

Gaining technological advantage A&D Insights

***Industrial Products
Aerospace & Defence***

*The second edition in our
A&D Insights series*



pwc

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Methodology

As part of this report, PwC interviewed 18 senior executives from Aerospace & Defence companies and associations in Brazil, Canada, France, Germany, India, the United Kingdom and the United States. The combined sales revenues of the companies exceeded US\$148 billion in 2010. The interviews took place in person between November 2010 and March 2011. Questions focused on investments in new technologies and adjacent markets, emerging technologies and the pace of innovation. The results of the interviews are supported by additional proprietary research, as well as analysis of publicly available information. The results are reported in US\$ unless specified otherwise.

Welcome



Neil Hampson
Global Aerospace &
Defence Leader

The Aerospace and Defence (A&D) industry has been the source of some of the most influential technological advances in modern history—computers and computer networking, satellites and satellite navigation, and important advances in physics—all have their roots in the sector’s research. That’s why it should come as no surprise to anyone that we at PwC believe there is a strong innovation imperative for the industry. The executives we interviewed agree. Differentiation has long been critical to gaining and maintaining contracts, programme positioning and market share. It’s even more important today given the increasing globalisation of the industry, a trend we examined in last year’s report, *A&D Insights: Accelerating global growth*. New competitors are already emerging, so maintaining a competitive edge is seen as absolutely essential by the executives we interviewed.

That’s not the only reason A&D companies are focusing their effort on innovation. Executives also see researching and developing the right new technologies as an essential way to build revenues and cut costs. We take a look at some of their top picks: stronger, lighter, smarter materials; process excellence; digitisation (advances in avionics and the more electrical aircraft) and improvements in monitoring and maintenance.

Another important way to build revenues is by expanding into adjacent markets. We discuss four key reasons

why companies may benefit from expanding beyond their traditional core: industry overlap, diversification, new technologies with cross-over applications and making the most of core skill sets. We also take a closer look at one or more adjacent markets developing from each of these key drivers.

We believe that working together with government, within the industry, and even beyond sector boundaries is more important than ever. Governments will continue to hold the purse strings not only on military budgets, but on some key adjacencies as well. Technological breakthroughs in key areas like biofuels will require cooperation across the supply chain. And succeeding in some of the most promising new adjacent markets—like smart grids—will mean cooperating across sector boundaries too.

There’s an extremely high level of synergy between new technologies and adjacent markets. That means companies are likely to get the strongest benefit from their research efforts when new product directions can also help build a presence in growing adjacent markets. And when those efforts are aligned with government priorities, and companies are able to collaborate effectively both within and beyond the industry, the future looks brightest.

The innovation imperative

Investments in new technologies and adjacent markets “are core to our growth strategy and are embedded in the business.”

Ian King,
Chief Executive, BAE Systems

Executives are convinced that a technological edge is the way to survive and thrive in a highly competitive environment. Differentiation is the name of the game, and most believe improving technology is one of the best ways to achieve it. Indeed, executives agree that investment in new and emerging technologies is absolutely fundamental. Embraer Executive Vice-President, Finance and Chief Financial Officer, Luiz Carlos Siqueira Aguiar says the company’s investments “*have total synergy [with the core business]. Everything is linked to the company’s long-term growth strategy.*”

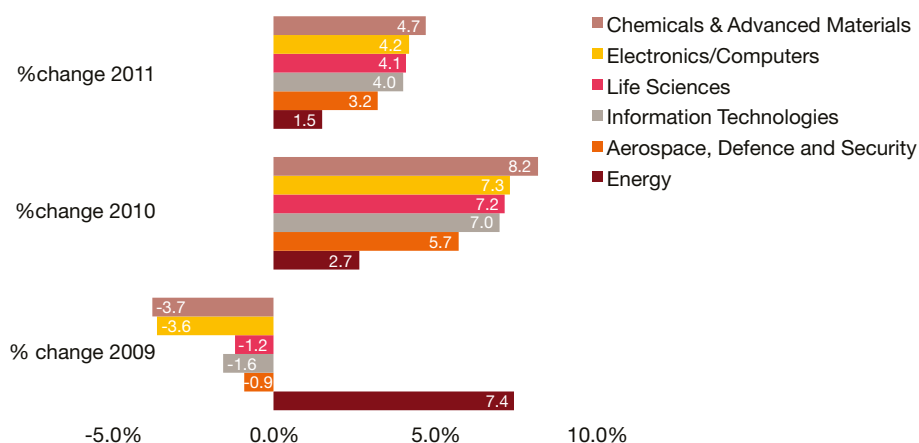
Companies are backing up these convictions with research dollars. The A&D executives we interviewed told us that the financial crisis hadn’t

reduced their focus on new technologies and adjacent markets, and most said they haven’t cancelled or even postponed any key initiatives.

In their 2011 *Global Research & Development Funding Forecast*, Battelle estimates that Aerospace, Defence and Security (ADS) spending overall did decline in 2009 compared to 2008, but rebounded strongly in 2010. Compared to other sectors, ADS spending on research and development (R&D) appears to fluctuate somewhat less, with a more modest drop in 2009, and a smaller upswing in 2010 (see Figure 1). These figures don’t take into account certain non-recurring development costs that Boeing incurred for the 787 and 747 in 2009; if that additional \$2.7 billion were added, ADS would join Energy as one of the few sectors that didn’t reduce industrial R&D spending in 2009.

A look at the top 20 companies in the sector showed most held R&D spending steady in 2009 and 2010. Total R&D dollars were down in some cases, but R&D expenditures as a percentage of revenue stayed within half a percentage point from 2008 to 2010 for nearly every company in the Top 20 (see Figure 2).

Figure 1: % Change in sector R&D spending levels, 2008-2009, 2009-2010 and 2010-2011 (forecast)



Source: Battelle 2011 Global R&D Funding Forecast, PwC analysis

Figure 2a: 2010 R&D expenditures (Top 20 A&D companies by revenue)

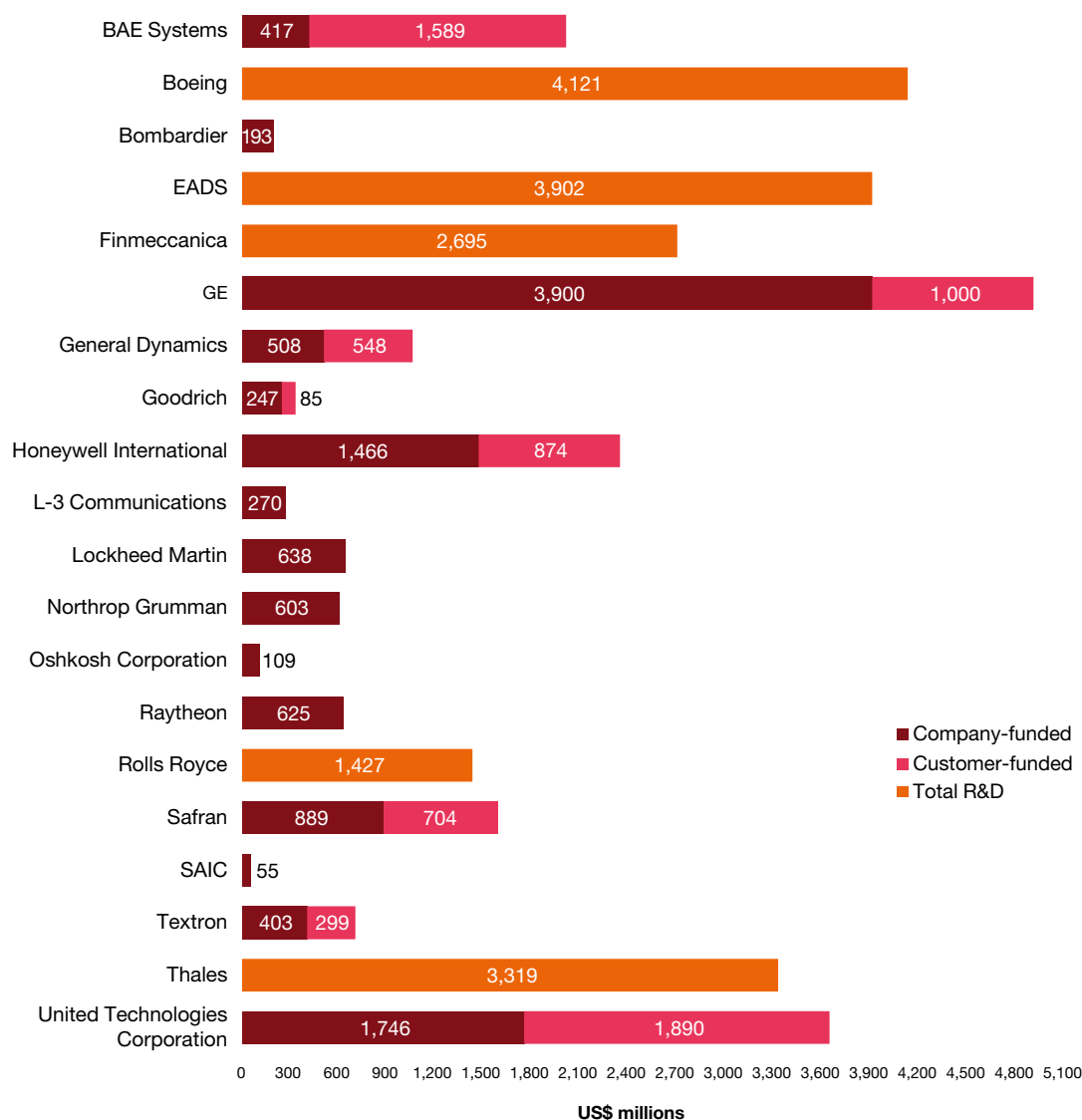
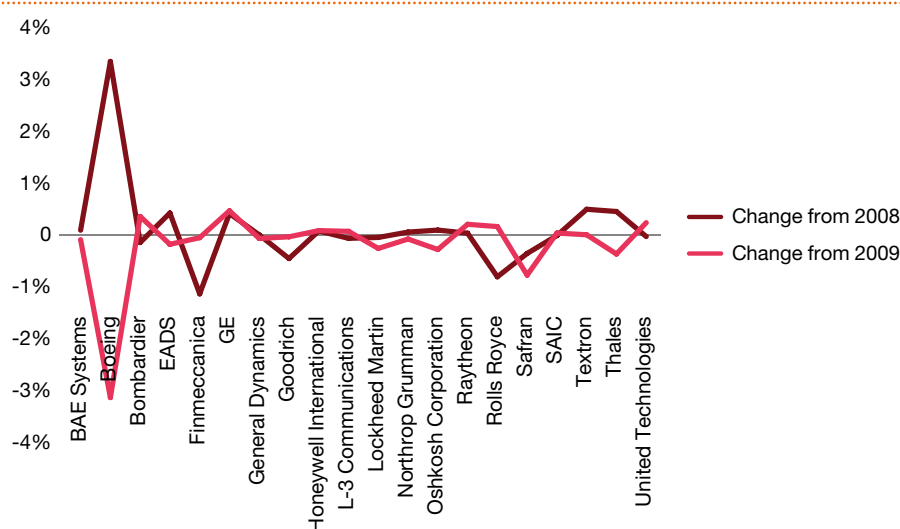


Figure 2b: R&D expenditures as a percentage of revenue: % change, 2008-2009 and 2009-2010



Source: Company annual reports, PwC analysis

Note (Fig 2a): 2010 revenues reported in other currencies were converted to US dollars in the 2010 R&D expenditures chart. For some companies, data reflects total company expenditures, including non-A&D business units: Bombardier, GE, Honeywell, Textron, Oshkosh and United Technologies Corporation. Customer-funded R&D expenditures are not disclosed for the following companies: L-3 Communications, Lockheed Martin, Northrop Grumman, Oshkosh Corporation, Raytheon and SAIC.

