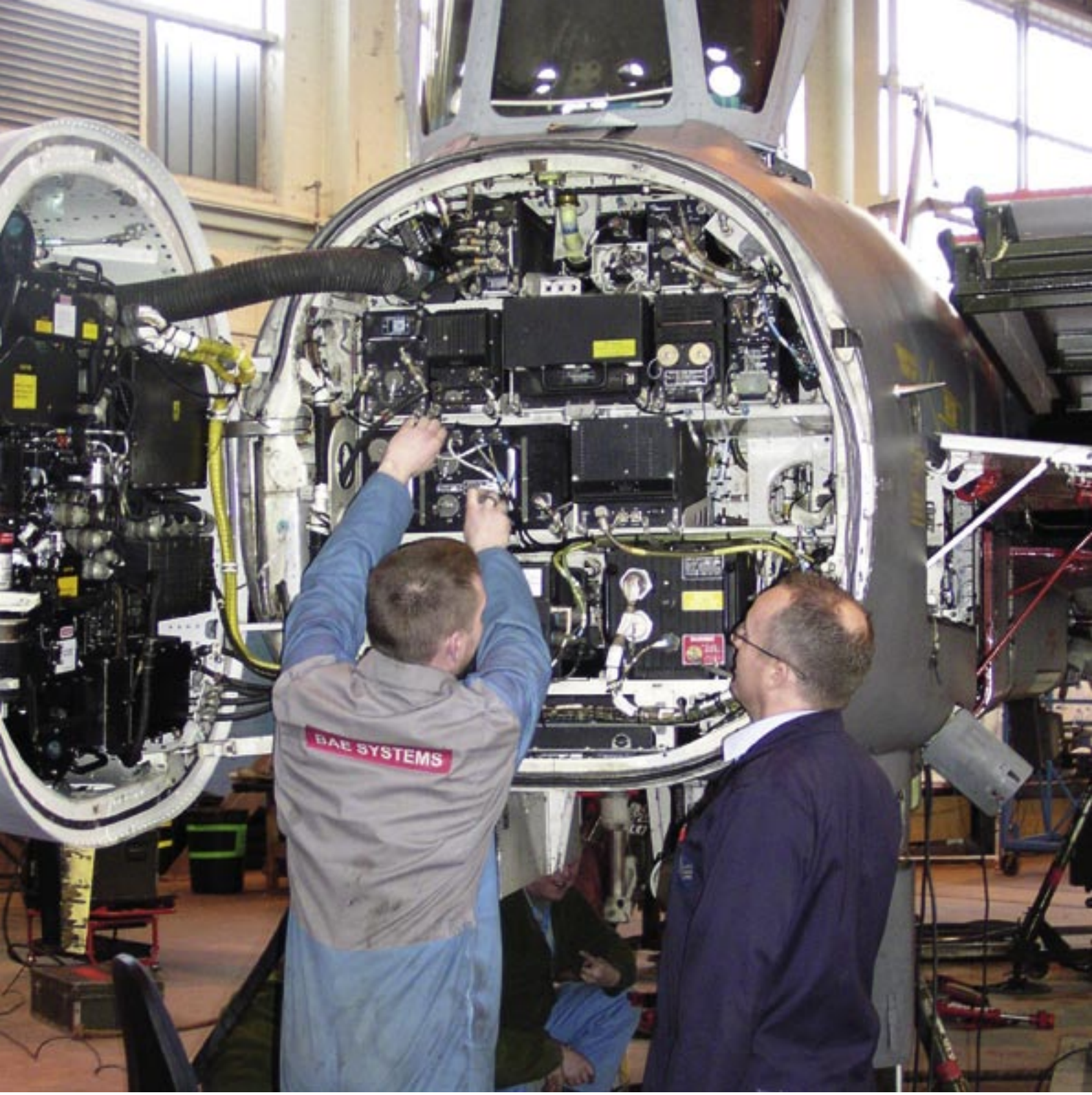

National Audit Office

Transforming logistics support for fast jets

REPORT BY THE COMPTROLLER AND AUDITOR GENERAL | HC 825 Session 2006-2007 | 17 July 2007

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National Audit Office

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Comptroller and Auditor General
National Audit Office

9 July 2007

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Photographs courtesy of BAE Systems and The Harrier, Jaguar and Survival Integrated Project Team

SUMMARY

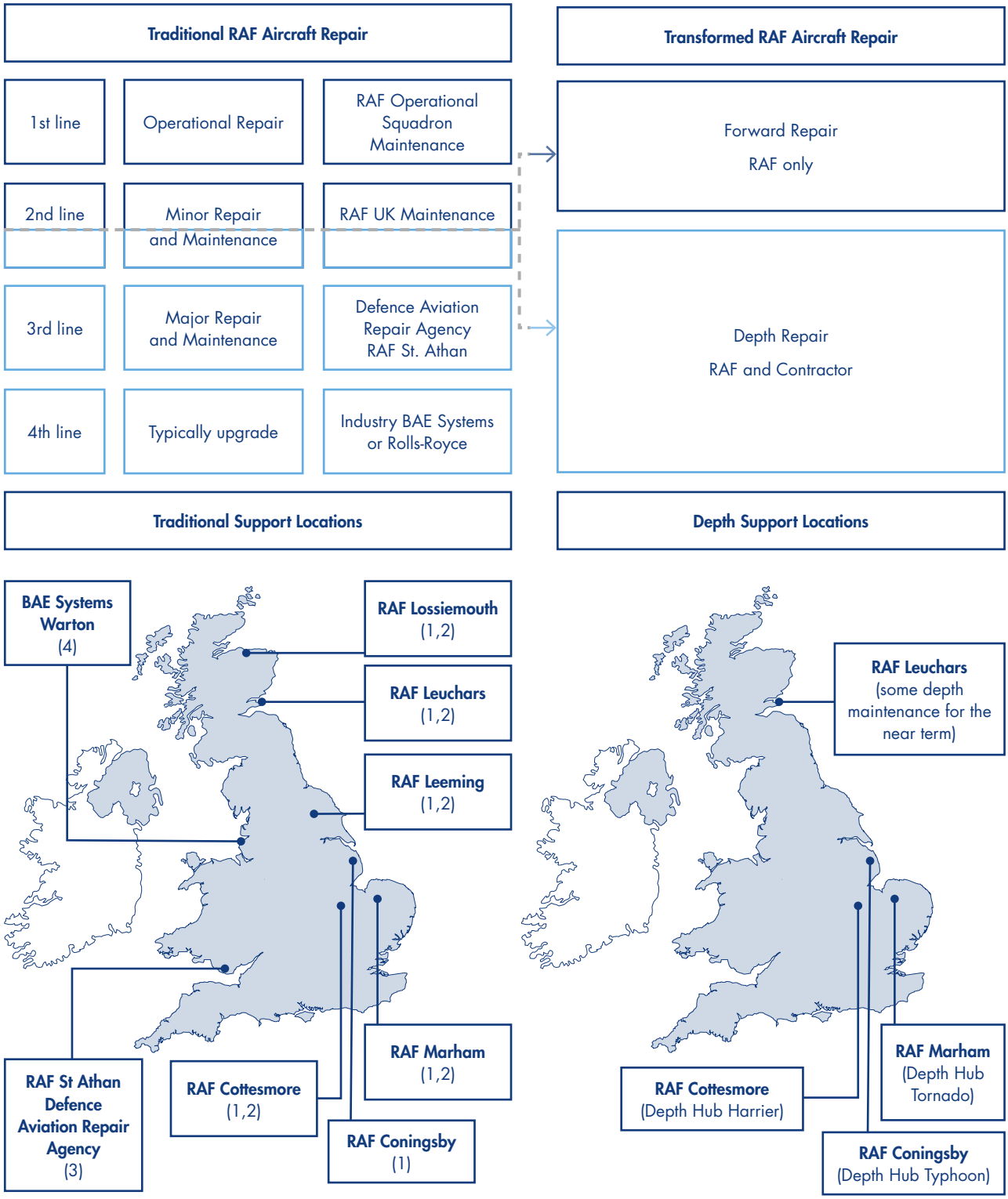
1 The Ministry of Defence (the Department) is transforming the provision of maintenance, repair and overhaul activity for Harrier and Tornado fast jet aircraft. The key driver for the change has been the Defence Logistics Organisation's[1] strategic goal of reducing operating costs by 20 per cent of the total by 2005-06 (around £1.862 billion). The changes have also been enabled by the changed threat against the United Kingdom following the end of the Cold War, which removed the requirement for a repair organisation dispersed across multiple airfield sites to provide contingent capability in the event of an attack on a Royal Air Force (RAF) main operating base. This has allowed the Department to pursue rationalisation where it makes operational and economic sense to do so.

2 In the three years since its 2003 End-to-End Review of logistics[2], the Department has significantly changed arrangements for logistics support for fast jets. The Department and industry previously carried out four levels of repair and overhaul on fast jets at multiple locations but has rationalised repair into two organisational structures: 'forward repair' is undertaken at each operational squadron; and the Department has rationalised the number of 'depth repair' locations to a single depth hub at which aircraft are maintained, repaired and overhauled. The new depth hubs are at RAF Marham for Tornado aircraft and RAF Cottesmore for Harrier aircraft **(Figure 1)**.

1 From 1 April 2007, the Defence Logistics Organisation ceased to exist as the Department established a single organisation, Defence Equipment and Support, to manage all equipment throughout its life, from acquisition to disposal.
2 Streamlining End to End Air and Land Logistics, Ministry of Defence, 1 July 2003.

1 Rationalisation of Fast Jet Repair Activity and Location

In the past the repair and overhaul of fast jets was conducted at four lines, at numerous dispersed locations. From 2004 this was changed to two organisations at a reduced number of RAF bases.



Source: National Audit Office

NOTE

Numbers in brackets denote the line of support.

3 In designing the repair processes and associated support at the depth hubs, the Department has applied lean techniques **(Figure 2)** to introduce more efficient repair processes, introducing 'pulse lines' for aircraft, engines and sub assemblies, similar to a motor car production line **(Figure 3 on pages 8 and 9)**. Upgrade work has been integrated within the depth repair process utilising pulse lines, including the major upgrade programme for Harrier from GR7 to GR9 variants, and the Department has significantly extended the number of flying hours for Tornado and Harrier aircraft between scheduled maintenance.

4 The Department has entered into new partnerships, consistent with the Defence Industrial Strategy[3], with industry Prime Contractors, BAE Systems plc and Rolls-Royce plc, which use industry managed collocated joint teams of contractors and military personnel at each depth hub. These mixed teams carry out repair and maintenance activity on the pulse lines and in the supporting repair workshops (Figure 3). The arrangements involve a move towards contracting for availability rather than traditional spares and repair contracts. Availability contracts deliver an agreed number of aircraft or engines at an agreed level of capability over the length of the deal. While there are differences in the processes and actual delivery of the maintenance of the Tornado and Harrier aircraft, the contractual approach remains broadly similar.

2 Lean techniques and pulse lines

The Department has redesigned its processes for repairing fast jets using lean techniques.

Lean techniques were developed from the Toyota Motor Manufacturer's production system in the early 1990s and have been subsequently used extensively in the manufacturing sector, and more recently in the United States Air Force. Techniques such as Value Stream Analysis and Rapid Improvement Events (Appendix 3) are used to identify and eliminate any activity or process that does not add value to the end user or customer, enabling the remaining activity to flow in the most efficient sequence possible. A typical application of these lean techniques is the pulse line production system. The Department has applied lean techniques and made use of pulse lines to transform the maintenance of its fast jet aircraft and associated sub-assemblies. In a pulse line production system, the total maintenance activity is divided into a series of equal packages, the aircraft or item is then physically moved or 'pulsed' from one pulse area within the hangar to the next. The pulse line and the use of a visual management system increase the consistency of the maintenance process. This enables the efficient management and forecasting of personnel, equipment and spares requirements within each pulse, leading to reduced maintenance times and greater visibility of remaining spares inventories.

Source: National Audit Office

5 These elements of transformation have been ongoing over recent years, with changes introduced at different times. The cost of support has decreased significantly; transformation has produced positive results in terms of reduced in-year budgets for aircraft support for Integrated Project Teams. Over the period 2001-02 to 2006-07, the Department has achieved cumulative savings on the support of Tornado and Harrier aircraft of £1.3 billion and £109 million respectively. The Department has reduced the number of Service personnel involved in depth repair by around 360. Further cost and manpower reductions are planned for both aircraft fleets. The main cost of change is associated with the super-hangar at St Athan[4] and the subsequent closure of the Defence Aviation Repair Agency's fast jet business. This is estimated to be in the region of £140 million, and is significantly outweighed by the savings achieved.

6 Performance has been broadly maintained throughout the transformation of support, with some shortfalls associated with the transition. The operational availability[5] of Harrier aircraft to frontline squadrons has been below target since 2001, pre-dating transformation. Operational availability dropped further in April 2003, with the start of the Harrier upgrade programme at BAE System's site at Warton, but improved as work was transferred to the new depth repair hub at RAF Cottesmore. In the last half of 2006 aircraft availability has been at or close to 100 per cent against a revised target, mainly because there were fewer aircraft in depth repair.

7 The Department has improved performance for the repair of Harrier aircraft. Established in 2002, the pulse line at RAF Cottesmore reduced the time taken to perform a minor maintenance by 19 per cent. Since the commencement of the Joint Upgrade and Maintenance Programme at RAF Cottesmore, which combines the minor maintenance of the aircraft with a major upgrade programme on a single pulse line, the Department has also achieved a 43 per cent decrease in the time taken to convert Harrier GR7 aircraft to GR9 standard. This allowed the Department to exceed, by two aircraft, its target of upgrading 24 aircraft by September 2006. The Department has also met a significant surge requirement for repair associated with operations in Afghanistan. These new maintenance arrangements have avoided having aircraft in depth repair and therefore an extra 11 aircraft are available to the frontline. Improved repair processes on the pulse line for the Harrier Pegasus engine have reduced turn around times by 59 per cent.

3 Ministry of Defence, *Defence Industrial Strategy: Defence White Paper*, Cm 6696, December 2005.
4 We are conducting a separate examination of the Ministry of Defence's investment in the super-hangar facilities at St Athan.
5 In the Department this is known as the Forward Available Fleet.

8 From 2000 to 2003, operational availability of the Tornado GR4[6] averaged 100 per cent of target. The start of the decline in performance pre-dates the establishment of the pulse line in December 2005 at RAF Marham, when availability averaged 93 per cent. Since September 2006 the availability trend has been rising and the target was met from the end of December.

9 The Tornado GR4 pulse line is less mature. Nevertheless, the Department has reduced minor maintenance repair time by 37 per cent compared with that previously achieved by the Defence Aviation Repair Agency. The Department expects performance to improve in a similar way to the Harrier programme, as pulse line learning increases and the specific supply chain problems are resolved. As with Harrier, the Tornado pulse line is designed to increase the number of modifications to the aircraft during repair, thus improving operational capability and mitigating the problem of having aircraft at numerous different capability standards within the fleet, but is not yet delivering an upgrade programme. The Department has improved performance for the 'off-aircraft' repair of engines and sub-assemblies. Since entering into a partnered availability contract with Rolls-Royce, the Department has achieved 100 per cent availability of the Tornado RB199 engine, and reduced rejection rates and hence the number of engines in depth repair.

10 The evolution from traditional spares and repair contracts towards contracting for availability of aircraft, engines and sub-assemblies, has required the Department to change significantly its approach to working with Prime Contractors. The Department characterises its historical relationship with industry as adversarial and it has worked hard to develop a culture of partnering. Joint working has been successfully established through combined Departmental and industry Integrated Project Teams, and the collocation of BAE Systems and Rolls-Royce personnel onto main operating bases. With this fundamental change the Department has moved away from the traditional model of paying for volume of repair and sought to motivate industry to reduce the cost of support through the use of gainshare and incentive payments.

11 There is potential for the Department to exploit transformation further, but there are risks that require careful management. There are two significant risks to the future performance of the depth repair hubs at RAF Marham and RAF Cottesmore:

- To date the Department has not been able to meet its contractual commitments for military manpower for either the Tornado or Harrier pulse lines and the skill and experience mix of the workforce does not match the plan. The Department has recognised the risk to manning the pulse lines arising from its challenging targets[7] for manpower reductions in the RAF, and is now committed to finding reductions to meet its targets from trades outside the logistics area.
- There continue to be problems with the timely supply of spares for both Harrier and Tornado pulse lines. Although the Department believes that performance is no worse than in the past, the supply chain is critical to the operation of the pulse lines and the Department is working with industry to resolve these difficulties.

12 There are promising signs that logistics transformation is becoming self-sustaining. The RAF is taking ownership of transformation, is adopting the lean techniques pioneered by depth organisations, and the Defence Logistic Organisation's Lean Teams have helped establish a culture of continuous improvement at station level. The lessons learned in transforming logistics support for Tornado and Harrier are being used in the design of support for the new Typhoon aircraft. Our recommendations highlight a number of issues that the Department needs to address in continuing to improve support to fast jets, which are likely also to be relevant to transformation in other areas of its business.

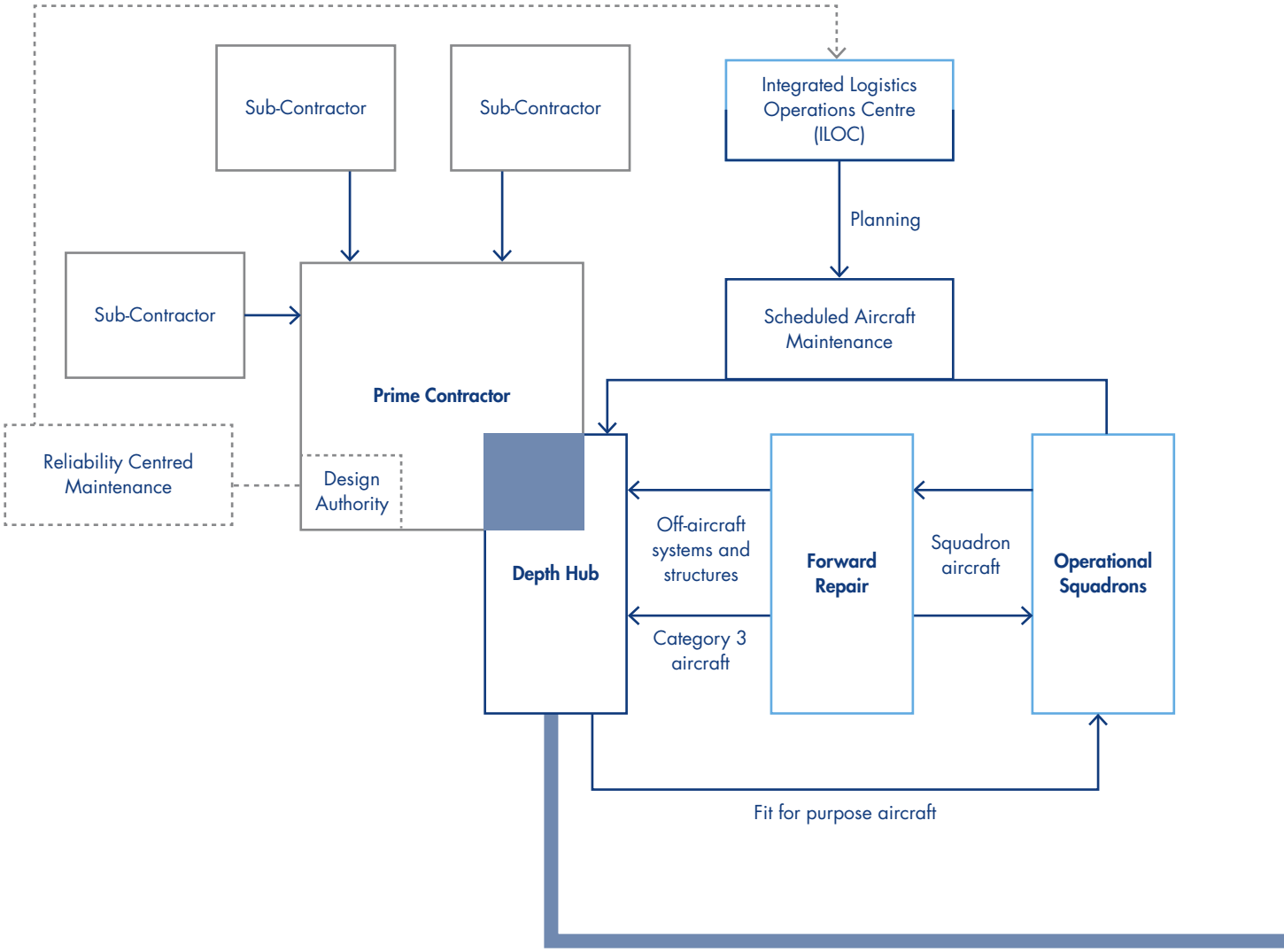
Overall Value for Money

13 The Department has made significant reductions in the cost of support to fast jets; the Tornado and Harrier Integrated Project Teams' costs have reduced from a total of £711 million in 2001-02 to £328 million in 2006-07, providing a cumulative saving of some £1.4 billion over the six-year period. At the same time, although aircraft operational availability declined during the transition to the new depth repair hubs, the subsequent meeting of availability targets on Harrier over the last five months suggests that availability can be achieved consistently on Tornado once the pulse line achieves a similar level of maturity. The Department has continued to achieve broadly the same level of performance in terms of flying hours throughout the transformation. On this basis, the Department's transformation of logistics support represents good value for money to date and although there are risks, the Department is working to manage them.

