The British Experimental Rotor Programme IV Technology Demonstration Programme

Exploiting Successfully Demonstrated Rotor Technologies

A paper for the European Rotorcraft Forum 34 (2008)

Simon Ransom
DE&S Rotor System Fellow
MoD BERP IV TDP Manager

BERP IV Technology Demonstrator Blades on ZJ117, the Merlin HC Mk3 Demonstrator aircraft, over the Dorset Coast in Oct 07

Disclaimer
This paper represents the independent views of the author and should not be construed to be official policy of the MoD or any other organisation named herein. Any mistakes or oversights are the author's.

THE BRITISH EXPERIMENTAL ROTOR PROGRAMME IV (BERP IV) TECHNOLOGY DEMONSTRATION PROGRAMME

EXPLOITING SUCCESSFULLY DEMONSTRATED ROTOR TECHNOLOGIES

ABSTRACT

The overall objective of the fourth British Experimental Rotor Programme (BERP IV) was to mature and establish the generic technology base for the next generation of Composite Main Rotor Blades (CMRB) by examining numerous technologies within the framework of a Technology Demonstration Programme. The specific aims of BERP IV were to reduce first and through-life support costs, to improve aircraft performance (in terms of payload and range), to control vibration and to manage the rotor signatures. Phase 3 of the BERP IV programme (detailed design, manufacture and demonstration) began in Mar 03, with numerous advanced technologies being combined within a single blade design and flight demonstrated on a RAF Merlin HC Mk3. The flight trials programme (Sep 06 - Aug 07) verified all of the originally advertised performance benefits. The outcome of the flight demonstration programme was so successful that BERP IV was selected for rapid exploitation; the blade design being taken into production, virtually unchanged, in order to support current UK operations.

As well as achieving the overall capability-driven technical objectives, the programme has developed design rules, manufacturing processes and materials required for the next generation of rotor blades to enable more cost effective rotor system design, manufacture and qualification, all within a shorter overall development timescale. Attention remains focused on the widest possible exploitation opportunities and the selection of the optimum balance of the now proven technologies to satisfy specific platform requirements. In addition to describing the BERP IV programme and its first embodiment on a production aircraft, this paper is designed to stimulate the debate on successful technology exploitation and what lessons may be learned from the programme's execution.

INTRODUCTION

The UK Battlefield Helicopter (BH) fleet makes a key contribution to the agility and flexibility of UK Manoeuvre Forces and plays a vital role in a wide variety of operational theatres. Helicopters contribute to a large number of military tasks and, especially post-Cold War with the shift in emphasis towards expeditionary operations, are now at the forefront of force commanders' effects based planning and thinking. Despite the potential ubiquity of helicopters and the benefits they bring to the whole operational spectrum, funding levels for helicopter research, technology demonstration, production engineering and new platform and system procurement remains stretched. The British Experimental Rotor Programme (BERP), which has been running for some 30 years, provides an excellent example of how rotor system technology can be successfully developed and exploited within relatively small budgets.

The purpose of this paper is to discuss the BERP IV technology demonstration programme (TDP) in the context of exploitation. To achieve this it is necessary to first place the BERP IV TDP in its historical context with a short discussion of the aims and results of the BERP I, II and III programmes and how they were exploited. This will set the conditions for a discussion about the BERP IV TDP itself. BERP IV was a TDP configured to mature, within industry, the next generation of generic rotor blade technologies and develop design tools and rules for use in future rotor blade designs. BERP IV did not focus on developing a single technology, but rather on developing and integrating several technologies into a single blade design. These are described and their benefits discussed in a lay fashion; it is not the purpose of this treatise to examine technical detail in-depth.[1]

Within the discussion of the BERP IV programme design, the importance of requirements and objectives setting is highlighted as a key activity related to exploitation, as is the need to include the operational perspectives of the user community. This latter, stakeholder issue is discussed through a short case study on erosion shields that drove the selection of a particular technology solution. The issue of stakeholder involvement and communication is further discussed in the exploitation section as an aid to improving the coherence of research and acquisition. The features of the blades are briefly introduced as well as the benefits they bring. Coupled with the results of the flight trial, these features provide the link to the exploitation discussion.

Generally, the purpose of a TDP is to develop and mature technology and generate knowledge in order to de-risk production applications. Exploitation of the knowledge gained into operationally beneficial equipment enhancements is the MoD's goal. In the context of BERP IV this is discussed through a collection of observations gained over nearly 10 years managing the TDP, before drawing some specific and general conclusions which, it is hoped, will be useful to any organisation addressing similar types of activity, not necessarily in the rotor system or aerospace field. In addition to describing the BERP IV programme and its first embodiment on a production aircraft, this paper is designed to stimulate the debate on successful technology exploitation.

[1] Readers seeking to inform themselves of in-depth technical analysis should consult the The AHS Paper at Reference 1.