Note (Fig 2b): Percentage change is based on company-funded R&D only, except in cases where only total R&D (including customer-funded) was reported: Boeing, EADS, Finmeccanica, Rolls-Royce and Thales. Percentage changes are based on revenues as reported in original currencies. For some companies, data reflects total company expenditures, including non-A&D business units: Bombardier, GE, Honeywell, Textron, Oshkosh and United Technologies Corporation. This may somewhat understate A&D R&D levels for these companies.

While A&D companies have been holding steady on their own investments in R&D, they may nonetheless find their overall budgets decreasing, when externally-funded investments are considered too. In the US, the government will fund over \$80 billion in defence-related research, development, testing and evaluation in 2011.¹ That number is set to drop to around \$75 billion in the FY12 budget request, although the final number is still a source of great debate on Capitol Hill.² While only a portion of the total goes to industry, government research spending in the defence sector is exponentially bigger than in any other sector, so cuts in government funding, or changes in research priorities, will have a more significant impact.

R&D investments in emerging markets are on the increase

It's clear that innovation is critical. But where in the world is it happening? And do some countries have an edge?

Historically, the US and some European countries—notably the UK, France, Germany, Italy and Spain—have dominated both research and manufacturing in A&D. But emerging

countries are beginning to catch up. Datamonitor estimates that the A&D industry in the top five emerging countries (Brazil, China, India, Mexico and South Africa) will reach a value of around \$260 billion in 2014. That's equivalent to a CAGR of approximately 15% over the 2009-2014 period. Companies in mature markets are taking note.

In our discussion of globalisation in last year's edition of *A&D Insights*, we noted that the number of investments in international markets by the top 50 aerospace and defence companies had reached a 10-year high in 2008. The upward momentum continued in 2009, but dropped again in 2010 (see Figure 3). We anticipate that investment levels will increase again in 2011, as companies grow more confident in the economic recovery.

Some investments were motivated by the need to access customers who will be the engines of future sales growth. India, for example, received the largest number of R&D investments and the second largest number of manufacturing investments between 2000 and 2010. Unlike a decade ago, today's emerging market investments rarely fulfil only offset requirements.

Figure 3a: Investments by top 50 global A&D companies in international markets (2000-2010)

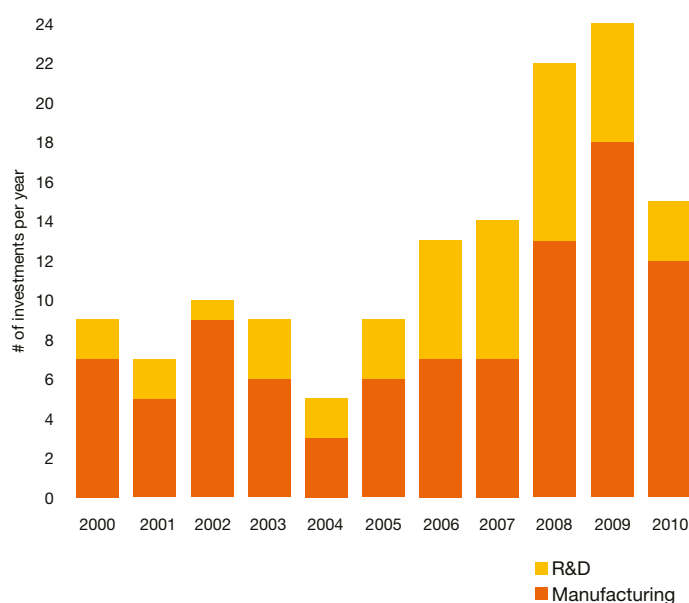


Figure 3b: By country, 2000-2010 (cumulative)

Country/Region	R&D	Country/Region	Manufacturing
India	10	China	21
US	7	India	18
Russia	5	US	13
W Europe	4	Mexico	8
UK	4	Russia	7
CEE	3	Middle East	6
China	2	UK	4
Mexico	2	W Europe	4
Middle East	2	CEE	3
S. Korea	2	N. Africa	3
N. Africa	1	S Korea	2
Other	2	Other	4
Total	44	Total	93

Notes: Data compiled for top 50 A&D companies as per Flight International Top 100 Rankings. Includes organic investments and discrete aerospace JVs where rationale for investment is known. Excludes acquisitions.

Source: Flight International, PwC analysis



“Fundamentally Goodrich is a technology company. We win because of technology. You don’t get through the door without technology.”

Harry Arnold, Vice President, Enterprise Technology, Goodrich

They represent large fixed assets, investments and relationships with trusted suppliers that cannot be abandoned without significantly increasing supply chain risk.

R&D investments reflect increasing talent scarcity, as companies look to find engineering and other critical talent all around the world. Even according to conservative estimates, for example, India is currently graduating about as many engineers as the US, and China produces significantly more engineering and technology PhDs than the US or India. A&D companies cannot remain competitive by relying solely on the traditional sources of talent. They must recruit the best people from around the world. The recruiting process can be more complex due to regulatory restrictions such as International Traffic in Arms Regulations (ITAR) and Export Controls.

Often, that means making a commitment to staying in a particular market for the longer term. The high-profile nature of many programmes requires contractors to build strong relationships with universities as well as local and state governments due to the long product life cycle. The footprint of an aerospace and defence company lasts decades rather than years.

Industry clusters, greater specialisation keys to future success

Not every market is equally well-positioned to develop a robust industry. For example, when we look specifically at the aerospace industry, what we call the ‘aerospace ecosystem’—factors like the supply and quality of engineers, the supply and cost of blue collar workforce, the depth of the supply chain and the potential to reach critical mass—is important. So is infrastructure and culture. And government support is critical. Some countries are already pulling above their weight in terms of aerospace exports—in large part due to excellence in one or more of these factors.

We believe that in the future, some countries may begin to specialise more within a particular tier, and potentially around particular systems of types of technology. That means that industry clusters may develop around a system or type of technology, like aerostructures, engines, interiors, avionics, control systems or landing gear, and potentially also focusing on a particular platform type.

Seeking sustainable growth

PwC's recent publication, *Aerospace & Defence 2010 year in review and 2011 forecast* took a close look at how A&D companies are performing and what to expect for the future.³ We found that the A&D industry had a strong 2010, finishing the year with record results. The top 100 A&D companies set records with \$646 billion in reported revenue and \$58 billion in operating profit. Revenues inched a modest 2% higher compared with 2009, while operating profit was up 19% over 2009. Perhaps the most notable factor affecting results was better programme performance. In 2010, there was a steep reduction in the large programme charges and impairments that had mitigated the industry's performance in recent years.

However, we see these changes more as a reflection of the development cycle of major programmes as opposed to a sustained trend. In 2009, for example, more than \$8 billion in programme charges and impairments was reported by Boeing (related to the 787 and 747); the European Aeronautic Defence and Space Company, or EADS (related to A380 and A400M); and BAE Systems.

Also affecting 2010 performance was a strong rebound in commercial aviation, which drove much better results in the aftermarket.

New narrow-bodies will drive the need for technology improvement in Aerospace

Despite strong order books, aerospace companies can't afford to relax their efforts around new technologies. On the contrary, as Boeing and Airbus's narrow-body aircraft (the 737 and A320 respectively) near the end of their anticipated life, a step change in innovation will be more important than ever. These aircraft are the workhorses of many airline fleets and demand will continue to be high (see Figure 4), so getting their replacements right will be critical—and many airlines are looking for significant improvements in fuel efficiency.

Airbus announced the A320neo (new engine option), a re-engined version of the A320, in December 2010. Boeing has not yet made a decision whether to re-engine the 787 or proceed with an all new aircraft. Mike Bair, vice president of Advanced 737 Product Development, says the company is talking to airlines to learn more about their requirements before making critical decisions about the new aircraft.⁴ What they decide will have a major impact on suppliers too.

Figure 4a: Aircraft in service by size (number and %), 2009

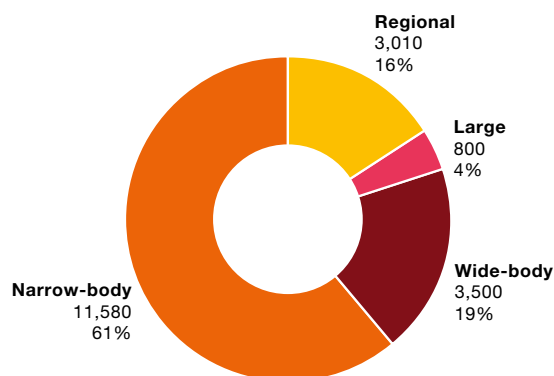
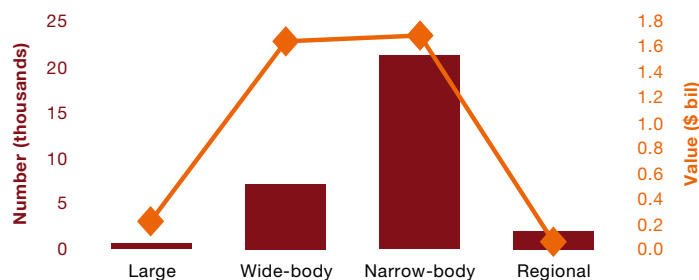


Figure 4b: Expected new aircraft demand by size, 2010-2029



Source: Boeing Commercial Market Outlook, 2010-2029

Regardless of the details, suppliers will play an important role in developing advanced technology for the new aircraft, just as engine manufacturers are clearly at the center of Airbus's plans to re-engine the A320. Speeding up the innovation process—and at the same time innovating around processes too—and focusing on delivering better systems, while using less resources, will be key.