6 Tornado has two variants: the fighter designated F3 and the bomber designated GR4; this Report deals predominantly with the GR4 variant.
7 Calculated top down in response to the cross-Government Gershon Efficiency Review.

3 The organisation and activity of forward and depth repair hubs

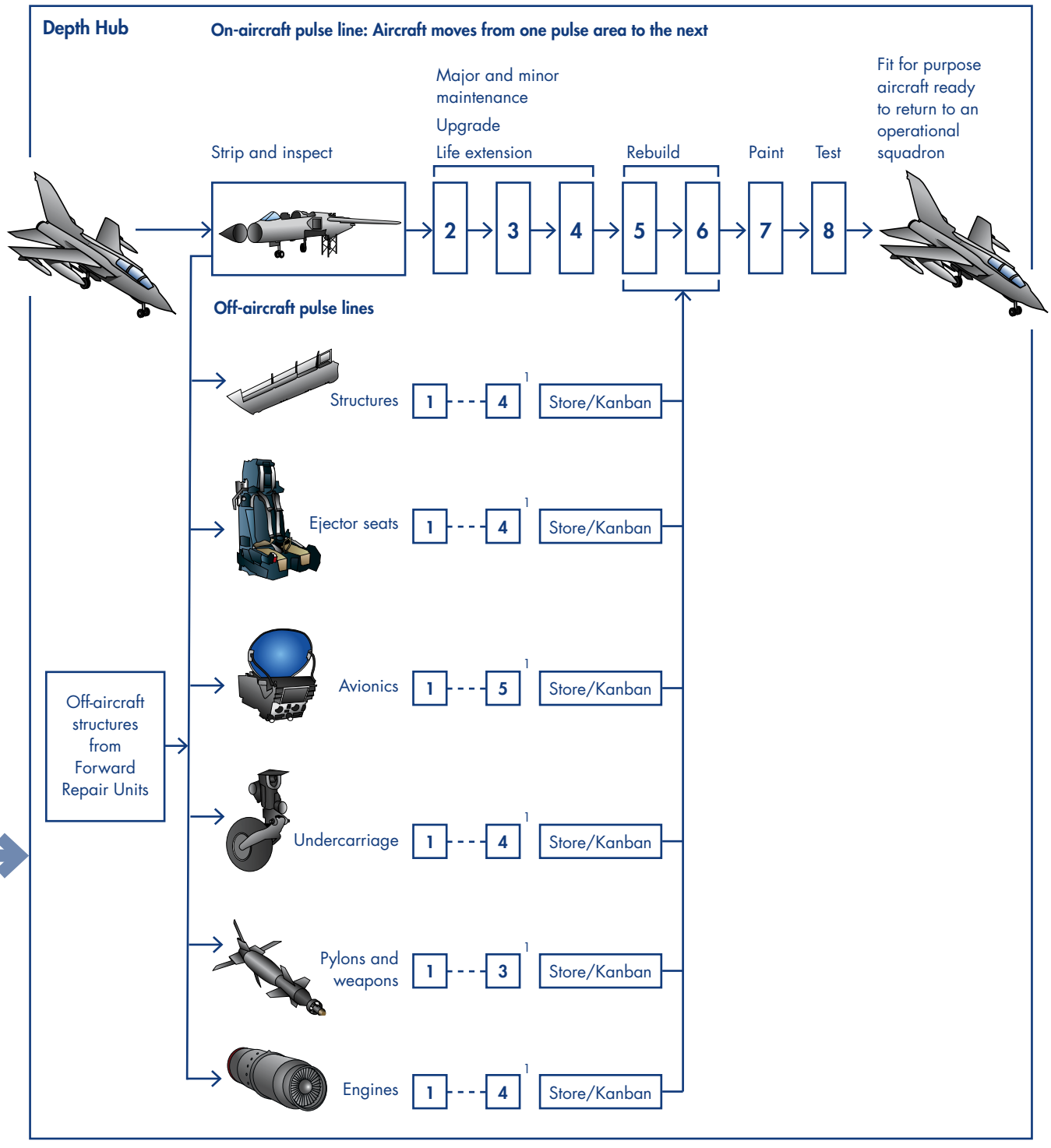
An illustration of how the new repair arrangements operate at RAF Cottesmore for Harrier aircraft and RAF Marham for Tornado aircraft.



Source: National Audit Office

NOTE

1 Length of off-aircraft pulse lines are for illustrative purposes only. The total number of pulses can vary depending on the level of maintenance and the particular piece of equipment being maintained.


Depth Hub
On-aircraft pulse line: Aircraft moves from one pulse area to the next
Strip and inspect
Major and minor maintenance
Upgrade
Life extension
Rebuild
Paint
Test
Fit for purpose aircraft ready to return to an operational squadron
2
3
4
5
6
7
8
Off-aircraft pulse lines
Structures
1
4
Store/Kanban
Ejector seats
1
4
Store/Kanban
Avionics
1
5
Store/Kanban
Undercarriage
1
4
Store/Kanban
Pylons and weapons
1
3
Store/Kanban
Engines
1
4
Store/Kanban
Off-aircraft structures from Forward Repair Units

14 The Department's financial information systems enabled us to calculate the key costs of support for fast jets borne by the Harrier and Tornado Integrated Project teams, and assess the overall savings achieved by the Department. However, the Department does not have sufficient data to be able to assess the impact on total costs of changes in the pattern of frontline operations, and further productivity increases through the extension of lean techniques. We recommend that the Department develop its management accounting capability and costing processes to develop a more comprehensive picture of the overall cost of output for each aircraft fleet, and a better understanding of the link between different cost drivers for support and the operational output achieved.

Recommendations

15 Given our conclusion that the Department's transformation of logistics support to fast jets represents good value for money to date, our recommendations aim to support and enhance the work the Department is already undertaking to manage the risks in the new support arrangements and further embedding the culture and practice of continuous improvement. Many, if not all, of our recommendations are likely to be relevant to changes in support arrangements, underway or planned, for other aircraft types and for land and maritime equipments. Our key recommendations are set out below, with more detailed recommendations in Appendix 1.

Managing the key risks to the performance of the pulse lines at the depth repair hubs

16 By implementing the following recommendations, the Department should be better placed to manage the key risks to the future performance of the depth repair hubs for Tornado and Harrier aircraft at RAF Marham and RAF Cottesmore:

17 **Recommendation 1:** The Department should improve its ability to provide the level of Service personnel contracted to work in the depth repair hubs at RAF Marham and RAF Cottesmore. The Department should also review if it has sufficient flexibility to meet operational contingencies.

18 **Recommendation 2:** The Department should improve the availability of spares by continuing to work with its industry partners to address the problems that are preventing the pulse lines from running as efficiently as planned.

Entering into future partnering arrangements

19 By implementing the following recommendations, the Department should strengthen its capability to enter into cost effective partnering arrangements with industry:

20 **Recommendation 3:** The Department should improve its guidance and consistently apply a common methodology for constructing internal value benchmarks against which to assess the value of proposed contracts. Internal benchmarks should make allowance for realistic efficiency improvements through any in-house solution.

21 **Recommendation 4:** The Department should assess whether it has sufficient commercial, cost modelling and project management skills to develop the commercially viable support solutions and negotiate contracts, given the increasing complexity and likely volume of industrial logistics support.

Prioritising further improvements to support for fast jet aircraft

22 By implementing the following recommendations, the Department should be able to prioritise better its future change activities for fast jets to derive the greatest operational benefit:

23 **Recommendation 5:** The Department should improve its understanding of the future output requirements, in terms of both operational and training flying demand, by modelling the relationship between the required output and different elements of repair and support. In doing so, the Department should improve its management information systems so that this data is routinely available, including the full costs of supporting aircraft across all of the budget holders involved.

24 **Recommendation 6:** The Department needs to conduct a high-level end-to-end assessment of key elements of change to identify which have delivered the greatest benefits to date and where there is the greatest potential for further transformation, given constrained resources.

Incentivising transformation and continuous improvement

25 By implementing the following recommendations, the Department should further incentivise the behaviours of project teams and industry to improve fast jet support and other activities across the Department:

26 **Recommendation 7:** The Department should take the opportunity afforded by the transfer of budgetary accountability to frontline commands, including RAF Strike Command, to align incentives further between the frontline customer and support organisations, so that the impact of frontline activity on support requirements is considered.

27 **Recommendation 8:** The Department's challenging targets for cost reduction have been a key driver for transformation but there is a balance to be struck between these reductions and the ability to invest in transformation. The Department should make a proportion of the savings from transformation, and particularly from gainshare achieved on contracts, available to teams to reinvest in future improvements. This could help embed the culture of continuous improvement by incentivising teams better to drive through change.

28 **Recommendation 9:** In time, the Department should use its experience of the newly introduced gainshare arrangements on fast jet support contracts to inform future decisions on the level of gainshare required to effectively incentivise industry. In doing so, the Department should assess whether industry has been sufficiently incentivised to drive through future efficiency gains and performance improvements in their own management of the service, and in the supply chain.

Maintaining the capability to apply lean methodologies

29 By implementing the following recommendations, the Department should further strengthen its capability to apply lean methodologies in logistics support and elsewhere in its business:

30 **Recommendation 10:** In order to maintain the momentum of transformation for fast jets, and facilitate successful transformation in other areas of its business, the Department should review whether it is able to deploy sufficient internal and external expertise in methodologies such as using lean techniques.

31 **Recommendation 11:** The Department should adopt a common toolset and language for lean techniques across all areas of its business. The Department should make its lessons learned material more evaluative to provide information on how the methods were applied, and quantify the results they achieved.

PART ONE

The Department has significantly changed logistics support for fast jets

1.1 Logistics is crucial to the success of military operations and in 2000, the Department created the Defence Logistics Organisation[8] to bring together the three single Service Logistics Commands into a unified structure. With a reducing defence budget and against the backdrop of the end of the Cold War enabling the Department to pursue rationalisation, the Chief of Defence Logistics set a strategic goal of cutting logistics support costs by 20 per cent by 2005-06, while maintaining or improving the quality of service to the frontline. In the light of these cost pressures, the Department re-examined its provision of logistics support to fast jet aircraft. This Part of the Report sets out the significant changes the Department has made in its arrangements. Elements of transformation have been ongoing over recent years, with changes introduced at different times. **Figure 4** sets out a timeline of the key developments.

The Department created depth repair hubs on main operating bases, collocated with industry

1.2 The Department and industry previously carried out four levels of repair and overhaul on fast jets at multiple locations (Figure 1 on page 5). This was to ensure that contingent capability remained in the event of an attack on one or more of the main operating bases. With the ending of the Cold War requirement for dispersed repair, and decreasing financial resources, the Department began to consider streamlining its available repair facilities for fast jets. The End-to-End Review of logistics recommended, in July 2003, that repair equipment and facilities for each aircraft fleet should be centred at one location, as far as is practicable.

1.3 With the rationalisation of repair two organisational structures were developed for each aircraft fleet:

- Forward – each operational squadron has associated forward engineering support, which undertakes all operational repair as before, plus some additional minor maintenance.
- Depth – most maintenance and overhaul procedures not undertaken by frontline squadrons are centralised at these depth repair hubs; on-aircraft minor, major and modification work once undertaken by RAF main bases and the Defence Aviation Repair Agency, and upgrade work typically carried out by BAE Systems; and a large element of engine and component repair previously carried out in dispersed locations across the RAF and industry (Figure 1 on page 5).

From March 2004 the Department collocated all deep repair and upgrade maintenance for Harrier at the main operating base of RAF Cottesmore. Subsequently, from September 2004, RAF Marham became the main location for the deep repair and maintenance of Tornado GR4 aircraft.

1.4 These new depth repair hubs are run by the Department jointly with industry partners, providing improved access to Design Authority as well as bringing their experience of supply chain and asset management to bear on the process. Therefore, under the new arrangements the Defence Logistics Organisation, along with its industry partners, is responsible for depth repair and RAF Strike Command is responsible for forward repair. RAF Strike Command also supplies the depth repair hubs with the appropriate level of military manpower and the on-base facilities (Figure 3 on page 8).

8 From 1 April 2007, the Defence Logistics Organisation ceased to exist as the Department established a single organisation, Defence Equipment and Support, to manage all equipment throughout its life, from acquisition to disposal.

1.5 Under the new availability contracts the Department pays industry for aircraft, engines and components to be available for the military to operate, rather than paying for the repair, spares and technical support used **(Figure 5 overleaf)**. As industry is paid for a level of availability, it is incentivised to reduce support chain costs and make the aircraft more reliable and processes more efficient.

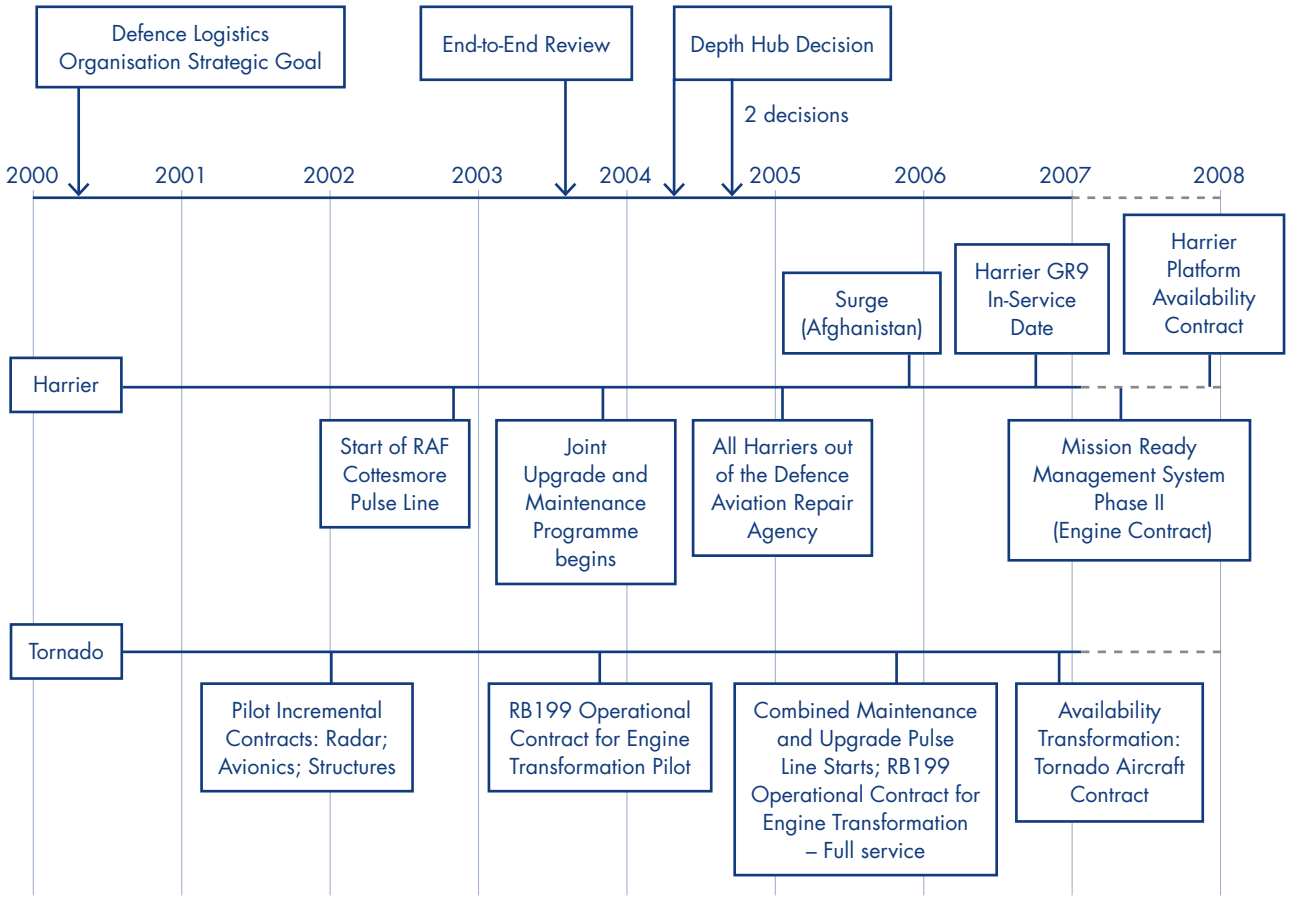
The Department has used lean techniques to improve the efficiency of the repair process

1.6 Fast jets require servicing or scheduled maintenance after they have flown a certain number of hours. The level of maintenance can be divided into three main types: 'primary' maintenance carried out by the forward organisation (not part of this Report) and 'minor' and 'major' maintenance carried out on average after 825 hours for Tornado and every 720 hours for Harrier in the depth repair hubs. To streamline and co-ordinate the process for managing its aircraft fleets across the squadrons and depth repair hubs, the Department established new Integrated Logistics Operations Centres in 2005-06. Defence Logistics Organisation and RAF Strike Command personnel staff these jointly, and they control the prioritisation of spares, the order in which aircraft enter the depth hub based on flying hours, and undertake an analysis to plan the work to be performed and the spares required.

1.7 As Figure 3 on page 9 shows, aircraft progress along pulse lines (akin to a production line in a car assembly plant) on entering the depth repair organisation. Previously aircraft were repaired in a stationary position and the maintainers brought spares and equipment to it. Now the necessary repair is divided into sequential packages of equal duration (the length of which depends on both the aircraft and maintenance type) and as the aircraft moves between the 'pulses'. The pulse lines speed up the repair process because they are designed to remove inefficiencies; for example

4 Time line of transformation events

Transformation was driven by the Department with changes in logistics support being progressed independently for Harrier and Tornado aircraft.



Source: National Audit Office analysis of Ministry of Defence data

by reducing tradesmen's waiting times by improving the scheduling of individual repair activities, and locating spares where they are needed rather than distributing them around the maintenance facility. The Department has devised pulse lines by using lean techniques (Appendix 3) from the lean production system developed by Toyota, which is also widely used in commercial manufacturing and already applied by the United States Air Force for aircraft repair.

1.8 During the depth repair process an aircraft is stripped and inspected to enable any emergent work to be determined. This work is added to the scheduled work previously planned by the Integrated Logistics Operations Centre. The stripping process removes a large number of components and systems that are not part of the airframe. (These 'off-aircraft' parts then follow their own repair pulse lines or are stored until being re-fitted to an aircraft later in the pulse line). Scheduled maintenance and upgrade is then carried out and the aircraft is rebuilt, tested and painted. The whole process is achieved using a mix of military and contractor manpower.

The changes in support to fast jets are now part of a larger programme of logistics transformation

1.9 In April 2004, the Chief of Defence Logistics established the Defence Logistics Transformation Programme to provide coherence to more than 1,000 transformational projects occurring across the entire logistics area, measure the benefits, communicate best practice and report on performance against his strategic and Departmental efficiency targets. The Programme, in its current form, is due to end in March 2008 and the Department's aspiration is for transformational activities to have become embedded in the Defence Logistics Organisation and frontline commands by this time.