HISTORICAL CONTEXT

BERP I and II

The BERP programmes have de-risked rotor blade technologies since 1975 and have specifically tackled risky technology development outside the confines of a production programme. BERP I was executed by the UK MoD Royal Aircraft Establishment (RAE) in conjunction with Westland Helicopters Ltd (WHL). This partnership, which included equal investment from both sides for the purpose of mutual benefit, was to endure throughout the subsequent programmes. The objective of BERP I was to exploit rotor design and composite manufacturing techniques developed in preceding years; this resulted in the design of the Westland Sea King composite main and tail rotor blades. In order to ensure parity of loads transferred to the transmission and fuselage with those of the original Sikorsky metal blade design the new main blade matched the dynamic and aerodynamic properties of the original Sikorsky metal blade, as well as its mass, and was successfully introduced into service on all UK Sea King variants. The new blade provided significant improvements in scheduled maintenance and component fatigue life, and an improvement in blade profile consistency from the composite manufacturing techniques used, resulted in a 5% reduction in fuel burn. This success underwrote the MoD strategy for future BERP programmes and illustrated the advantageous gearing that could be achieved by combining and focussing rotor research in government and industry.

Figure 1. BERP I: Westland Sea King

The second BERP programme, BERP II, was a short programme that built on the technology developed under BERP I and that laid the foundations for the BERP III programme. BERP II included a feasibility study for a swept tip blade design and recently developed high performance asymmetrical aerofoil sections. The programme ran between 1978 and 80 and addressed manufacturing, dynamic and aerodynamic design considerations within the context of providing useful vehicle and hence operational benefits to the UK Armed Forces.

BERP III

BERP III began in 1982 after a two-year period of risk reduction studies by the RAE and WHL. The objective was to design, manufacture, structurally qualify and flight demonstrate a blade of advanced design. The Westland Lynx aircraft was chosen as the demonstrator platform and the retrofit nature of the new blade's design enabled the flight test programme to include a true back-to-back comparison of the new rotor design compared to the original rectangular tipped metal blade. This comparison demonstrated a significant improvement in rotor-limited aircraft capability and confirmed early predictions that significant platform growth could be achieved for the UK Lynx fleet at less cost than more traditional engine performance or transmission enhancement programmes. In 1986, a prestigious demonstration of the new rotor was provided when a BERP III equipped Lynx helicopter claimed the World Speed Record, achieving 216 knots, a record that still stands today.

Figure 2. BERP III Westland Lynx

The BERP III rotor was exploited in Service first on the UK Lynx fleet in 1989 where it was embodied as a retrofit programme onto existing aircraft. The new rotor technology was also introduced into the early design activities for the EH101 Merlin. These aircraft illustrate the enhancement afforded to the UK BH fleet by early BERP technology. Both types benefited from the unique BERP blade tip, distributed cambered aerofoils and non-linear twist distribution. These features were only possible using advanced composite construction and provided almost 40% higher rotor loading compared to more conventional rotor technology, allowing additional lift for a given rotor size and platform weight. The Lynx rotor capability grew by 37%, which was taken partly as an increase in all up mass and partly as a hot/high performance improvement. The Merlin, which has exactly the same rotor diameter as the Sea King, but is almost 50% heavier, is able to operate from the same size spot and hangar on the Type 23 Frigate. In addition, the EH101 was designed with a very low rotor tip speed which provides an unprecedented low acoustic signature. The composite blades also had a fatigue life some 4 times greater than that of the original metal Lynx blades. Overall, the benefits obtained through exploitation of BERP III provided an audited through-life cost saving for the Lynx and Merlin fleets of £88M for a MoD Research and Development investment of £7.2M.[2]

The BERP IV TDP

Requirement and Objectives

As noted in the introduction, BERP IV was a TDP designed to mature, in the industrial supplier base, the next generation of generic rotor blade technologies and develop design tools and rules for use in future rotor blade designs. BERP IV was launched in 1997 against a background of uncertain and changing capability requirements that resulted from a more expeditionary style of operation post-Cold War. The UK is an island nation with global sovereign interests and places much importance on a strong autonomous military capability as well as the ability to cooperate in alliance. Some requirements remained unchanged, for example improved, lift performance and cost reduction in the context of the ever present scrutiny of defence spending remained unchallenged goals for the MoD. A strong emphasis was placed on the rotor in service, reflecting the need of the MoD to reduce future operating costs. This prompted a significant effort to gain operational feedback across the UK BH fleet,

[2] NAO 1994 audit of TDPs, Report HC361.

so that ‘best practice’ lessons could be learned and unreliable features avoided or improved significantly.

Operational experience from deployed operations in the Gulf region dominated feedback, and the application of rotor blade sand erosion protection illustrated the need to bring the design authority closer to the end user community. Interestingly, requirement for supplementary sand erosion protection to protect valuable rotor blade assets was inconsistent, with some operators demanding a solution whilst others actively avoiding the issue. Evidence suggested that operators of those aircraft types that had served several tours in theatre clearly supported the additional maintenance burden that erosion protection application represented, with full understanding of the reduced logistics requirement that resulted from improved component reliability. In contrast, those operators of aircraft types new to the region had little interest in taking on the additional maintenance task.

