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UNMANNED AERIAL VEHICLES: A NEW INDUSTRIAL SYSTEM?

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UNMANNED AERIAL VEHICLES: A NEW INDUSTRIAL SYSTEM?[1]

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Front cover: *Dassault nEUROn UCAV.* Dassault.

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An MQ-1 Predator unmanned aerial vehicle lands at a base in Southwest Asia. *USAF/ Staff Sgt Suzanne M Jenkins.*

EXECUTIVE SUMMARY

The Revolution in Military Affairs — these days often known as military transformation — with its emphasis on network centric warfare and exotic weapons systems, has threatened a comparable revolution in defence industrial affairs. The proposition is that the fundamental changes in defence technology implied by military transformation will challenge the existing structure of defence companies, encourage new entrants and new combinations of players, especially from the wider civilian high technology community, to enter the defence business. In many respects this view has overstated the real changes in the defence sector that have occurred over the past 20 years.

The unmanned aerial vehicle (UAV) or systems (UAS) sector is, perhaps an exception. UAVs are already having a major impact on operations.[2] UAVs are also transforming the industrial base underpinning the development of new programmes. This entails both a large number of new entrant countries as well as a new set of industrial players. The established defence aerospace suppliers are fast catching up, but they will have to adopt new approaches to design, development and production. This will entail new business models centring on faster cycles and low volume production of individual variants. The emergence of a civil market may also underline the challenges posed to conventional aerospace companies by UAS technology.

Although there are several important European UAV programmes underway, fragmentation and divergent national interests are again tending to conspire against a coherent European effort. There is a grave danger that Europe will become dependent on US or Israeli platforms. It is evident that unless Europe sorts its self out very soon, it could lose contact with one of the most dynamic defence and aerospace markets of the 21st century. However, if Europe is to capture the benefits of unmanned aerospace technology, the aerospace industry may also have to embrace new ways of doing business.

INTRODUCTION TO THE NEW EDITION

Two years ago, the Royal Aeronautical Society published a Discussion paper on the industrial background to the UAS phenomenon. Since then much has happened in this most dynamic of aerospace arenas: UAS operations — 'Drone Wars' in popular parlance, have become highly controversial, and increasingly subject to legal and ethical examination; while the dominance of US and Israeli suppliers remains evident, European companies have moved forward, and several collaborative projets have been launched. Similarly, over the past few years, the prospects for a UAS civil market have distinctly improved.

The basic outline of the original Discussion Paper has been retained but it has been updated and expanded to cover new developments. Operational questions were outside the terms of the original paper, and will remain so. However, this new edition will include an analysis of recent collaborative options as well as considering the implications of an expanding civil or quasi-civil market on the UAS business model.

In general, the thrust of the original paper remains valid: the advent of the UAS has changed radically many aspects of the aerospace industrial world; this will be a more complex environment with more players requiring a different approach to development, production and sales — in effect

[2] Ascribing an appropriate and internationally accepted name to the various uninhabited platforms has proved difficult and controversial. Popular parlance and headline writing often refers to 'drones'. This is both inaccurate and in some respects invidious, implying a lack of human involvement in flying and decision making. However, the alternatives rely on a range of acronymic formulae that lack the ease and memorability of 'drone'. This terminology is still best avoided in any serious discussion of the subject. An annex to this paper contains an informed guide to the subject provided by Tony Henley, Chairman of the Royal Aeronautical Society UAS Specialist Group. My own personal preference is now to use the term Remotely Piloted Aircraft System (RPAS), which reflects the fact that humans are still in the control loop, and that the platform is but one element in an integrated system of equipment and people. This paper however retains the UAV/UAS acronym used in the original paper. KH

a new business model. We do accept that the degree of change in the aerospace industrial system may be less evident at the technological pinnacle of this world — the high performance UCAV. But, even here, there are likely to be challenges to conventional attitudes and processes.

We further conclude that despite movement on the collaborative front, Europe could still struggle to make headway in the market unless industry is able to embrace the new ways of doing business implied by the UAS transformation. This includes the need to encourage new entrants as well as adopting a full systems approach to the market, offering an integrated package of hardware and services to a range of civil and military customers. In this respect, the paper urges the rapid adoption and implementation of the June 2013 EU Roadmap for the integration of UAS operations into European airspace.

INTRODUCTION

The Revolution in Military Affairs — these days often known as military transformation — with its emphasis on network centric warfare and exotic weapons systems, has threatened a comparable revolution in defence industrial affairs. The proposition is that the fundamental changes in defence technology implied by military transformation will challenge the existing structure of defence companies, encourage new entrants and new combinations of players, especially from the wider civilian high technology community to enter the defence business.

Yet a decade or more since this mantra was first rehearsed — and taken up in official studies in the US, the UK and elsewhere, the traditional defence industrial world today seems remarkably unchanged in terms of which firms continue to dominate the top 100 defence contractors. One recent study goes so far as to contend that the 'disruptive' power of the new technologies has been massively overrated.[3] While makers of defence-unique platforms might be under pressure from changing conditions, the bulk of transformational systems will still be procured from the established supplier base. This is primarily due to the persistence of traditional procurement and political processes affecting the design, development and purchase of weapons and defence systems.

The existing range of companies, especially those who inhabit its upper reaches, are still very much in business; they exploit their long-acquired and highly specialised knowledge of the military customer's requirements, the often arcane (usually reinforced by law) way of doing business, and a procurement process that links industry, the customer and a wider political environment. Furthermore, there may not be much in the RMA that will increase incentives for firms to invest more heavily in research to meet changing needs, nor necessarily will it improve the attractions of the defence market to outsiders. The barriers to entry are resilient and robust, with potential new entrants often lacking the political connections and trusted ties to the military that are essential to win business.[4] In short, so far most of the traditional defence industrial base (DIB) has matched the emerging demands of military transformation.

[3] Dombrowski, P and Gholz, E *Buying the Military Transformation*, Columbia University Press, New York, 2006.
[4] Dombrowski and Gholz, op cit, p 27.

UNMANNED AERIAL SYSTEMS — A REAL TRANSFORMATION?

If network-driven transformation may not be as 'transformational' as first billed, the development of unmanned combat vehicles might be the genuine article. According to P W Singer, "robotics alters not merely the lethality of war, but the very identity of who fights it".[5] Robotics challenges the traditional military industrial complex; "once developed robotic technology is often cheap and mass producible".[6] The basic technology is also easily copied and hence diffusible. Leading centres of UAS development are well distributed around the world. In 2008 the international trade association for unmanned aircraft had 1,400 members in 50 states. The diffusion of UAV technology and the 'immature' nature of the industry base, combined with remarkable growth has led the French Parliamentary Defence Committee to note: "the market for drones is not like any other market."[7]

This paper focuses on unmanned aerial vehicles (UAVs) — and the wider unmanned aerial system (UAS), and on the industrial structures that underpin their development and production. It does not examine the operational aspects of the UAS or delve too deeply into the technologies of either the UAS or its control.[8]

The advent of unmanned aerial vehicles poses some fundamental questions about the defence technological and industrial base and the structure of supply chains, which are fascinating to a defence industrial analyst. The UAS arena is an area where new entrants have made headway and more established aerospace contractors have often struggled to catch-up. As a senior Rockwell Collins executive observes, "a lot of success came out of nowhere, not out of the major airframe primes."[9] This is new territory, implying radically different business models if the potential of this technology is to be fully exploited. It crosses the civil and military boundary with a vengeance and presents many challenging regulatory issues. For governments, especially those in Europe it asks a number of important questions about the future of a key industry and military capability.

The emerging UAS sector is also immediately global in extent as UAV activity is found in several centres apart from the usual aerospace producing countries. The very ubiquity of UAS development and production in itself constitutes an important change factor in the world defence industry. Currently, there are over 80 states with some form of unmanned programme, with over 700 platforms in total either in development or deployed. A significant number of these may be proposals rather than flying vehicles, or one-off experimental concepts, but this represents an impressive challenge to the oligopoly of established combat aerospace design centres. Similarly, with so much of the UAS capability dependent on communications equipment and sensor packages, the avionics and software community may have as much right to claim systems integrator status as the traditional prime contractor.

For many of the new entrants, the UAV offers an entry point into the aerospace sector; as one US study observes, "the UAV market is one that developing nations can enter on the low end and move up market. The wide variety of UAV

[5] Singer, P W *Wired for War: the robotics revolution and conflict in the 21st century*, New York 2009, p 10.
[6] Singer, op cit. p 240.
[7] Assemblee Nationale, 1 December 2009, Report No 2127.
[8] UAV is the platform, its propulsion, sensors control and software — UAS encompasses linked communications networks and ground support.
[9] *Aviation Week*, 8 June 2009.

types means that the barriers to entry at the mini UAV end of the market are substantially lower than for any other type of aircraft."[10] The market is so relatively new that there is a chance that a new concept will attract customers and for a customer-government there is the prospect of starting up a UAV industry. There is a perception among many national planners that UAVs are "bite-sized systems that can open the door to new technologies."[11] Countries with established IT industries are especially well-placed, particularly if they are able to exploit clusters of related companies and capabilities. Similarly, the potential for ultra-long-duration surveillance and communication modes, and the evolution of micro UAS vehicles exploiting nanotechnology and insect like forms, are areas of development open to new entrants drawing on a new range of technologies.