5 The main contracts for Harrier and Tornado GR4 aircraft

The numerous existing contracts for the repair and overhaul of fast jets will be rationalised into two or three high value availability contracts with Prime Contractors.

Contract	Detail	Costs	Date signed
Joint Upgrade and Maintenance Programme (JUMP) with BAE Systems plc	Upgrade of Harrier GR7 to GR9 standard combined with scheduled maintenance	£59.6 million	November 2004
RB199 Operational Contract for Engine Transformation (ROCET) with Rolls-Royce plc	Availability contract for Tornado engines	£501 million	December 2005
Availability Transformation: Tornado Aircraft Contract (ATTAC) with BAE Systems plc	Providing maintenance and upgrade of Tornado aircraft through an incentivised availability contract	£1,472 million	December 2006
Harrier Platform Availability Contract (HPAC) with BAE Systems plc	Spares inclusive whole aircraft availability contract for the Harrier aircraft	around £700 million	Planned around December 2007
Mission Ready Management System Phase II with Rolls-Royce plc	Similar to ROCET, whole engine availability contract for both Harrier Pegasus Mark 105 and 107 engines	around £350 million	Planned May 2007

Source: National Audit Office analysis of Ministry of Defence data

NOTE

Availability transformation: Tornado Aircraft Contract and RB199 operational contract for Engine Transformation costs are for 10 years; the Joint Upgrade and Maintenance Programme contract is planned to end in 2009.

PART TWO

Logistics transformation has produced positive results in terms of cost and performance

2.1 This Part of the Report examines the impact on the performance and associated costs of the changes in arrangements for maintenance and upgrade undertaken for Tornado and Harrier aircraft.

The cost of support has decreased significantly

Tornado and Harrier support costs have reduced significantly, as has the cost per flying hour

2.2 The Tornado Integrated Project Team's costs have reduced from £601 million in 2001-02 to £258 million in 2006-07 **(Figure 6 overleaf)**. The cumulative savings over the period amount to £1.3 billion. The Department projects that the annual cost will fall further, to £250 million by 2010-11. The Harrier Integrated Project Team's costs have reduced from £110 million in 2001-02 to £70 million in 2006-07, excluding the capital cost of the upgrade programme **(Figure 7 on page 17)**. The cumulative savings over the period amount to £109 million. The majority of the cost reductions have been achieved through working with industry to reform traditional contracts, as the Department prepared for and introduced the Harrier Joint Upgrade and Maintenance Programme in November 2004, and the Tornado Combined Maintenance and Upgrade pulse line for the Tornado GR4 in December 2005. Over the same period, the Department has maintained a broadly similar level of flying hours (see paragraphs 2.9 and 2.18) and the cost per flying hour has reduced for both aircraft fleets **(Figure 8 on page 17)**.

The Department does not have an overall picture of the cost of repair and maintenance for the Tornado and Harrier fleets

2.3 Supporting fast jets is the responsibility of multiple budget holders and the Department does not have an overall picture of the cost of repair and maintenance of the Tornado and Harrier fleets. The Tornado and Harrier Integrated Project Teams are the largest purchasers of support services, but other teams are responsible for supplying spares and equipment common to more than one aircraft type. RAF Strike Command is responsible for the associated manpower and infrastructure costs but these are small relative to the Integrated Project Team budgets for the aircraft, and the Department does not expect these costs to have risen following transformation.

The main cost of transformation, associated with the closure of the Defence Aviation Repair Agency St Athan, is outweighed by the savings

2.4 In line with the move away from traditional repair contracts, the Tornado and Harrier Integrated Project Teams have reduced their spend with the Defence Aviation Repair Agency by 80 and 95 per cent respectively over the last five years (Figures 6 and 7). However, the reduced throughput of aircraft has meant Defence Aviation Repair Agency has required additional financial support in addition to payment for the actual maintenance and upgrade work. The Tornado Integrated Project Team has contributed £15.4 million, 34 per cent on top of its contracted spend, over the last two years.

2.5 The cost of redundancies and the ultimate closure of the Defence Aviation Repair Agency site at St Athan as a fast jet maintenance facility are being borne centrally by the Department. Current estimates of the total cost are in the region of £140 million. In addition, the Department has spent some £18 million on creating the depth repair hubs, excluding the cost of military personnel involved in the events to redesign processes by using lean techniques. The cumulative budget savings as a result of the transformation of logistics support in fast jets of £1.4 billion over the period 2001-02 to 2006-07 more than offsets this.

The Department has reduced the manpower required to support depth repair

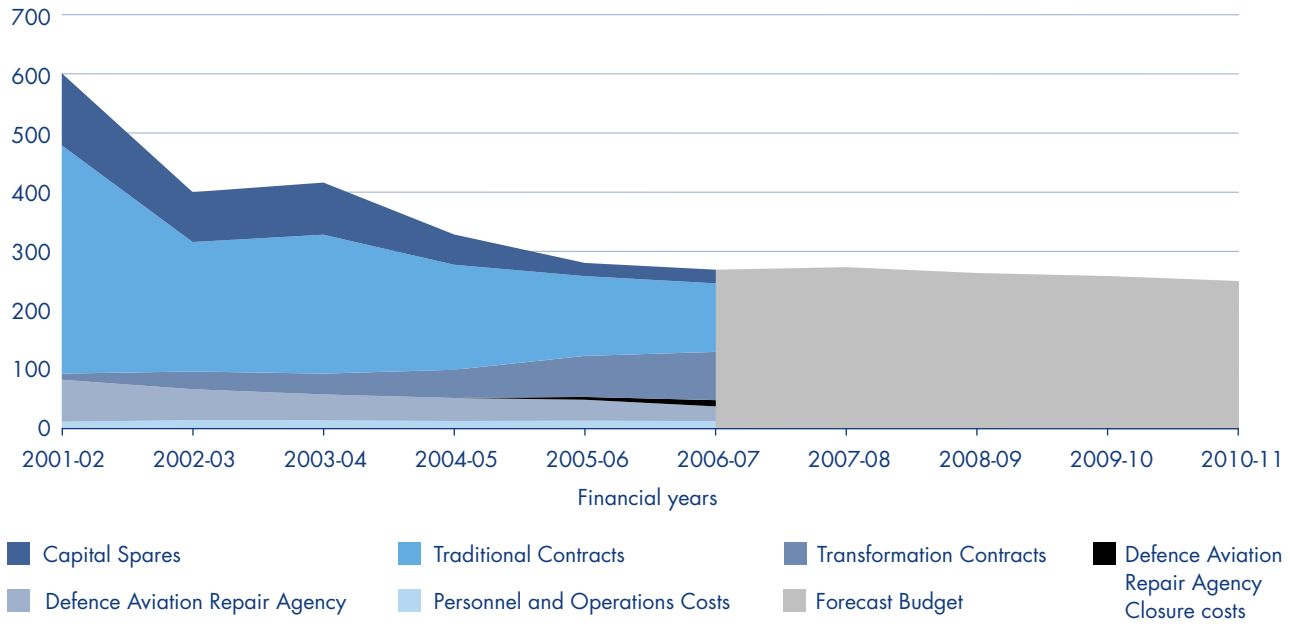
2.6 In addition to the manpower reductions in the Integrated Project Teams of eight per cent for Tornado since August 2005 and 21 per cent for Harrier since March 2001, the Department began to reduce its maintenance and upgrade manpower requirements in line with the transformational activity at each main operating base from April 2004. The number of Service personnel employed in Harrier repair has reduced from 1,078 to 984 (8.7 per cent) between 2004-05 and 2006-07, and the number employed in Tornado repair has reduced from 5,282 to 5,012 (5.1 per cent), with further reductions planned **(Figure 9 on page 18)**. These reductions would equate to an additional saving of £12 million, but there is often then a time lag between the date the post is axed and the actual saving to the defence budget.

Performance has broadly been maintained throughout the transformation of support to fast jets, with some shortfalls associated with transition

2.7 The Chief of Defence Logistics and the Commander in Chief RAF Strike Command annually agree the number of available aircraft by type and the quantity of flying hours required to meet the training and operational task as set out in the Defence Planning Assumptions. Generally, this agreement makes a minor adjustment to the previous year's target, accounting for in-year changes in demand.

6 Support costs for Tornado

Support costs for Tornado have reduced significantly, from £601 million in 2001-02 to £258 million in 2006-07.



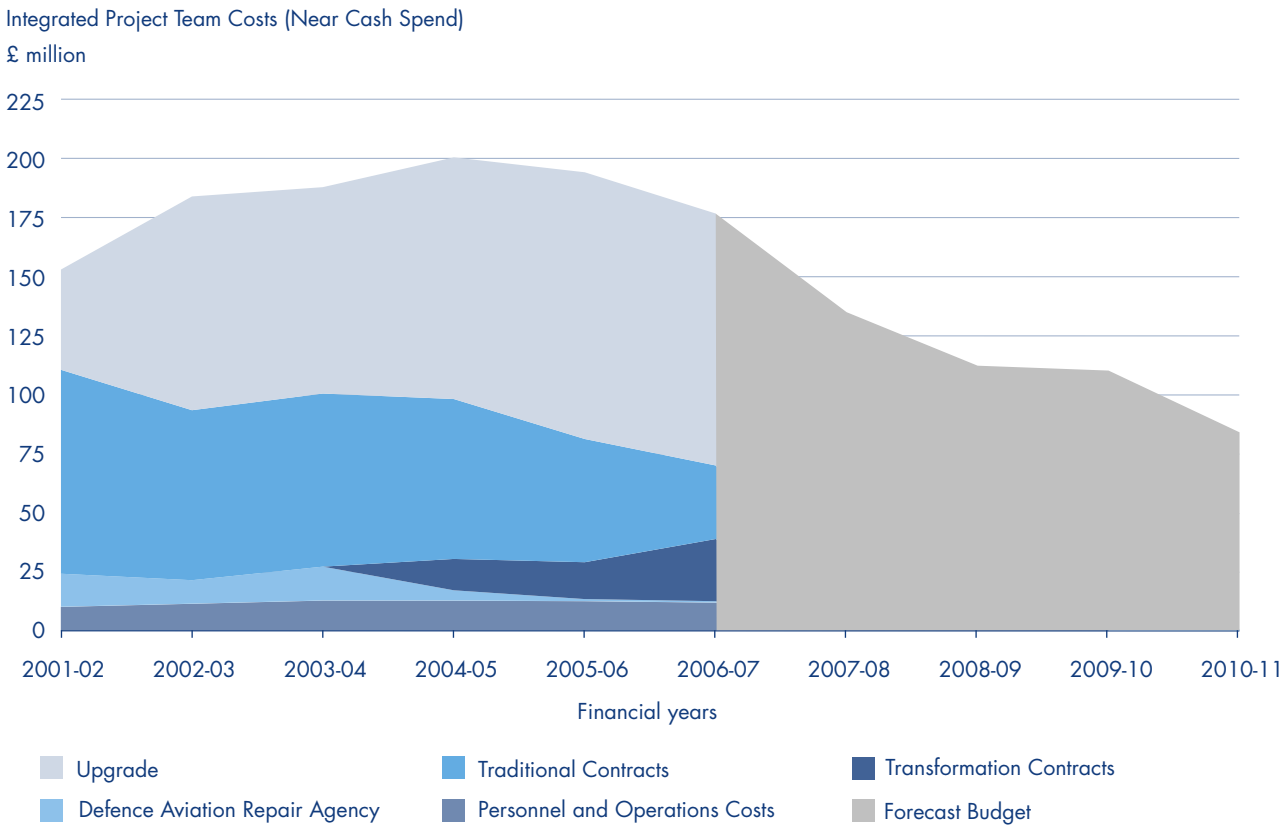
Source: National Audit Office analysis of Ministry of Defence data

NOTE

This figure includes the cost of support of the F3 fighter fleet as the Tornado Integrated Project Team do not account for the two variants separately and was unable to split out the costs.

7 Support costs for Harrier

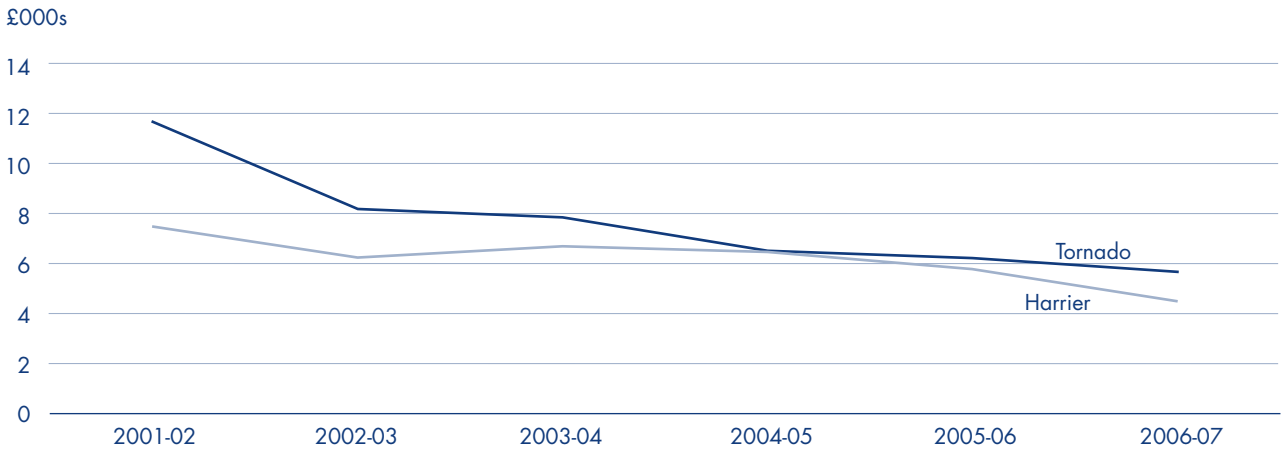
Support costs for Harrier have reduced significantly, from £110 million to £70 million, excluding the capital costs of upgrade.



Source: National Audit Office analysis of Ministry of Defence data

8 Cost per flying hour for Tornado and Harrier aircraft

The cost per flying hour for Tornado aircraft has reduced by 51 per cent and for Harrier by 44 per cent based on the Integrated Project Team budgets.



Source: National Audit Office analysis of Ministry of Defence data

NOTE

Harrier budget excludes the capital cost of the GR9 upgrade programme.

The operational availability of Harrier aircraft has been below target for years but is now meeting a revised target

2.8 The drop in operational availability against the targets set in the Customer Supplier Agreement from April 2003 coincided with the start of the Harrier upgrade programme at BAE Systems' site at Warton, but improved as work was transferred to the new depth repair hub at RAF Cottesmore. The fall in availability between September 2005 to April 2006 reflects the surge in repair of aircraft for operations in Afghanistan (paragraph 2.16). During 2006 the number of Harrier aircraft in depth repair and upgrade has been falling, releasing more aircraft to the frontline **(Figure 10)**.

9 Total Manpower reductions for Tornado and Harrier repair

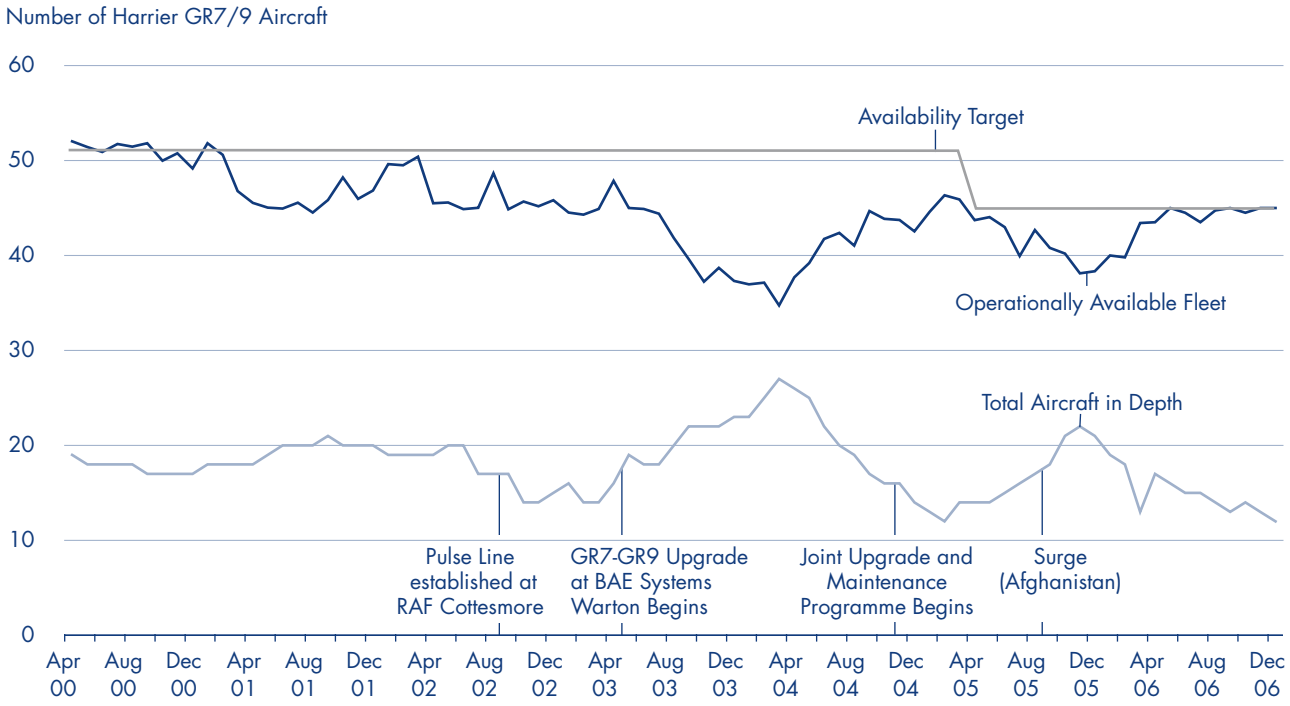
The Department has reduced the number of Service personnel employed in both forward and depth repair.

Establishments	2005 Starting Establishment	2005-06	2006-07	2007-08 Forecast
Tornado Actual	5,282	5,171	5,012	–
Tornado Planned	–	–	–	4,859
Harrier Actual	1,078	1,079	984	–
Harrier Planned	–	–	–	926
Total	6,360	6,250	5,996	–
Planned	–	–	–	5,785

Source: National Audit Office analysis of Ministry of Defence data

10 Operational availability of Harrier aircraft, 2000-06

The number of Harrier GR7/9 aircraft available to RAF Strike Command fell below target from April 2003 but is now back on track, against a revised target.



Source: National Audit Office analysis of Ministry of Defence data

NOTE

The change in the Customer Supplier Agreement Availability Target in March 2005 reflects the change in the Department's definition of operational availability (Forward Available Fleet) to exclude all aircraft in depth maintenance.

Planned flying hours have been achieved rarely historically, but performance has shown some improvement after transformation of Harrier aircraft maintenance

2.9 Achievement against the targets set within the Customer Supplier Agreement has been rare. The Department sets these targets as the likely upper limit of flying hours and does not expect them to be exceeded. The performance of the repair system can affect the achievement of flying hours, although it is only one of the factors which also include: changes in operational demands, crew availability, weapons availability and adverse weather conditions. The Department achieved 90 per cent of flying hours for the Harrier fleet before the pulse line began at RAF Cottesmore in October 2002 and 91 per cent afterwards.

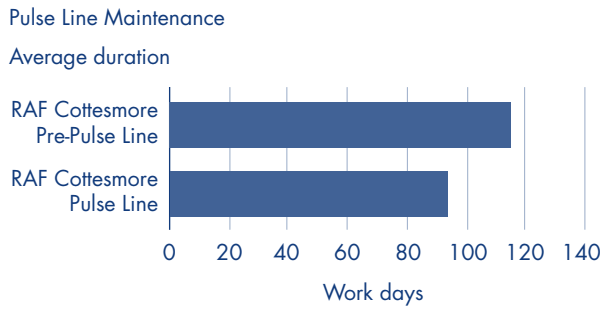
The introduction of pulse lines and the use of lean techniques has decreased the time taken to repair Harrier aircraft

2.10 The Department introduced a pulse line at RAF Cottesmore in October 2002 to conduct minor maintenance of Harrier aircraft. Over the subsequent two years, the reduction in the number of days required to achieve successful minor maintenance was on average 19 per cent, down from 115 to 93 days **(Figure 11)**.