Working in conjunction with the design authority the reasons behind the problem became clear. The mechanism of sand erosion is such that it provides a false sense of security, with no visual indication of the damage being accrued by the erosion shield until sudden failure. Specialist support from industry was required to advise those operators with limited in-theatre experience of the problem. Timely intervention was required to avert the problem, which would otherwise result in a rapidly increasing erosion shield failure trend across the blade population. The interaction between the operational community and industry drove the selection of a non-metallic erosion shield as one of the technologies for BERP IV.

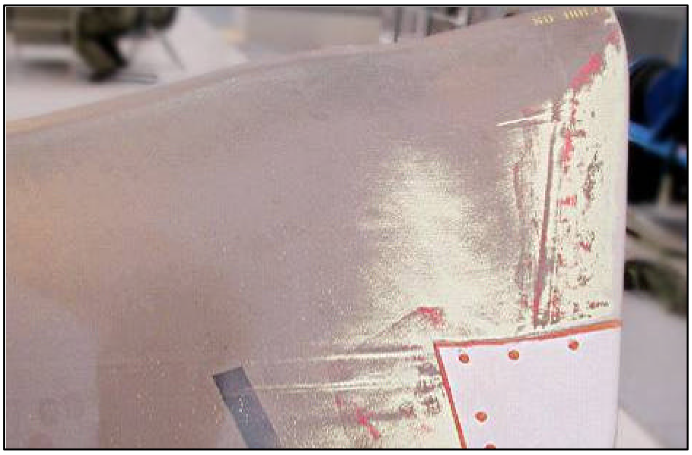


Figure 3. Sand Erosion on AW Lynx Blade Tip

The BERP IV TDP was not however, just about maturing individual technologies to relevant TRLs. Because the TDP aimed to deliver cross-platform benefits, it was essential to develop an understanding of how the selected technologies behaved in combination. This would allow different, *BERP IV based*, blades to be designed that met the role specific requirements of the individual platform, rather than using the design set pursued within the TDP. This understanding of how to trade-off between technologies was used during Phase 3 to preserve the overall timescale without sacrificing demonstrated performance. The output knowledge from the TDP would therefore be equally applicable to all helicopters and not just those in the AgustaWestland (AW) range.

The overall BERP IV programme objectives outlined below were therefore broad ranging and, with no fixed targets set in order to prevent undue constraints between design objectives, reliance was placed on the commitment of both the MoD and WHL to maximise the benefits achieved.

a. Reduced acquisition and through life costs, including reduced design complexity, increased robustness and improved production quality.

b. Improved performance, including hover, payload and range, reduced vibration.

c. Improved battlefield survivability.

Programme Structure

With the requirements and objectives established, a three-phase programme structure was put in place with clear demarcation between initial technology identification, preliminary design scheme integration and final detailed design and test. In contrast to typical defence development activities, the early phases of the contract deliberately maintained a generic platform target. This decision reflected important MoD priorities. It maximised the flexibility of the programme to be directed toward any target demonstrator aircraft type at a later date within the TDP. In addition, it enabled the longer-term objective of ensuring that the resulting technology developments would position the UK to address future capability requirements for various UK helicopter types.

To meet the need to consider a range of BH types and also to pursue the MoD requirement for reduced operating costs, the Front Line (FL) Services were engaged. Military pilots were employed on judgment panels to provide a priority weighted link between design features and aircraft performance attributes. Assessments considered each helicopter role, for example attack, lift and scout, in isolation, and obtained a priority weighted aircraft performance attribute profile against a range of mission scenarios. The results indicated that whilst some specific battlefield survivability attributes may receive additional emphasis for the attack aircraft, all aircraft required a broadly similar mix of attribute improvements that related to basic aircraft performance enhancement, vibration control and survivability. This conclusion re-enforced the design studies within BERP IV and dictated the technology capability mix of the final demonstrator blade based on the need to demonstrate improvements of all performance attributes simultaneously.

In pursuance of the MoD goal to reduce operating cost, significant effort was directed toward characterising the current rotor blade maintenance burden across the UK helicopter fleet, including AW and non-AW aircraft. The contribution of scheduled and un-scheduled maintenance to the overall aircraft budget was determined using databases held by MoD and industry. FL personnel were again engaged to provide clarity of picture not possible to derive from the study of statistical evidence alone. Thus BERP IV drew on the extensive knowledge base built up in the Services that is all too rarely acknowledged or capitalised on. Candidate design features being developed under BERP IV were also reviewed with service personnel in order to assess their likely ability to either address known problems or improve ease of use when operationally deployed. The result of this work had three important effects on the BERP IV TDP. Firstly, a design feature selection process was enabled on a 'best practice' basis, adopting clearly preferred blade features and configurations in the BERP IV design. Secondly, an ethos of 'making a difference for the user' was engendered in the design team, and the need to optimise design to aid serviceability rapidly became an underlying assumption for much of the contract's activities. Thirdly as the TDP progressed, those who would one day be the recipients of new rotor systems became involved as customers during the research and technology demonstration stages. This early and comprehensive stakeholder engagement is has again been identified as a recommendation to improve the coherency of the research and equipment acquisition process.[3]

[3] MoD R&D Coherency Study, Oct 07.