In many instances, the traditional aerospace prime contractors have been drawn to the more expensive and complex end of the unmanned spectrum, often leading development of the high-performance UCAV combat platforms. This is perhaps understandable, as the UCAV will most resemble the conventional combat aircraft platform in terms of cost, complexity and, perhaps, a more traditional industrial footprint. As a result, the traditional barriers to entry will remain high. Procurement of such an expensive and complex item will also favour traditional defence primes linked to national weapons acquisition systems. But the UCAV will not only compete with conventional aircraft but also with advanced, loitering cruise missiles. The latter will also be cheaper — a $15 million item compared to a $35 million platform that might itself only survive in a contested environment for a limited number of missions.[12]

Finally, developing an export market for some types of UAS platforms could be hedged with regulatory problems. Selling advanced combat aircraft often has to overcome a number of formidable controls, mainly of a domestic origin. In the case of UAS equipment, the Missile Technology Control Regime (MTCR) may also apply. The MTCR is primarily designed to limit the proliferation of weapons of mass destruction (WMD), and is a voluntary agreement involving 34 states, including the US and EU members. Most MALE UAS platforms come within the 500kg payload and 300km range MTCR restrictions.

Israel and China are not parties to the MTCR, and may not be constrained in selling platforms or technology to foreign customers. Equally, there is nothing legally to prevent the US or other MTCR adherents disengaging from the MTCR, but diplomatic and strategic interests are likely to act as a powerful deterrent. The US may be torn between the need to maintain international cohesion over WMD and the commercial benefits that would follow from a reinterpretation of the MTCR rules in respect of UAS technology, but the overriding interests of US security may limit commercial exploitation of domestic UAS technology. By the same token, some US allies might also be deterred by the implicit threat of US sanction. There have been suggestions that the MTCR could be defined to provide UAS suppliers with more leeway, but

[10]*Aircraft Industry*, Spring 2012 Industry Study, The Industrial College of the Armed Forces, National Defense University, Washington DC, p 14.
[11]Dewar Donnithorne-Tait, Association for Unmanned Vehicle Systems International, Flight, 1 March 2005.
[12]*Aircraft Industry*, spring 2012 Industry Study, op cit, p 16. It should also be noted that the USAF has decided to discontinue further development and procurement of the HALE Global Hawk on the grounds of cost compared to a conventional platform. The USAF will extend the life of the U-2. However, this set back to UAS deployment may reflect issues between the USAF and the contractor more than fundamental questions over the use of unmanned platforms for complex, high altitude ISTAR missions. The International Global Hawk for NATO use is continuing, as is the US Navy's contract for a naval version. *Aviation Week*, 25 February 2013.

An RQ-4 Global Hawk taxies on the flightline as a U-2 makes its final approach at Beale Air Force Base, California. USAF.

for the moment this remains problematic, and might serve to slow the growth of a global market in civil UAS applications.[13]

THE UAS INDUSTRIAL LANDSCAPE — GLOBAL OVERVIEW

Over the past five years, the number of unmanned aerial vehicles and the number of UAV producing states has increased significantly — both by around 20%. There is a wide disparity between vehicles in terms of size, complexity, state of development and numbers produced. Many on the list are design concepts, or 'one-off' products of enthusiasts. Others are test and demonstration vehicles, possibly presaging a more substantive commitment.

Market leaders — US and Israel

The US remains the world's most important UAV player with 20% of the world's recorded projects and 42 separate design centres. The sheer range and depth of the US UAV industry is astonishing. It is manufacturing and deploying large numbers of tactical platforms from Global Hawk and the Predator and Reaper, to hand launched platoon-level vehicles. The 2010 Quadrennial Defence Review (QDR) underlined the continued value of unmanned vehicles, not only airborne but also ground and sea robotics.

The current US fleet of UAVs comprises 6,000 vehicles, ranging from micro tactical UAS aircraft to several hundred Predators and Reapers. Future production values for the US alone are put at $17.9bn over the next ten years, about half of that sum on payloads and ground stations. Unsurprisingly American firms now have over 66% of the world market. Israel has a little less than 2% of the market but it is growing rapidly, with several other countries using its platforms as a basis for indigenous UAV development, including the UK's Watchkeeper programme. Packages will often include operational training and full turnkey solutions.[14]

Israel, with a continuing sense of threat and determination to protect its service personnel from routine danger, has developed an extensive and innovative UAS capability. Focusing

[13]*Aircraft Industry*, Spring 2012 Industry Study, op cit, pp 31-32.
[14]*Defense News*, 1 February 2010.

primarily on the smaller platform, Israel has deployed both surveillance and armed UAS for several years. Its technology has been widely exported and Israeli UAS platforms feature in several national inventories.

European catch-up

Europe in total represents only 4% of the world market.[15] Forecasts of potential sales of UAVs suggest a market worth over $38bn over the next ten years. This includes some $20 billion on research. The US is likely to account for at least 60% of this business.[16] The US currently accounts for 77% of all UAS research, testing and evaluation, and 69% of procurement spending on such these systems. In terms of future markets, the US also accounts for 15% of outstanding procurement for UAS contracts.[17]

European firms are now in the hunt for UAS business, but the European market is already well penetrated by US and Israeli products. Given the variety of its announced UAV programmes, and the rapid acquisition of key technologies, European UAV development appears to be reasonably healthy, but duplication and dispersal of effort remains a potential problem and, as will be discussed below, its position in the UAV business is fragile, despite the active engagement of European institutions such as the EU Commission and the European Defence Agency (EDA). To be on a par in the market with Israel perhaps only serves to underline European relative weakness, all the more telling given its standing in conventional aerospace markets.

Already a global industry

Equally, if not more significant is the number and range of other states engaged in UAV development and how fast some states have grown a capability. Numbers of declared projects can flatter: for example Russian UAV activity has shown considerable growth, but few projects have flown. Less aerospace-developed countries such as China, Turkey and Pakistan are focusing on UAV development. In the future, Asia is set to become the second most important UAS market behind the US. China and Japan are likely to be the primary industrial players.

Poland is a typical new entrant nation: WB Electronics and the Military University of Technology and other agencies are developing a range of unmanned platforms and associated miniaturised electro-optical and synthetic aperture radars. The aim is to develop in the first instance a 40kg vehicle with 12-hour endurance and a smaller tactical, hand-launched system.[18] Access to basic technology and collaborative partners also allows emerging states such as Pakistan to develop indigenous capabilities. In the summer of 2009, Pakistan signed an agreement with Selex Galileo to co-produce the Falco 14-hour endurance UAV.[19]

Similarly, Turkey, with a geo-political situation driving requirements, and blocked by technology transfer controls from buying US equipment has a $4bn requirement for UAVs over the next ten years, and is developing a domestic industry to satisfy the bulk of this demand.[20] Several Asian countries also have active UAV programmes. South Korea, for example, is working on a UCAV demonstrator in a

The first flight of Watchkeeper in the UK. Crown copyright/Peter Russell.

government-industry funded programme. A key aim is to maintain domestic aerospace skills as several conventional projects face cuts or cancellation.[21]

China is perhaps the most dynamic new entrant. With a strong political and strategic commitment to military aerospace modernisation, UAS platforms are a central feature of future developments. A number of design concepts have evolved into demonstrator programmes, including armed variants. China has also announced work on a series of civil unmanned platforms. A key feature of Chinese activity is that this is outside any international regime governing technology transfer and other arms export controls.[22]

India too is set on developing a domestic UAS capability. With an estimated $2bn market, India has requirements for an extensive range of UAS platforms. The domestic aerospace industry, led by HAL, is looking for international partners to force the pace of development. However, progress is likely to be limited by India's notoriously slow and bureaucratic procurement system.[23]

To summarise the global UAS industrial landscape: the US is by far the most extensive user and producer of UAS platforms and associated equipment; Israel has carved a very important niche; Europe is catching up, but is struggling to stay in the game; more important perhaps, UAS activity is already globalised, with basic technology and industrial capability widely spread and ubiquitous.

NEW COMPANIES AND THE USUAL SUSPECTS

The 'transformatory effect' is further evidenced by the emergence of new industrial players. At the top end of the UAS business, platforms have the weight and complexity of an executive jet or combat aircraft. Powerplants, which tended to be conversions of low-technology aero-engines or derived from non-aviation sources such as motorcycle engines, are becoming more sophisticated.[24] Again, while in many cases control systems are still largely one-to-one, platforms already have some degree of autonomy. The differences are reflected in cost. A Predator costs about $4.5 million a copy and 25% of the cost is in the nose-

[15] *Aircraft Industry*, spring 2012 Industry Study, op cit, p 15.
[16] *Aviation Week*, 19 October 2009.
[17] *Aircraft Industry*, spring 2012 Industry Study, op cit, p 15.
[18] *Flight*, 3 September 2009.
[19] *Flight*, 26 August 2009.
[20] *Defense News*, 12 October 2009, 24 June 2013, *Aviation Week*, 10 June 2013.