2.11 The improved aircraft availability delivered by the pulse line means that for the first time, a buffer stock of two Harrier aircraft are held by the depth repair hub, which can be made fit for the front line squadrons within 72 hours. From 2008 the pulse line will perform all maintenance packages and so in January 2004 a single aircraft was repaired at the major maintenance level, whilst other aircraft were undergoing minor maintenances, as a proof of concept. The aircraft was repaired in 91 days, a significant reduction on the average of 136 days taken by the Defence Aviation Repair Agency.

11 Duration of minor maintenance for Harrier aircraft

The number of work days taken for minor maintenance of Harrier aircraft was reduced with the introduction of a pulse line.



Source: National Audit Office analysis of Ministry of Defence data

The transformation of engine repair and overhaul has improved the time to repair Harrier engines

2.12 The use of pulse lines and lean techniques has improved the speed with which Harrier Pegasus engines can be overhauled. The turn around time has been decreased from an average of 277 calendar days to 114 days, a reduction of 59 per cent.

Transformation of Harrier depth repair by combining maintenance with major upgrade has released more aircraft to the frontline

2.13 Traditionally upgrade tasks took place at the original equipment manufacturer's site. The Department was concerned that the planned upgrade of Harrier from the GR7 to GR9 standard would lead to fewer aircraft being available to the frontline (Figure 10) whilst the work was carried out. In early 2003, the Harrier Integrated Project Team pursued a procurement strategy which combined the maintenance and upgrade of the aircraft into one programme on the single pulse line at RAF Cottesmore with the aim of reducing the number of aircraft unavailable to the front line during this Joint Upgrade and Maintenance Programme.

2.14 From July 2003, an initial block of aircraft for upgrade were trialled at BAE Systems' Warton site, to ensure the planned sequential work packages were correct and enable military tradesmen to develop the necessary experience. Just prior to this period, some of the Harrier GR7 aircraft had been upgraded at the Defence Aviation Repair Agency to take a more powerful engine and the programme had experienced some delay. The Harrier Integrated Project Team calculated that, had the resulting maintenance and upgrade task continued in this traditional form, based on the performance of BAE Systems Warton and the Defence Aviation Repair Agency, the number of Harrier aircraft in depth repair and therefore unavailable to the front line would have increased by 11 **(Figure 12 overleaf)**.

2.15 Under the Joint Upgrade and Maintenance Programme, Harrier aircraft are only stripped and overhauled once, achieving both the scheduled maintenance and the upgrade to enhance capability. The single pulse line at RAF Cottesmore, which started in November 2004, has shown a 43 per cent decrease in the time required to upgrade the Harrier GR7 aircraft to GR9 standard over the time achieved at BAE Systems' Warton site **(Figure 13 on page 21)**. The upgrade programme overachieved by two its initial aim of delivering 24 upgraded aircraft by the target in-service date of September 2006.

2.16 While undertaking the significant upgrade programme at RAF Cottesmore, the depth repair hub also had to overhaul the operational fleet for deployment to Afghanistan by March 2006 **(Figure 14)**. A further five aircraft are now undergoing the same minor maintenance programme in readiness to deploy to Afghanistan later in 2007.

The fall in operational availability of Tornado aircraft pre-dated transformation

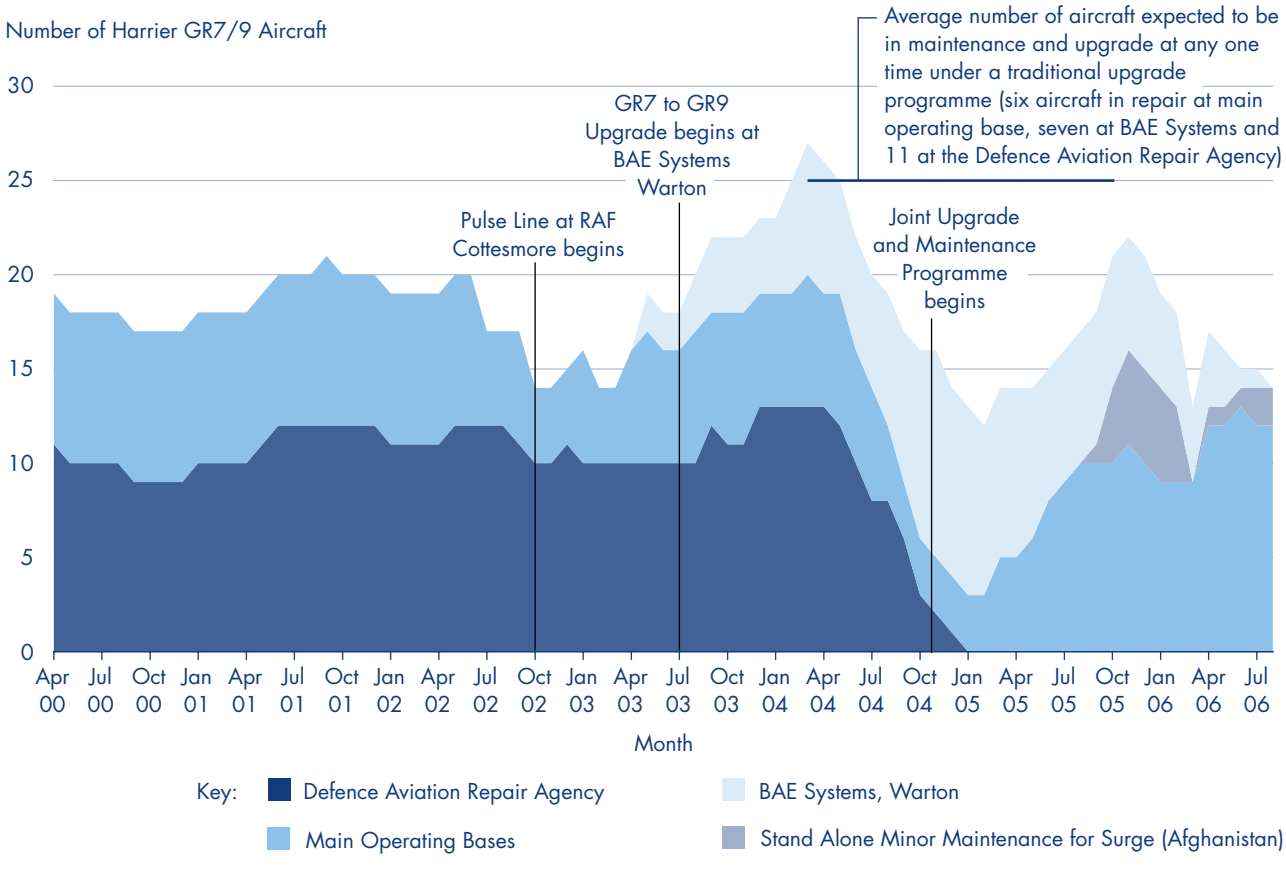
2.17 The decline in operational availability of Tornado GR4 aircraft, from the beginning of 2004, pre-dates the introduction of the pulse line at RAF Marham in December 2005. Average aircraft availability since the pulse line was introduced, at 93 per cent of target for the period December 2005 to December 2006, is slightly worse than performance for the two years to January 2004, when aircraft availability averaged 96 per cent of target. There has been a steady improvement since September 2006 with the required operational availability being met from the end of December 2006 **(Figure 15 on page 22)**.

Planned flying hour performance for Tornado GR4 Aircraft has shown some improvement after transformation

2.18 Tornado GR4 aircraft achieved 93 per cent of flying hours before the pulse line began at RAF Marham and 108 per cent for the period December 2005 to March 2006, with achievement above the target due to operational requirements. In contracting for availability, the Department has set banded targets whereby output needs to fall within a range of flying hours.

12 Number of Harrier GR7/9 aircraft in depth maintenance and upgrade, 2000-2006

The number of Harrier aircraft required to be in depth maintenance has decreased since transformation.



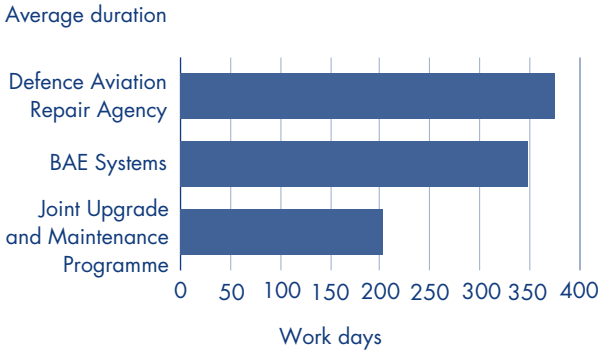
Source: National Audit Office analysis of Ministry of Defence data

Transformation of Tornado aircraft maintenance has reduced the average turnaround times for minor repair but are not yet meeting the previous best standard

2.19 Since December 2005, when the Combined Maintenance and Upgrade Programme established a pulse line at RAF Marham, the elapsed time for Tornado GR4 aircraft undergoing scheduled minor maintenance has decreased by 37 per cent from that achieved previously at the Defence Aviation Repair Agency **(Figure 16 overleaf)**. Initial infrastructure, facilities and supply chain problems have meant that in comparison with previous stand-alone minor maintenance at RAF Marham, which took around 80 days, performance is poorer. However, this maintenance did not encompass the current extent of upgrade modifications. The Department expects performance to improve in a similar way to the Harrier programme, as pulse line learning increases and the specific supply chain problems are resolved.

13 Duration of upgrade activity for Harrier aircraft

Upgrade activity carried out under the Joint Upgrade and Maintenance Programme has, on average, decreased the time taken to achieve both maintenance and upgrade.



Source: National Audit Office analysis of Ministry of Defence data

NOTE

At the Defence Aviation Repair Agency the upgrade activity consisted of a lower complexity of work than that programmed and achieved by BAE Systems at Warton and currently underway with the Joint Upgrade and Maintenance Programme at RAF Cottesmore.

14 Maintenance for Harrier aircraft deployed to operations in Afghanistan

The minor maintenance for Harrier aircraft to be deployed to Khandahar was achieved in record time.

On the 26 July 2005 the Minister of State for the Armed Forces announced the extension of the deployment of UK forces in Afghanistan. This meant that each of the Harrier GR7A aircraft deployed on Operation HERRICK would have flown over the limit for their next scheduled maintenance work. Consequently it was decided to rotate the aircraft from Afghanistan with aircraft of similar capability from the UK fleet; the returning aircraft would then be maintained at RAF Cottesmore.

The challenge was therefore to maintain the Joint Upgrade and Maintenance Programme on schedule, while overhauling the returning GR7A aircraft. The requirements for this 'Surge' programme were:

- Develop a programme solution within five weeks of the Ministerial decision;
- Deliver the minor maintenance of five GR7A aircraft within seven months, including engine servicing. This required the matching of the previous best turn around time of 80 days achieved by the Harrier pulse line;
- Complete within a budgetary limit of £3.9 million; and
- Protect the GR9 in-service date.

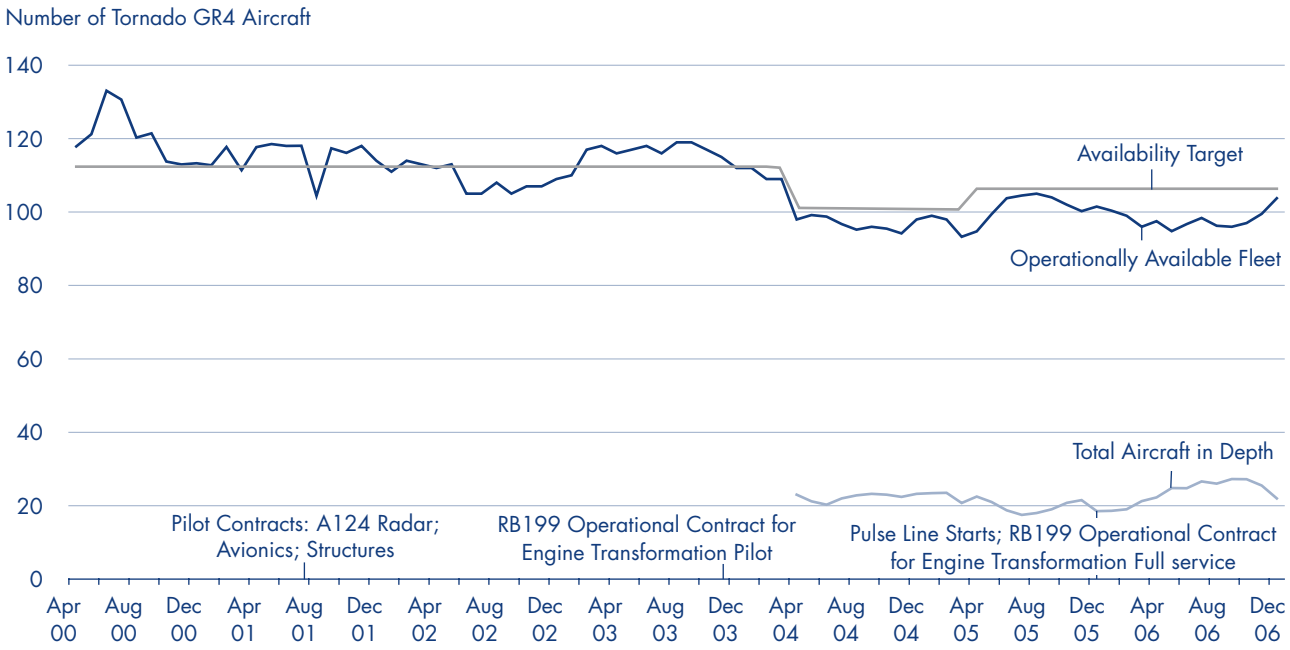
In order to meet this, 110 additional personnel were recruited and trained and the hangar was re-designed to accommodate a second pulse line. The Surge output was successfully achieved within the timescale and budget, despite a higher than normal occurrence of deep structural damage. The GR9 upgrade in-service date remained unchanged. The aircraft delivered back to theatre had the required capability and were fit for purpose.

This exercise proved that the Harrier partnered depth approach could handle unexpected surge requirements while maintaining its core output and won the BAE Systems Chairman's Award for Enhancing Customer Performance.

Source: National Audit Office visits and interviews, RAF Cottesmore

15 Operational availability of Tornado GR4 aircraft, 2000-06

The number of Tornado GR4 aircraft available has in recent years failed to achieve the required target, but the fall in availability pre-dated transformation.



Source: National Audit Office analysis of Ministry of Defence data

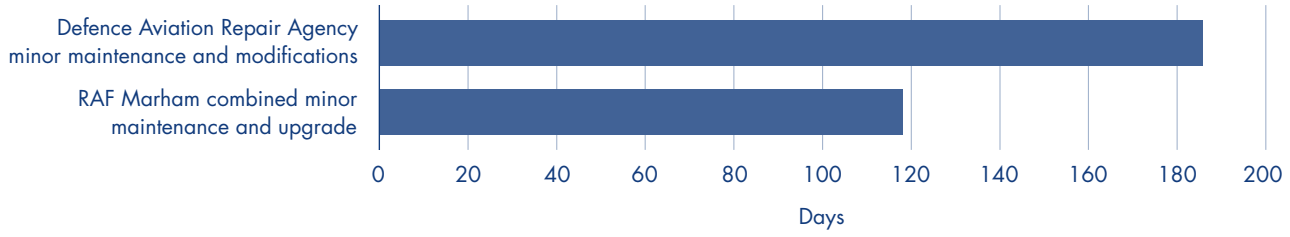
NOTES

1 The change in the Customer Supplier Agreement Availability Target in March 2004 reflects the change in the Department's definition of operational availability (Forward Available Fleet) to exclude all aircraft in depth maintenance. The subsequent change, in March 2005, reflects a release of aircraft to the front line from a planned upgrade programme.

2 The Tornado Integrated Project Team was only able to provide a consistent picture of the number of Tornado GR4 aircraft in depth repair from March 2004 onward.

16 Duration of minor maintenance for Tornado GR4 aircraft

The number of days taken to maintain Tornado jets has been reduced when compared with the previous arrangements.



Source: National Audit Office analysis of Ministry of Defence data

The transformation of engine repair and overhaul reduced the number of engines required to be produced for Tornado aircraft

2.20 After the Department closed the engine bays at RAF Leuchars in January and RAF Leeming in February 2003, the RB199 Operational Contract for Engine Transformation, signed in December 2005, further rationalised engine repair practices. The Department established a single engine maintenance facility at RAF Marham with Rolls-Royce and using lean techniques developed a pulse line similar to that used for the Harrier Pegasus engine. This resulted in the reduction of a significant number of engine bays, while still providing the same level of support.

2.21 Previously, once a fault was suspected, squadrons undertook a full engine change in order to keep the aircraft operational, this was traditionally a key driver of overall support costs. Working in partnership, Rolls-Royce and the Department formed a joint Propulsion Support Team which includes Service personnel and the Rolls-Royce Field Support Representative. The Propulsion Support Team aims to improve on-aircraft engine troubleshooting and diagnosis in order to reduce the number of unnecessary engine rejections whilst working within an acceptable level of safety. Working closely with the Rolls-Royce Operations Centre in Bristol, the Propulsion Support Team can gain rapid access to the Design Authority's technical expertise; tools such as 'JetScan' oil debris analysis and 'video borescoping' give real time access to images of the inside of the engine and allow engine specialists in the Operations Centre to make informed decisions, enabling problems to be resolved and engines to be cleared for continued use with minimal disruption to the operation.

2.22 The Department calculated that under previous arrangements the total cost of engine repair was £399 million over five years. The RB199 Operational Contract for Engine Transformation will cost the Department £136 million (34 per cent) less over the five years from December 2005. The Department has calculated that it has prevented some 325 rejections, avoiding approximately £72 million of costs. Over the first six months, the level of engine availability consistently met 100 per cent and consequently the number of engines in depth maintenance has reduced from 35 to 22.

PART THREE

There is potential to exploit transformation further, but there are risks that require careful management

3.1 This Part of the Report examines the key issues faced by the Department in implementing changes for Tornado and Harrier support, the use of contracting for availability and lean techniques to enable transformation, and the process of transferring lessons learned to other support areas, particularly for the Typhoon aircraft.

The Department does not fully understand how changes in input affect output

3.2 Transformation of logistics support has been driven largely by financial imperative not by an assessment of the Department's output demand. The Department does not currently have a clear understanding of the link between different support cost drivers and the flying hours it achieves. However, it is beginning to examine this through the Defence Logistics Transformation Programme sponsored Support Optimisation methodology.

3.3 This is particularly important given the need to reduce support budgets in the face of the Department's financial constraints. At present, the Tornado availability contract is only expected to deliver to a level of 90 per cent of the requirement unless risks due to the transition and legacy support arrangements can be reduced. From 2009-10 the contract is only funded to deliver on average 80 per cent of the required output. Any shortfalls in funding will have to be met through efficiency savings, a rebalancing of the repair and maintenance support budget, mitigation of risk to release funding retained by the Department or output cuts.

Reliability Centred Maintenance and changes in frontline behaviour have been essential in delivering operational output and cost savings in repair

3.4 The manufacturers' specification for the number of hours flown before a jet requires maintenance is set when aircraft first enter service and the Department reviews the maintenance schedules every five years. Analysis of aircraft and engine fatigue over time leads to the development of a revised schedule, which is rolled out to the fleets. Previous reviews have led to change in the number of flying hours available before scheduled maintenances. The most recent work has resulted in a more significant extension in maintenance intervals of 44 per cent (from every 500 to every 720 hours) for Harrier in June 2005, and 38 per cent (from every 600 to every 825 hours) for the Tornado fleet in December 2006.

3.5 There is a relationship between the way in which frontline squadrons maintain and use aircraft and the amount and type of resultant repair activity required. Improvements in the deep repair side of fast jet operations have convinced senior officers in forward squadrons of the merits of redesigning processes. **Figure 17** details some of the new processes that have led to an increased amount of flying hours achieved and a reduced requirement for repair. Not all of these practices have yet been adopted across all of the aircraft fleets.