The three-phase structure also provided clear progression through technology maturity as shown in figure 5. This allowed the technical content to be critically reviewed periodically, thus providing visibility of those technologies that either required more effort to de-risk or that were clearly not going to meet Technology Readiness Level (TRL) 6-7 at the point of demonstration. The importance of closely monitoring technology maturity was seen as critical by the MoD, as the primary purpose of a TDP must be to identify and confront technology risk early, outside the context of a production environment.

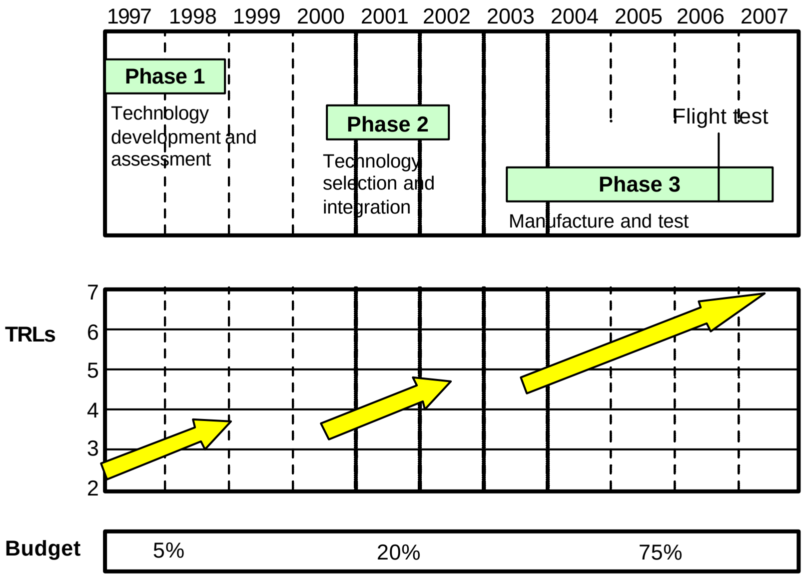


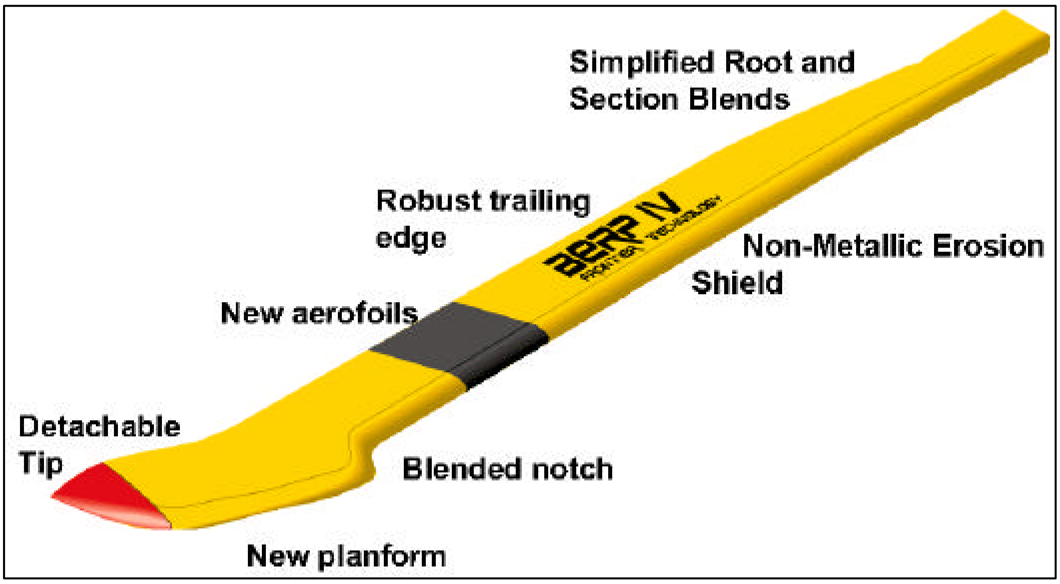
Figure 4. Timescales, Technology Readiness levels (TRLs) & relative budget split

The BERP IV TDP structure was evolutionary in nature and addressed a wider set of requirements and employed more novel technologies than previous BERP programmes. It was therefore important to ensure that the foundations laid within BERP III were robust enough to be built upon. An example was the in-depth re-evaluation of the unique BERP tip shape against numerous contemporary designs. The basic mechanics and overall performance benefits of the BERP tip shape were confirmed as the correct design with which BERP IV should proceed with and the opportunity was subsequently taken to refine the tip's characteristics from both an aerodynamic and manufacturing perspective. Moreover, whilst the programme focussed on new and immature technologies, all design and manufacturing processes and procedures employed were readily applicable to production. This ensured that the subsequent 'time to market' was minimised to enable early exploitation, an approach that was subsequently to prove beneficial for the Merlin Mk3a urgent operational requirement task.