Both the A320neo and Boeing's next generation narrow-body will face new competition. China's COMAC expects its C919 to enter service in 2016. Japan and Russia also have aircraft under development. And while Bombardier's new CSeries commercial jet (seating 100-149) is being positioned as a replacement for Fokker 100's and MD-80's, it may take some sales away from the traditional narrow-bodies as well. Indeed, Airbus is explicitly positioning the neo as a competitive alternative to the CSeries.⁵ Both will offer Pratt & Whitney's new geared turbofan engine technology, which will also be used on the Mitsubishi MRJ and the Irkut MS-21. Airbus is also offering engine technology from CFM International (a GE Aviation/Safran joint venture), the same technology planned for the C919. Both engine technologies promise significant improvements in fuel economy and reduced nitrogen oxide (NOx) emissions.

The major contributions expected from the supply chain mean that all new aircraft under development could potentially benefit from emerging technology, not just Airbus's and Boeing's offerings. While the A&D sector has already made some progress in terms of co-innovating, the bumps in the development of the A380 and the B787 suggest there's still room for improvement. Looking to other industries—notably Automotive and Information Technology—and drawing upon their successful strategies should help.

Defence budgets in mature markets are likely to get squeezed, and productivity will need to improve

Although overall industry results were at record levels, not all the news was cheery. Pressure has continued to mount on global defence budgets and on contractors to improve productivity. As a result, many defence contractors trimmed payrolls, consolidated operations, and deferred some non-product investments, such as upgrades to their information technology systems. These actions aren't usually associated with record profits.

Defence spending is clearly softening and we are starting to see modest erosion in defence backlogs, so defence contractors are preparing for leaner times ahead. And while it's difficult to predict the overall health of the defence industry, we believe it's likely that defence budgets will get squeezed over the next several years. In the US, the world's largest defence spender, mandatory expenses (in particular debt service) look set to take up a larger proportion of overall outlays (see Figure 5).

Any cuts will have a significant impact globally as well, given that the US has represented just over 40% of the world's military expenditures for the past seven years. Whatever the final US budget numbers turn out to be over the next several years, there will be a strong focus on increased productivity. US Defense Secretary Robert M. Gates wants to save around \$100 billion through cost-cutting efforts over the current decade, and spending with contractors will be under close scrutiny. We've noted elsewhere that US defence industry productivity lags the Dow Jones Industrial Average (DJIA), even when adjusted for the differences created by cost-based contracts.⁶ So there's room for improvement.

Ian King, Chief Executive, BAE Systems, calls the US defence market 'a conundrum', because although overall growth is expected to be flat, it's still massive and "*within the US defence market there exist a number of growth opportunities.*"

Some of those opportunities may relate to re-shaping portfolios to match defence spending priorities—for example, the growing focus on cyber security. This trend drove merger and acquisition activity in 2010, and we believe such deals will continue to be part of the landscape in 2011 and beyond.⁷ Future funding prospects look promising: in the proposed FY12 US defence budget, the Defense Advanced Research Projects Agency (DARPA) will receive an extra \$500 million for cyber security research.

In Europe, pressure on budgets is also acute. France intends to cut initially planned defence spending by 3.5 billion Euros between 2011 and 2013 as part of government efforts to decrease the public deficit.⁸ The revised defence budget for 2011 will be 30.15 billion Euros, 30.5 billion in 2012 and 31 billion in 2013.⁹ And in the UK, the government's October 2010 Strategic Defence and Security Review also advocated greater fiscal responsibility. In a statement about the review, the government noted that "Defence cannot continue on an unaffordable footing."¹⁰ In April of 2011, the UK Ministry of Defence (MOD) was reported to be facing a moratorium on military spending.¹¹

How do you achieve cost cuts and still make necessary investments in new technologies and new markets? Given the long-term programmes in place in the sector, it's difficult to make significant changes to the cost-

Figure 5a: US federal outlays, FY12 (estimated)

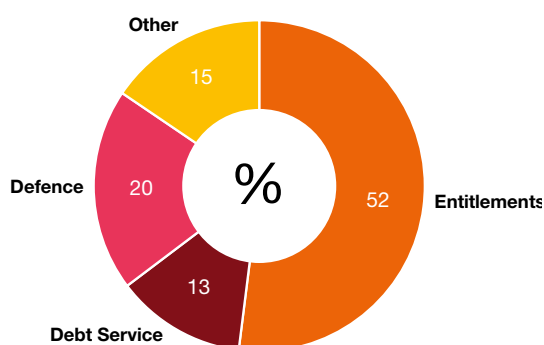
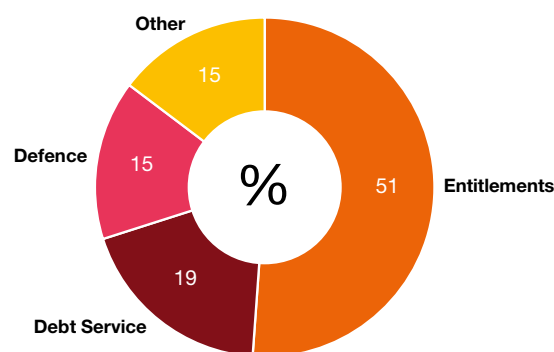


Figure 5b: US federal outlays, FY16 (estimated)



Note: Entitlements include Medicare, Income Security, Social Security and Veterans Benefits & Services. Debt Service is gross interest on treasury debt.

Source: US Office of Management and Budget

structure in mid-stream. We believe that focusing on making the right choices about which markets to pursue is absolutely critical. Investments which make the most of synergies between new technologies and adjacent markets are likely to bring the most benefit. Another strategy is to consider carefully how new technologies can help cut costs (of production or of operation) on existing products or systems.

Governments shaping the research agenda

The enormously important role that governments play in the A&D sector goes well beyond being the primary customer for the defence industry. They also serve an important regulatory function for both aerospace and defence. And they're highly influential in setting the technological agenda for the sector, both directly and indirectly.

Professor Keith Hayward of the Royal Aeronautical Society believes that political decisions are dictating technology innovation. And while making some products available beyond military operations through Commercially available Off-The-Shelf (COTS) will provide some savings, it won't be enough to fund investment in all new technologies, with "system of system" costs going up.

We see the government as playing a key role in driving research priorities in the aerospace sector as well—both through regulation, such as the inclusion of aviation in the EU Emissions Trading System (EU ETS) beginning in 2012, and through joint efforts to promote environmentally-friendly R&D, like the Clean Sky Joint Technology Initiative (JTI). The programme, a combined effort shared between the European Commission and industry, is dedicating an estimated 1.6 billion Euros to researching 'breakthrough developments' across the entire aeronautic supply chain.

The Strategic Research Agendas produced by the Council for Aeronautics Research in Europe (ACARE) have already had a major impact on the research agenda in the European aerospace sector. They include the industry's ambitious goals for reductions in CO₂ and NO_x emissions. Many of the innovative technologies used in the A380, Falcon7X, Eurocopter 175 and AgustaWestland GRAND were largely developed in the context of ACARE-driven research programmes (or their predecessors).¹² In March 2011, the European Commission issued a follow-up publication, Flightpath 2050, with even loftier goals for sustainability—and a potentially high price tag. Tom Enders, Airbus CEO, estimates it at over \$350 billion.¹³

That kind of spending is meant to improve, not detract from, European players' ability to compete. Siim Kallas, the European transport commissioner, quoted in Aviation Week, notes that the Flightpath has three aims "competitiveness, competitiveness and competitiveness."¹⁴ Kallas also says the report and an upcoming technology roadmap will help guide how limited resources should be spent. Given that it's still uncertain whether or not the European Union will include funding for aerospace in its next Common Strategic Framework, the resources may be limited, despite the perceived need.

And while European governments are, arguably, taking a leading role in shaping aerospace research, Hayward sees the US as having an advantage over Europe in terms of generating innovation in defence. That's partly because the scale of the US defence budget allows more scope for research, but also because of some of the institutional machinery in place to drive innovation in the US, particularly DARPA.

“And the thinking today... is to do collaborative research. And all the incentives push you towards that, to work with your customers, to work with suppliers, to work with academics, with universities. ... I think it’s good because... to force a dialogue we need to break this mold of doing it all ourselves.”

Patrice Gauvin, Vice President, Business Development, Héroux-Devtek

The strengths of DARPA go well beyond its \$3 billion budget, which isn’t tied to achieving any specific military objectives. DARPA, the agency many credit with inventing the internet, is one of the strongest proponents of open innovation—recent examples include crowd-sourcing algorithms for its space station research programme, and developing an open-source environment for developing systems like vehicles, aircraft and spacecraft.¹⁵ The agency has long used ‘challenges’ around particular themes as a way to mobilize innovative ideas. The model allows small companies the chance to get a piece of the funding that might otherwise go only to major players.

DARPA’s also known for bringing multiple companies together to work on projects. One recent example: in the fall of 2010, both Boeing and Raytheon received \$21.3 million for work on DARPA’s Triple Target Terminator (T3) programme, a new high-speed, long-range missile that would take advantage of smaller seekers, memory and processors to enable multiple targeting modes.¹⁶ It will also have the ability to hit three types of targets—aircraft, cruise missiles, and ground-based radars.¹⁷



Emerging ambitions

DARPA has some prominent admirers in the BRIC markets. Press reports suggest that Russian President Dmitry Medvedev wants to found a similar agency for driving basic research as part of an ambitious plan, announced in November 2010, to upgrade Russia’s military over the next 10 years. Defence spending will rise sharply, beginning with a hike of around 50% planned for 2011.¹⁸ Much of the increased investment is expected to go into innovative military research.

China continues to enhance its military capabilities as well. China’s official military budget is set to



increase 12.7% to \$91.5 billion in 2011, a return to double-digit growth rates after a smaller increase in 2010.¹⁹ Some of the budget is likely to go to research programmes around missiles, aircraft carriers and stealth fighters, three areas where China is said to be actively developing new systems.

India is also planning a double-digit increase of 11.6% in 2011, but the focus there will be on capital expenditures and maintaining the country's standing army, rather than on driving innovation.²⁰ Brazil, in contrast, cut funds in 2011.²¹

Collaborating on break-through technologies and common standards

Many key emerging technologies and new adjacent markets are notable in that advances are being driven as much by collective research efforts as by individual companies. For example, research on aviation biofuels crosses company lines, with competitors Boeing and Airbus both participating in key research partnerships like the Commercial Aviation Alternative Fuels Initiative (CAAFI). It also expands across the supply chain. In the biofuels

example, engine makers are working together with Original Equipment Manufacturers (OEMs) and airlines to develop universal standards.