The evolution from traditional repair and spares to availability contracts has required a fundamental change in the way the Department works with industry

3.6 The Department characterises its historical relationship with providers of logistic support as adversarial. It believed that incentivising and partnering with repair providers was therefore the only way that contracting for availability could become a realistic mechanism for the support of RAF aircraft fleets. Subsequently the Department decided that it would be most efficient to focus on prime contracts with the original equipment manufacturers, an approach that is now wholly consistent with the Defence Industrial Strategy. **Figure 18 overleaf** outlines how the key features of traditional contracts compare with availability contracts.

3.7 In the context of fast jet repair, availability contracts deliver an agreed number of aircraft or engines at an agreed level of capability over the length of the deal. While there are differences in the processes and actual delivery of the maintenance of the Tornado and Harrier aircraft, the contractual approach remains broadly similar. **Figure 19 on page 27** shows some examples of the Department's current contracting arrangements along with international and commercial comparators (also see Appendix 4 on British Airways). The Department will pursue contracting for capability where appropriate. It may be difficult for the Department to achieve it in the same form as commercial aviation, because of a number of issues. These may include: ensuring that the through-life costs associated with leasing aircraft do not exceed the total costs of owning a similar fleet of aircraft; the ability to obtain affordable insurance given the aircraft's operation

17 Transformation activities at frontline squadrons

Tornado and Harrier forward squadrons have used lean techniques to redesign their operating processes to increase operational availability.

Activity	Description
Hot refuelling	Previously Tornado GR4 aircraft returning from a sortie were shut down in order to prepare for the next flight. The cycle of powering up and shutting down an aircraft tends to introduce a number of minor faults, for example leaks and minor electrical problems. Keeping the systems powered while refuelling has reduced the number of faults reported and increased the number of sorties achieved per aircraft. In addition allocating planned parking bays to each aircraft reduces the amount of time to refuel as fuel bowsers are waiting when the aircraft arrives.
Changes in the way the Tornado GR4 is flown	For example the use of wheel brakes instead of air brakes on landing or limiting the use of afterburners in transit to an exercise. Both can impact on the wear rate of the engine.
Single man see in/see off	Reception and dispatch of aircraft (see in/see off) entails pre- and post-flight checks and replenishment of consumables, such as fuel. Using lean techniques, the tasks have been simplified and manpower reduced from two personnel to one for each aircraft.
Flying programme	Using lean techniques forward squadrons identified and removed wasted time in between sorties. For example by crews sharing aircraft more sorties are achieved.
Forward repair scheduling	Harrier – 'primary' and 'primary star' services were traditionally performed after a certain number of flying hours. This work has been organised into equalised work packages that are undertaken more regularly when aircraft are already on the ground for fault rectification. Tornado – Use of lean techniques has reduced primary services from 15 days down to 2.5 days and primary star services from 20 to 15 days.
Transfer of aircraft	Harrier – Smarter Acceptance Procedures. Due to the large number of GR7 and GR9 aircraft transferring from depth repair hubs to forward squadrons as part of the upgrade programme a more efficient acceptance procedure has been developed.
Reorganising work areas in hangars	Through using lean techniques squadrons have reorganised work areas so that the right tools are in close proximity to areas of specific repair, reducing the need to search for equipment and walking time.
Project Eurystheus	Twelve areas of Tornado GR4 forward activity were identified as having the most potential to improve the operational availability of aircraft. Work is ongoing to establish any benefits to changes in practice, for example training and induction, more efficient recording of repair activity and extension of intervals between maintenance for components.

Source: National Audit Office visits to RAF Cottesmore, RAF Lossiemouth and RAF Marham

in high threat environments; limitations on use or return conditions that would be necessary for the contractor to protect its investment, but may be unacceptable to the demands of military operations; and the changing nature of the military requirement whereby new capabilities need to be introduced at short notice to meet new threats.

There are risks to a long-term partnered approach and the Department has sought to mitigate these through incremental contracts

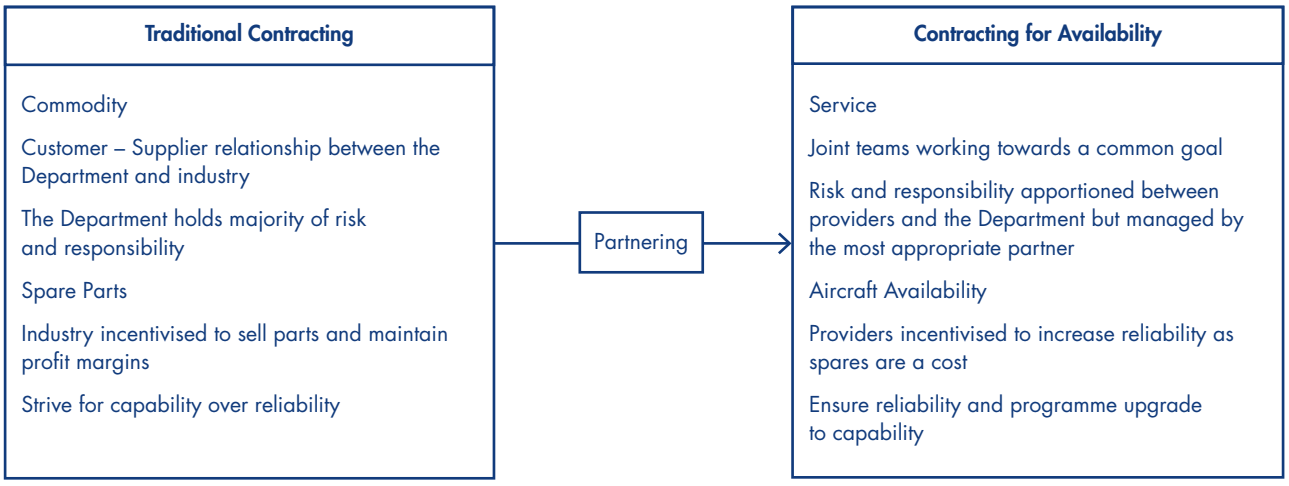
3.8 It is good practice to de-risk a full availability contract through a series of incremental contracts. Both BAE Systems and the Department see the Availability Transformation: Tornado Aircraft Contract (ATTAC) as the template for contracting for availability for fast jet aircraft and while incremental contracts leading up to ATTAC were planned, they have had difficulty in letting them against the planned schedule. It was a resource intensive exercise to finalise these smaller contracts and it was the Department's view, that as its partnership with industry and the pre-contract work were sufficiently mature and in order to achieve greater and earlier efficiencies through economies of scale, a main contract should be let rolling up the work completed on the incremental packages. In doing so the Department accepted a greater degree of risk. The planned Harrier Platform Availability Contract with BAE Systems will be the equivalent of ATTAC, wrapping up the existing incremental support contracts, provision of repair schemes and technical services, mechanical component and avionics repairs.

Collection and analysis of robust data is key to developing long-term availability contracts

3.9 The Department uses internal value benchmarks to determine the lowest cost at which it could deliver a service itself to inform its decisions on entering into partnered contracts with industry. It has not set internal value benchmarks using a consistent method. The cost model developed to calculate internal value benchmark for the Tornado Combined Maintenance and Upgrade contract was also used to assess the Department's estimate of the contractor costs. The model includes an estimate of the effects of both extending the interval between maintenance and the use of lean techniques to redesign processes (increasing the amount of available upgrade time within maintenance) on the cost of aircraft repair. The internal value benchmark, constructed in accordance with Departmental guidance, provides the lowest cost by which the Department could have been able to achieve Tornado support by modifying its in-house arrangements. The Department's view is that efficiency improvements, through the use of bespoke information technology systems to enable improved maintenance scheduling and manpower utilisation, could only be made with the pro-active engagement of the Prime Contractors and the joint sharing of intellectual property. Any scope for continuous improvement and overall cost reduction over the life of the aircraft under the internal value benchmark was therefore limited.

18 Comparison of key features of traditional contracting with contracting for availability

Partnering with industry has transformed the way in which the Department contracts for repair and overhaul of fast jets.



Source: National Audit Office

3.10 The Harrier Integrated Project Team's Joint Upgrade and Maintenance Programme cost model contained all the appropriate efficiency levers, but its starting point was the budget available and the estimate from the Prime Contractor on how much a contract may cost. **Figure 20 overleaf** outlines one case where the Department developed an internal value benchmark which demonstrated that redesigning repair processes using lean techniques and increasing maintenance intervals meant that retaining the repair capability in-house was more cost-effective than the proposed contractor-based support solution.

3.11 Appropriate analysis of demand and usage data is also fundamental to calculating the level of repair service required from a Prime Contractor and it is essential to achieving an affordable contract price. A lack of robust data has meant that reaching positions from which to negotiate availability contracts has been difficult and time consuming.

19 Contracting for availability on a continuum of contract types

The Department has moved from spares and repair towards contracting for availability, but this does not go as far as commercial contracting for capability contracts.

Contract Type	Spares and Repair	Cooperative Partnership Contract	Contracting for Availability	Contracting for Capability
Contract Detail	A traditional arrangement whereby the contractor supplies the Department with spare parts with which to repair and overhaul its equipment. Maintenance is conducted separately either by the Department or a sub-contractor. The Department solely holds responsibility for the repair and overhaul and any risk associated with it.	The Cooperative Partnership is similar to the traditional spares and repair contract in terms of supply of spares, however joint industrial and military teams undertake the actual repair and overhaul. Responsibility for the delivery of the equipment remains with the military, although risks are jointly shared with the contractor.	The contractor is usually the Design Authority for the equipment and is responsible for the repair and overhaul and the ultimate delivery of a fit for purpose piece of equipment. Provision of spares is sometimes included within the contract, as is the case with the Department's C-17 transport aircraft. However, usually the provision of enabling resources (spares, ground equipment, staging and manpower) is split between the contractor and the Department with risk and responsibility managed by the most appropriate partner. The contractor also brings to the partnership its technical expertise and commercial experience of supply chain management and asset tracking. The contracts are performance-based partnerships that commit both parties to contractual performance guarantees.	The contractor is responsible for the delivery of a capability, such as an aircraft that can fly for a set number of hours carrying a set number of passengers including any support, spares and repair that the aircraft may need within those hours. The risk and responsibility for delivery lie solely with the contractor; the customer does not own the equipment and therefore has no requirement for a repair or support organisation.
Example	Spey engines which power the Royal Navy's Type 23 Frigates.	Contractor MTU Aero Engines and the Luftwaffe have developed the contract to undertake maintenance of Tornado and Typhoon engines.	RB199 Operational Contract for Engine Transformation for the Royal Air Force Tornado fleet. C-17 Globemaster III Support Partnership contract for the Royal Air Force's heavy lift transport aircraft.	Rolls-Royce Total Care whole engine package and Boeing Gold Care whole aircraft packages.

Source: National Audit Office visits and interviews

The Department may have insufficient personnel to negotiate contracts successfully

3.12 Each Integrated Project Team is currently more than ten per cent under strength at a time of increasing activity to rationalise in excess of 70 existing contracts and set up two or three availability contracts. The Department has insufficient personnel of a skill level commensurate with their industry counterparts. The Tornado Integrated Project Team had only one cost modeller during negotiations with BAE Systems, which had a full time team of six estimators working on the same project. In modelling the costs for the support contract for the Pegasus engine, the Harrier Integrated Project Team had to bring in a former employee who had worked on the initial costings to plan the transformation of the Harrier engine bays, but the project was delayed by at least six weeks while the external contract was re-approved.

3.13 There is also a limited pool of people with experience of partnering and teams which set up the contracts do not contain personnel whose responsibility it will be to implement and run them. Without their advice there have been revisions to the signed contracts and re-engineering of some processes to achieve delivery. The solid foundations for partnering may be weakened if both the Department and industry do not co-ordinate their succession planning.

Partnering has caused the Department and industry to align their behaviours

3.14 The Department's Integrated Project Teams have broadly followed the best practice recommendations outlined in the Gold Standard contracting practices report,[9] such as joint teams with a common aim, open book accounting and the sharing of information and benefits between projects. In particular, the use of collocated teams has improved the pace of communications and decision making. In addition, Prime Contractors have been willing in many cases to invest, take on work and share information prior to contract signature, based on an informally agreed behavioural charter and the knowledge and trust that was built up during the course of contract negotiations.

3.15 Using gainshare and incentive payments the Department is seeking to incentivise industry to deliver higher levels of repair performance than has previously been achievable. If industry and the Department deliver the contract for less than the target price, the benefits are split in accordance with the contract. There is also a clear mechanism for the apportionment of the penalties of any cost or time overruns between the Department and industry, but the Department has to date preferred to work jointly with contractors to resolve issues arising. The Department has been successful in incentivising

20 Ejection seats

Retaining repair capability in-house is sometimes more cost-effective than contracting out.

The Aircrew Escape and Survival Branch of the Harrier, Jaguar and Survival Integrated Project Team are responsible for the provision and maintenance of ejection seats used for all in-service fast jet aircraft. Both Royal Air Force personnel and contractors in the depth repair hubs maintain ejection seats. In 2004 the Integrated Project Team received an unsolicited bid from Martin Baker Aircraft Ltd, the original equipment manufacturer, to take over the maintenance of all ejection seats, including systems yet to be introduced in aircraft such as Typhoon.

As part of the Integrated Project Team's drive for continuous improvement, a series of Reliability Centred Maintenance studies verified the increase of seat maintenance intervals from two to three years. In addition with the implementation of lean techniques, this has brought a quantified reduction of whole life support costs for all seat systems by 20 per cent.

Taking the most mature assessment from the Tornado aircraft, a joint Lean Team conducted a Value Stream Analysis and projected the following results would be possible through the introduction of flow in the repair cells and combining the repair activity from RAF Leeming at RAF Marham. The team projected savings of £2 million in inventory reduction alone and an overall reduction of 28 per cent to whole life support costs.

Tornado efficiency figures	Pre-Lean Techniques	Post-Lean Techniques (expected)
Manning	40 Personnel	15 Personnel
Repair Time	190 hours	58 hours
Floor space required	1002 m^2	286 m^2
Inventory	330 pairs of seats	225 pairs of seats

When considering the Martin Baker Aircraft bid, the Integrated Project Team produced an internal value benchmark as a comparator. In September 2006, the exercise concluded that repair processes redesigned using lean techniques and rationalised Ejection Seat Bays at military bases offered greater value for money than the Martin Baker bid. Although there is still a small risk that the projected performance post-lean techniques will not be achieved, to date repair times and resources required are decreasing and the transfer of activity from various locations is underway.

A study is also being conducted into the feasibility and value for money merits of a single, 'civilianised' repair facility by 2009.

Source: National Audit Office visits and interviews

9 *Using the Contract to maximise the likelihood of successful project outcomes*, HC 1047 Session 2006-2006, 7 June 2006.

Prime Contractor behaviour, to move from a traditional model of supplying spares and undertaking repair, to one where industry provides technical knowledge and innovation whilst minimising cost.

Recent contracts set by the Department with BAE Systems and Rolls-Royce have incentivised both parties to deliver and resulted in some gainshare

3.16 In two years the Department has received around half a million pounds in gainshare from the new partnered contracts. The Joint Repair Organisation contract with BAE Systems for structural airworthiness advice, Design Authority solution and repair equipment to both Harrier frontline squadrons and the depth repair hub has delivered significant benefits to both partners with faster turnaround times for the military customer and additional profit[10] for the shareholders **(Figure 21)**. The Tornado RB199 Operational Contract for Engine Transformation with Rolls-Royce although still in its infancy has, in its first year, resulted in savings of around £12 million, which will be shared between the Department and Rolls-Royce in accordance with the contract incentive arrangements.[11] With such incentives the Department expects that, through the life of the contracts, both it and industry will strive to become more efficient and the original equipment manufacturers will improve the reliability of their products.

3.17 The Department's policy on gainshare is to recycle any income for the benefit of defence as a whole. Commercial organisations allow their workforces to use proceeds to re-invest in the business in order to further incentivise innovation and the United States Air Force has used this principle. This has a positive impact on morale and embeds the concept of continuous improvement. By recycling benefits at defence-level rather than where they are generated, the Department may lose some of the impetus for transformation and it will be a greater challenge to embed the changing culture. It is also unclear as to whether the incentives are large enough to alter the behaviours of the Prime Contractors, particularly as they, in turn, should seek to extend the gainshare principle through their supply chain to make it more efficient.

21 Joint Repair Organisation

The contract for the Joint Repair Organisation has resulted in a dramatic improvement in service to the military customer and gainshare of £500,000 to the Department.

The design and vertical lift capability of the Harrier aircraft makes it susceptible to structural damage. Aircraft were often grounded awaiting repair information if the damage was above the norm, as the RAF Structural Repair specialist surveyors from RAF St Athan were required to assess the damage and to design and undertake the repair scheme. This delay, on average four days, could be further lengthened by around two months if the damage was novel, as it required the expertise of BAE Systems' design and stress engineers.

The introduction of the Harrier airframe pulse line resulted in a four-fold increase in the incidence of structural repair, due to more rigorous inspection, and the need for significantly shorter repair timescales. The Harrier Integrated Project Team introduced a trial whereby BAE Systems deployed key Design Authority personnel at RAF Cottesmore to provide advice direct to the pulse line. This reduced delays of 139 days down to 22, and those of 166 to 91 days.

The Joint Repair Organisation contract built on the trial by employing a permanent embodiment team of RAF tradesmen within the Structures Bay and the Forward Support Fixed Wing, RAF St Athan. BAE Systems advise and complete repair schemes to determined timescales and provide control and storage of repair design data. The aim of the contract was to provide around five times the historical volume of Design Authority repairs, in a quarter of the previous timescales, for significantly less cost than the traditional approach. It was signed on 30 June 2004 for annual fee of £1.6 million[1] through to the Harrier aircraft's out-of-service date, with price reviews at five year points.

Since the contract award no aircraft with serious structural damage have had to be removed from the pulse line and in the first year there was a 25 per cent reduction in turnaround time and cost savings of 30 per cent, including gainshare for the Department to the value of £241,000. In year two, tasking levels rose by 30 per cent because of the urgent operational requirement for Afghanistan and the Harrier GR9 upgrade programme on the pulse line, but the Joint Repair Organisation still delivered a further 15 per cent reduction in turnaround times and £202,000 in gainshare. Additionally the Joint Repair Organisation, through the use of digital photography and measurements made by the squadron, has been able to provide real-time technical advice and repair drawings to Kandahar (average turnaround time of two days).

Source: National Audit Office visits and interviews

NOTE

1 A ceiling price limits financial liability.

10 1.7 per cent.

11 The share is approximately 53 to 47 per cent in favour of Rolls-Royce, with an expected first year incentive payment of around £6 million to Rolls-Royce.

The Department's business model is altering with implications for its financial processes

3.18 Partnering is currently viewed as a Defence Logistics Organisation/ industry concern but logisticians have little influence over activity that results in the need for repair and overhaul. In April 2007 the Department transferred budgetary accountability for logistics support to RAF Strike Command. This will give a single organisation responsibility for both the input and output measures and with this improved oversight, RAF personnel should be in a better position to trade off resources and performance.

3.19 While not best practice in forecasting and budgeting, Integrated Project Team Leaders currently have the ability to veer and haul between resource lines in order to overcome short-term funding issues. However, the ability to be flexible with resources is diminishing due to the transition to availability contracts, as most of the budget will be pre-allocated. The requirement to veer and haul should diminish as improvements in the scheduling and performance of depth maintenance, resulting from better information systems, take effect.

The use of lean techniques for depth repair has been successful but the process was driven by a few individuals at the outset

3.20 The first application of lean techniques to fast jet repair was by the United States Air Force in 1999 (Appendix 5). Having explored its success in the United States of America, the Defence Logistics Organisation and the RAF introduced lean techniques (Appendix 3) to Harrier deep repair at RAF Cottesmore in 2001 and to Tornado at RAF Marham in 2003.

3.21 Primarily transformation of Harrier and Tornado depth repair occurred independently, even though the same industrial partners were involved and the challenges to make savings were similar. The Department employed the same external consultants to facilitate the use of lean techniques and encourage best practice. Although personnel undertaking repair were heavily involved in the re-design of the core processes, a few RAF personnel, who have become champions of lean techniques and experienced practitioners, drove through change.

3.22 The most striking transformation in the physical process of deep repair was the introduction of pulse lines and there are already significant benefits in both on- and off-aircraft repair that are typical of transformation which used lean techniques; increased throughput but with less man hours, workspace and spares holdings **(Figure 22)**. Over time specialist Lean Teams have managed to step back from the identification of areas to which lean techniques could be applied and to encourage those involved in the repair process to generate ideas for change, thereby reducing the perception that 'transformation was done to us'.

