This would exploit the key difference between NACs and previous consultative bodies: that they involve the funders in delivering the objectives as well as in formulating a view of future needs and priorities.

The NACs should work together in order to address the relationships between competencies and technologies within the total system.

For example, the design and manufacture of an aircraft draws upon elements of each of the nine NACs. The Synthetic Environments and Systems Engineering NACs could play a particularly important role in this context.

The NACs should be encouraged to expand their activities to cover the whole defence sector.

Some NACs already cover a wide field within the defence and aerospace sector, though most are more specifically concerned with aerospace. Aerospace is clearly a key area, but there are also other industries within the sector that are important from the viewpoints of both national defence and wealth creation. It would be key to get more positive involvement of the defence (non-aerospace) companies for this to succeed. For example, the Aerodynamics NAC could be broadened to include hydrodynamics, whilst Avionics and Flight Systems could be expanded to cover other vehicle electronics and control systems. Some NACs cover a field of interest wider than defence and aerospace (e.g. Electronic Materials and Devices). The core of the NACs activity remains in the defence and aerospace sector but wider use of their core competencies is to be encouraged.

The NACs should continue to advise on the need for training and the supply of people.

As part of their authoritative role, the NACs should certainly continue to advise in this area, including the need for relevant Centres of Excellence, and should take on the role of influencing those bodies responsible for the provision of appropriately trained people.

The Challenge for the Future

Unless mechanisms such as these are adopted, there are real risks that the UK will lose its capability in critical areas and hence lose its place as an industry leader within the European and world community. UK industry would be left with those low value items that others do not want, with consequential impact on wealth creation and military capability.

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Annex A
National Advisory Committees
Activities and Priority Areas

Objectives

The NACs are national fora for defence and aerospace research and technology development with a commitment to:

- Develop and communicate a shared understanding of industry, funding agency and other stakeholders needs and priorities for research and technology development;
- Maintain an overview of UK competitiveness in the relevant technology;
- Advise the Defence Aerospace and Systems Foresight Panel of key themes and directions for the national effort in research and technology development, taking account of European and International initiatives.

Representation

Membership of each NAC is drawn from the relevant areas of all stakeholders and may include:

- Industry, including representatives, where relevant, from materials suppliers through system integrators to equipment operators;
- Government Departments, Agencies and Research Councils;
- Universities and Research and Technology Organisations;
- Trade or Professional Associations.

Method of Work

Each NAC typically meets twice a year in plenary session, but many NACs also set up smaller working parties, sub-groups or task forces to tackle specific aspects of their work. Seminars, involving a wider cross-section of the relevant community, are also held to provide a forum in which to present, debate or explore ideas.

Areas of Interest

The nine NACs cover a very wide range of areas of interest within the defence and aerospace arena, though there is a strong emphasis on the latter. The NACs can be divided broadly into three categories.

- Six NACs relate to different areas of technology, equipment, or system - Aerodynamics, Avionics and Flight Systems, Electronic Materials and Devices, Human Factors, Materials and Structures, and Transmissions and Mechanical Systems.
- One NAC relates to the production of equipment - Aerospace Manufacturing.
- Two NACs relate to the much broader issues of total system design, manufacture and through life support - Synthetic Environments and Systems Engineering.

Priority Areas

Clearly, there are many areas of common interest and interaction between the different NACs, but given the diverse range of their activities, it is to be expected that the perception of priorities will also differ substantially between them, not only in terms of specific technical issues, but also in terms of the nature of the priority areas. Thus individual priorities range from modelling complex viscous flow phenomena, to understanding the propensity of human beings to err, to investigating more complex models of business/engineering/production trade-offs in the product introduction process.

For this reason, the priorities identified by the NACs are best addressed within the context of their individual reports. Nevertheless, a number of issues can be identified that have a broader application. Those of a more strategic and generic nature are addressed in the main body of this report, but examples of some specific technical issues are set out below.