[21] *Aviation Week*, 22 February 2010.
[22] *Defense News*, 26 November 2012; *Aviation Week*, 26 November 2012.
[23] *Aviation Week*, 1 July 2013.
[24] However, this is only acceptable for flight in segregated airspace. Aircraft certified equipment will be necessary for any operations in controlled airspace. See www.ausi.org/AUSI/AUSINews/AssociationNews/.

mounted sensor package. A Global Hawk on the other hand costs $35 million and its total system cost is around $123 million. A fully-fledged Unmanned Combat Aircraft (UCAV) will cost as much as a conventional fighter aircraft, and interest in this type of programme is largely confined to the traditional defence prime.

However, as UAS inventories grow towards a third of national 'airforce' platforms (as is projected in the current US unmanned vehicle 'roadmap') — let alone the swarms of micro unmanned platforms in the hands of future infantry and ISR operators, today's aerospace industry will face major challenges, as much process-driven as by technological novelty. These challenges could be especially hard hitting down the supply chain and to well-established business models based on traditional development and production systems.

AeroEnvironment Raven. *AeroEnvironment.*

New entrant companies

The ability of new entrants to stake a claim is in part due to the relatively primitive nature of the standard UAV platform — often little more than a sophisticated model aeroplane. As one observer put it, "the modern UAS stems from model aircraft that got fancy and to manned aircraft with their cockpits yanked out. A single sensor package — typically optical — and simple control systems is the rule".[25] Alternatively, a specialist aerospace research based SME, as the Swiss designers of the Swordfish UAV, could develop the basic technology, perhaps up to demonstration stage, and then look for a partner for further development, or sell or licence its technology to another company.[26]

A typical small UAS project teams a sensor maker with a small UAV platform. The TOWHawk, a micro tactical UAV built by Irvine Sensors and Applied Research Associates, exemplifies this approach. Their system employs two cameras and an electric powered 26-inch wingspan UAV launched from a TOW missile tube. But it is also increasingly the case that new, high technology based companies are gaining traction with specialised UAS applications, which depend on radical solutions to low weight, constrained size and high performance requirements.

Aurora Flight Sciences was a spin off from MIT's Aeronautics and Astronautics Institute, and its Research centre is still co-located there, although manufacturing is based in Virginia where the company does its development engineering and fast prototyping. Their approach is to tap the innovative concepts generated by MIT and combine them with practical engineering. This approach has also linked Aurora and MIT to NASA research programmes. This approach has, however, required Aurora to build-in firewalls to cover ITAR issues where foreign students might be involved in a programme.[27]

AeroEnvironment is another example of a pure research/technology demonstration company. Founded in 1971, the company developed an expertise in human and solar-powered aircraft. Its current focus is electric and micro unmanned vehicles, and activities include indoor nano-systems based on 'insect' concepts.[28] Government-funded laboratories such as the USAF 'bird' and 'insect' flight research activities also support similar nano concepts. The USAF is also investing in high-speed engine technology and tailor-made precision strike weapons for deployment on next-generation UAS.[29]

At this end of the business, there is often a very close link between UAS designers and a research agency or academic centre. The New Zealand Skycam UAV Ltd. Skycam is the country's only UAV manufacturer and has four employees. Other sub contractors are used on an *ad hoc* basis. It has produced several target drones and UAVs for the New Zealand Defence Forces. A key element of its technology base — an autopilot system — was developed by the New Zealand Defence Technology Agency. Its philosophy is summed up by one of its founders: "the larger UAV manufacturers do it for money, we do it for passion".[30] This attitude has led to frequent comparisons between the UA community and the pioneers of heavier than air flight. But a number of dominant players have already begun to emerge; and many established defence contractors are fast catching up.

The 'Established' Outsiders

One of the most successful of the aerospace prime 'outsiders' is General Atomics Aeronautical Systems Inc (GAAS), maker of the Predator and Sky Warrior. GAAS, established in 1993, is an affiliate of General Atomics, which still focuses on its original business of nuclear power plants and energy sector generally. GAAS' initial interest in unmanned aircraft followed its acquisition of a small company, Leading Systems, which was developing a small-unmanned aircraft, the Amberdrone. This was launched as a private venture, which attracted Pentagon interest and in time led to the Predator series. The aeronautical systems affiliate now provides unmanned aircraft, radar, and electro-optic solutions for military and commercial applications worldwide.

The company makes most of the parts for its vehicles, primarily from composite materials. This allows the firm to respond rapidly to changes in customer requirement, with a 60-day cycle up to integration. The aviation subsidiary remains at heart a small company, described by a RAND analyst "like a Californian speed-shop where they hand-build hot rods".[31] Its watchwords are simplicity, innovation and risk-taking. The company eschews gold plating and the search for higher margins through complexity. As a result,

[25]*Aviation Week*, 8 June 2009. The European Commission notes that some 80% of European companies involved in small UAS development are SMEs. European Commission, op. cit, p 9.
[26]Telephone conversation with a Swordfish executive.
[27]*Aviation Week*, 2 November 2009. The relationship between UAS and space systems is an interesting issue in its own right; satellite communication links are vital and there other areas of technological convergence. In Europe, EDA and the European Space Agency (ESA) are engaged in joint activity.
[28]*Aviation Week*, 2 November 2009.

[29]*Defense News*, 5 October 2009.
[30]*Defense News*, 14 September 2009.
[31]Cited in Singer, op cit, p 255.

GAAS has captured 81% of the MALE market and 33% of the entire UAV market.[32]

The Israeli UAS industry has made a successful penetration of world markets. Based on a strong national requirement and innovative companies, Israel has sold extensively to a range of customers either directly or by providing licences to overseas UAS developments. It is also unconstrained by the MTCR. However, Israeli unmanned air systems (UAS) manufacturers are at a critical junction. While they have technology able to produce very advanced capabilities, they may lack the necessary mass to be able to continue and compete in the world market. Israel Aerospace Industries (IAI), Elbit Systems, Aeronautics, BlueBird, Innocon and UVision are developing new systems, but the market is getting tougher. The Israeli companies not only have to compete with American and European rivals, they must also fight with each other, and this is reflected in the prices they quote to potential customers. Recently, there has been talk about the need to join forces. This would not be easy. IAI is state owned, while the other companies are private — and this is but one hurdle. The only solution could be pressure from the Israeli ministry of defence, which must approve every presentation of an Israeli-made UAS, let alone its export.[33]

The traditional primes strike back

The emergence of the UAS and predictions of future business growth has led established aerospace companies to take an interest. In some respects this is a defensive reaction to a technology that threatens to replace a major market — the conventional combat aircraft; but it also represents genuine opportunities for new business. One response has been to acquire specialist companies. Northrop Grumman, whose Global Hawk is one of the largest and most complex unmanned ISR unmanned platforms, gained much of its UAS capability by buying Ryan Aeronautics. Ryan had developed a range of target drones and, with significant input from Northrop Grumman's all-round capabilities and financial strength; this led to the Global Hawk. More recently Northrop Grumman bought Swift Engineering, designers of a blended wing UAV, and specialists in quick prototyping.

Boeing also acquired its long-term UAS partner, Insitu Group, as part of a re-organisation of its UA assets. Insitu started out using surfboard makers to build basic UAV platform for tuna spotting. The Insitu take-over was triggered by the latter's decision in July 2008 to seek UAS work on its own. Boeing now operates Insitu as a separate subsidiary, with an independent operating model, as part of Boeing's unmanned aircraft systems business unit in the company's military aircraft division. The challenge of retaining the small company's innovative spirit in the larger organisation remains an issue, although so far the benefits of Boeing's political and wider resource base seem to have benefited the Insitu team. As one of the main losers in the Gates review of US defence spending, Boeing wants to build its unmanned business, either with further acquisitions or organic growth to over $1bn in sales over the next five years.

BAE Systems has developed its own UAS competence through a series of company and government/industry technological demonstrators. It has also bought capability, notably the US-based Advanced Ceramic Research, a 60-person tactical UAV manufacturer. BAE has recently created a Global UAS Strategy Team based at Warton, with American and Australian arms, to spearhead and to co-ordinate its unmanned systems business in the UK and worldwide. The company is targeting an estimated $10bn annual market. The company has skipped a generation to focus on autonomous operations and to exploit other advanced technologies. This has including teaming with Cranfield Aerospace and the National Flight Laboratory Centre at Cranfield. BAE Systems' current UAS programmes include the Mantis advanced concept demonstrator programme jointly funded with the MoD and with partners Rolls-Royce, QinetiQ, GE Aviation, SELEX Galileo and Meggitt. BAES is also involved in a collaborative programme with Dassault. The UK has also established a UAS centre of excellence at Aberporth, partially funded (up to 30%) by the EU.[34]

nEUROn UCAV demonstrator. Dassault.

QinetiQ has expanded its robotics interests generally through acquisition. In 2004 it bought the US Foster-Miller, which among an array of high technology manufacturing capabilities, produced a range of robots for the US Army. QinetiQ, having proven the basic technology of its ultra long duration Zephyr high altitude UAS, is looking for a production partner to bid for US and UK defence business. This type of system calls for fuel cell technology and again relies on composite materials. Thales (UK) is also prime contractor on the Watchkeeper programme based on an Israeli platform.