Nonetheless, companies will still need to place very individual bets on which new technologies and adjacent markets to focus on. In the next section of this report we take a look at where some executives see the greatest promise.

New technologies

“Technology is supposed to be an efficiency play, a productivity play. People use it to make life cheaper, simpler and better. So from our perspective, cost is important.”

Nick Leontidis,
Executive Vice President of
Strategy and Business Development,
CAE

The A&D sector works on long research time-scales, and it can be difficult to separate hype from commercial reality when new technologies first begin to emerge. Demand for new systems may evolve more slowly than originally thought. In the space arena, commercial human spaceflight is one example. David Thompson, Chairman and Chief Executive Officer, Orbital Sciences points out that: *“Commercial human spaceflight systems will become a reality in this decade, but the market for them may be slower to develop than currently projected.”*

Companies need to track demand trends for new and emerging technologies, and design organisational structures that allow sufficient agility to react to changes in demand projections. And while it's important to invest in areas where demand will be sustainable, we've found that companies may need to consider sustainability in terms of supply and production issues too. Will the materials and minerals that are needed for these advanced technologies still be available? The EU has already warned about coming scarcity of key materials for high-tech products, like the antimony needed for advanced batteries.²²

Cutting costs, building revenues

One of the top reasons executives are keeping the emphasis on new technologies is the most pragmatic: new technologies can drive significant cost savings, throughout the life of a platform and during its production process. That means more value for customers, and better margins for companies. Bombardier's Director Strategic Technology, Fassi Kafyeke explains it this way: *“We're looking at the value for the customer. So in terms of costs of ownership—cost of operations, cost of maintenance, cost of disposing the aircraft in its lifecycle—all of these are very important competitive advantages of our products. And for us in the company, it's the cost of putting that aircraft together in terms of trying to generate margins for a given product that we sell.”*

Today's jets are around 70% more fuel efficient than those produced 40 years ago, but there's still room for improvement. The next generation will be most cost efficient yet. Bombardier estimates its new CSeries will cost 15% less to fly than the current generation of aircraft, thanks to a more efficient engine from Pratt & Whitney and an airframe made of 70% advanced materials (46% composites, 24% aluminium-lithium alloy). Better fuel efficiency also



10-20%

Typical
anticipated
ROI on new
technology
projects

increases sustainability. As Safran's Executive Vice President, Strategy and Development, Jean-Pierre Cojan notes, *"the pursuit of improving engine efficiency often results in environmental benefits."* The same principle applies to increasing fuel performance through other advances too.

And it's not just aerospace OEMs and primes who are looking to new technologies to help trim costs; suppliers of all sizes are directing research efforts in this direction as well. More efficient engines, lighter structures, wings, and landing gear, more integrated control systems and better avionics—all of these are already playing a role in making aircraft more fuel efficient, which means lower running costs. New coatings that extend the life of wings or landing gear can also reduce replacement and maintenance costs.

Not every good idea makes the cut. Most A&D executives expect new technologies to be an important source of revenue growth in the future. While they're willing to wait a bit—time scales in the industry are longer than in many other sectors, with 10 years seen as a standard development horizon—they're looking for greater profitability. Most see the expected

return on investment (ROI) as in the 10-20% range. That means some ideas, no matter how innovative, won't get pursued if the ROI doesn't add up.

Strategies for enhancing capabilities around new technologies

While in-house R&D is essential, there are other ways to enhance your position in emerging technologies. Working together with supply-chain partners is one strategy, although we believe prime contractors need to be careful not to move too far in this direction, as risk issues related to development and intellectual property can crop up later.

Some major players have acquired small companies or start-ups and put their own more substantial resources behind the new technologies they've already developed. That usually means a quicker ramp-up in revenue generation. And while executives are willing to start small and give new investments time to grow, they do expect new business units to start pulling their weight within 5 to 10 years.

“UTC has a fundamental commitment to develop new technologies. While there is an important role for the globalisation of engineering, our starting point is generally not to outsource innovation.”

Dr. J. Michael McQuade,
Senior Vice President,
Science and Technology,
United Technologies Corporation

Outsourcing R&D is another option. Data suggests that 8.3% of global A&D investment was outsourced in 2008—around half the level seen in Pharmaceuticals & Biotechnology (16.5%) and Software & Computer Services (15.8%).²³ The inherent complexity, uncertainty, skills needed, export restrictions, and the risks involved in high-tech R&D pose very different challenges for outsourcing compared to the predictable and repetitive processes of the finance back-office. The Cranfield School of Business and PwC are currently researching how companies in high-tech industries maximise the value of R&D. The results, including key lessons learned from leading companies across several industry sectors, will be the subject of a detailed report later in 2011.

In the rest of this section, we take a look at some of the stand-out technologies we heard about from the executives we interviewed—improved materials, better process technology, digitisation, and real-time monitoring and maintenance.

Stronger, lighter, smarter materials

Not surprisingly, composite materials top the list of important emerging technologies for the A&D executives we interviewed. There’s already a big market—and its getting bigger. One estimate suggests that total demand for composites in the global aerospace market is expected to be worth \$41.8 billion over the next 10 years.²⁴

Fibre-reinforced polymer (FRP) composites are now used in nearly every part of an aircraft. By reinforcing a plastic (or resin) matrix with fibres made from glass, carbon, or other materials, engineers are able to reduce weight, while adding benefits like corrosion resistance. For some uses, composites are so common that the process of commoditisation has already begun, and low-cost countries are developing production capabilities. GKN Aerospace’s Chief Executive, Marcus Bryson, told us that his company is responding by taking composites from an ‘art’ to a ‘science’ through the use of automation and advanced product design concepts.

That commitment is seen in GKN’s long list of “firsts” for composite use, from the world’s first large wing composite spars in the A400M, to the first electronic wing ice protection system in the B787, to the first civil aircraft composite wing in the A350.²⁵ Research into further applications—like composite fan blades—continues. The continued investment in technology development helps the company maintain an edge over low-cost players in emerging markets.

Composites do have drawbacks. Some are more difficult to repair if they break. That means Maintenance, Repair, Overhaul (MRO) companies need to make sure they have enough technicians skilled in the techniques needed to fix composites.

The latest generation is improving, though. Boeing’s Bair says that “the built-up laminates that we’ve done on the 787 are actually harder to damage than aluminum, and we have dropped stuff on these things more

often than you can imagine.”²⁶ Around half of the 787 (by weight) will be made from composites, a major jump from Boeing’s previous aircraft—and significantly more than Airbus’s A380 (see Figure 6).

Still, Boeing is looking at all options for its next narrow-body aircraft. That’s because composites aren’t the only materials that are getting better. Aluminium manufacturers have also been working to develop lighter, stronger alloys with better resistance to heat, cold, and corrosion.

Smarter, lighter materials aren’t only relevant for commercial aerospace. They’re vital to military aircraft, including unmanned aerial vehicles (UAVs) too, and that’s only the beginning. Advances in embedded sensors and electronics are leading to more accurate missiles and new stealth technologies. New ships and

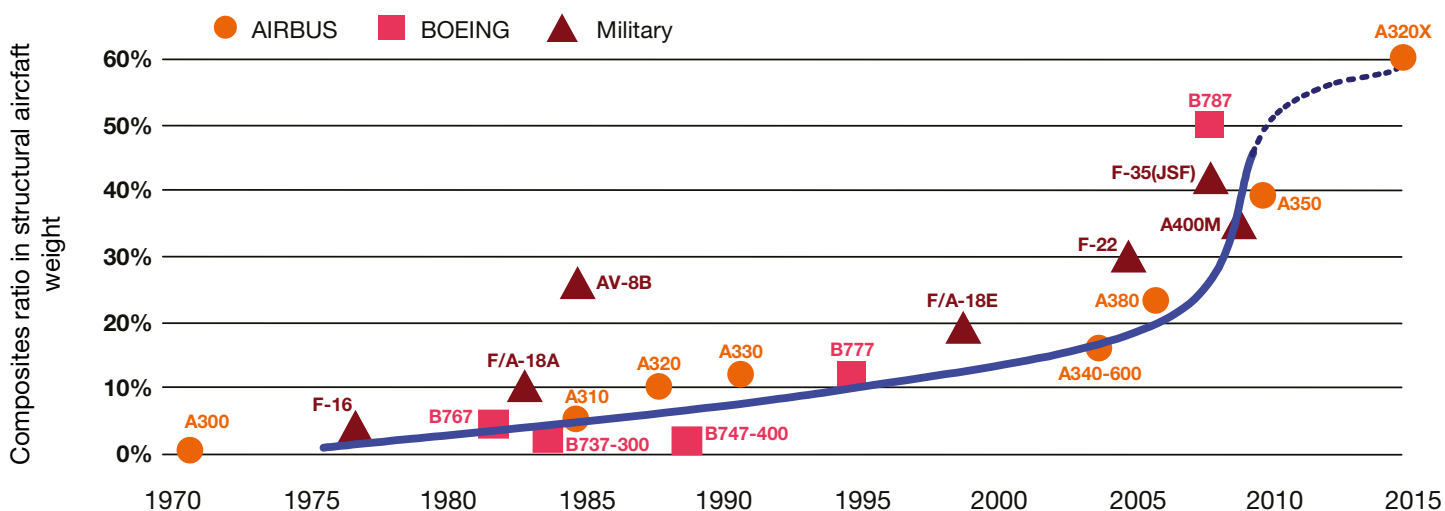
submarines are also getting lighter and more fuel efficient through the use of composites. And in the security sector, new composite solutions are being developed for bullet-resistant materials.²⁷

Advanced materials are important for the space sector too, helping make satellites lighter and less complex. David Thompson, Chairman and Chief Executive Officer, Orbital believes that, “New technologies in space applications have tended to be incremental improvements, such as advances in radio-frequency communications and advanced materials, which increase communication bandwidth or reduce the mass, complexity and costs of the satellite architecture.”

“When we mix [nanotechnologies] with composite materials we can make them harder, more resistant to impact, more conductive to electricity, things like that. And the result of all that will be for us to downsize, to reduce the weight of the carbon composite solution. This is coming, but it’s still far off. It’s all in the laboratory.”