3.23 Although the initial re-design of repair processes for the two aircraft types is complete, overall, the use of lean techniques is still in its infancy. Experience in the private sector suggests that the true benefits of transforming processes using lean can take anything up to five years to become apparent. Transformation has been conducted independently at and within RAF bases and, due to a lack of a strategic overview, some areas' processes may have to be changed to fit in with best practice for end-to-end logistics, rather than their own individual area.

There are advantages to Pulse Lines but the timely provision of inputs is key to success

The management system for both on- and off-aircraft repair is visual enabling repair effort to be prioritised

3.24 Boards by each pulse phase have progress indicators based on traffic lights, which instantly attract the supervisor's attention and allow the development of solutions to problems and/or decisions on prioritisation. For repairable spares, the kanban (see glossary) system prioritises effort so that there is always a sufficient stock of repaired components 'on the shelf' for immediate use. Complex legacy repairs are only attempted if time is available and they are cost-effective.

Better fleet management and the increased embodiment of modifications has been a major benefit of transformation

3.25 Pulse lines are effective in a manufacturing context as the output is without variation and the length of each phase is calculated by the number of outputs required over the days available. Repair adds a level of complexity; although aircraft will fly a set number of hours before requiring a routine maintenance package, involving a certain number of man-hours and spare parts, there will be emergent work and activity to address faults and limitations that are particular to each aircraft. The Department may not have the same short-term flexibility in repair volume as it once had, and so it has to weigh up the costs versus the benefits of putting aircraft through the pulse line before they have flown their requisite hours or paying the contractor for work not undertaken.

3.26 Nevertheless, the regular timing of the aircraft entering and leaving the pulse line has increased the discipline for planning for repair and the detail for planning usage of the aircraft. Historically, due to inefficiencies in the repair system, minor modifications were often never embodied in whole fleets. The result is a

situation where the Tornado fleet is modified to a number of varying standards with large numbers of unused modification kits in storage. Now, in the unassigned hours from the total duration of the pulse line, the engineers plan to include minor modifications to upgrade the aircraft. The embodiment of three specific modifications is a Key Performance Indicator of the Combined Maintenance and Upgrade contract for Tornado, ensuring BAE Systems are incentivised to address the problem of multiple fleets within fleets **(Figure 23 overleaf)**, although significant new investment is required if this problem is to be addressed through life. An upgrade programme that is planned to be implemented from 2008 would, if funded, reset the fleet configuration and introduce three essential new capabilities: tactical data link, secure voice and the precision guided bomb. If, as planned, the pulse line system begins to deliver more capable aircraft, there is a decision to be made about fleet sizes as the available fleet may be larger than is required by RAF Strike Command.

3.27 The fleets within fleets situation complicates fleet management, but more importantly limits the numbers of aircraft that can perform operational tasks and the amount of training that frontline pilots can achieve on certain standards of aircraft. This is particularly pertinent with the Harrier fleet's continued deployment in Afghanistan, as only the best and most capable aircraft can be rotated to Kandahar. The Harrier pulse line system has enabled both legacy modifications and the upgrade capability to be embodied in a timely fashion **(Figure 24 overleaf)**. The GR9 entered service 1 October 2006, One (Fighter) Squadron was trained up to combat ready status and in January 2007 two GR9 Harrier aircraft departed the UK for a three day journey to Kandahar. Routinely these flights are interrupted by a range of technical, diplomatic and environmental factors; however this time the aircraft arrived two hours early, were serviced, armed and brought to readiness within 110 minutes and then flown on their first operational mission.

22 Examples of the benefits of lean techniques

The Department has applied lean techniques to many areas of repair and support activity, with significant benefits.

Off-aircraft repair processes are essential to keeping aircraft operational as they feed spares to the main pulse lines and to forward squadrons.

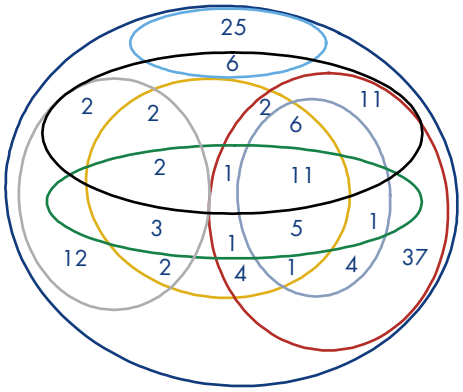
Improved maintenance cycle times	Maintenance cycle time refers to the time from receiving a component, through the subsequent repair process, to its return to stock for re-use. The Tornado flight guidance system and the practice bomb repair lines have improved by 18.4 per cent and 12 per cent. The cycle times for Harrier Pegasus engine modules have improved by 75 per cent, with a 43 per cent decrease in actual hands-on repair activity. The Harrier supply line has improved the time taken from receiving an order to placing the component on the shelf for use by 120 per cent, and the Harrier Test Measurement Equipment Cell repair line has reduced from 90 to one day.
Improved quality	Increasing the quality of repair decreases the number of components subsequently rejected as being faulty and requiring re-repair. Tornado Armaments (Gun) and practice bomb repair lines have improved quality by 40 per cent and 33 per cent respectively. Since February 2006, all the repaired Pegasus engines have worked on installation to Harrier aircraft.
Reduced inventory/ Work in Progress	The longer it takes to repair, the more spares an organisation needs to hold. Applying lean techniques to the repair and overhaul of the Tornado practice bomb line has resulted in a 75 per cent reduction in inventory. The Harrier Test Measurement Equipment Cell has reduced the number of components that are repaired at any one time (work in progress) by 95 per cent.
Reduced manpower	Using lean techniques has helped the military achieve the required repair output despite the planned reductions in staff. Manning for Tornado flight guidance system repair activity has reduced by 50 per cent, with staff on Armaments (Gun) and practice bomb repair lines reducing by 40 per cent and 33 per cent respectively. The Harrier Test Measurement Equipment Cell has the same manning but has increased capacity by 33 per cent. Reductions in manning for the Harrier supply line have led to a cost reduction of 33 per cent. In some cases the lean techniques resulted in a predicted required level of manning that was lower than that allowed by Royal Air Force rules on contingency manning levels.
Reduced work space	As processes become more efficient and waste is removed, the amount of space and infrastructure required should also reduce. The amount of repair activity based at RAF Cottesmore and RAF Marham has increased, so infrastructure is at a premium. The Tornado flight guidance system, Armaments (Gun) and Practice bomb repair lines have reduced the space required by 75 per cent, 50 per cent and 57 per cent respectively. Adopting lean techniques in the redesign of the Harrier supply line has led to a reduction in space required of 20,000 square feet and freed up four buildings.

Source: National Audit Office interviews

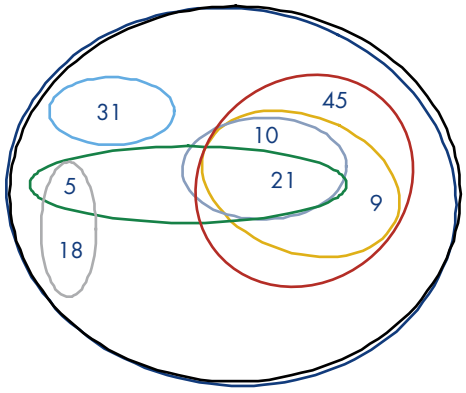
23 Tornado 'fleets within fleets'

The new maintenance and upgrade arrangements aim to solve the 'fleet within fleets' issue for the Tornado GR4.

Tornado GR4 fleets within fleets (now)



Tornado GR4 fleets within fleets (future)



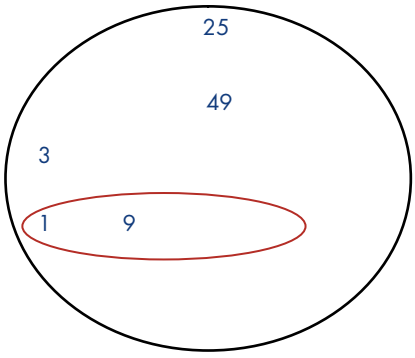
139 – GR4 fleet
85 – Strike aircraft
23 – Reconnaissance aircraft
31 – Trainer aircraft
Capability 1
Capability 2
Capability 3
Capability 4

Source: Ministry of Defence

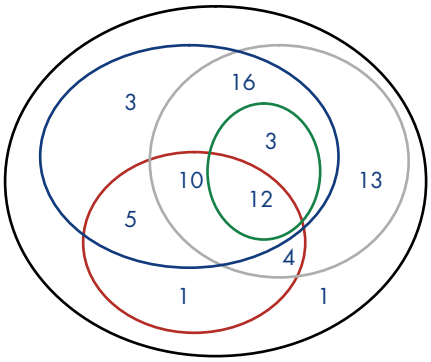
24 Harrier 'fleets within fleets'

The Harrier GR9 programme fits a baseline standard of capabilities; these include an improved engine, reconnaissance, precision bombing capability and an upgraded targeting system. As more aircraft receive these enhancements, the Harrier fleet will become more capable and there will be a notable reduction in the 'fleets within fleets' position.

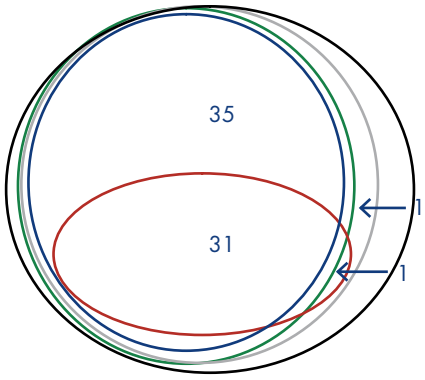
Harrier GR7 fleet (2003)



Harrier GR7/9 fleet (as is)



Harrier GR9 fleet (future)



Total fleet: 68
Capability 1
Capability 2
Capability 3
Capability 4

Source: Ministry of Defence

The delays experienced by the pulse lines have been attributed largely to failure to deliver supplies on time

3.28 Poor delivery performance by the supply chain has always caused delays in repair. Pulse lines are dependent upon the required spares being available at each stage and within a significantly shorter window than under traditional stand-alone arrangements; therefore the supply chain is under even greater pressure to perform.

3.29 The Department sees acquiring BAE Systems' information system, linked to its extant systems, as key to improving the management of demand and input of spares. The on-time spares delivery performance for the Harrier and Tornado aircraft pulse lines averages at 72 per cent and 81 per cent respectively. The Department did not measure delivery performance rigorously in the past, but believes current performance is broadly similar. In addition, regular fora monitor issues with individual components in the supply chain to develop solutions to the delays and/or prioritise those spares available across the whole fleet.

3.30 A traditional way to circumvent supply chain problems is to take a part ('rob') from another aircraft; in 2003 there were on average 93.5 robs per Harrier aircraft per month, the figure fell to on average 35 robs per aircraft per month in 2006. This masks delays and so limits have been placed on the number of robs to ensure that poor supply performance is highlighted and appropriate measures can be taken to rectify systemic deficiencies. Robs have not been limited on the Tornado GR4.

3.31 The actual sourcing of parts for the pulse lines may be through a range of Integrated Project Teams. For example, the Harrier Integrated Project Team controls purchases for only 77 per cent of items required by the Joint Upgrade and Maintenance Programme pulse line and it has limited influence over the procurement priorities of the UK Defence Procurement Office and other Integrated Project Teams, despite the existence of internal business agreements. In the future, industry will take on full responsibility for supply of spares to the pulse line as part of the transition to availability contracts.

3.32 Currently spares are held in multiple locations: on bases and in the main storage depot run by the Defence Storage and Distribution Agency. Rationalisation activities have revealed large holdings of spares, for some of which the Department has inaccurate records on their condition. In a recent example, the RAF Marham pulse line suffered delays due to a shortage of Tornado wing flaps. After an investigation, approximately 300 flaps in the main depot were reassessed for suitability for repair, and subsequently the shortage was resolved without significant repair effort.

3.33 As the Department moves to contracting for availability its direct relationship with second and third tier suppliers will end and the Prime Contractors will take over management of the supply chain. This will allow greater flexibility in spares provisioning because industry can decide to invest in lifetime buys and apply commercial leverage. However, the Department cannot afford to be unsighted on issues further down the supply chain as ultimately the risk of insufficient serviceable aircraft remains with the Department.

There has also been a significant issue with the provision of manpower to the pulse lines

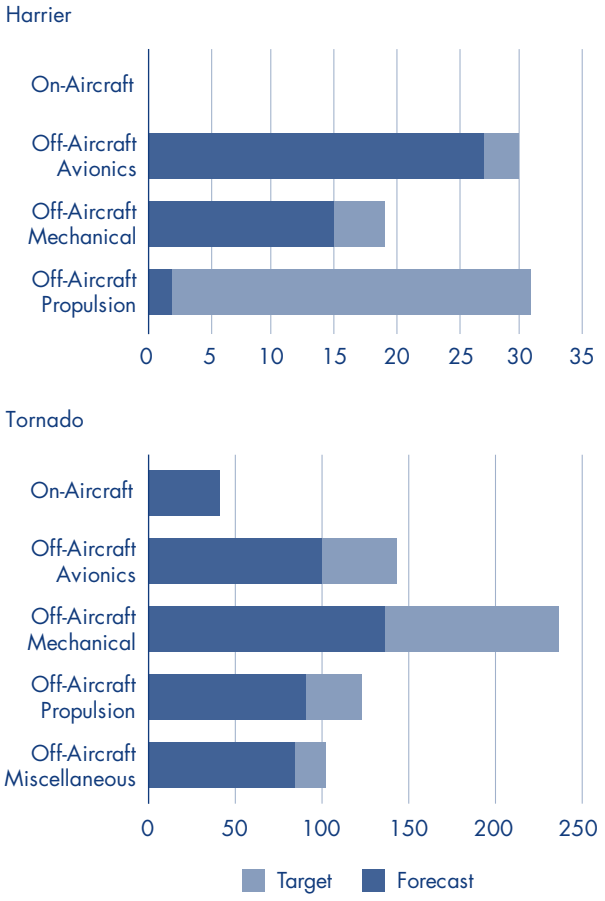
3.34 Concurrent with logistics transformation the military has been scaling down in size. The Defence Logistics Organisation has entered into the repair and overhaul contracts with industry and these specify the number of hours trained military tradesmen will work on the pulse lines. However, it is RAF Strike Command that has responsibly for determining the number of Service personnel on the bases and directing when and what activities they undertake. RAF Strike Command's foremost concern is to deliver military capability. There may be some conflict between the aim to maintain its personnel in their primary role as war-fighters and the need to provide sufficient manpower and man-hours to meet the obligation to the industry partner. The risk will therefore need to be balanced.

3.35 The reductions stipulated in the Department's Medium Term Work Strands under the Gershon Efficiency targets have been generated top down, while the Harrier and Tornado Integrated Project Teams' requirements for engineering personnel and their skill mixes have been calculated bottom-up. Failure to marry these exercises has led to forecasts that there will not be enough available man-hours from personnel to fulfil the maintenance task and mismatches between the balance of skills required and available **(Figure 25 overleaf)**. The issue is further compounded by early retirement criteria, as senior Non-Commissioned Officers are generally the first to be eligible, leading to a hollowing out of experience.

3.36 RAF attendance on the Tornado airframe pulse line over the first six months averaged 82 per cent of the approximately 28,000 contracted man-hours over that period. The same period saw 22 per cent more work performed by sub-contractors than was planned. For the Harrier pulse line military personnel have achieved between 85 and 90 per cent of the 1,248 contracted hours per month. However, of even greater impact on the smooth running of the Harrier airframe pulse line has been the significant variability between trade groups and ranks in the hours worked, particularly for those with electrical skills.

25 The skills requirement against the Department's planned manning reductions

There are mismatches between the achievable reductions in numbers of personnel in different trades in depth repair and those that have been planned centrally.



Source: National Audit Office analysis of Ministry of Defence data

NOTE

There are no planned reductions for the Harrier on-aircraft repair trade.

3.37 There are always disparities between complement and headcount, due to resettlement leave and training, but this has been exacerbated by some atypical factors, such as the redundancy programme, high levels of personnel moving in and out of depth repair organisation in the Harrier Force (estimated as 40 per cent per annum), the conversion to multi-skilled tradesmen and 'overborne' personnel, that is those who are qualified to work on another type of aircraft and are awaiting a posting. Failure to provide manpower at the contracted levels increases the risk of late delivery and shortfalls in output on the part of BAE Systems and Rolls-Royce while the Department will incur the costs of replacement contractors or will fail to meet the depth maintenance task.

There are signs that transformation is becoming self-sustaining but the Department must maintain the momentum

3.38 The Chief of Defence Logistics established the Defence Logistics Transformation Programme to provide coherence to over 1,000 transformational initiatives occurring within his organisation. He tasked the Programme Team with measuring the benefits of these initiatives, communicating best practice and reporting on performance against his strategic goal[12] and Departmental efficiency targets. The Programme will end in March 2008, by which time the Department expects that transformation will be broadly self-sustaining.

3.39 The Department removed funding from the Integrated Project Teams' support budget in the early stages of transformation. The aggressive reductions in budgets have been a clear driver for transformation and the contemplation of changes that perhaps would previously not have been considered. The extent of the budget cut was based on an extrapolation of savings from a small number of narrowly focused projects without reference to the extent to which lean techniques had been applied. This was combined with the Integrated Project Teams' own predictions of potential savings, which in many cases were not founded on robust data. As a result, some associate transformation with economy, reducing their will to make further changes.

12 Reduce output costs by 20 per cent by 2005, while maintaining or improving the quality of logistics support to the frontline.

3.40 Transformation may be inhibited by not being linked to continuous improvement. The multiple budget holders that input into logistics support all have their own targets to meet. Without an understanding of the impacts at the macro level, there is a risk that perverse decisions can be taken. For example, there is little incentive for one organisation, on becoming more efficient at conducting repair, to take on extra work. This is because there is no discernable saving to the organisation itself, although other budget holders and the Department may be beneficiaries.

Although the Defence Logistics Transformation Programme acted as a catalyst for change and provided support, this was less than logisticians expected

3.41 While the Programme did provide initial assistance through contracts with external consulting services and its own Lean Support Continuous Improvement Team, this could not be available to all. Those involved in designing transformation wanted generic frameworks on how to maximise the benefits of activities to reduce some of the uncertainty they felt. The Benefits Tracking Tool, set up to record savings, has compounded some negative perceptions of the Defence Logistics Transformation Programme as users saw it as onerous and not adding value.

3.42 In 2005, the Programme Team produced consistent guidance on the definition of benefits and began to identify which would count towards each of the different efficiency targets and they simultaneously released a comprehensive Benefits Management Strategy. In the Autumn they looked at developing a tool to allow the Environment Logistics Programme Boards[13] to measure and monitor how thoroughly transformation was embedded in their areas. The Strike Board's One Star Level Co-Chairs assessed achievement against criteria statements in the ten logistics transformation 'themes' of the Maturity Matrix Tool (Appendix 6) and agreed a Level 2.6 (on a scale from 1 to 5) in the first scoring round in June 2006. From this baseline the Board will set its incremental priorities to achieve the targeted maturity level by the planned date and monitor progress quarterly to ensure the concepts and culture become fully embedded.

Dissemination of information on transformation of support for fast jets is good but its use in the development of other projects is limited

3.43 The Defence Logistics Transformation Programme made information on the successes of transformation of repair processes for Harrier and Tornado aircraft easily accessible through internal magazines, briefings, training courses, the Department's intranet and the internet. The Integrated Project Teams and depth repair organisations for both aircraft have hosted a significant number of visits for interested parties from both the Department and other companies.

3.44 Our interviews confirmed that this publicity had increased awareness. However, the content was descriptive, rather than demonstrating how to quantify the cost and benefits to select an appropriate activity and then to deliver the planned efficiencies successfully. Interaction between teams is key for lessons to be learned but without this type of information, it is difficult for people to establish whether the transformation is applicable to their own areas and if the true value of an exercise is unclear, they are less likely to invest their time and effort to find out.