All of the other major European aerospace design centres have embarked on UAS development, either nationally or in collaboration with neighbours. Dassault is leading a $500 million collaborative technology demonstrator programme, the Neuron, in a partnership that includes Saab, the Hellenic Aerospace Industry (HAI), EADS (Spain), Alenia-Aeronautica and RUAG of Switzerland. The Neuron flew for the first time in November 2012. With half of the funding coming from the French side, the Neuron has a strong French-led management structure.[35]

Two of the Neuron partners are also independently working on UAV technology — Saab has its SHARC (Swedish Highly Advanced Research Configuration) and FILUR (Flying Innovative

[32]*Aircraft Industry*, spring 2012 Industry Study, op cit, p 16.
[33]*Robotics and Autonomous Systems*, Spring 2012 Industry Study, The Industrial College of the Armed Forces, National Defense University, Washington DC.
[34]The Aberporth facility allows extensive UAS operation over water and has become a major centre for UAS test and development.
[35]*Aviation Week*, 10 November 2012.

Low Observable Unmanned Research) projects. Alenia has the Sky-X UCAV Technology Demonstrator. EADS (Germany) promoted a tri-national EADS Talarion programme, which in the event was abandoned through lack of official interest in Germany or France. Thales, EADS-Astrium and Indra are developing unmanned VTOL concepts, which could satisfy a number of emerging European requirements, including one from the British Royal Navy.[36]

Some companies are also prepared to export technology to reinforce their UAS competence. Elbit and other Israeli UAS platform makers have built a significant market presence through technology transfer and partnership agreements. Finmeccanica is following suit; deals with Malaysia and the United Arab Emirates have included partnership agreements to help build local UAS competence. This is seen as a means of winning business from Israeli and US competitors.[37]

Another entry path may be from the complex weapons sector. Raytheon has such ambitions, using its skills in sensor and control systems as well as its experience in the missile business to develop UAS capabilities. As one Raytheon executive put it, "when you get smaller (wingspans) it's not an aircraft business, it's a missile business." Raytheon intends to bid for follow-on programmes for the Reaper and Predator.[38] Goodrich has also exploited existing equipment for unmanned use, in this case miniaturising the SYERS 11 camera carried by the USAF U-2.[39]

THE EMERGING UAS INDUSTRIAL BASE

Propulsion

Many of the current unmanned platforms use adapted conventional systems, especially powerplants. Commercial-off-the-shelf (COTS) systems are a central spine of UAS products, ranging from light aircraft parts, rally car components, generators, optics, imaging sensors and hydraulics. These sources will often be supplemented by modified equipment derived from standard aerospace products. But there is increasingly a need for specialised, design-to-type equipment and more innovative concepts. The UAS market is also attracting crossovers from other sectors. For example, Cosworth, the UK-based autosport engine maker has been selected to develop a heavy fuel engine for the US Navy's Ultra Endurance Unmanned Vehicle (UEME) programme. In order to meet the lightweight and reliability demands of the specification, Cosworth are using modified COTS components.[40]

Developing the most advanced UCAV platforms may require designing around the engine, which will have to deliver more than just power for movement, generating electricity to power and cool an increasing range of on board equipment in confined spaces, with limited scope to use air flow or fuel tanks to dissipate the heat. On the other hand, the need for smaller, more reliable sources of power and perhaps more important, long duration electrical generators is transforming technical requirements. Ultra-high-endurance platforms, such as the QinetiQ Zephyr and the US DARPA Vulture programme, will further push the frontiers of airborne fuel cell and battery technology. Already, specialist suppliers are emerging and established propulsion companies have

Cassidian TANAN UAV. EADS.

spotted the potential for their more conventional product lines, including civil airliners.

The more exotic requirements notwithstanding, the impact generally of UA requirements on the propulsion industry is likely to be subtle. A core new technology is the Integrated Power System or IPS. As mentioned, the move to electrical actuation of aircraft control, the large transient electrical requirement of sensors, weapons and mission systems, and the need for thermal management of this, has put totally new requirements onto the powerplant. But novel propulsion technology is just one of the requirements. Innovative new Power System Architectures are needed to solve this complex interactive systems engineering problem. For example, engine companies will have to acquire more expertise in electrical engineering either through retraining personnel, hiring a new generation, or acquiring companies with existing skills. This may have been one of the reasons why GE bought Smiths Aerospace.

While unmanned platforms are an obvious early use of IPS, and would benefit significantly from a more compact, high power and more flexible power generation system, IPS is being driven by demand generally in aerospace, both civil and military. The core propulsion unit will have to be small, but for an engine prime like Rolls-Royce the challenge is to sustain margins off what may be a relatively small production run. The solution could be to become a 'systems integrator', delivering a complete IPS, with the power unit bought in and the more complex associated sub-systems provided by a small number of high-level suppliers. This too is an established trajectory for the big three engine companies — the unmanned sector provides a more intense and demanding rationale for adapting, rather than revolutionising business models.

Subsystems

Systems suppliers have already realised that there is a market for sensors, control systems and other on-board equipment designed specifically for UA operation. Radar technology, for example, is being driven by a combination of new tasks (detecting IEDs from persistent UAV platforms) and environmental needs (see-and-avoid sensor suites for use in civil airspace), This equipment has to be lighter and less power-hungry, without loss of capability, a particularly testing specification for the SAR mode radars needed for IED detection and insurgent tracking. Lockheed Martin

[36]*Aviation Week*, 5 November 2012.
[37]*Defense News*, 10 August 2009.
[38]*Aviation Week*, 10 August 2009.
[39]*Flight*, 10 August 2009.
[40]*Flight*, 14 August 2009.

and Selex Galileo are both developing UAS specific radar concepts.[41]

Rockwell Collins has attributed its success in unmanned platforms to be "entirely down to approaching the avionics with a clean sheet, and not shoehorning manned aircraft systems into unmanned aircraft."[42] Specialist manufacturers are emerging to fill the gap. These too may become acquisition targets, exemplified by Rockwell Collins' purchase of Athena Technologies, a specialist in lightweight flight control systems. UAS systems technologies may also feed back into the conventional aerospace sector. Rockwell Collins' DARPA funded work on damage-tolerant autonomous flight control systems may well improve the safety of manned aircraft.

Even-more-exotic technologies will stress the conventional supplier base still further. The development of nano-technology applications for defence and aerospace have already attracted the attention of established companies. BAE Systems for example has been associated with the UK government's nano technology university-based programmes.

Lockheed Martin has a strategic partnership with Rice University to exploit concepts as they evolve. The USAF has also funded component companies such as Nanocomp Technologies to develop lightweight carbon nanotubes. There is a long way to go before this technology is deployed in operational systems. But, again, the defence industrial base implications point to the need for solid competences in micro engineering and production — the sort of capability that is embedded in the microchip etching and associated industries.

Open systems

Open systems architectures are emerging as a key element in future UAS development. This will enable greater flexibility in designing and procuring UAS equipment and also facilitate increasing through-life adaptability. It will also reduce initial costs by allowing different subsystems to be incorporated onto a common platform. BAE Systems' Mantis demonstration programme for example, has explored low cost construction techniques and "plug and play" systems concepts. BAE Systems is further exploring modularity in its Reliant Mauser, a possible family of air vehicles where major systems and airframe structures could be rapidly reconfigured or adapted depending on roles. As BAE Systems' Chris Hunter put it, "With customers' requirements evolving so quickly, we wanted to look at a Lego-type approach. You would plug together the bits, which would be self-configuring".[43]

The US intends to adopt an open-systems approach to ground control in order to encourage competition and innovation in the manpower-intensive ground segment (GCS). In February 2009, the DoD directed the armed services to initiate a joint effort to develop and demonstrate a common, open and scalable GCS architecture supporting UASs from Fire Scout to Global Hawk. They were also directed to separate GCS development and procurement into a subprogram within each UAS programme. The competition will be facilitated by open and modular interface standards, which will increase ground-station functionality, adding new applications and tools, allowing software reuse across systems, easing integration of new payloads and accelerating automation of unmanned aircraft.

BAE Systems Mantis under test at Woomera. *BAE Systems.*

The Pentagon is keen to attract commercial suppliers into the ground control business to improve 'cockpit' visualisation, interfaces and to facilitate multiple platform operations.[44] More generally, open systems architecture has the potential further to transform the unmanned vehicle supply chain, with more potential for outsiders to enter the business as 'off-the-shelf' component suppliers, or even as specialised sub-systems developers.

Process management

A common thread for the new supply chain is flexibility and low cost combined with high technical specifications. For example, the US Special Forces wanted a man-portable unmanned system for use in Afghanistan; the requirement called for a camera to be developed in 11 days and the complete system in eight months.[45] This approach also drove the Rolls-Royce SEED demonstrator programme, which aimed to use non-traditional aerospace suppliers and to make use of SME technology and manufacturing capabilities. The goal was to produce an IPS demonstrator at 20% of the current cost model. The results were startling and impressive, demonstrating the huge potential waiting to be tapped in this area, where process is the driver and not just technology.

BAE Systems' entry into unmanned vehicles (its interest includes submersibles and robotic vehicles) stems directly from its evolution as a 'lean' manufacturer. Over the past decade or so, the company has invested heavily in advanced process technology, pioneering jig-less, digitally-driven production and other techniques that have cut weeks off production and greatly simplified the sequence of design, development and testing. This has facilitated rapid prototyping approaches that underpin the company's UAS development. As a result, BAE Systems can now offer a 4-5 month turn-round from initial customer interest.