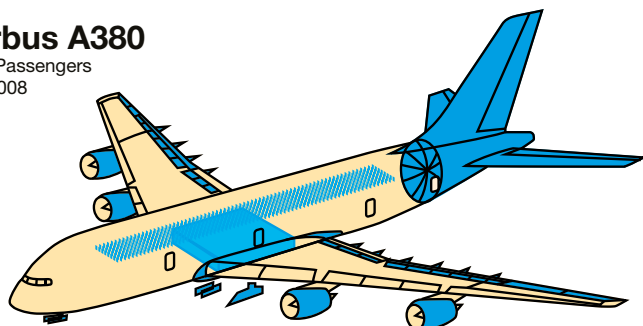
Fassi Kafyeke,
Director Strategic Technology,
Bombardier Aerospace

Figure 6: Increasing importance of composites



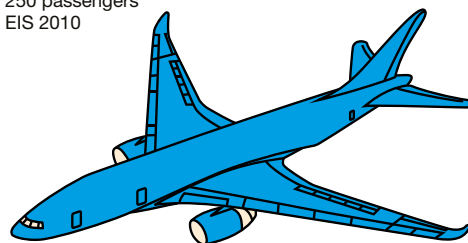
Airbus A380

550 Passengers
EIS2008



Boeing B787

250 passengers
EIS 2010



■ Main composite parts

Hiding in plain sight

A&D Insights: *Dr. Jacobson, some of the executives we talked to are very enthusiastic about potential benefits coming from further improvements to composites, like embedded sensors and better properties that can be achieved by using nanotechnology. What types of advances do you see coming in this area?*

Dr. Jacobson: “Nanotechnologies and new types of surface treatment using specialised laser techniques will give rise to materials and surfaces whose strength and electromagnetic wave absorption and radiation properties can be dynamically altered. These will likely lead to the emergence of adaptable ‘radar cloaking’ of low-profile stealth fighters and bombers. Nanotechnologies and surface treatments might well

create new surfaces which, like a chameleon, change their patterns and reflective properties according to the background and incoming radar probing signals.”

A&D Insights: *Will this type of breakthrough only be useful for the military?*

Dr. Jacobson: “Absolutely not. Civil aviation and deep-space vehicles of the future will benefit too. Novel materials developed for the military are likely to have a whole range of commercial applications.”

About our futurist: *Dr. David Jacobson, PhD, BSc (Eng), is Director – Emerging Technologies at PwC. Respected internationally for his breadth and depth of technology understanding and contributions, David is a Fellow of the Institute of Electrical and Electronics Engineers*

(IEEE) (US) and has been a member of the Editorial Board of the premier international emerging technologies journal IEEE Spectrum. He is currently a member of the IEEE Press Editorial Board.

David has deep technology and business experience as a former professor at Harvard University, senior executive in the international aerospace, multimedia, telecoms, electronics, electrical and ICT industry, in venture capital, and in advisory services. He is recognized internationally as founding the field of risk-sensitive decision making using exponential performance criteria and for major contributions to Differential Dynamic Programming techniques for optimization of system performance.

There’s still room for more incremental improvement in areas like impact performance, lightning protection and embedded technologies. And in the future, composites that can repair themselves may become the next frontier, if academic research on “self-healing” polymer composites at the University of Bristol and the University of Illinois at Urbana Champaign leads to commercial applications.²⁸

Alongside new materials are new coatings that can also improve durability and performance. GE Aviation’s Shane M. Wright, Chief Financial Officer, told us that his company is looking to tile luminite and other coatings “*to really improve engine life and time on wing, as well as lower maintenance cost.*”

Researchers focusing on advanced materials and high tech coatings are looking to nanotechnology as the next frontier for even better performance. PwC’s Futurist, Dr. David Jacobson, believes such techniques have the potential to trigger significant

advances in the military’s stealth capability—and commercial aircraft and deep space vehicles will benefit too (see *Hiding in plain sight*).

How you make it matters

Innovative materials alone aren’t enough to create great new products. Manufacturing processes are important too. The executives we interviewed highlighted a number of examples. Some of these are actually older techniques, like welding, which are now being revisited by the aerospace industry. By welding metal rather than machining single pieces, scrap rates can be reduced—and that cuts costs.

Another technology that some executives singled out as particularly important is selective laser sintering (SLS). This type of additive manufacturing uses high-powered lasers to build three-dimensional shapes from a Computer Aided Design (CAD) file or scan data.

The system can be used for various plastics, including some composites, and for some types of metal. It's used to build prototype parts during the design cycle, and it can also make smaller, customised parts run more cost-effectively.

Process innovation is critical whether you're in an emerging market or a more mature one. Ashok Nayak, Chairman of India-based Hindustan Aeronautics (HAL), told us he believes that investment in modern production technologies will be an enabler in helping his company meet its production and delivery goals. And Rik Armitage, Business Development Director of UK-based Chemring Group agrees that *"manufacturing investment is critical"*. For his company, that means ensuring the manufacturing capability exists to deliver high volumes of largely consumable products to customers.

Digitisation

Fly-by-wire systems revolutionised aircraft and space craft by allowing systems to be controlled by lightweight electrical (and more

recently optical fibre) cables. They also added a variety of automated systems, for example stabilisers that respond automatically to changing flight conditions. Fly-by-wire systems depend on sophisticated avionics systems to guide pilots' control of aircraft. Boeing and Airbus are both using fly-by-wire in their new aircraft, although their approach to pilot controls is somewhat different.

Improved flight control systems are also a priority for United Technologies Corporation (UTC), according to Senior Vice President, Science and Technology, Dr. J. Michael McQuade. He sees the goal as reducing demands on pilots.

The interface between pilot and aircraft is one area where Bombardier believes improvements will help drive growth. Mairead Lavery, Vice President, Strategy, Business Development and Structured Finance, sees the company's Global Vision offering as *"... a product enhancement where we're putting basically new avionics and cockpit in... That will upgrade our existing product offering."*

'Smart dust' for safer, lighter planes

A&D Insights: *Dr. Jacobson, A&D executives told us they are banking on improvements in areas like fly-by-wire/wireless, avionics and sensors. What do you see as the key trends in this area?*

Dr. Jacobson: "Current control theory emphasizes adaptive control. It's leading to smarter avionics, and advances in electronics are changing systems too. We're already seeing electronics becoming more distributed as sensors have gotten smaller. [Gordon] Moore's Law predicts that the number of transistors that can be placed on an integrated circuit doubles approximately every two years, an exponential rate of improvement that has held true for

40+ years, leading to smaller and smaller devices. If improvements continue, it may become possible to design several layers of tiny embedded devices, otherwise known as 'smart dust', which may communicate wirelessly to back up avionics systems."

A&D Insights: *Why is that important?*

Dr. Jacobson: "It will have tremendous advantages. The layered back-up will reduce the chances of sensor or software failures leading to a shutdown of flight-critical function, without adding weight. That means planes could fly with greater safety and use less fuel."

A&D Insights: *Can the current improvement curve be sustained?*

Dr. Jacobson: "Many experts believe Moore's Law will reach its limit by 2020, at least for silicon-based devices, but that won't necessarily mark the end of technological improvements. Printable semiconductive polymers—basically smart plastics—and new materials created with the help of nanotechnology may help researchers continue to make progress on developing tinier, more versatile devices and self-healing systems well beyond 2020."



What's next?

Goodrich's Vice President, Enterprise Technology, Harry Arnold, ranked the development of wireless sensors for aircraft based on a new dedicated radio spectrum for commercial aircraft high on his list of important emerging technologies: *"Wireless sensors will replace certain currently wired sensors on more of the aircraft. Wireless sensors also have the ability to monitor different parts of the aircraft that are not presently being monitored with current technology."*

In the future, PwC's Futurist believes wireless devices may even get small enough to embed into other materials (see *'Smart dust' for safer, lighter planes*).

Bombardier's Lavery also sees modular avionics as an important future trend, and other aircraft manufacturers are focusing efforts in this direction. That means one black box to control a variety of systems. Modularity will mean easier upgrades. It also means the need for common standards is more important than ever.

Patrice Gauvin of landing-gear maker Héroux-Devtek, agrees about the importance of integrating control of systems with avionics. *"More and more, the customer wants to have a solution from, we call it cockpit to tarmac, so from the pilot to the asphalt where the aircraft is landing."* That means understanding the actuators and sensors that operate the systems. So some aerospace companies may need to make strategic acquisitions in key areas.

Researchers are working on the architecture of the electrical systems required for tomorrow's 'more electric' aircraft. Some existing hydraulic systems will be replaced by electrically-driven versions in the

aircraft of the future—but that's not all. Integrating electrical systems will be important too. Safran's Jean-Pierre Cojan says the company is investing in this promising area. He believes that such systems can offer major advantages: *"Safran is also interested in power electronics technology that can modulate electrical power as needed. This technology makes it possible to provide each system of the aircraft with the right type of electric power at the right time according to its needs."*

UTC also sees promise in this type of technology. Both Sikorsky and Hamilton Sundstrand are developing more electric aircraft technologies, according to McQuade.

Electronic control systems also have a whole range of applications for defence systems. Chemring's Armitage believes they're becoming increasingly important for pyrotechnic sequencing, for example.

Autonomous systems have the potential to reduce costs as well as improve capabilities—and to reduce the amount of manpower needed for some military operations. A recent report from the US Air Force's Chief Scientist argued that "The single greatest theme to emerge from "Technology Horizons" is the need, opportunity, and potential to dramatically advance technologies that can allow the Air Force to gain the capability increases, manpower efficiencies, and cost reductions available through far greater use of autonomous systems in essentially all aspects of Air Force operations."²⁹ There are a whole host of examples, and they're not limited to the Air Force. Micro UAVs the size of insects are being tested for use in reconnaissance. Underwater unmanned vehicles (UUVs) and ground vehicles (SUGVs) are under development too—and both have strong potential for commercial applications.

Real-time monitoring, more effective maintenance

A&D equipment and systems are maintenance intensive. Improving technologies that help to monitor aircraft health are becoming increasingly important. Structural health monitoring and aircraft health monitoring both hold promise for reducing maintenance costs without compromising safety.³⁰ Structural health monitoring uses sensors in parts like fasteners to test for fatigue cracks in airframes. Aluminium maker Alcoa is investing heavily in this area. The company is working with Stanford University's structure and composite laboratories to turn its airframe fasteners into sensors. The technology is designed to work with both aluminium aircraft structures and hybrid structures that combine composites with aluminium, and may reduce the frequency of inspections needed on wing stringers by one-half.³¹ That's because cracks most often begin at fastener holes.