3.45 In 2006, the Defence Logistics Transformation Programme developed a joint online 'Breeding and Sharing Best Practice' Information Repository with BAE Systems. There are few examples of good practice recorded as yet and not all contributions have completed the evaluative section of the template, which limits the Department's ability to learn from past experience.

Close working relationships between the Harrier and Tornado Lean Teams is yielding benefits that other areas of the Department could profit from

3.46 Some key individuals involved in the early transformation work for the Harrier aircraft were transferred to Defence Logistics Organisation posts for the Tornado aircraft, which has clearly benefited transformation. The Harrier Lean Team developed a

13 Environment Logistics Programme Boards monitor the progress of transformation in the Air, Land, Maritime, Joint and Acquisition areas and provide a forum for the frontline to express concerns and issues.

Route to Event guide to help on-base personnel plan their transformational activity to maximise the chance of delivering the envisaged efficiencies. After an expression of interest from the Tornado Lean Team, this guidance has been jointly reworked to produce a common approach to transformation using lean techniques. Regular meetings between the teams have also yielded a common lexicon for lean techniques and led to the formation of a lean techniques working group across the Defence Logistics Organisation and RAF Strike Command in 2006.

The Department is beginning to employ lean techniques to non-engineering processes

3.47 After the reported successes of lean techniques in engineering, forward squadrons, particularly at RAF Lossiemouth, have used the techniques to improve effectiveness in areas such as training and administration. The use of lean techniques at RAF Cottesmore was the trigger for a successful project to improve the efficiency of Harrier sortie generation on HMS Illustrious (Appendix 7).

Lessons learned in transforming logistics for legacy aircraft have been used by the Typhoon Integrated Project Team to inform the design of its support

3.48 The cost of supporting the Typhoon aircraft is three to fours times greater than that of the Harrier and Tornado respectively at an estimated £13 billion over 30 years, and consequently there are significant benefits from making repair and maintenance cost-effective. Many key military and industry personnel engaged on the Typhoon project have a background in Harrier or Tornado support and other project members have actively sought to learn from the experiences of their counterparts in the legacy aircraft teams. The initial thrust of their work has been in developing partnerships with BAE Systems and Rolls-Royce.

3.49 A single depth repair hub will perform Typhoon maintenance and the aim is to design it to maximise efficiency using lean techniques. Personnel from RAF Conningsby have undertaken a programme of visits to RAF Marham, RAF Cottesmore and RAF Waddington, documenting the successes and failures during implementation of the new repair arrangements and assessing their applicability to Typhoon support.

3.50 The Whole Aircraft Scheduled Maintenance and Upgrade contract for Typhoon, signed with BAE Systems in November 2006, is similar to Tornado Combined Maintenance and Upgrade, in that depth maintenance (after 400 hours) will be performed simultaneously with embodiment of modifications on all 43 Tranche 1 aircraft. This will limit the number of aircraft in maintenance at any one time and ensure up-to-date and common technology standards for the fleet. The Department estimates that if it were to conduct maintenance and upgrade separately, as in the past, then the frontline would have six fewer available aircraft at any one time.

3.51 The goal is to progress through a series of incremental contracts for the other aircraft systems to an overall availability contract. However, it may be some time before this support solution for Typhoon is realised because of the four-nation involvement in the aircraft design and production.

The Department needs to manage the personnel with experience of lean techniques more strategically

3.52 The current system relies on ad hoc interventions at local level to secure the posting of personnel experienced in lean techniques to a suitable role. The RAF Personnel Management Agency attach markers to personnel records to indicate experience and qualifications in lean techniques and this should lead to improved tracking and more strategic decisions on postings.

The RAF has begun to take ownership of transformation activities

3.53 Senior personnel within RAF Strike Command are now taking ownership of the application of lean techniques and appreciating it is not just an activity for logisticians. Best practice advocates that a member of the Board is responsible for driving transformation from the start. In September 2006, Commander-in-Chief Strike Command, announced the RAF policy on the use of lean techniques.

3.54 Station commanders have been made responsible for acting as quality system owners on base and ensuring read across of good practice with other bases, but it is envisaged that some resourcing from the Defence Logistics Organisation through the Integrated Project Teams will remain. Given the level of maturity of transformation, an expert in lean techniques advised us that most organisations would need to keep bespoke teams experienced in lean for at least another two years before assessing whether a culture of continuous improvement has developed. Nevertheless, initial signs are good with the new Quality Continuous Improvement Teams and a common lean toolbox across the entire RAF.

APPENDIX ONE

Detailed recommendations

1 Given our conclusion that the Department's transformation of logistics support to fast jets represents good value for money to date, our recommendations aim to support and enhance the work the Department is already undertaking to manage the risks in the new support arrangements and further embedding the culture and practice of continuous improvement. Many, if not all, of our recommendations are likely to be relevant to changes in support arrangements, underway or planned, for other aircraft types and for land and maritime equipments. This Appendix sets our additional detailed recommendations associated with the key recommendations (in blue) set out in the Summary.

Managing the key risks to the performance of the pulse lines at the depth repair hubs

2 By implementing the following recommendations, the Department should be better placed to manage the key risks to the future performance of the depth repair hubs for Tornado and Harrier aircraft at RAF Marham and RAF Cottesmore:

3 **Recommendation 1:** The Department should improve its ability to provide the level of Service personnel contracted to work in the depth repair hubs at RAF Marham and RAF Cottesmore. The Department should also review if it has sufficient flexibility to meet operational contingencies.

- The Department should look to increase the flexibility of its manpower planning to ensure that the top-down manpower reduction targets are aligned with the size of workforce required and the efficiencies that can be achieved through applying lean techniques.
- The Department needs to plan better for the periods of activity which reduce the input of Service personnel to the pulse line, including necessary military tasks and training, and on-the-job training for their pulse line task.

4 **Recommendation 2:** The Department should improve the availability of spares by continuing to work with its industry partners to address the problems which are preventing the pulse lines from running as efficiently as planned.

- The Department and its industry partners should continue to develop systematic exercises to ensure holdings and procurement are appropriate to predicted spares consumption, starting with those where there are availability problems or those that are high value.
- The Department, through availability contracts with industry, needs to improve asset management and tracking and its ability to progress priority spares requirements.
- Even where, under new contracts, the responsibility for managing spares lies with the Prime Contractor, the Department needs to maintain its visibility of the risks in the supply chain, including through monitoring and controlling carefully spares 'robs' and understanding the resilience of the lower tiers of the supply chain.

Entering into future partnering arrangements

5 By implementing the following recommendations, the Department should strengthen its capability to enter into cost effective partnering arrangements with industry:

6 **Recommendation 3:** The Department should improve its guidance and consistently apply a common methodology for constructing internal value benchmarks against which to assess the value of proposed contracts. Internal benchmarks should make allowance for realistic efficiency improvements through any in-house solution.

- The Department should routinely assess contract costs based on what the service should cost, rather than starting from the likely contract cost or affordable level of expenditure. In addition to facilitating more effective contracting, the Department will be better able to make trade-offs for given levels of affordability.

7 **Recommendation 4:** The Department should assess whether it has sufficient commercial, cost modelling and project management skills to develop the commercially viable support solutions and negotiate contracts, given the increasing complexity and likely volume of industrial logistics support.

- The Department should also consider whether it has sufficient flexibility to move resources around the business, and whether succession planning properly allows for appropriate continuity in its relationship with industry, at key points in the set up and implementation of new contractual arrangements.

Prioritising further improvements to support for fast jet aircraft

8 By implementing the following recommendations, the Department should be able to prioritise better its future change activities for fast jets to derive the greatest operational benefit:

9 **Recommendation 5:** The Department should improve its understanding of the future output requirements, in terms of both operational and training flying demand, by modelling the relationship between the required output and different elements of repair and support. In doing so, the Department should improve its management information systems so that this data is routinely available, including the full costs of supporting aircraft across all of the budget holders involved.

- The Department should examine different approaches to improve the effectiveness and efficiency of the support chain to mitigate current risk for maintaining output, given that to date the sole aircraft availability contract signed is expected to deliver to less than 100 per cent of the current projected requirement. (At present 90 per cent but this will reduce to 80 per cent in 2009-10 unless additional efficiencies are found).
- The Department also needs to assess whether the budget reductions and/ or transition to the new depth repair arrangements have resulted in any hollowing out, for example whether some spares stockpiles have reduced too far whilst waiting for contracts to be agreed, and take appropriate mitigating action.

10 **Recommendation 6:** The Department needs to conduct a high level end-to-end assessment of key elements of change to identify which have delivered the greatest benefits to date and where there is the greatest potential for further transformation, given constrained resources.

- Lean techniques have to be applied iteratively and, to achieve the full benefits of transformation across the system as a whole, the Department will need to re-examine processes to which lean techniques have already been applied while looking at the interconnection between them.
- Given constrained resources for transformation, the Department needs to develop further its performance management regime in order to prioritise between different initiatives and across its business based on planned, quantified cost or performance benefits.

Incentivising transformation and continuous improvement

11 By implementing the following recommendations, the Department should further incentivise the behaviours of project teams and industry to improve fast jet support and other activities across the Department:

12 **Recommendation 7:** The Department should take the opportunity afforded by the transfer of budgetary accountability to frontline commands, including RAF Strike Command, to align incentives further between the frontline customer and support organisations, so that the impact of frontline activity on support requirements is considered.

- The Department should also adopt mechanisms to ensure that Integrated Project Teams providing spares and commodities are incentivised to do so in a way that supports efficient and effective repair activities at frontline squadrons and depth hubs.

13 Recommendation 8: The Department's challenging targets for cost reduction have been a key driver for transformation but there is a balance to be struck between these cuts and the ability to invest in transformation. The Department should make a proportion of the savings from transformation, and particularly from gainshare achieved on contracts, available to teams to reinvest in future improvements. This could help embed the culture of continuous improvement by incentivising teams better to drive through change.

14 Recommendation 9: In time, the Department should use its experience of the newly introduced gainshare arrangements on fast jet support contracts to inform future decisions on the level of gainshare required to effectively incentivise industry. In doing so the Department should assess whether industry has been sufficiently incentivised to drive through future efficiency gains and performance improvements in their own management of the service, and in the supply chain.

Maintaining the capability to apply lean methodologies

15 By implementing the following recommendations, the Department should further strengthen its capability to apply lean methodologies in logistics support and elsewhere in its business:

16 Recommendation 10: In order to maintain the momentum of transformation for fast jets, and facilitate successful transformation in other areas of its business, the Department should review whether it is able to deploy sufficient internal and external expertise in methodologies such as using lean techniques.

- The Department needs greater flexibility in its posting and careers system to deploy those personnel that have developed expertise in lean techniques to best effect.
- As part of this review, the Department should re-consider the timescale on which it plans to withdraw external consultancy support for transformation.

17 Recommendation 11: The Department should adopt a common toolset and language for lean techniques across all areas of its business. The Department should make its lessons learned material more evaluative to provide information on how the methods were applied, and quantify the results they achieved.

- The Department's guidance should also include lessons learned from initiatives where the intended benefits were not achieved.
- In publicising the benefits of transforming its processes, the Department should encourage the application of lean techniques, or similar, to other areas of its business, including administrative functions and operational planning and activities, not just engineering and logistics.

APPENDIX TWO

Methodology

1 This Appendix sets out the scope of our examination of logistics support to fast jets and the methodologies we used in the course of our study.

We preliminarily investigated transformational activity across all areas

2 Initially we focused on the transformation of logistics support as a whole. As transformation has not been a top-down initiative our preliminary work was to understand the breadth of the transformational activity. This involved desk research, attendance at national sector conferences, meetings with key personnel in the Defence Logistics Organisation, and visits to fast jet and helicopter main operating bases, the Royal Electrical and Mechanical Engineers, the Army Base Repair Organisation, Land, Fleet and RAF Strike Command and the original equipment manufacturers. During the completion of the preliminary work we quickly came to the conclusion that we should focus on a single area of transformation within the Department.

Our work has been to investigate

- Whether transformation has delivered benefits of improved performance and cost savings in the support of two Royal Air Force fast jet aircraft, the Tornado GR4 and the Harrier GR7(9), and their associated sub-assemblies.
- If the Department can appropriately attribute the benefits of transformation to the changes in the way the two aircraft are supported.
- Whether the Department has a coherent change programme which supports transformation and will facilitate learning to develop new support solutions for other equipment.

We undertook a series of interview and visits

3 In order to carry out a detailed examination of the performance of the maintenance and repair of the two fast jet aircraft, we conducted visits and semi-structured interviews with the appropriate personnel responsible for each stage of the support and usage of aircraft. We sought information and data pre- and post-transformation regarding the performance of the repair organisations, the overall operational availability of the aircraft and the ability to achieve the annual flying task.

4 We visited the Integrated Project Teams of the Defence Logistics Organisation responsible for managing the repair of the Harrier and Tornado aircraft. Typically this included interviews with the Team Leader, the Business and Finance Manager, the Commercial Manager, the Heads of Branch who manage repair contracts and the Transformation Project Team Leader, as well as individual members of the Integrated Project Team who had detailed working knowledge of their aircraft's repair.

5 To gain an insight into the key issues that staff faced on the main operating bases for depth repair at RAF Cottesmore and RAF Marham, and to a lesser extent RAF Wittering and RAF Lossiemouth where Harriers and Tornados are used, we met with military and industry personnel working there.

6 We also visited staff at RAF Conningsby and entered in to discussions with the Typhoon Integrated Project Team at Abbey Wood, to gain an awareness of how the Department has transferred lessons learned from the transformation of support arrangements for Tornado and Harrier to support the new Typhoon aircraft.

7 In addition we conducted a series of interviews with RAF Strike Command personnel at RAF High Wycombe to gain an understanding of how the aircraft are used and how the transformation of the repair organisations may affect the availability and operational performance of the aircraft.

We undertook a detailed examination of the support to selected aircraft

8 We identified a range of financial and non-financial measures that could be used to assess performance and cost, for example the time and resources required to repair Harrier aircraft within the depth repair hub. A number of different sources within the Department supplied this data.

9 We reviewed documents which included policy and planning papers related to the Defence Logistics Transformation Programme, regular reports for and by the Integrated Project Teams, the results of studies by the Department into various aspects of transformation and other information produced, such as answers to Parliamentary Questions, promotional literature and detailed guidance manuals.

10 Other information consisted of time series data both pre- and post-transformation regarding the overall performance of the repair organisations, the overall availability of the aircraft and the ability to achieve the annual flying task. Using this data combined with the financial data collected it was possible to conduct our own analysis of the cost effectiveness of the transformation of maintenance and repair for both Harrier and Tornado aircraft.

We discussed aircraft support and wider transformational issues with key industrial providers and experts

11 We contacted the Maritime Propulsion Integrated Project Team within the Defence Procurement Agency, the United States Air Force, MTU aero engines (Germany), British Airways and Rolls-Royce. At each organisation we interviewed or corresponded with senior directors and their staff to find out how they manage deep repair and maintenance and the benefits of their systems. We also employed Professor Daniel T Jones, a world renowned expert in the application of lean techniques, to explore and advise us on the Department's implementation of lean techniques to enable effective transformation.

The stakeholders within the Department and other organisations which we visited

Defence Logistics Organisation

Headquarters Bath

Defence Logistics Transformation and staff

Director General Logistics Strike

Logistics Support and Continuous Improvement Team

RAF Wyton

Project Management Organisation

Tornado Integrated Project Team including Industry partners (BAE Systems and Rolls-Royce)

Harrier Integrated Project Team including Industry partners (BAE Systems and Rolls-Royce)

Defence Procurement Agency

Headquarters Bristol

Typhoon Integrated Project Team

Maritime Propulsion Integrated Project Team Leader

C17 Integrated Project Team Leader

Type 45 Support Solution Team Leader

Ministry of Defence

Castlewood House

Director Projects Saudi Armed Forces Project

Royal Air Force Stations

Headquarters Strike Command High Wycombe

Air Officer Commanding One Group

Chief Of Staff Support

Assistant Chief of Staff A4

RAF Marham

Station Commander

Officer Commanding Tornado Forward Support and staff

Officer Commanding Tornado Depth Support and staff

Rolls-Royce RB199 Operations Manager

BAE Systems Head of Operations and staff

RAF Cottesmore

Officer Commanding Harrier Forward Support and staff

Officer Commanding Harrier Depth Support and staff

BAE Systems Operations Manager and staff

RAF Wittering

Officer Commanding Harrier Aero Squadron

Rolls-Royce MRMS Operations Manager

RAF Conningsby

Officer Commanding Typhoon Depth Support and staff

Industry Headquarters

Rolls-Royce plc Defence Aerospace Bristol

Rolls-Royce plc Civil Aerospace Derby

BAE Systems plc Farnborough

British Airways Engineering, Heathrow Airport London

McKinsey & Company, Jermyn Street London

APPENDIX THREE

The Department has successfully applied lean techniques

1 The use of lean techniques, developed from the Toyota production system in the early 1990s, is widely held as good practice in the manufacturing, engineering and financial sectors and there is growing interest in their application to the public sector. Lean techniques aim to identify and eliminate any activity that does not add value to the end user and make the remaining activity flow in the most efficient sequence possible.

26 The most common lean techniques used at RAF bases

In 2005, the Harrier and Tornado depth organisations held approximately 80 to 100 events to redesign processes using lean techniques.

Value Stream Analysis	**Develops evidence-based decision making and clear planning** The RAF, in accordance with industry practice, uses Value Stream Analysis at the start of every application of lean techniques, which typically involves the following: 1 Development of an "as is" process map to illustrate each step involved in bringing a product from order to delivery, split into flows of material and information. The map includes the resources required and time taken to complete each step. 2 Identification and removal of steps which do not add value to the end user; that is waste. 3 Production of a "future state" process map which ensures the remaining steps are placed in the most efficient order. The Rapid Improvement Event focuses on how to implement the future map in the most practical way.
Rapid Improvement Events	**Achieves buy-in** A weeklong analysis to test the validity of the improvements identified during the Value Stream Analysis and to decide how best to implement them. The success of this method has been attributed to the fact that it is the staff on the shop floor who are involved in the day-to-day operations generating the ideas. The RAF uses a standard approach of three weeks preparation, one week Rapid Improvement Event and three weeks to implement in their use of lean techniques.

26 The most common lean techniques used at RAF bases *continued*

5S	**Increases visibility – cuts management time and time wasted searching** "Everything has its place" philosophy. Workplace practices made conducive to visual control and lean production: Seiri – Separate what is needed and discard the rest Seiton – Arrange what is left in its own clearly marked place Seiso – Clean and wash the workspace Seiketsu – The resulting state of cleanliness and organisation Shitsuke – The organisation and discipline required The RAF has used 5S in applying lean techniques. For example, the provision of vacuum-packed spares for use on the pulse lines. The RAF and BAE Systems have identified the spare parts required for the planned work at each stage of the on-aircraft pulse line at RAF Marham. The requisite parts are vacuum packed together on a board and the pack is delivered to the pulse line every ten days. The tools required are stored next to the work area; each tool has its own place carefully marked out. All other tools and parts have been removed from the work area.
Kanban	**Increases visibility of shortages – cuts management time and inventory and helps set the requirement to which each process will work** The Japanese word for "sign", a kanban system is a means of visually managing production. For example, the RAF has a buffer stock of repaired engines and when a squadron requests a new engine, it is pulled from the kanban stock. This results in an empty slot in the buffer stock which triggers the pulse line to complete the repair of another engine.
Pulse Lines	**More efficient repair – everything is planned to occur at a certain time levelling demand for spares and personnel** A technique invented by Henry Ford, adapted by Toyota and applied extensively in the manufacturing sector. The main advantage of a pulse line, in comparison to traditional stand-alone repair, is it increases consistency and visibility. The repair is divided between different phases of an equal duration and the aircraft is 'pulsed' from one to the next; for example, the Tornado GR4 pulse line comprises eight phases of a duration of ten days. The number of personnel and spares required every ten days for each pulse is therefore easier to predict. The Department uses pulse lines for both on- and off-aircraft repair (Figure 3).

Source: National Audit Office

APPENDIX FOUR

British Airways

1 British Airways operate a fleet of 243 aircraft to around 140 destinations in 75 countries. It carried over 35 million passengers in 2006, generating approximately £8.5 billion in revenue, a 9.6 per cent increase in an industry sector which shrank by £5.5 billion over the same period. Since 2000, British Airways has reduced fleet size by approximately 15 per cent while the total number of hours flown per aircraft has increased by ten per cent.