The MALE demonstrator Mantis took less than 24 months to move from outline concept to first flight. The programme was based on spiral development and was the first indigenous European MALE platform. Mantis was also designed from the outset to anticipate operations in controlled airspace. The airframe is 70% composite, with a centre wing section that is one of the largest single pieces of carbon composite used in European aerospace. More conventionally, the Mantis uses undercarriage units adapted from existing aircraft. In order to cut development times, BAE Systems also passed on considerable design authority down the supply chain.[46] This rapid cycle may not be appropriate

[41] *Aviation Week*, 23 November 2009.
[42] *Aviation Week*, 8 June 2009.
[43] *Aviation Week*, 17 March 2008.
[44] *Aviation Week*, 10 August 2009.
[45] Singer op cit. p 145.
[46] *Aviation Week*, 22 February 2010.

BAE Systems Fury, the armed version of Herti. BAE Systems.

to their most advanced platforms such as Taranis, the UCAV technology demonstrator; but progress at even this level of complexity will benefit from fast prototyping philosophies. In short, BAE Systems is looking to revert to the 1950s in terms of project generation and costs.

BAE Systems' rapid prototyping also depended on using a different set of suppliers. In some cases, this was based on targets of opportunity: need an engine — buy a couple of BMW motorcycles from a local dealer; need simple parts — visit the local hardware superstore. More systematically, the company has found suppliers that can deliver high specification products quickly, preferably off the shelf or with a minimum of adaptation. Mountain bike manufacturers, glider companies, and other non-aerospace firms have all made contributions to the various BAE Systems UAV programmes, including Slingsby and Lola Group composite structures used on the Mantis.[47]

To an extent, the unmanned nature of the business has enabled a more relaxed approach to 'qualification', for example using time expired drone engines from Cobham on a lease basis, and payback in the event of a write-off. But there is a lot of lateral thinking involved in this activity. Looking for small actuators, BAE Systems eventually used actuators produced by Claverham Limited. Claverham did not know how long these would last in use — after all a missile flight is not very long. In practice the parts were so well engineered that BAE Systems can expect a long lifetime from the component. Similarly, arming Herti presented the challenge of where to procure a small air-to-ground missile: the solution was a partnership with Thales Northern Ireland to convert the shoulder-launched Starstreak missile system to operate from a UAV platform.

In the case of BAE Systems, a significant trend is beginning to emerge in its UAV supplier relationships, links with autosport. The two sectors have long had a symbiotic technical and engineering relationship, but the UAV business is reinforcing links at a process and business model level. Specifications and technology are of a similarly demanding level; turn round times for new products in autosport match those of the UAV market. BAE Systems has links with McLaren and Lola for composite structures, and are discussing with Prodrive how to support UAVs in the field on the basis of its experience in supporting rally cars in difficult conditions. A number of supplier companies selected for the simplicity and cheapness of their product — and because a big player may have had less interest in the work precisely because of the low tech and low margin nature of the business — have begun to go up the value chain on the basis of their UAS work.

Process-driven change is not always the usual recipe for the defence supply chain from top down. There are better precedents in the civil sector. But this underlines the challenge posed by the UAS revolution: demands for real value for money, and to make money from relatively low volume and a limited aftermarket. Disposable capability and very fast cycle times reflect the established business models for mobile phones, games players and the well-established domain of civil microprocessor IT-driven products.

An important potential route to reducing the overall development and lifecycle costs for UAS equipment is to maximise commonality between systems. BAE Systems, for example, is aiming at a 70% commonality between generations of unmanned systems. Opportunities in this area would be much improved with the adoption of open systems and modular design. As a recent US General Accountability Office report notes, "adopting a common architecture would provide a forum for competition among companies to provide new capabilities."[48] This would also apply to upgrades, with competitions for new payloads that can be simply plugged into the aircraft — so called 'plug and play' payloads. The open systems approach would provide more avenues for new entrants to get into the UAS supply chain, as well as affording more options for the customer.

THE CHALLENGE TO ACQUISITION PROCESSES

National procurement agencies are still coming to terms with the unmanned systems supply chain — although old practices are creeping into UAS procurement, with the US recording cost escalation and delay among several major UAS programmes. Lip service is paid to the need to attract new entrants into the defence business, especially from innovative small companies. But, in practice, the lack of conventional institutional ties and knowledge of procurement practices hampers the connection. This helps to explain why the established defence contractors may offer a more familiar and experienced route to market. The downside is the risk of losing the innovative spark in small companies, as the small independent design team becomes part of a larger unit.

The incentives to achieve a balance between innovative spark and flexibility within a large corporate entity go beyond just balance sheets. The UAS revolution implies a return to faster cycles of design, development and production inspiring young engineers and scientists who might otherwise have been deterred from entering an industry where one project can dominate a career and where individual responsibility and challenge can get buried in a large development team. As a British industrialist observes, "The ability to design, make, test and analyse, and repeat the cycle in three or four months is so rewarding. I fully believe that this is an area that this type of activity can improve the match fitness of our Engineers."[49] A similar view comes from an American UA specialist, the founder of Aurora Flight Sciences, John Longford; coming from Lockheed Skunk Works, he wanted to be part of "a smaller entrepreneurial group, where you could see the whole life cycle of an idea." The only place in aerospace for this was in 'robotic airplanes'.[50]

[47]Again certification caveats will apply if an aircraft is to operate in controlled airspace.

[48]Accountability Office, *Defense Acquisitions*, GAO-09-520, July 2009.
[49]Private correspondence.
[50]*Defense News*, 2 November 2009.

GAAS faced some criticism from the GAO, the US Congress audit arm, for a perceived failure to meet a doubling of demand; but this were strenuously denied by the company. Nevertheless, there is an obvious tension between the 'UAV' approach to development and the bureaucratic demands of conventional acquisition systems. While this is seen as a positive reflection of a growing maturity in the defence market for UAVs, GAAS continue to believe that private funding of new technology will enable them to maintain an innovative edge.[51]

For governments, the UAS revolution implies nurturing the technology base, and parts that hitherto might have been neglected. Commitment to pure research cannot be stinted; too often this is sacrificed to pressing operational needs, support for employment heavy platform makers and budget cuts generally. Given the speed of change in this sector, nobody with ambitions of having a 21st defence industrial capability can afford to under-spend in the upstream technologies, especially as the leverage from initial expenditure is very high indeed. This has been shown by the trajectory of UAS development and deployment to date.

Sky-Futures is one of many companies pioneering the use of UAS in remote sensing. Sky-Futures.

CIVIL MARKET PROSPECTS

Apart from the emerging, very high technology combat platforms, UAS technology has dual use potential. An integrated approach to R&D and technology acquisition would help to force the pace generally of the UAS industry. Tapping a civil market could revolutionise the economics of production and operation. However, this in turn depends on a rapid evolution of the regulatory regime governing remotely piloted aircraft. This includes air traffic management, safety and other legal and ethical issues. It will also depend to some extent on the convergence of military and civil requirements, ensuring that where feasible R&D and other concerns could be jointly addressed. This may again be easier for a unitary political authority such as the US rather than Europe, despite EDA pressure to harmonise national and functional requirements.[52]

The regulatory challenge

Qualification and certification[53]

The main challenge today is that very small UAS (under 20 or 25kg) do not have to meet any real airworthiness requirements, but anything larger are likely to have to conform to something equivalent to manned aircraft requirements, at least if they want to fly over centre of population. For the current MALE platforms full certification has not yet been addressed and will be very difficult to retrofit into existing designs. The only thing that does seem to be widely agreed is that 150kg mass is not a useful break point and EASA intend to remove this from their basic regulation. The implication of civil certification is potentially a significant increase in cost of manufacture resulting, not least from the need to use qualified components.

This may give traditionally manufactures an advantage because they understand the processes and have the appropriate process in place. These can be costly to establish and to maintain. A consequence is that it is very unlikely that Reaper/Predator would be allowed to operate in UK airspace due to the inherent difficulty of getting a Certificate of Airworthiness for an aircraft that was not designed with that aim. BAE Systems has suffered similarly with Herti having struggled to convince the regulators that conventional safety targets should not apply.

Various European approaches currently under consideration that would to some extent set requirements for a tailored airworthiness certification down to the very small RPA platforms (which could restrict operations that are already allowed in the UK) or more pragmatically they might set the mass limit for full certification at, for example, 500 or 600kg (roughly equivalent to the lightest existing manned aircraft), and develop a classification scheme for smaller RPAs depending on their role. The basic argument being that for civil RPA there is considerable scope for specialisation: for example if an RPA is designed (and intended to be used only for low altitude polar exploration) it would not need to be certified for flight over population centres. However, the outcome of this debate could seriously limit the scope for small manufactures and restrict the expansion of a civil UAS market.

The other significant factor is that the size of military platforms will diminish and capabilities increase. Today there are a number of small twin engine long-endurance (700km) satellite-linked platforms with a mass of less than 35kg. These have the potential to be equipped to fly in ATC controlled airspace (although they would struggle to meet 'normal' certification requirements.