Alcoa's fastener business is a good example of using acquisitions to develop a new business area. Alcoa broke into fasteners in 2002 by acquiring Fairchild's fastener business and more acquisitions followed.³² In March 2011, Alcoa completed the acquisition of the aerospace fastener business of TransDigm Group Inc.³³

Other companies are focusing on better monitoring as a way to enhance the expected life-span on some systems. Héroux-Devtek's Patrice Gauvin told us: *"Some of the technology we're looking at is to gather more real-time data of the landing gear so that we can better monitor the health of the landing gear and potentially extend its life. Let's say, typically, we built the landing gear, after five years you can gather the profile for the first five years and say: hey, now we can extend it to eight years and reduce the cost, reduce the impact on the environment."*

Comprehensive solutions that look at the entire aircraft are under development too. GE Aviation's Shane M. Wright, Chief Financial Officer, highlighted the company's integrated vehicle health management (IVHM) offering. He describes the goal of the system: get important information on aircraft health to both the pilot and ground personnel in real time. GE uses an open architecture technology, so that aircraft manufacturers can tailor IVHM to meet customer needs.³⁴ Benefits include reducing missed or delayed flights, avoiding unscheduled maintenance, and reducing Aircraft on Ground status away from home.³⁵

Such solutions could help cut costs on operating and maintaining military aircraft too.

Wright also sees the company's innovative smart phone/tablet applications as an important differentiator. GE Aviation's myEngines software lets users access service bulletins and airworthiness directives as well as track engines that are being repaired. It also offers real-time data monitoring, so customers will be notified on their smartphone if there is an engine anomaly in-flight.



Adjacent markets

Most of the executives we interviewed report their companies are already earning modest revenues from adjacent markets, and a few are already generating major revenues. That's probably why they ranked revenue growth as the top factor driving investment in adjacent markets. For many, access to growth markets outside North America and the EU is important too. But it can be difficult to choose which market is most promising, particularly when some of the same risks that are involved in globalisation crop up with expansion into adjacent markets.

Indeed, there will always be some actions needed to mitigate risks when you move beyond your primary markets, whether in terms of geography or products. For GKN Aerospace Chief Executive, Marcus Bryson, one of the most important is controlling valuable intellectual capital: *"Adjacent markets which are close to primary applications are the most promising. That's because it's important to contain and focus R&D—and the farther afield you go from your core market, the more likely it is that you'll need to be concerned about intellectual property leaks."* It's a powerful argument for preferring some types of adjacencies over others.

In some cases, adjacencies develop because there's significant overlap between A&D activities and another market. Security is the classic example here.

We've identified several other key reasons for looking to adjacent markets. Diversification is a major one for companies facing cyclical markets—particularly in Aerospace. Another is pragmatic—R&D spending on new technologies may have a greater ROI if those technologies can also be used in other settings. Strong engineering skills are the backbone of research efforts in the sector—and those same skills may also represent a great resource for growing in adjacent markets.

Significant overlap with your current market

In the new digital age, boundaries between industries are blurring and shifting. There's no longer a distinct border between the telecommunications and entertainment & media industries, for example, as streaming media and smart phones become commonplace and cable operators own content providers.

For A&D companies, areas of "overlap"—like security—can be promising adjacent markets.



Defence companies are taking advantage of stable spending trends to grow in the security sector

The global security market is now estimated to be worth between \$140 - \$180 billion per year and expected to double in the next decade.³⁶ BAE Systems, Thales, Boeing, Lockheed Martin, Northrop Grumman and Raytheon are all major players, competing with and in some cases working together with security-focused companies, technology companies and IT integrators/consultants.

We see security as comprising the protection of both physical things (people, offices, ports, vehicles, infrastructure, computers, etc.), and also information (non-physical things). Some of the key fundamental drivers of the need for security are also critical to defence efforts—like terrorism and espionage. Others are also important to governmental stability—crime, conflict, political instability, societal unrest and natural disasters.

The proliferation of information technology is playing a role too. As systems become more dependent on IT, new vulnerabilities emerge. Defence agencies are deeply concerned about cyber security, but so are companies in many other industry sectors, like online retail and banking.

BAE Systems' Chief Executive, Ian King, says his company *"is well placed across our home markets for cyber growth opportunities which now represents 6% of our business,"* and adds that *"there is a grey area as to what falls into defence and what does not, and that is likely to remain."* This ambiguity reflects the fact that the boundaries between the public sector and private companies are still evolving. Where security resides at the interface of the public and private sector, it is not yet clear who should and will take responsibility for implementing security measures. King feels his company is *"well placed to match requirements, regardless of the ownership."*

“The more you reduce uncertainty, the more the company’s stock rises—revenue will automatically rise as a result of reducing a venture’s risk.”

Luiz Carlos Siqueira Aguiar, Executive Vice-President, Finance and Chief Financial Officer, Embraer

There are many industries affected by this ambiguity, for example, Telecoms, Financial Services and Utilities. It’s also made the market difficult to assess; however, the majority of defence companies have developed and implemented market entry or expansion strategies for the security market, particularly in the cyber security segment where there are opportunities to cross-sell products and services developed for the military to civilian government and commercial customers.

Regulation is likely to drive further focus on cyber security in a variety of contexts. In the US, six separate cybersecurity bills were pending as of March 2011.³⁷ Other countries are also considering how to treat security for heavily regulated industries. And the Information Security Forum (ISF) expects government regulation to increase over the next two years.³⁸ Legislation around cyber security may strengthen the position of A&D companies in other adjacent markets like smart grids, if requirements increase.

Will lessons learned in the adjacent market reshape the core business?

The Royal Aeronautic Society’s Professor Keith Hayward believes that the increased presence of major defence companies in the security market may have a far-reaching impact on the entire industry. The requirements in the information security market are rapidly evolving, necessitating more

rapid responsiveness from industry. There are approaches to product development and innovation in the security market that could be applied to the defence environment.

Diversification

The aerospace industry has historically been very cyclical. As Embraer’s Luiz Carlos Siqueira Aguiar points out, this can create what he terms ‘undesirable’ volatility in profitability. That’s why he believes that *“controlled diversification, in our areas of technology, synergy and logistics, is ultimately good for us.”* The defence sector is also betting on diversification as a way to hedge against fluctuations in military budgets.

Harnessing the wind

Wind power is another major focus for a number of A&D companies. The number of wind power installations is expected to more than double over the next five years and A&D companies are taking note of a range of opportunities. One of these is the wind turbine blade market. The A&D sector hasn’t yet made significant in-roads, although a number of companies, including GKN and EADS, are now entering the fray. The barriers to entry are formidable, with complex production processes requiring major investments coupled with the need for sophisticated design and research skills. A&D companies already have the latter, though, and some companies have production capabilities in place too, or are working with governments to develop them.



>100% in
5 years

Global Wind
Energy Council
growth estimates
for wind capacity
from 2010-2015.

The growth in wind power offers other possibilities for A&D players too. Finding the perfect site for a wind farm is tricky; not only does it need to take advantage of natural weather conditions, it also has to take into account the transmission infrastructure available and potential concerns of neighbouring communities. And national security is also a factor. That's because the currents created by wind turbines can confuse radar systems.

Lockheed Martin is helping address the first concern, with its WindTracer[®] sensor that helps improve site selection by mapping the wind across large areas. Other defence companies are also tackling the security issue. In February 2011, Raytheon won a \$22 million contract from the US Department of Homeland Security to create a tool that can predict how proposed wind farms would interact with radar installations.³⁹ That means developers can tell if their design is likely to be approved, and if they need to rethink the size, placement or mix of turbines to minimise potential interference with radar systems. Raytheon is also developing add-on systems that can help existing radar systems distinguish between a wind farm and other objects, so that the wind farm won't be mistaken for a target, and security forces won't need to blank out zones around wind farms.

Wind patterns aren't completely consistent or predictable, and that means the power produced by wind farms is variable too. Lockheed Martin is also developing a portable microgrid for mobile air bases that integrates

solar and wind energy into the existing power grid, reducing the Air Force's reliance on fuels. This type of technology helps military forces bring their own renewable generating technologies to help power mobile operations.

Flying with greater fuel efficiency

While new technologies are bringing major jumps in fuel efficiency, the reality is that many older planes continue to fly—and likely will for the next 10 to 20 years. That means other ways to improve fuel efficiency are important too. Efforts are underway to improve flight approaches, for example, with both Boeing and Airbus actively working together with air traffic control authorities. In the US, the Federal Aviation Administration (FAA) is undertaking what it terms a “comprehensive overhaul of our National Air Traffic System,” a programme of improvements known as NextGen and designed to improve efficiency.⁴⁰ NextGen will replace a number of land-based systems with more advanced satellite-driven navigation and is expected to reduce delays and increase fuel efficiency significantly. First tests are already underway, although meeting the programme's schedule may be challenging.⁴¹ In the meantime, there are already some strategies for reducing fuel burn under the existing systems—and providing advice on these is another emerging adjacency.

“Nations should look to increase their clean energy RD&D spending by five times by 2020.”

Recommendation from the Pew Center report
*Degrees of Risk: Defining a risk management framework
for climate security*



CFO Shane M. Wright says GE Aviation has launched Fuel & Carbon Solutions, a data-driven solution that “will help our customers with their fuel conservation efforts and provide a significant savings on their operating costs.” He adds that this offering “has the potential to have a tremendous impact on the environment for very little cost.” It also helps GE Aviation expand beyond its core of engines and systems—and hedge against cyclicalities.

Enhanced service offerings

Rolls-Royce is a well-known example of an A&D company that is relying more heavily on services to drive revenue growth. In their 2010 Annual Report, the company notes that it has achieved a 10 percent compound increase over the past 10 years. They’ve increased service revenues from 2,443 million GBP in 2001 to 5,544 million GBP in 2010.

As A&D companies have increased their focus on service offerings over the past decade, there has been a transition towards more sophisticated and more integrated service solutions. The executives we spoke with are paying close attention too. They saw

MRO as their top area for investment; logistics and operations and maintenance were also high on their list.

We believe that this shift in priorities will have a profound impact on the innovation agenda. Services technology, outsourcing and offshore software development are just a few areas that will need greater focus, and more research dollars. Working together with customers is an integral part of service delivery, so increasing service offerings may lead to greater collaboration with customers around innovation too. We think it will be important to work together with customers when looking to cut costs, for example.

New technologies have direct applicability for other uses

Climate change and ‘energy security’ are at the top of the agenda for many governments. That’s translating into greater funding for clean energy research, and increasing demands on the defence sector to improve the environmental profile of military applications. So it’s not surprising that there are already a whole range of examples where the defence industry is finding ways to use renewable fuels,

Figure 7: Top 20 A&D companies' activities around energy adjacencies

Company	Biofuels	Fuel Cells	Nuclear or mini-nuclear	Sea-wave, tidal or ocean thermal energy	Solar and/or sun concentratos	Wind power
BAE Systems	▲	▲	▲	▲		▲
Boeing	▲	▲	▲		▲	▲
Bombardier Aerospace	▲	D				
EADS	▲	▲			▲	▲
Finmeccanica		D			▲	▲
GE Aviation	▲	▲	D		D	D
General Dynamics		▲				
Goodrich						
Honeywell Aerospace	▲	▲				
L-3 Communications		▲				
Lockheed Martin	▲	▲	▲	▲	▲	▲
Northrop Grumman	▲					▲
Oshkosh Defense					▲	▲
Raytheon	▲				▲	
Rolls Royce	▲	D	D			
Safran	▲	▲				
SAIC	▲			▲	▲	▲
Textron						
Thales						
United Technologies Corporation	▲	D				D

Note: "D" indicates that research and/or business activities are underway in a non-A&D business unit or division.