System Design and Integration All NACs recognise the importance of adopting a total system design and integration approach, including design, manufacture and through-life support, and this is reflected in the support given to the MOD Smart Procurement Initiative and the EPSRC Systems Integration Initiative. Synthetic environments can have a key role to play in concept evaluation, system design, risk mitigation and life cycle evaluation, but if the process is to work effectively, it is important to identify the precise purpose of the synthetic environment and the trade-offs that need to be explored. The development of modelling for all aspects is key to the ability to perform these trade-offs. Particular priorities in the system design and integration process include:

- Integration of safety issues in the system engineering process.
- Integration of sensors into the platform - both physical integration and data fusion.
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System architectures for complex management functions.

- Human factors integration.
- Adopting a system approach to the interconnection and packaging of electronic devices.

Safety and Reliability Safety and reliability are key areas for many NACs and give rise to a number of priorities for research and technology development, ranging from design to in-service monitoring and support. Specific examples include:

- Improved processes for certification of safety critical software.
- Improved methods for deciding how to allocate functions between humans and equipment, for example in controlling an aircraft.
- Improved understanding of the causes of human error, particularly cognitive error, error prediction, factors influencing error, and design for the mitigation of error.
- Improved ability to model and predict reliability based on a sound understanding of the effects of the operating environment on any given component or design feature; improved structural and usage monitoring systems; and hence improved ability to establish preventative maintenance, including autonomous systems.
- Fault tolerance and dynamic system reconfiguration.

Environmental Issues These include reductions in pollution by both noise and atmospheric gases and other substances.

- Reduction in engine emissions (carbon dioxide, oxides of nitrogen, unburnt hydrocarbons and particulates), including combustor technology.
- Prevention of lubricant leakage and development of less environmentally damaging lubricants.
- Prediction and control of noise from platform (e.g. airframe), engines, rotors and propellers.
- Development of environmentally friendly processing techniques and coatings.

Cost Reduction All technology areas contribute to cost reduction. There is emphasis on affordable manufacture in structural design and faster design and development cycles to keep first costs low. Operating cost reduction for aircraft comes from greater efficiency of aerodynamics, structural and systems design. In integrating these aspects, a key aspect can be the use of synthetic environments to improve and accelerate the design process and reduce risks, but it is also necessary to improve understanding of both manufacturing and through life costs for all elements of the total system, and hence derive better cost models. Costs include not only equipment costs but also human resource costs, both the number and type of personnel required to operate and maintain the equipment, and the initial and on-going cost of training.

Mission Performance The platforms covered by the NACs range from civil aircraft to nuclear submarines and the range of missions is equally broad. However, a number of technical priorities are more generic in nature.

- Improved multi-function sensors, including electronically scanned radars and electro-optic sensors.
- Improved passive navigation techniques, to cope with periods when satellite navigation might be unavailable.
- Improved data fusion techniques.
- Improved decision aids, including improved understanding of which design features offer good decision making interfaces with humans.
- Improved understanding of human situational awareness (also relevant to safety issues).
- Enhancements to visual performance to improve capability in night/bad weather.
- Development of wide field-of-view, lightweight, helmet-mounted displays.

Aircraft Performance In addition to improvements in mission performance, several priorities reflect a desire to improve the performance of the aircraft as a vehicle, including both airframe and engines. These include:

- Greater use of electric power, including electro-mechanical actuators, embedded generators in the engines and active magnetic bearings: "The More Electric Aircraft".
- More efficient power distribution, either by use of electric technology, or by higher pressure hydraulic systems.
- Improved understanding and modelling of viscous flow phenomena for steady and unsteady flows, leading to improved performance and reduced costs for engines and airframe.

Materials Many of the improvements in system performance will entail concurrent improvements in materials technology. For example:

- Revolutionary aircraft wing technologies will require innovative self-sensing/ smart composite materials, metallic foams and novel processing for conventional and lightweight nano-crystalline metallic materials.
- Revolutionary aero-engines will require the use of lightweight and fire resistant alloys, together with refractory tiles / ceramic and metal matrix composites and thermal barrier coatings for high temperature combustors.
- More Electric Aircraft will require higher performance magnetic materials capable of sustaining high temperatures for actuation and control, as well as novel materials for power electronics in high temperature environments.
- New piezoelectric single crystal materials offer improvements in performance for certain sensors and high efficiency actuation.

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