UCAV platforms will always tend to be much larger aircraft but because of the very significant additional cost implied in meeting the certification requirements necessary to fly in home airspace, they may not fly outside a war zone or segregated airspace. Virtually all training would also be achieved using simulators or much smaller surrogates.

Operation in controlled airspace

Generally, military UAS currently operate in segregated airspace. There are significant technical and regulatory challenges to overcome before UAS of any meaningful size can operate outside of strictly determined parameters. To date, a number of police users and civil operators of 'line of sight' vehicles excepted, military customers have been the primary market for UAS products. Compared to a conventional

[51] *Aviation Week*, 1 March 2010.
[52] This may be a matter of degree, given the complexity of the US Federal government.
[53] I am very grateful for a note from Tony Henley Chairman of the RAeS UAS Specialist Group on this issue.

platform, UAS use cannot yet compete on a single mission basis — a fixed wing platform can cover a much greater area — but for frequent missions the cost differential is much less and is in the direction of the UAS option.

Expansion into civil markets will depend on including UAS in the regulatory environment, and the speed of adaptation and adoption may well determine the winners and losers in the civil UAS market. The US FAA is already moving to create guidelines and standards for UAS use. In July 2014, it issued the first type certificates for unmanned aircraft, and operating approvals for the first flights in commercial airspace, albeit for very small platforms and in very limited wilderness areas. The FAA is also easing the rules for very small UAS platforms used by police departments. The aim is to select a number of test sites for R&D into the process by September 2015. However, plans to complete the safe integration of UAS into controlled airspace by 2016 may well be optimistic.[54]

Europe is also developing approaches to UAS operation in controlled airspace, including the EDA supported MIDCAS programme, which aims to facilitate UAS integration into civilian airspace by proposing a number of approaches to mid air collision avoidance. Japan and Australia (an ideal market environment) have already begun to allow unmanned flights in designated areas.[55] At an international level ICAO is working on creating global standards. There is, however, some risk that the US, EU and other national regulatory procedures may differ, complicating the expansion of civil UAS use.[56]

With the advent of an expanded civil market, the UAS industry business model may achieve full transformation. The most likely civil markets for UAS platforms will echo those of the military — 'dirty, dull and/or dangerous' — police surveillance, fire mapping, border security, real estate photography, and coverage of natural disasters. Satisfying this new customer base may well require a radically different approach to the conventional aerospace market. For example while surveying will be a particularly important market, especially in large or remote areas, customers may also demand a range of new, integrated services. As in the space sector, increasing platform availability and capability will generate a new wave of 'downstream' applications where the platform hardware comprises a relatively small element in the total value chain.

Currently, the most favoured UAS platforms for civil applications tend to be in the micro UAS (0.5-3 kilo range) sector, reflecting safety concerns about operation over population centres. A key feature is the preference for autonomous systems for ease of deployment by relatively unskilled operators, and also the ability to plot accurately. Increasingly, miniaturisation of on-board equipment (such as GPS receivers and multispectral sensors) Micro-UAS suppliers such as senseFly, Gatewing, and Hawkeye have begun to offer complete hardware and image processing services.

[54]*Aviation Week*, 5 August 2013.
[55]UK industry has a comprehensive research programme — ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation & Assessment) — focusing on the technologies, systems, facilities, procedures and regulations that will allow autonomous vehicles to operate safely and routinely in civil airspace over the United Kingdom. The aim of the ASTRAEA programme is to enable the routine use of UAS (Unmanned Aircraft Systems) in all classes of airspace without the need for restrictive or specialised conditions of operation. This will be achieved through the co-ordinated development and demonstration of key technologies and operating procedures required to open up controlled airspace to UAS. The £62 million programme is led by a consortium of seven companies: AOS, BAE Systems, Cassidian, Cobham, QinetiQ, Rolls-Royce and Thales; see http://www.astraea.aero/
[56]*Aviation Week*, 7 January 2013.

The Trimble UX5 has a 1m wingspan and is built by Gatewing in Belgium. *Trimble.*

If this trend is conformed, the major aerospace companies may not be the best placed to increase market share, underlining the industrial challenge posed by UAS technology. The US could have some 30,000 UAS operating in the national airspace by 2020. The US UAS trade association (AUVSI) predicts an impact of $13.6bn on the US economy in the first three years of operation in civil airspace. This would include the creation of 70,000 new jobs.

The European UAS 'Road Map'

The cancellation by the German Defence Ministry of the EuroHawk project in May 2013 was seen as a set back for European hopes of opening up controlled airspace. The European Aviation Safety Agency (EASA) reportedly announced it would not allow flights over populated areas because the aircraft lacked a certified detect-and-avoid system.[57] The European Commission however has taken a more dynamic, proactive role in pushing forward work on integrating UAS into controlled airspace and in promoting new business opportunities. In it view, civil UAS use could "foster the emergence of a totally new service industry offering (UAS) operations and aerial work to commercial and state customers."[58]

The Road Map, published in June 2013, outlines a staged approach to the integration of UAS into civilian airspace.[59] This is viewed as "the main priority to support the development of this sector in Europe" and will "bring aviation into the realm of the third industrial revolution." It seeks ultimately to replace the current highly restricted case-by-case approval for UAS operations with a 'seamless regulatory framework', fusing the various R&D initiatives underway in Europe. The process will be 'gradual and evolutionary' matching regulatory relaxation to developments in technology and societal acceptance. While the main focus of the Roadmap is vehicles weighing less than 150kg (seen as the primary platform for civil applications), the proposals would also go a long way towards resolving the problems that stymied EuroHawk deployment in Europe.

[57]Costs of $775million may also have contributed to the decision. The ministry also appeared to assume the data submitted by the US manufacturer would not be sufficient for European certification. In this case, information needed by EASA was apparently missing and it would have cost the Bundeswehr hundreds of millions of euros to run tests to provide the necessary data. NATO still hopes to continue with a UAS based on the Global Hawk. .http://www.dw.de/defense-ministry-was-aware-of-euro-hawk-doubts/a-16830076. The cancellation also led to a political crisis in the German government over whether the Defense Minister was or was not fully aware of the certification issues. *Financial Times*, 5 June 2013.
[58]European Commission, Towards a European strategy for the development of civil applications of Remotely Piloted Aircraft Systems, Commission Staff Working Document, SWD (2012) 259 final, Brussels 4 September 2012, p 3.
[59]European RPAS Steering Group, Roadmap for the integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System, June 2013. The RPAS is a group of UAS stakeholders set up by the European Commission.

A co-ordinated European approach is needed as so 15 EU member states have published, or are developing some elements of UAS regulation. Each differs in several ways and if left unco-ordinated, would have a direct impact on cross-border operations — "A true European Single Market for (UAS) based on common rules is necessary to support the development of the European industry."[60] A first step would be to integrate harmonise national procedures and these with emerging European Aeronautical Safety Agency (EASA) rules. This would form the basis of an initial EU-wide regime for vehicles under 150kg. As technology evolved to fill gaps in standards needed for fully safe and secure UAS operations, the regime could be gradually relaxed. This process will also have to be integrated into more general moves towards creating a Single European Sky and new air traffic management systems. This would be accompanied by the development of privacy and data protection protocols, third party liability and insurance rules and measures to ensure the security of UAS operations. The Study suggests that by 2028, UAS operations should be fully integrated into a pan-European controlled airspace environment, flying safely along side manned aircraft and "following the same ATM procedures and ensuring the same level of safety and security."[62]

Civil UAS operations — still someway to go

In general, the civil market offers a major new direction for the UAS industry. But aside from the regulatory question, which may be slowly resolving itself, there are other problems to be overcome. Public acceptability could be undermined by fall-out from the ethical backlash from armed UAS missions conducted by the US. There are questions associated with the potential for intrusive use of surveillance UAS — the fears here relate to the possible ubiquity of surveillance, as cheaper UAS platforms replace conventional aircraft. This, however, might reflect a vociferous anti-UAS lobby more than a substantial public resistance to a new technology, once it is proven reliable and safe to operate in a controlled airspace environment.[63] One line of thought might be that "things will work out" and civil authorities will eventually find ways to enable large numbers of UAVs into the national airspace. But, as one US analyst notes, 'we should probably allow for a more pessimistic line that may result from civil bureaucracy, open processes, and public fears... similar to the US nuclear power situation, where vocal interest groups have used the open certification process to hold up new construction for decades'.[64]

THE POLITICS OF EUROPEAN UAS DEVELOPMENT

The world of UAS platform makers is wide and extends way beyond the normal core aerospace manufacturers — at least in terms of individual players. But in terms of current UAS deployment, planned budget allocations for UAS procurement and research and the range of its established manufacturing base, the US is the major player in the UAS business. Israel has established a secure niche position and its platforms are used worldwide as the basis for several national programmes. In this respect, if the development of a UAS industrial base does constitute a defence industrial transformation, the US defence industry is already well down the track. Even if the extent of the systematic transformation turns out to be overrated, American defence contractors will still have an edge in the market for unmanned platforms and complete systems, particularly in the higher cost, higher complex segments.

Unarmed Predator-Bs of the US Customs and Border Protection.