Sources: Company websites, annual reports, press articles, PwC analysis

or use standard fuels in ways that reduce emissions (see Figure 7). Given the military's increased focus on energy security, research around energy efficiency and renewability can now be seen as part of A&D's core market. These new technologies are highly marketable in commercial settings too—which means research dollars have the potential to generate more revenue in the long run.

One major defence player that is pursuing renewable energy solutions in a big way is Lockheed Martin. The company's activities include a prototype Solid Oxide Fuel System (SOFC) that turns fuel into electricity without combustion (and with significantly reduced carbon

emissions); a utility-scale wave farm; a pilot plant using Ocean Thermal Energy Conversion (OTEC); and large-scale photovoltaic and concentrated solar power solutions. Chris Myers, a Vice President of Government and Energy Programmes for Lockheed Martin Mission Systems and Sensors group says, "We are not wedded to any technologies. We try to find key areas where the commercial marketplace isn't—we are looking for places where we can be innovative."⁴²

Individual soldiers are using more electronic equipment in the battlefield. How can they keep the power flowing in remote locations?

In the US, an innovative small player, AdamWorks, has developed a backpack-transportable wind turbine under the DARPA-funded PoWER (Portable Wind Energy Recharger) initiative. AdamWorks president Kim Burquest says, “Energy needs are a huge issue for the military and often a limiting factor for soldiers. The average warfighter consumes nearly 100 AA batteries on a five-day mission and they take up a significant portion of a soldier’s load.”⁴³ The turbine uses composites to keep weight down and is highly engineered for perfect balance. It’s simple to assemble—the company’s initial trials timed assembly and set up at under five minutes. And while the unit is designed for the military, it could have civilian uses as well.

Wind isn’t the only renewable power source soldiers are taking into the battlefield. The US Army sent the Rucksack Enhanced Portable Power System, or REPPS, into the field in Afghanistan in the summer of 2010.

Tony Bui, an engineer with the Army Power Division of the Communications-Electronics Research, Development and Engineering Center, the organisation that developed the system, thinks portable renewables will power the military of the future.⁴⁴ He believes further improvements in the size, weight and cost of such systems could mean greater acceptance in the near future. And that may translate into an “energy-independent Warfighter [who] will enable reduced logistics and improved readiness in future US army operations.”

These types of technologies are appealing to non-military users too. Just as nearly every hiker and sailor takes along a hand-held GPS navigation system, we may find backpack solar panels for charging these devices, along with mp3 players and smart phones, becoming *de rigeur*. There are already a number of models to choose from, with and without storage capability.

In some of these areas the market size is already growing fast. Wave power and ocean thermal solutions, if they can be scaled up to utility-sized institutions and deliver power at a commercially competitive price, have enormous potential. One report in 2008 anticipated that ocean power would grow to an annual market size of over \$500 million by 2014.⁴⁵ In 2009, PwC and The Climate Group argued that Concentrated Solar Power also deserves attention as a promising low-carbon energy source.⁴⁶

Strong skills can add value in other contexts

Canada’s CAE focuses on modeling and simulation, as well as integrated training solutions for the A&D industry. The company is branching out, though, and now offers solutions for the mining and healthcare industries too. Nick Leontidis, Executive VP of Strategy and Business Development, explained why drawing on his company’s skills base to serve other sectors makes sense: *“For us, it’s growth. We believe that we’ve got leverageable competencies, things that can really deliver their value and provide significant growth opportunities.”*

Leontidis’ comments underline the importance of the skills set that A&D companies develop. That’s by no means confined to companies like CAE; the same principle applies in both the aerospace and defence sectors.

As we’ve already noted, some of the most promising advances in A&D are coming from process improvements. AeroSpace, Defence, Security Group (A|D|S) Chief Executive Officer Rees Ward sees the industry’s process skills base as one of its key strengths.

He argued that development processes, systems manufacturing, infrastructure and procedures can be as important to ensuring profitability as products themselves. Ward cited the avian flu scare as one example. Distribution, targeting, storage and patient follow-up processes were just as important as the vaccine itself in protecting public health. He thinks many companies may not yet be looking at ways to take advantage of their people, though. Additionally, he warns that companies need to protect their technological edge: *“If you lose system integration skills, then it will be very costly to re-instate them and it will take time to rebuild the continuity of experience and expertise—you risk never returning them to the same level.”*

Where can system integration skills best be put to use? One answer may be the emergence of the smart grid. Some defence companies already have in-depth experience in managing energy networks for the military; perhaps more importantly, they also have the systems integration and project management capacity to manage 'mega projects'.

Installing, protecting and managing the smart grid

Smart grids may represent an extremely promising adjacent market for some defence companies. While government funding may be set to decline for the defence sector, it's on the increase for energy-related projects, with the US awarding \$3.4 billion in smart grid grants in October 2009 as part of the federal government's economic stimulus programmes.

The worldwide market is growing fast: one source estimates it will more than double from \$69.3 billion in 2009 to \$171.4 billion in just four years.⁴⁷ That reflects the importance of smart grids to the power utilities industry—and to governments—worldwide. They offer the potential to significantly reduce grid inefficiency, enable more interactive demand management, better integrate distributed power sources into the grid, change customer experience and facilitate new uses for electric power. However, the realisation of these benefits is not a given. Like any major project, smart grid installation efforts face the challenges of delivering on time, on budget and operating successfully.

And while utilities will drive such projects, they won't be able to manage them alone. PwC hosted a roundtable discussion with around 40 participants, including senior executives from the utilities industry and PwC smart grid experts in the fall of 2010. We found that since smart meter projects are 'mega projects,' the increased level of complexity and scale requires an enhanced level of control.⁴⁸ Other industry sectors have learned valuable lessons that can help.

US defence giants are looking to the smart grid

Major players like Lockheed Martin, Boeing and Northrop Grumman are looking to smart grids as a key new adjacency: "We know that we have to reposition our business, and that repositioning is something we are very aggressively doing," Dennis Muilenburg, president and CEO of Boeing Integrated Defense Systems (IDS) told Bloomberg in a 2009 interview. "One idea is to take some of our defense technology and use it to help solve problems in the energy sector."⁴⁹

Boeing has already had some success. In November 2009 they received an \$8 billion smart grid stimulus grant directly, and participated in two other grant proposals as a subcontractor.⁵⁰ And in December 2010, Boeing announced the signing of a Memorandum of Understanding with energy consulting specialist KEMA to collaborate on smart grid technologies.⁵¹

Lockheed Martin is also taking the smart grid market very seriously. It was one of the first defence players to enter the market—in 2009 the company was reportedly advising eight utilities seeking Department of Energy smart grid stimulus grants. Lockheed's Ken Van Meter, general manager of energy and cyberservices, sees the company's role as an integrator of systems.⁵²

In January 2010, Lockheed Martin launched a platform series, SEEsuite, to market its grid integration expertise to utilities. The company's involvement goes well beyond smart meter or other installation projects; its products position Lockheed Martin to play a role in on-going management of smart grids. Pike Research predicts that the market for managing smart grid services will jump from \$470 million in 2010 to \$4.3 billion in global revenues by 2015.⁵³



As energy networks become more automated, they also become more potentially vulnerable to attack, so cyber security solutions are vital.

Making the smart grid more secure and resilient

Both Boeing and Lockheed Martin are looking to capitalise on security expertise as an integral part of their smart grid offerings. As energy networks become more automated, they also become more potentially vulnerable to attack, so cyber security solutions are vital.

We think there's another key strength of the industry (as well as aerospace companies) that will become increasingly important too: modeling complex systems. Users will be able to respond to information about overall demand by changing their own energy consumption; how exactly they may react may be nearly as difficult to predict as the weather. Energy grids will need robust processes to maintain the smooth flow of power, and that will mean understanding how many different sources of data potentially interact.

Using A&D material and process expertise to re-think automotive design

The smart grid represents a new opportunity that crosses industry boundaries. But older manufacturing industries rely on technological improvements too. Automotive manufacturing has many similarities with A&D. Both industries rely on extensive R&D, and in both, the emphasis on reduced weight and greater fuel efficiency has grown hugely in recent years. There are

still key differences, though, as the automotive industry relies primarily on mass production, whereas most A&D products are based on a core design, which is then highly tailored to individual specifications—much like a car which has been tweaked for rally racing.

Composite use is growing in the automotive industry, but there's still a lot of potential. Some experts see significant future potential in structural applications, based on the successful use of such elements in A&D. Design and production challenges are many. Experts point out that to use composites effectively, it will be necessary to re-invent car design from the ground up, rather than simply replacing designs for steel or aluminium with composite materials. And there's a sharp learning curve around the manufacturing, assembly and tooling process too.⁵⁴ Some carmakers are already moving in this direction—take BMW's plans for a new electric vehicle for use in the city.⁵⁵ The BMW 3i will radically depart from previous car design. BMW and partner SGL Group are building an ultra-modern new plant in the US to manufacture the composites that make it possible.⁵⁶

A&D companies that have learned how to take advantage of the unique properties of composites may be well positioned to partner with automotive companies for two reasons. Firstly, they have the design expertise to help automotive companies better understand the fundamental differences between metals and composite materials. In addition,

production processes developed for A&D applications may be suitable for automotive parts too—saving significant equipment costs.

Government support is driving the research agenda in key adjacent markets and across industry lines

We've seen a whole range of examples where A&D companies are developing key adjacencies around climate change and sustainability issues, by increasing fuel efficiency, developing a wide range of renewable energy technologies, and helping install, manage and secure the smart grid. While rising energy costs are partly responsible for driving such efforts, government policy has had a significant impact too, through regulation, procurement policies and funding of research.

In the US, the Obama administration is explicitly linking government support of “clean tech” to job creation and economic growth. That's a powerful motivation for government efforts supporting some other key new technologies too. In the UK, the government has developed a Vision to promote the domestic composites

industry, including launching a National Composites Center. Major A&D player GKN is playing a leading role in this cross-industry effort, which includes a state-of-the-art production facility that should reduce the capital costs necessary for high-tech composite production.