Demonstrator Blade Features

The BERP IV programme was initially planned to employ a Lynx demonstrator aircraft. However, mid-way through Phase 2 the decision was taken to target initial demonstration on the Merlin aircraft, in support of on-going efforts toward assessing the best solution to addressing the medium lift shortfall within the UK helicopter fleet. Despite this selection of what was considered to be the most likely first production application for Phase 3, the generic technology demonstration aspect of the TDP was preserved. A modular blade design was adopted to enable demonstration of a number of features that may not be required in a subsequent production blade, by virtue either of continued technical risk or because the desired aircraft capability dictated a different balance of attributes. Figure 6 pictorially represents the final design features of the demonstrator rotor blade for the target Merlin demonstrator.

Figure 5. Demonstrator Blade Features



The modular approach had the added benefit of enabling the subsequent Merlin Mk.3a activity to employ the structural qualification evidence accrued under BERP IV. The contribution of individual blade features to the programme aims are detailed in Table 1.[4]

Attribute	Feature	Comments
Cost	Reduced curvature tip planform & notch	Provided a smooth fibre path for the composite material, resulting in improved manufacturing product consistency.
	Simplified root end and aerofoil section blends	
	Non-crimped fabric trailing edge	Significant reduction in manufacturing complexity of the item by reducing parts count and labour content. Improved robustness providing lower in service maintenance burden.
	Detachable tip	Reduced service maintenance burden to tip strike damage.
	Non-metallic shield	Major improvement of erosion shield life for operations in sand laden environments.
Performance	New aerofoils	Enhanced hover and forward flight performance.
	New tip planform	
	Increased span-wise twist	
	Structural optimisation & aeroelastic tailoring	Vibration levels of baseline BERP III rotor aircraft preserved or reduced at higher all up weight. Control load increase suppressed.

Table 1. Demonstrator Blade Features & Attributes

[4] A more detailed description of the blade's design is given at Reference 1.

Demonstrator Aircraft and Flight Trials Programme

A series of flight test demonstrations were undertaken towards the conclusion of the BERP IV TDP in order to demonstrate and confirm achieved benefits.

The BERP IV rotor was first flown on the AW owned AW101 demonstrator aircraft. A five-hour programme commenced 26 Sep 06 to confirm basic blade and aircraft behaviour. This included assessments of engine handling, rotor response, hover and low speed manoeuvres and forward flight performance as well as verifying acceptable aircraft loads and vibration.

The main flight test programme involved the MoD owned Merlin HC Mk3 trials aircraft ZJ117 as decided during Phase 2. The flight tests included a large amount of 'back-to-back' flying with the BERP III rotor in order to ensure absolute parity between the BERP III and BERP IV data, enabling a true rotor-to-rotor comparison to be established as well as highlighting any implications on the rest of the aircraft due to the change of rotor system. The provision of two data sets from a single trials programme, using the same aircraft, provided the MoD with further confidence that the benefits indicated could be achieved very rapidly if the technology were exploited on the Merlin fleet; i.e. the same basic aircraft type.

The flight test programme, addressed the following primary subjects:

a. Dynamic component loads gathering.

b. Level flight and hover performance.

c. Airframe and engine vibration.

d. Handling qualities.

e. Battlefield signatures and operationally realistic tactical manoeuvres assessment.

Trials flying on ZJ117 began on 12 Jan 07 and, 75 flying hours later, concluded on 9 Nov 07. The 75 hours included additional flying qualification activities required to support the RAF Merlin HC Mk.3a service release under Urgent Operational Requirement (UOR). AW personnel conducted all the TDP and Mk3a qualification flying and QinetiQ personnel under the direction of the MoD were involved as observers during the qualification flying task. The maximum speed demonstrated during the flight trials was 198 knots TAS, without any indication of the onset of blade stall, and the aircraft operated comfortably at a take-off mass of 16500kg. This compares well with the initial Merlin design max gross weight of 14600kg. The results of the flight test programme activity confirmed the achievement of performance goals, postulated towards the end of Phase 2, as follows.[5]

a. Power consumption in the hover was reduced by approximately 5%; equating to around a direct 650kg increase in payload.

b. Power consumption in the cruise was reduced, with a saving of approximately 10-15% under typical hot and high conditions.

[5] Further details of the Flight Test programme & the results achieved are available at Reference 1.

c. The blade stall envelope was improved by at least 12 knots.

d. Vibration levels were maintained at very low levels and a reduction compared with BERP III was achieved at high speed.

e. Vibration levels were halved in the transition from forward flight to the hover.

f. Aircraft handling characteristics were unchanged compared to BERP III in both steady and manoeuvring flight.

g. The introduction of the BERP IV blade had no significant adverse effect on any other aircraft system or component, confirming the suitability for retrofit onto the Merlin fleet.