Europe, only just ahead of Israel in numbers of UAS programmes and deployment and more important, market share, will have to play catch-up with a vengeance. Europe will have to work hard to match the sheer versatility and depth of commitment already shown by the US and Israel to UAS development and technology acquisition All of the European members of ISAF have deployed national, American or Israeli platforms in support of operations in Afghanistan. Europe has a number of active and innovative programmes; the leading aerospace and defence manufacturers are engaged in acquiring the necessary technologies; and there is a clear recognition of the importance of building UAV capabilities — a view endorsed by the European Defence Agency.

The Anglo-French UAS agreement

As we have noted, while there are several European national and international UAS programmes, but progress has been patchy and lacked cohesion. However, European collaboration was given impetus by high-level meetings between Prime Minister Brown and President Sarkozy in 2008. These preliminary contacts were confirmed by the Lancaster House Agreement of 2012, which contained specific reference to co-operation on UAS technology. Both the UK and France, but especially the UK, have become enthusiastic UAS users. They have active UAS programmes, but are still heavily dependent on US platforms for current MALE operations. There has been a growing awareness in both countries of the need to master UAV technology to sustain domestic combat air capabilities. Britain and France have also drawn increasing closer as military partners, and the concept of an Anglo-French UAS programme was not necessarily likely to be a surprise.

The announcement by BAE and Dassault surprised commentators and many of their erstwhile partners. This formed the basis for a formal link between the two countries. The agreement centres on development of a MALE UAV, using the BAE Mantis as an advanced technology demonstrator. The $1.45bn programme, Telemos, saw Thales and Selex UK collaborating on sensors and other

[60]RPAS, op cit. p 7.
[61]The latter primarily relates to the possible hijack of a UAS platform for a terrorist attack.
[62]RPAS, op cit. p 15.
[63]*The Guardian*, 7 May 2013.
[64]Interestingly, the US may have some advantages in a tight regulatory context due to the large volumes of restricted military airspace over the Nevada, California, Utah, and Arizona deserts. The author is grateful to Dr Andrew Williams of the US National Defense University (Washington DC) for this and other observations on regulated airspace. A recent US poll suggests that 57% of US citizens support the use of UAS for any application; this rises to 88% for search and rescue.


An artist's impression of the Piaggio P.1HH Hammerhead UAS. Piaggio Aero.

systems. Rolls-Royce and Safran might also co-operate to develop a propulsion system. BAE Systems was designated prime contractor for the platform with Dassault responsible for systems and integration.

Expanding the partnership

An Anglo-French initiative in UAS programmes could head off a repeat of the damage done to European defence industrial solidarity by the Rafale-Typhoon-Gripen competition. Equally, a bilateral programme implies a simpler approach to procurement and project management: Storm Shadow/Scalp rather than A400M. However, the European UAV scene is not just a bilateral affair involving the British and French; there are at least two other key players involved as well — Germany and Italy, and their respective primary defence companies EADS-Cassidian and Finmeccanica. There is also the over-riding question as to whether an Anglo-French order would be sufficient to justify the cost of a more complex and expensive future UCAV programme.

The prospect of an Anglo-French programme that might dominate UAS procurement in two of the key European defence states led to anguished responses from EADS-Cassidian and Finmeccanica. In Rome, politicians warned of a threat to Italian industry. EADS stated that it could lead to a rearrangement of industrial partnerships. Dassault has hinted of possible Cassidian involvement in Telemos; but EADS wanted to be more than a junior partner in development and preferred a European multilateral approach. Failing that, EADS tried to link up with other European partners (outside the EADS multinational components that is), but again this depended on Berlin's willingness to carry the bulk of the development cost.

In principle, Europe undoubtedly has an industrial base capable of sustaining a strong UAS capability. However, it is already evident that Europe will have to work hard to avoid the perennial trap of duplication and redundancy. There are powerful industrial and political interests in supporting 'sovereign' capabilities and European industrial politics could damage the prospects of launching a coherent set of collaborative UAS programmes.[65] The BAE-Dassault-Thales option appeared to exclude EADS and Finmeccanica, and cut across the Neuron partnership. The WEU warned that the Neuron team was too narrowly drawn and excluded several key European players.[66]

[65]*Aviation Week*, 5 February 2010.
[66]WEU, *Unmanned Combat Air Vehicles and Military Aeronautics of the Future*, A/1884, 30 November 2004.

Following the 2012 French Presidential and Assembly elections, and a change of government to one more sympathetic to wider European UAS options, the Anglo-French initiative began to evolve towards a broader European effort. Nevertheless, national programmes or overlapping European ventures are still competing for resources, with the risk of splitting the European market. Having failed to attract commitments from the French, German and Spanish governments to mature the Talarion MALE UAS, EADS promoted a German-Italian agreement to work on several aspects of UAS technology, including UCAV developments.[67]

Any collective approach to UAS development will have to address the vexed issue of work sharing. The practice of *le juste retour* is still present in too many European programmes, even if hidden by pre-contract manoeuvring. More importantly, if Europe is to develop a fully world class competence in next generation UAS technology and manufacture, the supporting industrial system must also be open and accessible to a wider range of players, including from outside the region. This will demand a transformation of the European defence industrial base, as well as a substantial modernisation of multinational procurement. The newer European defence institutions including the EDA have identified UAS equipment as a key component of Europe's future; the key will be giving sufficient power and competence to ensure adequate co-ordination of UAS research, development and production. Above all, to facilitate the transformation to a new industrial structure that will nurture new ideas and concepts.

And why collaborate at all?

Of course, collaboration in its traditional European sense may not be the best approach to UAS development; compared to many advanced weapons platforms costs are relatively low, at least in the tactical segment of the market. The UK is continuing with its national UAS programme, and the Italian Piaggio Aero P.1HH, Europe's largest UAS, is in an advanced stage of development.[68]

In some respects, tactical UAS, even up to the Reaper scale, may be ideally accomplished by a well-managed national programme (pace Watchkeeper) — the mode of collaboration must be carefully selected. In the case of very advanced UAS platforms, there may be little alternative but to seek foreign partners. The overriding problem remains the availability of money to support development and the need to sustain production on a market that, at best, will demand a limited number of platforms at any one time, but with a built-in capability to respond to events and to replace losses. In the UK the probability that MoD budgets will not adequately support indigenous programmes is causing concern in the domestic UA community.[69] This may force European companies into collaboration; but a lot could be done to improve the terms on which joint ventures are launched.

As matters currently stand, European UAS activity faces several uncertainties. Failing to obtain firm government backing, BAE Systems and Dassault shelved the Telemos project, but EADS, Finmeccanica and Dassault announced an interest in promoting a European MALE UAS to compete with US and Israeli companies.[70] However, Dassault and

[67]*Flight*, 11 September 2009; *Aviation Week*, 5 February 2010; Assemblée Nationale 1 December 2009, No. 2127, *Defense News*, 2 June 2012.
[68]*Aviation Week*, 25 February 2013.
[69]*Aviation Week*, 23 November 2009.
[70]*Financial Times*, 16 June 2013.

BAES remain committed to a more advanced UCAV demonstrator to meet Britain's Future Combat Aerospace System (FCAS) requirement. There are still some differences of emphasis over involving other European companies, but these are less evident than they were. The British would still prefer a clear bilateral effort, which could at a later stage bring in other European companies while the French want a broader coalition from the outset. As financial pressures began to bite, the UK has moved somewhat towards the French position, prepared to welcome a wider European participation from the outset of a new programme.[71]

A number of fundamental questions must be resolved before a substantive European UAS programme emerges. These include different viewpoints about capability/complexity, timescale and safety. Then detailed agreement will be needed about who does what (airframe, sensors, weapons, and communications/control) and how these contracts might be competed. The temptation to go it alone is strong; to buy off the shelf from the US may be even stronger.

But there is a fundamental economic case for a European approach to UAS development. Any future European combat air system (manned or UCAV) is likely to be the subject of very low off-takes: nearer 100, rather than the 650 of the initial Eurofighter off-take. The development costs of a UCAS would be in the region of $7-10bn — unaffordable by any single European nation, and probably realistically beyond an Anglo-French bilateral programme.

The likely loss of economies of scale also applies to mid- sized MALE and UCAS platforms, implying the ~adoption of a new business model and approach to procurement. In considering the EADS Scavenger it was generally accepted that a European demand for MALE UAS would probably be in the region of 50-100 (based on UK and French current interim solutions with Predator/Reaper and an estimate for other countries). This will make it near impossible to amortise the development costs of £1-2bn and the cost of producing a certified C2/Management system. Assumptions that a successful export campaigns scale economies could improve the palliative would be highly questionable. For example, continuing adherence to the MTCR may also constrain exports by signatory states of larger, longer range UAS platforms.[72]

There is no doubting the wider importance to Europe of developing a UAS capability. Both the EDA and the Commission of the EU are promoting common approaches to requirements and an integrated dual use R&D programme. As Christian Scherer, Cassidian's head of international operations put it; "It's a matter of sovereignty; we need to master this technology in Europe, or end up having to buy the technology for top dollar from outside." His boss, Tom Enders, was even more blunt in stating categorically that Europe was "ten years behind the US and Israel."[73]

European efforts to force the pace of UAS development took an important step forward with the announcement of a Euro 100 million programme for military UAS development and further assistance towards dual technology acquisition. While the main UAS users — France and Britain especially — have decided to buy US made Reapers for current MALE deployment, the EU hopes that a successor could be available by the 2020s. This would also include parallel developments on airspace clearance for UAS operations.