2 Despite the obvious differences, there are some similarities between the challenges facing British Airways and the Department:

- the operational environment of commercial aviation has changed considerably due to external factors such as the events of 11 September 2001, the emergence of low cost airlines and rising fuel prices. Similar to fast jets, although for differing reasons, this acted as a catalyst for work examining the cost of operations and identifying the potential to become more efficient.
- repair and overhaul is based on forecasted maintenance schedules. The turnaround time for maintenance, particularly unplanned repair, has a critical effect on operational output.
- both are contracting in a support market where there are few competitors. The original equipment manufacturers' business models are moving towards the after sales support market through the provision of repair and overhaul services.

3 British Airways has responded to the above situation through a transformation which has some similarities with that currently underway in fast jets.

Rationalisation

- Like the Department, British Airways had a high cost base associated with its own on- and off-aircraft repair facilities. This has been reduced by relocating repair activity away from Heathrow airport to Cardiff (long haul aircraft) and Glasgow (short and medium haul aircraft). Unplanned repair is performed at Heathrow or in situ if overseas through a contracted network of home airlines. Engineers can be flown to the aircraft on the next flight if necessary.
- Over the last five years British Airways has reduced its engineering workforce by half.

Repair and overhaul

- Repairs are performed as stand alones rather than in pulse lines. Each component has an expert technical engineer to discuss performance with their counterpart in the Design Authority. British Airways believes that this expertise is required to maintain the status of an intelligent customer, even when repair is outsourced. Original equipment manufacturers do not necessarily have access to performance data of their components when on-aircraft and data analysis allows British Airways to drive reliability improvements which are evidence based.
- Keeping repair in-house gives quality and reliability benefits. Technical personnel can be rotated to multi-skill on other areas of repair for both personal Continuing Professional Development and operational capability improvements, an approach currently being adopted by the Department.

- Process improvement methodologies have been applied, resulting in similar outcomes to lean techniques; faster maintenance cycle times, standard work packages and ensuring that spares and equipment are located where required. Application to the Boeing 747 repair line has led to the equivalent of an extra aircraft being available to the fleet.

Contracting and fleet management

- Unlike in fast jets, British Airways does not have to contract with the original equipment manufacturer for repair and overhaul. A robust initial contracting position followed by strong project management should ensure access to technical documents and technical advice. Although British Airways has some of its Rolls-Royce engine fleet under Totalcare support contracts, they have also contracted the repair of other Rolls-Royce engines to General Electric.
- British Airways believes that the key to effective contract performance is robust data management and have invested £150 million in performance management information systems in order to better understand the true cost of owning and operating assets. Hence it is in a better position to make decisions on out-of-service dates when aircraft become uneconomical to repair. It also has a ten year fleet management tool in order to forecast when an aircraft needs maintenance and what modifications to embody, for example upgraded entertainment suites.

4 The results of the transformation have seen British Airways reduce the cost of support by 28 per cent through rationalisation and manpower reductions, while improving repair time and increasing the availability of aircraft.

APPENDIX FIVE

Use of lean techniques in the United States Air Force

1 High tempo of operations, generating more repair, at the same time as procurement of new equipment constrained the United States Air Force's repair budgets and required it to make changes to repair and maintenance. The use of lean techniques began in 1999 at Warner Robbins, the home of repair and overhaul facilities for four transporter and one fighter aircraft, and spread to other bases. With 20,000 employees and repair contracts of an annual value of £2 billion, it is a significantly larger operation than anything in the United Kingdom.

2 Lean techniques were applied as an "experiment" in F-15 fighter avionics repair; this was expanded to wings and then to the entire F-15 production line. The C-5 transport production line followed using this pattern of experimenting, learning and diffusing in early 2001.

3 There are similarities between the logistics transformation in the two countries:

- Lean techniques were initially used in engineering processes and then rolled out into other areas
- Although originally performed at bases, lean techniques have been adopted in an Air Force-wide initiative
- More modifications have been incorporated while reducing the cost, resource or time needed to perform repair

4 There is one significant difference from the transformation in the RAF in that United States of America Defence policy states that any benefit resulting from lean techniques are retained by the organisation that generated them, which generally means they are reinvested in additional events to use lean techniques.

27 United States Air Force results after using lean techniques

As in the United Kingdom there have been demonstrable improvements in performance as a result of redesigning repair processes.

	C5 – large transporter	F-16 – fighter	F-16 weapons pylons	KC-135 – tanker
		Percentage change		
Available Aircraft	+20	–	–	+5
Throughput	+24	–	+75	+32
Work in progress	–	–44	–84	–52
Repair time (Days)	–38	–12	–88	–54
Supply Chain Shortages	–97	–	–	–
Modification Insertion	–	+25	–	–
On time delivery to customer (achieved)	100	100	100	–

Source: United States Air Force

APPENDIX SIX

The Defence Logistics Transformation Programme Maturity Matrix

28 The assessment of the level of logistics transformation

Compared to the individual criteria in ten logistics transformation themes RAF Strike Command assessed its overall maturity as 2.6, against an average target for maturity of 4.2.

	Level 1	Level 2	Level 3	Level 4	Level 5	Target descriptors	Overall Maturity	Target Maturity
Frontline confidence, force level readiness and sustainability	✔	✔	✔			■ Defence Logistics Board Performance Management System is a key tool for: addressing Defence Logistics issues; ■ Planning and forecasting initiatives, projects and activities ■ There is a strong culture of planning, forecasting and managing initiatives, projects and operations based on the assessment of Logistics Performance and Preparedness ■ There is high confidence in the supply chain and frontline command behaviour and culture has changed significantly (stock holdings kept to a minimum, increases in equipment availability maximised)	2	5
Build capability in lean techniques	✔	✔	✔	✔	✔	■ Opportunities for re-applications of successful leaning improvements are actively sought and actioned following initial improvements – continuous improvement ■ Lessons learned are shared within and across environments to assist others in applying new lean techniques in new ways	4	5
Through life management	✔	✔	✔	✔	✔	■ Through Life Management policy and practice is applied consistently and coherently across the environment ■ Evidence that programme decisions take full account of the long term Through Life Management implications on defence capability ■ Customers and stakeholders are engaged in trade-off and management decisions based on Through Life Management policy ■ 'Support Solutions Envelope' and 'Support Options Matrix' applied to a broad range of value streams	2	4

28 The assessment of the level of logistics transformation *continued*

	Level 1	Level 2	Level 3	Level 4	Level 5	Target descriptors	Overall Maturity	Target Maturity
End-to-end	✔	✔	✔	✔	✔	■ All process in control, with sufficient capacity to meet performance specification, including output volume, quality and lead-times, and with clear ownership and responsibility for their upkeep and maintenance. Joint customer and supplier implementation of processes ■ Joint governance of the end to end value chain, including a jointly defined and managed risk register ■ Materiel supply directly linked to usage, with process output/deliveries directly linked to customer demand. Routine planning cycle with all participants involved	2	3
Optimisation of industry	✔	✔	✔	✔	✔	■ Evidence that lessons learnt are shared within and across environmental boundaries and a culture of shared best practice exists across industry groups ■ Leaning conducted as business as usual in Industry ■ Contracts for availability operating effectively and regularly reviewed for further benefit ■ Significant number of contracts placed for capability, where appropriate and are functioning effectively	3	5
Identification and deployment of innovative ideas	✔	✔	✔	✔		■ Levers/innovative ideas predominantly developed within the organisation and any reliance on external assistance or Defence Logistics TP DLTP Enabling Service is on an approved, one-off basis ■ Evidence of widespread reference to internal and external best practice, and promulgation of it ■ Benefits of new levers/innovative ideas are clearly articulated and managed and they are proactively sought out in order to meet close 'wedges without a lever' ■ Benefits captured, reported and analysed by lever/innovative ideas to support decision making ■ Evidence that benchmarking is used as a tool to identify best practice	3	4
Change management	✔	✔	✔	✔	✔	■ All staff understand what change management is and why it is important to logistics transformation ■ Common change management approach is agreed and implemented: 1) Managers and leaders are formally trained in change management; 2) Business Change Management function is in place ■ Resistance and non-compliance occurs only in isolated instances ■ Staff empowered to explore non-traditional ideas and rewarded accordingly	3	4

28 The assessment of the level of logistics transformation *continued*

	Level 1	Level 2	Level 3	Level 4	Level 5	Target descriptors	Overall Maturity	Target Maturity
Change management *continued*						■ Logistics transformation is linked to personal, team and organisational objectives		
Benefits management	✔	✔	✔	✔	✔	■ All projects have fully defined financial and non-financial benefits profiles. Evidence of widespread coherent benefits management within the organisation, with emphasis on analysis and decision making rather than benefit recording and reporting ■ Business Change Management function has been identified within the organisation to embed benefits and ensure they are realised (using existing or new roles) ■ All new Business Cases contain Benefits Management Profiles and Plans	2	4
Programme management	✔	✔	✔			■ Outcomes of proactive programme management activity embedded within the environment are evident and quantifiable in terms of value delivered ■ Strong culture of effective programme management and majority of programmes adhere to formal frameworks/ approaches and all key staff have been trained accordingly ■ Evidence of extensive proactive challenge on programme delivery becoming business as usual and decisions are taken at Board level as a result of this 'challenge' function ■ Programme management systems, processes, data and staff competencies are so advanced and mature that the majority of time is spent on value adding dependency, issue and benefit information analysis leading to better management decisions	2	5
People skills	✔	✔	✔	✔	✔	■ Staff actively use the Intranet and other information management tools to gather and share information and a model for best practice sharing is in place and delivering benefits with respect to basic levers for change ■ Learning and development plans are in place for all staff and line managers proactively seek to close any required logistics transformation skill and competency gaps ■ Structured approach to 'on the job' coaching and learning; lever teams are expected to play an active role in upskilling environment staff, using tools provided for this purpose ■ Staff supported in incorporating externally acquired knowledge and skills into their work	3	3

Source: Ministry of Defence

NOTE

✔ All criteria assessed as achieved ✔ One or more assessed as acheived

APPENDIX SEVEN

HMS Illustrious

1 HMS Illustrious is one of the Royal Navy's three Invincible class aircraft carriers and can accommodate a mix of Harrier GR7/9 jets along with Sea King, Chinook and Merlin helicopters depending on the requirement.[14] The successes of lean techniques reported by the Harrier Integrated Project Team inspired key Royal Navy personnel to investigate if, during trials after a two year major upkeep period, their application to HMS Illustrious could improve the Sortie Generation Rate; that is the amount of sorties that could be performed by the embarked aircraft per day.

Historical Sortie Generation Rate	Target Sortie Generation Rate	Sortie Generation Rate post-lean techniques
16 sorties per day	30 sorties per day	26 sorties per day

Source: National Audit Office interviews

NOTE

Target is potential only as generation rate could not be enacted during peacetime operations.

2 Using external and Harrier Integrated Project Team staff, Royal Navy personnel applied lean techniques and developed their understanding of their activities to unprecedented levels, identifying areas of waste that inhibit sortie generation. After mapping all aspects of the ships activity, from weapons loading and repair to feeding the crew, the team generated a benchmark set of data in order to establish the major areas affecting sortie generation, enabling a more informed approach to resource allocation.

3 The transformation is ongoing; 24 Rapid Improvement Events have generated 17 complete solutions, 34 are ongoing and 19 are yet to be fully approved.[15] Resulting improvements identified so far include:

Weapons preparation – Weapons availability was historically a major factor limiting sortie generation until the introduction of flow into cells. This has enabled an 80 per cent improvement in performance. The build time of a 1,000 pound bomb has reduced from 142 minutes to 28 minutes, with the distance walked reduced from 621 metres to 120 metres and a reduction in manpower from five personnel to two.

Deck Lifts – Deck lifts are vital as they move aircraft to and from the flight deck and the hangar. If lifts fail then sortie generation is zero. It was established that 84 per cent of inoperable lifts were caused by human error. Through better instructions and signposting, errors have been reduced and lift availability is now at 99 per cent.

Reorganised deck processes – Reducing movement of aircraft is key to improving efficiency. If a pilot suspects their aircraft has developed a fault in flight, its nature is radioed using an improved set of standard codes. The aircraft most likely to require maintenance is recovered first and allocated a parking spot to reduce the number of nugatory moves. In addition, crew are incentivised to repair aircraft on the deck. The Rapid Improvement Event identified a system of deck marking to enable the optimal use of space although approval for this did not occur until one year later.

14 Namely power projection onto land, helicopter support or acting as a Command and Control centre.
15 As of March 2006.

Reorganised hangars – Space is at a premium on an aircraft carrier. Through redesigning repair processes and applying '5S' methods, two extra aircraft can now fit into the hangar with an extra 150 cubic metres for storage, increasing the interval between re-supply. The distance personnel must walk to perform repair processes has also reduced. For example, changing a Pegasus engine required the team to walk over 60 kilometres, post lean techniques this has been calculated as seven kilometres.

4 The application of lean techniques to HMS Illustrious was focused upon improving operational effectiveness rather than delivering cost savings, although an estimated £18 million has been achieved. When completed, the potential results appear impressive. Furthermore, the Royal Navy has now established a Fleet wide continuous improvement plan incorporating lean techniques which has already reaped dividends in administration, training and operational planning. Although as with fast jets, the rotation and posting of key individuals with lean experience is a risk to sustainability. One of the key benefits of applying lean techniques on legacy equipment is the potential for better financial and operational performance of the future aircraft carriers.

GLOSSARY

Bays	The location used to perform repair for a specific component; for example a hangar could have an engine bay, a structures bay, an armaments bay etc.
Benefits Tracking Tool	IT system used by the Department to report any benefits derived from logistics transformation to the Defence Logistics Transformation Programme Team.
Contracting for Availability	A type of contract whereby the Department pays industry based on the equipment being available. Under previous arrangements the Department paid industry for spares and to repair faulty components. Instead industry is incentivised to make the equipment more reliable and therefore increase availability.
Crisis Manpower Requirement	Minimum level of manning which in the event of a major conflict the Royal Air Force would need to deploy. The personnel also fulfil other roles when there is not a major conflict.
Defence Aviation Repair Agency	Ministry of Defence trading fund which specialises in the maintenance, repair and overhaul of rotary and fixed wing aircraft, avionics, systems and components. Third line maintenance (see *Four lines of repair*) used to occur at its St Athan site for both Harrier and Tornado aircraft.
Defence Logistics Organisation	Responsible for supporting the Armed Forces throughout the various stages of an operation or exercise; from training, deployment and conduct of operations, through to recovery and recuperation ready for redeployment. It annually spends £8 billion, approximately 20 per cent of the defence budget.
Defence Logistics Transformation Programme	A single programme established by the Chief of Defence Logistics to provide coherence to more than one thousand transformational projects occurring across the entire logistics area, measure the benefits, communicate best practice and report on performance against his strategic and Departmental efficiency targets.
Depth Repair Hubs	The single location for the depth repair activity associated with a particular aircraft type; RAF Cottesmore for Harrier, RAF Marham for Tornado and RAF Conningsby for Typhoon.
Design Authority	The organisation which holds the intellectual property rights for the equipment. If a component has developed a minor fault, the Design Authority will judge how serious the fault is and can authorise continued use if appropriate. BAE Systems is the design authority for the Tornado and Harrier aircraft. Rolls-Royce is the design authority for the Pegasus and RB199 engines.
End-to-End	The span of the logistics process from the point where industry creates components of logistic support to their use by the frontline.

Forward/Depth	Forward refers to logistical elements that provide immediate support to the operating environment and comprises of line 1 and about half of line 2 (see *Four lines of repair*). Forward is located on base and is managed by RAF Strike Command. The Forward elements are deployable on operations. Depth refers to platform support elements and comprises of lines 2 (remaining half), 3 and 4 (see *Four lines of repair*). Depth elements are mainly non-deployable to operations but there are "Deployable-depth" units if necessary. Depth is managed by the Defence Logistics Organisation but manpower and infrastructure are provided by RAF Strike Command.
Four Lines of repair	Traditionally the repair and overhaul of aircraft was conducted at four lines; 1 Minor Repairs performed by Operational Squadrons on base 2 Major repairs performed by Operational Squadrons on base 3 Major repair performed by the Defence Aviation Repair Agency 4 Major repair (as 3 but for crashed/damaged aircraft) and upgrade performed by industry.
Frontline Command	Fleet (Royal Navy), Land (Army) and Strike (Royal Air Force).
Gainshare	Contractual arrangement whereby any benefits derived from the partnering arrangement between the Department and industry are shared. The opposite is painshare.
Integrated Logistics Operations Centre	A joint Defence Logistics Organisation and Strike Command initiative. The Integrated Logistics Operations Centre responsible for planning the use of the aircraft and therefore scheduling their entry into depth repair hubs for maintenance and overhaul.
Integrated Project Team	A team of civilian and military personnel responsible for managing an aircraft from concept to disposal. The Harrier and Tornado Integrated Project Teams are part of the Defence Logistics Organisation. They are responsible for the procurement of spares and repair to support the aircraft, meeting cost and performance targets within budgeted resources detailed in the Customer Supplier Agreements. They do not manage all the commodities within the aircraft, for example the ejection seat, avionics and weapons.
Intellectual property	People or businesses can own their creativity and innovation in the same way that they can own physical property. Intellectual property rights very broadly are granted to creators to protect their work while allowing the general public to access it at the same time.
Internal Value Benchmark	Calculation to establish how much a particular activity would cost if performed efficiently in-house rather than contracted out to industry.
Kanban	The Japanese word for "sign", a kanban system is a means of visually managing production levels (Appendix 3).
Logistics	Logistics can comprise the following activities; Design, development, acquisition, storage, transport, distribution, maintenance, recovery, re-generation and disposal of materiel Transportation of personnel Acquisition, construction, maintenance, operation and disposition of facilities Acquisition or furnishing of support services Medical supplies support.

Logistics Support	Logistics Support is the activity and resources required to train and maintain Force Elements at the readiness states mandated by the Departmental Plan (and that are required to generate those Force Elements ready for deployment).
Maintenance Cycle Times/ Turn around time	The time between the receipt of an aircraft or component to its exit from the repair facility. This is not the "hands on" repair time, but is a more useful measure of availability.
Off-aircraft/on-aircraft repair	Off-aircraft refers to components repaired separately, including engines, structures, avionics and general systems. On-aircraft is the repair of the airframe.
Prime Contractor	The contractor who has overall responsibility for co-ordinating and integrating the activities of a number of sub-system contractors; in the case of fast jets: BAE Systems and Rolls-Royce.
Pulse line	Akin to a production line. Depth repair activity is broken down into packages of work designed to last for an equal period of time, for example 10 days. After the period has elapsed all aircraft are "pulsed" or moved to the next area.
Rejection	Engineering personnel reject a component if they judge it to be faulty. Rejections are a measure of quality and reliability.
Reliability Centred Maintenance	Preventative repair of an aircraft based on predicted failure rates of individual components.
Royal Air Force's Strike Command	The military organisation which controls the majority of the United Kingdom's combat aircraft. It was formed by the merger of Bomber Command and Fighter Command and later absorbed Coastal Command, Signals Command, Air Support Command (formerly Transport Command) and RAF Germany.
Stand-alone maintenance	Depth repair activity undertaken outside of the pulse line, the aircraft is worked on in a static location for as long as is required.
Supply chain	The policies, processes and activities associated with the receipt of stocks from industry to their delivery to the unit from which the demand came and the return loop.
Support Optimisation methodology	A process developed by the Department to manage availability/ serviceability of its equipment. Optimised Support Planning is built on three concepts – a frontline activity plan, cause and effect analysis and a performance management system.
Surge	The ability to increase the amount of repair activity for a short period of time in order to cope with an out of the ordinary situation.
Throughput	The amount of activity being "put through" a repair process.
Typhoon	Formerly known as the Eurofighter; multi-role aircraft.
Upgrade	The addition of equipment or software to enable the aircraft to perform new tasks or to perform existing tasks better. The scale of the upgrade can range from a single component to a full aircraft upgrade such as Harrier GR7 to GR9 standard.
Work in progress	Equipment in various stages of repair, including all parts ready for initial processing up to equipment awaiting final inspection and acceptance as finished good inventory.

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