Figure 6. BERP IV Composite Main Rotor Blades on TDP trials aircraft RAF01. First Flight, 12 Jan 07, AgustaWestland, Yeovil

BERP IV EXPLOITATION

The successful flight demonstration, on a Merlin, of a single blade design that simultaneously delivered all the cost and performance objectives, concluded the TDP. Although the programme's primary output was the establishment of a suite of rotor blade design and manufacturing capabilities (design knowledge) that underpins the next generation of rotor blades for any type, the TDP also enabled the production version of the BERP IV blades to be fitted to the new Merlin Mk3a.

In Jan 07 the author briefed the Director Equipment Capability (Air and Littoral Manoeuvre) (DEC(ALM)), the user community and the capability scrutiny staffs about the flight test performance demonstrated to date, including the projection of operationally relevant performance projections. The table below represents example mission improvements derived from the actual flight test data obtained during the BERP IV TDP flight trials programme and was required, as an auditable, agreed baseline by the various stakeholder communities; equipments sponsor, acquisition, scrutiny, service release authorities, the operational commands and Industry. The improvements cited represent the percentage change due to the BERP IV blades compared directly with BERP III on either the Merlin Mk3 or Mk3a platforms.

Mission Type, Elevation & Conditions	Improvement Arising from BERP IV Rotor Blade
Trooping Mission 1 T/O at MSL, 50°C	Range/Radius of Action increased by 30%
CSAR Mission T/O @ 3000ft AMSL, 45°C	Radius of Action increased typically by 20 - 35% dependent on role configuration
Trooping Mission 2 T/O @ 3000ft AMSL, 45°C	Range / Radius of Action increased by >25%
High Altitude loiter @ set radius of action, T/O @ 3000ft AMSL, 45°C	Endurance typically doubled

Table 2. Improvements arising from BERP IV blade versus BERP III blade on either the Merlin Mk3 or Merlin Mk3a variant.

Due to the clearly demonstrated performance enhancement that BERP IV provided Merlin the TDP blade design was adopted, virtually unchanged, and incorporated into the Merlin HC Mk3a baseline configuration. The contract for six Merlin HC Mk3as, incorporating BERP IV production standard blades, was placed in Jun 07 and the first two aircraft were delivered to RAF Benson in Dec 07. Looking back over the TDP, exploitation can be broadly attributed to the following factors all playing their part:

a. The high priority given to exploitation by both MoD and WHL staff throughout the programme. For example the original flight demonstration platform was to be a Lynx. Having established during Phase 2 that the Merlin would provide an earlier exploitation route, the detailed design, manufacture and flight demonstration phase (Phase 3) was re-focussed on Merlin.

b. The joint MoD/Industry programme structure that ensured a singularity of purpose and a constant re-affirmation of contract objectives and technical direction in support of the ultimate common goal of exploitation in service.

c. The benefits that the technologies bring address current capability requirements and offer simultaneously the potential for reduction in through life costs.

d. The generic nature of the technologies. Each is applicable to all of the MoD's BH fleet and exploitation is therefore robust to changes in the Equipment Programme.

e. The successful demonstration of the technologies in a representative environment and therefore mostly at TRL 7.

f. Other circumstances, for example operationally driven requirements from theatre.

g. Regular communications with, and operationally relevant briefings to, senior MoD decision makers.

In terms of exploitation, the ultimate success of a TDP can only be fully judged retrospectively via an examination of how widely the demonstrated technologies were adopted into new production rotor blade designs. However, there is clearly benefit in understanding what enabled the BERP IV programme to address such high technical risk and still conclude by providing the UK with what was required to enhance operational capability in so timely a fashion. It is therefore worth considering some of these points more closely.

The high priority given to exploitation from the outset is indicative of an exploitation culture within the joint programme team. This is not an easy culture to adopt and both the MoD and WHL cite exploitation as one of the key challenges both during and after the TDP. The technologies developed during BERP IV truly have something to offer every helicopter platform both in the traditional arenas such as improved lift performance, vibration reduction, and improved supportability through improved reparability and through unique survivability benefits. The inhibitors are establishing clearly articulated requirements and associated production investment. AW & MoD have already jointly invested over £25M to get to this stage, and AW is continuing to invest in BERP IV technology, beyond the TDP, to enable exploitation beyond the Merlin Mk3a onto other AW101 variants. Even though the TDP has established a reduced lead-time needed to produce and qualify a new rotor blade design; clear decision making is imperative if operational benefits are for other types are to be delivered to the front line. The trend at present is to slip decision dates for equipment programmes without slipping the in service date (ISD). This creates the risk that a truly world leading UK engineering capability will remain under-exploited due to planning uncertainties and indecision.