Such partnerships across industry lines are becoming increasingly common. Moving power infrastructure to a smart grid will only be possible through cross-industry collaboration. In the future, forestry companies may partner with energy companies, engine-makers and aircraft OEMs around biofuels—and the list goes on. We think that's a positive trend for the industry. Diversity of all kinds can enhance innovation. In another report, we argued that the recruitment of R&D resources should be more open to profiles from other industries (only 4% were already).⁵⁷



Preparing your business to gain technological advantage

There can be no doubt that A&D companies will need to succeed in researching, developing and commercialising new and emerging technologies in order to succeed. It won't be easy though, particularly as costs get squeezed. Reducing the total cost of operation—maintenance, support, training, fuel, etc. may help free up the necessary investment. New technologies are key to trimming costs and growing revenues, but companies will need to separate fashions from long-term trends and understand issues around sustainability on both the demand and supply sides of the equation. We believe that they'll need to expand into adjacent markets too. And again that will mean picking the winners.



There are likely to be a whole host of questions that executives will need to answer. These may start with discussions about overlapping or nearby industry sectors, commercial applicability of new technologies under development and ways to make the most of key skills sets, but they shouldn't stop there.

Most A&D companies focus their attention on particular technologies and products, or sometimes service offerings. In our experience, fewer take a closer look at their own organisations when evaluating new markets. Succeeding in an adjacent market requires the right technology—but it also needs an understanding of how another industry works. Does it operate on a much faster development to market R&D timescale? Are customers intimately involved in co-developing new design features? That may be a tough act to implement for A&D

companies used to working on long-running programmes, rather than responding to rapidly changing customer requirements. What types of contracts and deal structures prevail?

In many ways it comes down to understanding more broadly and laterally what your company is looking to exploit in adjacent markets. Then make sure that you have not only the right products and services, but also the sub-systems/components, technologies, skills, infrastructure/assets, resources, supply chain partners—and ultimately business models—needed to succeed.

It also means being ready and able to work together, with government, academia, supply chain partners and competitors—and across geographies, as the industry continues to globalise. That creates new risks. But taking a very defensive stance may jeopardise growth in the long run.



Further reading

Publications from PwC's Global Aerospace & Defence industry practice are available to download from www.pwc.com/aerospaceanddefence.

PwC provides thoughtful analysis of the challenges and opportunities facing business leaders in the A&D industry. Our thought leadership publications help inform the strategic decisions guiding many of the industry's leading organisations.



Aerospace & Defence 2010 year in review and 2011 forecast

This report analyses the path the A&D industry took through the recent global recession and dares an outlook at this year's performance. While the recent global recession took a heavy toll on many industries, evident in waves of layoffs, lost revenue, bankruptcies, and a general sense of

uncertainty about the future, the A&D industry as a whole continues to buck the trend, finishing 2010 with record results.



Mission control 2010 annual and fourth-quarter review

The Mission control series provides a quarterly window on A&D deal activity and this annual edition combines fourth-quarter data with a review of the whole of 2010. Deal activity has recovered strongly in 2010, as companies responded to a challenging procurement environment in the defence sector

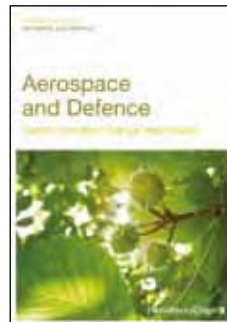
and an improving competitive environment in commercial aerospace. We are seeing a continuation of the high volume of deal activity coupled with a significant increase in average deal value.



A&D Insights: Accelerating global growth

Most companies agree that their firms would benefit from increasing the pace of globalisation, but a number of challenges are slowing their efforts. These include the expansion of offset requirements, increases in financial risk due to a more international supply chain, different interpretations of business ethics across cultures, the

cost and complexity of export control compliance and the potential loss of intellectual property. Companies that do globalise faster will accelerate improvements in recruiting, efficiency and R&D. They will also gain leading positions in the growth markets of the future, which lie outside of North America and the EU.



Different shades of green?

PwC launched a short thought leadership paper on the impact of the climate change agenda post Copenhagen and the business implications for our A&D clients. This paper is accompanied by an A&D sector supplement providing a background on the current state of the industry followed by an analysis of the leading A&D clients and how they are

responding to climate change issues based on publically available information. We found that many aerospace and defence companies are already taking pro-active steps to reduce greenhouse gas (GHG) emissions and energy consumption.



How to fortify your supply chain through collaborative risk management

This whitepaper presents PwC's analysis on how A&D companies can work with their global partners to effectively and collaboratively manage supply chain risk. Insight was gained through various interviews with senior management in the A&D industry, as well as with cross-industry thought leaders. Radically changed. The phrase describes the A&D supply chain. Over the past 20 years, vertical integration has all but disappeared. The days when primes directly managed most of their suppliers are also over. First and second tier suppliers now supervise a huge portion of sub-system integration and with it, a huge segment of the supply chain. Today, more than ever before, programs succeed or fail because of supply chain execution.



Creating competitive advantage: How to transform program management

This whitepaper shares PwC's point of view on the A&D industry's program management challenges and our framework for programme management effectiveness. Both government and private customers in the A&D industry are demanding greater innovation and programme execution from their contractors. As supply chains are becoming more global and outsourced, program management has become increasingly complex. This complexity has contributed to the well-publicised cost overruns, schedule delays, and quality issues currently plaguing the industry.

Related Material:



Smart from the start: Managing smart grid programmes

Smart grids are one of the biggest developments in the power utilities industry worldwide in modern times. They offer the potential to significantly reduce grid inefficiency, enable more interactive demand management, better integrate distributed power sources into the grid, change customer experience and facilitate new uses for electric power. In Autumn 2010, we brought together around 40 people in a roundtable of senior executives from the US, Europe and the Middle East, as well as PwC smart grid experts, to gain first-hand insight into the rollout of smart grids. This discussion paper documents their views.



14th Annual Global CEO Survey

In the last quarter of 2010, we set out to uncover how are CEOs approaching growth, during a time when sustainable economic growth appeared far from assured. We surveyed 1,201 business leaders in 69 countries around the globe. Combined with its supplements, the Survey paints a complete picture of CEOs' three focal points to drive strategic change internationally: innovation, talent and a shared agenda with government.



Decoding Innovations's DNA

This report examines enterprise innovation and the role of information technology. It answers the question, is innovation the result of inscrutable, opaque genius, or can innovation be treated as an end-to-end process subject to performance optimization by adopting proven methods and systems? The time is now ripe for organizations to develop, manage, and continually improve an end-to-end innovation process, which moves from ideas to cash. The key area for technology support is the systematization of problem solving activities, which is at the heart of how innovation happens and progresses, and idea management systems that organize and streamline the flow from ideas as they mature into products or services and ultimately business outcomes.



Demystifying innovation: Take down the barriers to growth in your organisation

Innovation is high on the agenda for 2011 in virtually all industries. The accelerating pace of change is a major reason why CEOs polled for PwC's 14th Annual Global CEO Survey believe innovation is now as important to growing their businesses as expanding in existing markets. Our new report highlights some of the misconceptions surrounding innovation and looks at how successful innovators create the right processes, structures and culture to move viable ideas through to implementation.

PwC aerospace and defence experience

Deep aerospace and defence experience

PwC's A&D practice is a global network of 1,200 partners and client service professionals who provide industry focused assurance, tax, and advisory services to leading A&D companies around the world. This A&D experience is enhanced by our Public Services practice, which includes an additional 600 partners and 9,000 professionals focused on assisting federal, state, and local governments, international agencies, and healthcare entities. We help A&D companies address a full spectrum of industry-specific challenges across areas such as assurance, tax, operational improvement, supply chain management, programme management effectiveness,

IT effectiveness and security, compliance, export control, and government contracting.

PwC's A&D client service professionals are committed—both individually and as a team—to the relentless pursuit of excellence, building insights, and advancing leadership on a wide range of the most critical challenges and issues confronting A&D organizations. PwC is a sponsor of leading industry conferences and frequently writes articles for, or is quoted in, leading industry publications. We are proud of our relationships with Aviation Week and Flight International as well our participation in industry conferences and associations, such as the Aerospace Industries Association (AIA), AeroSpace, Defence, Security Group (A|D|S), and American

Conference Institute (ACI). Our involvement in these organizations reflects our commitment to addressing industry needs and the furthering of dialogue with A&D industry leaders.

Local coverage, global connection

In addition to the 1,200 professionals who serve the A&D industry, our team is part of an extensive Industrial Products group that consists of more than 32,000 professionals, including approximately 17,000 providing assurance services, 8,300 providing tax services, and 7,000 providing advisory services. This expands our global footprint and enables us to concentrate efforts in bringing clients a greater depth of talent, resources, and know-how in the most effective and timely way.



Visionary strategy consultants

The Strategy practice helps corporate and private equity investors develop or appraise strategic business plans in both deal and non-deal related situations through the rigorous analysis of the business's market environment, competitive landscape and internal capabilities. We help our clients determine the right strategic priorities for profitable growth and offer support and practical solutions into achieving these growth objectives. Structured into dedicated industry teams, we draw on an extensive bank of direct experience, as well as utilising the firm's market leading global network of industry and technical specialists, local knowledge and resources.

Quality deal professionals

We help clients do better deals and create value through mergers, acquisitions, disposals and restructuring. We work together with them to help develop the right strategy before the deal, execute their deals seamlessly, identify issues and points of negotiation and value, and

implement changes to deliver synergies and improvements after the deal. Teamed with our A&D practice, our deal professionals can bring a unique perspective to your transaction, addressing it from a technical as well as industry point of view.

Innovative research and development specialists

Overcoming R&D challenges can seem overwhelming and internal resources may be insufficient or already over-stretched to be able to come up with new strategies and business practices to succeed in this changing environment. We work closely with our clients to help formulate new strategies for success and achieve increased performance by improving the efficiency and effectiveness of the company's R&D operations. Our advisors have a wealth of industry based R&D experience and expertise with a deep understanding of finance, tax, risk management/compliance, IT systems, operations and human resources. We

help our clients evaluate their R&D Strategy & Portfolio Management, improve management and control, and identify cost saving initiatives.

Forward thinking technology advisors

We are ready to help guide and nurture your emerging company from start-up through maturity with the advice and services needed for your industry and the development phase you are in. Our thought-leadership publications and presentations provide valuable insights into current and emerging technologies and their new business applications. Our multi-disciplinary professionals understand the business, technology and industry drivers that are critical to making strategic decisions. Whether your organization is merging with another organisation or is seeking a longer term strategic plan, we can help you develop a blueprint and roadmap that aligns your technology investments with your business priorities while managing related risks and compliance issues.



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