There are several potential methods that could mitigate this risk. R&D success criteria could be articulated in terms of both the closure of a discreet project and the future adoption into operational use. This would shift the focus of programme managers from overseers of discreet contracts onto delivering capability enhancements, through life. Such enhancements are sought by the MoD within the framework of Through-Life Capability Management (TLCM) driven by the equipment customer community who are themselves informed by the FL Services and the MoD Forces Permanent Joint HQ. This provides reassuring endorsement of the approach adopted by the BERP IV programme ten years earlier, ensuring that 'buy-in' from all levels of the MoD to a new programme's objectives are seen as critical element. This buy-in of stakeholders is an increasingly important programme management tool that allows a continuity of message to be preserved through the duration of the task and for them to be invested rather than merely involved. Clearly, the ECC must retain a sponsoring role or else a management by committee situation might develop, but the benefits might help set aside any prejudicial mistrust that typically exists between MoD and industry. The recent move to establish the Unified Customer, which includes the user community, should assist this. For example, at the outset of Phase 3 of the TDP, the JHC engagement was supportive and now as a full member of the Unified Customer they have had significantly more presence, particularly in the exploitation phase.

Two other elements of stakeholder buy in include the ability to overcome misunderstanding and to challenge established protocols. In the BERP IV TDP, such misunderstandings existed right up until the blade was flown. Momentum was regained with continuous and specifically capability-focussed briefings to the ECC by the combined MoD and AW project team. The communication of how technical progress has bearing on operational capability, through the clear identification of military benefit to those decision makers, is therefore an essential element of exploitation. Such briefings are outside the normal day-to-day business of the organisational structures necessarily promoted within MoD and industry; going beyond the established norms of formal reporting of progress to meet a commercial obligations. Challenging the 'business as usual' concept of doing things in a certain way proved successful in the BERP IV TDP. Front line military personnel were engaged in user-designer dialogue to strong effect and programme staff found that they were often empowered to inject pace and innovation. Such empowerment required that they communicate openly and honestly the right message with the right stakeholder.

Perhaps the most critical building block for exploitation is funding. Funding for TDPs faces near constant scrutiny within the MoD and it is not always only non-productive programmes that face the threat of cancellation. The BERP IV TDP spending indicated in Figure 4 suggests that up to 75% of funding will be needed to mature technology from TRL 5-7. The funding stream does not necessarily need to be absolutely constant, but once a TDP has been agreed it should be subject to a streamlined process of funding provision and reaffirmation, if it is to meet any exploitation based success criteria. In BERP IV, a little over 30% of the time was spent waiting for further funding approvals through the MoD system despite the presence of an overarching approval for the entire concept prior to commencement of Phase 1. Even though the change of demonstrator aircraft from Lynx to Merlin necessitated a re-approval, incurring the delay observed between Phases 2 and 3, the objectives in technology maturation and demonstration remained the same throughout the programme and this suggests that the BERP IV rotor could have been fielded operationally somewhat earlier.

Finally, it is worth commenting briefly on two elements that are considered to have contributed to the exploitation success of BERP IV. The first is working on the working relationship; an extension of stakeholder investment. The MoD and WHL programme managers were very joined-up and worked extremely closely together, so much so that they were essentially part of the same team. Working within this partnering way occurred before the strategic partnering initiative, but the latter validated and encouraged the behaviours that made the relationship work. A US Army briefing stated that the collaboratively managed nature of the entire BERP relationship was in their view a key enabler to its success.[6] Secondly, although the AW programme managers have moved on from the TDP into other roles, they remain charged with acting as project champions within the AW rotor systems department. This clear mandate is not however the norm within the MoD because of the frequent turnover of personnel. The FBG project manager (author) has been tasked to act as a specialist within the rotor system domain although the formal role to pursue exploitation resides within the other DE&S Integrated Project Teams. The key point is that exploitation is not finished at the end of a TDP, it is only just beginning. As suggested earlier, true success from a TDP comes when the technologies are implemented on production equipment and this requires a significant effort post the TDP activities, not least because of the myriad additional stakeholders involved.

CONCLUSIONS

The BERP IV TDP has simultaneously demonstrated new rotor blade technologies in a representative environment at, and in some cases above, TRL7. Thus, the original programme objectives have been achieved. The programme has also demonstrated that with a truly integrated design, there is the potential for many tangible benefits for front line aircrew and the operational capability they deliver. But in examining BERP IV in the context of exploitation, it becomes apparent that exploitation relates both to the technology involved in, and to the methods used in, running the programme.

[6] Koontz et al, US Army / NASA delegation “Exit Brief” to the MoD-AW BERP IV team, Farnborough Jan 03.

It is important to remember the context of the programme. BERP IV exists in the UK BH domain, which comprises mainly legacy platforms that already have a through life cost associated with them. In the pipeline will, eventually, be replacement BH programmes, solutions to which could be new build, or new design, but are most likely to be a retrofit onto existing designs. Such a context probably exists within all other military BH operators and within the companies that manufacture them. Within the UK however, one thing is certain, provision of financial resource is stretched. Extrapolating out with BERP IV, this context remains for all programmes involving UK BH helicopters. It was recently commented by one of the author's colleagues who arrived after BERP IV was complete but in time to learn about the programme, 'that the principles of BERP IV should be applied to future TDP programmes within the MoD.' Similar programmes are already underway within FBG and span multiple equipment types.

Equally, one might comment that the methods, processes and principles are not, like the technology involved, 'rocket science', but rather principles enshrined in the good project management of complex programmes. This is not to dismiss the efforts of the AW TDP team but rather to congratulate them on ensuring that the critical activity of requirements capture involved front line discussions, for creating an open, honest and inclusive atmosphere in which communications and stakeholder buy-in were facilitated and for maintaining a focus on keeping the programme generic to maximize exploitation opportunity. The context of the TDP reflects also some sensible early decisions. BERP IV was not a TDP developing one technological item for a single platform, but rather one where several technologies were integrated. Remaining independent from any particular platform, the MoD project manager (outside the regular IPT structure) ensured exploitation remained a strong focus in addition to success on any individual programme. It is hoped this will, in time, deliver the widest exploitation across the BH fleet.

The flight demonstration programme was pivotal to achieving buy-in from the wider MoD stakeholder and securing the decision to exploit BERP IV onto Merlin HC MK3a. Verification of new technologies and benefit needs to be sufficiently representative, implying flight demonstration, as opposed to ground rig running (for example) is required to both capture the interest of the decision makers as well as demonstrating the maturity of the technology. One principle being applied to the forthcoming FBG BH related programmes was learned from this. Figure 5 implies that maturing the programme through to the higher TRLs (7+) might require up to 75% of the funding of an entire research and demonstration package. Vibration management and platform survivability programmes are therefore being profiled this way as a 'starter for 10', recognizing that without a benchmark in another contextually similar TDP to BERP IV, we cannot be certain that the ideas developed BERP IV will guarantee success.

With reference to the technology and specifically TRLs which, it is recognised, are often defined differently by different organizations, it is important to note that without an over-riding imperative to pull-through relatively immature technologies at TRL5, the demonstration of technologies to TRL7 (Technology system demonstration in an operationally relevant environment) is necessary to convince the decision makers that there is sufficiently little risk remaining to adopt a technology for rapid implementation. Thus, BERP IV gleaned knowledge suggests that the traditionally held view that demonstration to TRL6 is enough de-risking activity to ensure exploitation is incorrect. TRL 6 (Technology prototype demonstration in an appropriate environment) certainly would not have been enough for BERP IV technologies as momentum only started to gather towards exploiting the demonstrated technology on the Merlin HC Mk3a after the literal take-off of the blades in Sep 06.

As for the future, studies are underway to investigate the detailed operational and through life cost benefits that would be available to other platforms in the UK fleet, should BERP IV based blades, specific to those types, be incorporated. The MoD has already identified a BERP IV based blade as being required to meet the platform weight growth for the Future Lynx derivatives at some point early into its life cycle. All other legacy platforms, including those not sourced from AW, could benefit from the application of a BERP IV based blade; the improvements, once established, would inform the start of a bespoke rotor blade development programme using the BERP IV knowledge base. This approach is aligned with that clearly stated in the MoD's Defence Industrial Strategy.[7]

REFERENCES

1. S Stacey, R Harrison, R Hansford, *BERP IV - The Design, Development and Testing of an Advanced Rotor Blade*; The American Helicopter Society, May 08.

ABBREVIATIONS

AMSL	Above Mean Sea Level
AW	AgustaWestland
BERP	British Experimental Rotor Programme
BH	Battlefield Helicopter
CMRB	Composite Main Rotor Blade
DEC(ALM)	Director of Equipment Capability (Air & Littoral Manoeuvre)
dstl	Defence Science and Technology Laboratory (UK MoD)
ECC	Equipment Capability Customer (UK MoD)
ISD	In Service Date
JHC	Joint Helicopter Command
MSL	Mean Sea Level
MoD	Ministry of Defence (UK)
PJHQ	Permanent Joint Head Quarters
R&D	Research & Development
RAE	Royal Aircraft Establishment
T/O	Take Off
TDP	Technology Demonstration Programme
TLCM	Through Life Capability Management
TRL	Technology Readiness Level
UOR	Urgent Operational Requirement
WHL	Westland Helicopters Ltd

[7] MoD Defence Industrial Strategy, Page 94, Dec 05.

ACKNOWLEDGEMENTS

The author would like to fully acknowledge the achievements of AgustaWestland (Yeovil) in the successful completion of the BERP IV TDP. In addition to the whole team of dedicated engineers at AW, I would like to make special mention of my two colleagues; Mr Simon Stacey (AW BERP IV Task Leader) and Mr Rob Harrison (AW BERP IV Team Leader) for their constant enthusiasm for the project & their support over the past 9 years. Without the working relationship we together forged and their goal focussed approach to problem solving along the way, it is unlikely I would be in a position to consider writing this paper.

A special acknowledgement must go to Mr Tim Moores, lately MoD Research Director (Air and Littoral Manoeuvre) for his endeavours to maximise the exploitation of research and technology into helicopters. My sincere thanks also to Sqn Ldr Stu Clarke RAF, for his significant effort applied in gathering, structuring and editing and proof-reading the paper.

Figure 7. BERP IV team photocall, 19 Jul 07, AgustaWestland, Yeovil.