[71]*Defense News*, 25 June 2012.
[72]These do not include either Israel or China.
[73]*Defense News*, 24 June 2013.

A Royal Air Force MQ-9 Reaper prepares for take-off in Afghanistan.
Crown copyright/ Corporal Steve Follows RAF.

This might enable European manufacturers to leap frog current US or Israeli platforms by offering dual civil/military cleared products. However, approval will depend upon a decision by European ministers at the EU Defence Council in December 2013.[74]

There is still time for Europe to establish a common approach to UAS development, perhaps centring on a UCAS programme, but this may depend on the UK-France axis coming up with a substantive proposal, or something emerging from the Neuron. But without commitment to a substantive project, Anglo-French co-operation on UAS technology could collapse, and with it a chance to create a powerful European UAS core community. As ever, the temptation of working with the US might tempt some European states into a transatlantic strategy, replicating the F-35 experience.[75]

FINAL WORDS

So, has the advent of the UAS transformed the aerospace supply chain and associated industrial structure? The temporising answer is that it is too early to tell. Using a familiar analogy used by the UAS community, in the parallel lifetime of unmanned aircraft, the Wrights flew just over a decade ago, the military have discovered aviation's value as a weapon, technology is moving very fast, and a cottage industry of inventors and enthusiasts is gearing up for mass production. Unmanned platforms seem to have reached their Western Front moment. But where are we likely to go in industrial terms?

At one level, unmanned by its very nature removes one entire element from the traditional supply chain — anything to do with keeping the pilot alive and safe. A cheap point admittedly, but a significant one if UASs were totally to supplant conventional combat aircraft — which is still unlikely.[76] Similarly, flash forward several years, perhaps decades, to the 'unmanned' civil airliner, and the supply chain will be much the same as now, although given the likely changes in airliner design, there will have been other drivers of change in the civil supply chain.

The impact of UAVs on industrial structure has so far

[74]*Defense News*, 19 August 2013.
[75]The UK would be an obvious suspect but the Italians have also hinted of looking outside Europe for partners. *Defense News*, June 2013.
[76]The key point here is that UAS have none of the constraints of manned aircraft and can be used for tasks unsuited for manned aircraft. This is a substitutional factor in military aviation, but largely additional in a civil context.

reflected general trends. More capability in less space; more power and stealthier; increased value for money and a leaner production system have been part of the defence and aerospace mantra for at least two decades. Going to the more exotic end of the technological spectrum, the nanobots will have more in common with integrated circuit production than conventional aerospace systems. There will be the custom-built, one-offs that will reflect satellite construction, as well as aping their role as very long endurance, high altitude platforms.

In the case of the very high performance UCAV, the potential long-term winners in this segment will be the systems architects or integrators. This remains, GAAS aside, the strongest suit of the large defence aerospace prime contractor, as the UCAV is likely to reflect their dominance of conventional high technology combat aircraft. Whether there is enough meat on this market to support all of the current pretenders is debatable. The supporting supply chain is also likely to differ significantly from its current configuration and composition.

The real challenge will be to provide an appropriate industrial base for the MALE UAS — the workhorse sector of the UAV market. Fundamentally, the long-term future of this UAV sector will demand a different business model. The adage 'price low for development and make it up on production' will not work for low-volume but relatively high-cost product. Customers will also want a new 'system' in a shortened development and delivery cycle. Think higher end 'plug and play' hi-fi units, or computers and add-on peripherals; or even better supercars. Profits have to come from the first production model, which might even be the second vehicle. Traditional aerospace suppliers, certainly from the aero structure side, will have to match these demands. Higher-level sub-systems suppliers may have more scope to adapt; but they too will have potentially to share business with a novel set of sources.

This market segment is ripe for a new approach, and perhaps yet another set of new players. As more civilian, private customers appear, the demand is likely to be far more service oriented. Suppliers will be asked for a 'turn-key' operation, leasing hardware or even delivering a total package of acquired and analysed data. They might be asked to run a security-surveillance operation for government or quasi-government entity, or perhaps a private customer (for example oil/gas pipeline security). Fulfilling such demand might engage the traditional defence aerospace company, especially if the client demands a high level of systems integrity and security. But as the basic hardware technology comes down in price and increases in capability, there will be other competitors.

As the market leader in terms of both demand and commitment to UAS technology acquisition the US remains best placed to dominate the market. US companies, especially some of the newer players, have already demonstrated early signs of a more service orientated business model. This would be underlined by a steady adoption of regulations to encourage civil use.

However, while in the long-term, research and development spending for unmanned aircraft will continue, in the short term funding levels are uncertain due to bipartisan pressure to cut spending. There will also be pressure on a diverse UAS industrial base; consolidation within market segments, through mergers or bankruptcy, may be inevitable as the market settles on a few winning firms and products. The market is also likely to move toward commoditisation — for instance, sensors, manipulators and control mechanisms — and modularity, as standards will shift away from closed and proprietary architectures.


The EADS Barracuda UAS demonstrator. EADS.

Europe is at a very important juncture. Over the past 40 years, Europe has held its own in conventional aerospace markets. There is a wide spread understanding of the industrial stakes at risk in missing the UAS wave. More important, fragmentation and divergent national interests are again tending to conspire against a coherent European effort. As the French Parliamentary Defence Committee warns, Europe is at a 'crossroads' in UAS development; there is a grave danger that Europe will become totally "dependent on US or Israeli platforms."[77] In this respect adoption of the EU UAS Road map would also be an important step to encourage the European UAS industry and to stimulate the service sector potential of UAS civil operations.[78] As a minimum, the European Defence Council in December 2014 must endorse the EU Euro 100 million UAS programme. Failure to do so would condemn Europe to a continuing catch-up situation and the loss of an important new aviation market.

Europe will have to be less conservative in terms of encouraging new entrants and novel combinations of specialisms to meet newly emerging markets. The aerospace sector starts with some competitive advantages, but these are not guaranteed or indefinitely durable. It is evident that unless Europe sorts its self out very soon, it could lose contact with one of the most dynamic defence and aerospace markets of the 21st century.

ANNEX: NOMENCLATURE

The International Civil Aviation Organization (ICAO) has set out some basic concepts in recent changes to Annex 2 and Annex 7 to the Chicago convention and the UAS Circular 328

Unmanned aircraft are aircraft not Aerial vehicles therefore the terms UAV Unmanned Aerial Systems UAS is an obsolete term. UAS stands for Unmanned Aircraft System

All aircraft without a pilot on board are 'pilotless' in respect of the use of this term in the Chicago Convention

The terms Unmanned Aircraft and Unmanned Aircraft

[77] Assemblée Nationale 1 December 2009, No. 2127; four European NATO forces in Afghanistan are using Israeli platforms to fulfil urgent operational needs, and the French are still pondering a decision to buy more Predators.
[78] RPAS, op cit.

Systems, UAS cover all aircraft fixed, rotary, lighter than air etc., that are pilotless.

For the 'foreseeable future', only Remotely Piloted Aircraft (RPA), that is UAS that have a human pilot located somewhere (on the ground, on a ship, another aircraft, in space, etc.) who is able to control the flight of the aircraft, will be able to operate in non-segregated airspace.

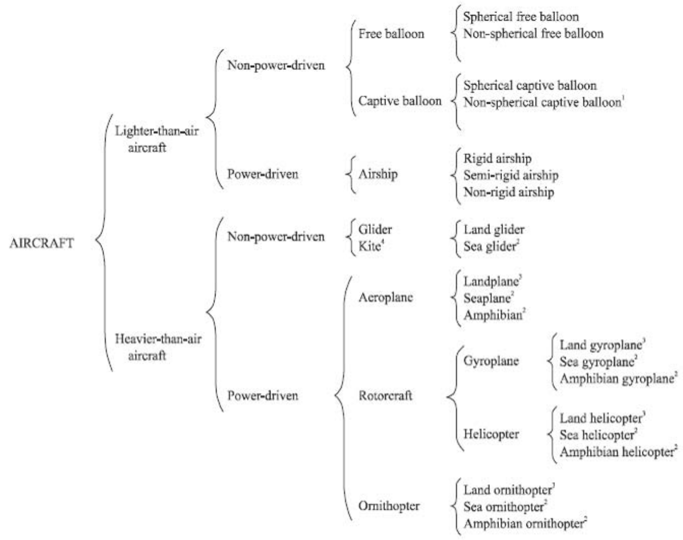
In arriving at this position, ICAO has adopted a very ridged definition of 'autonomous' as operation of the aircraft where a human pilot is not able to intervene in the management of the flight. This does not align with the NATO and other 'scales' of Autonomy which relate to levels of authority and decision support. The term RPA it is not intended to imply that aircraft is expected to routinely be flown manually or even that it has the potential to be flown manually (use of autopilot, etc., is allowed) — the requirement is that the pilot can manipulate the flight controls, as appropriate, during flight. As yet there are no requirements on the form of the controls although this may come, for example, is it sufficient for control to be limited to waypoint steering?

From this is follows that RPA and Remotely Piloted Aircraft Systems RPAS (which include the 'pilot station' and the C2 infrastructure) are a subclass of Unmanned Aircraft and Unmanned Aircraft Systems respectively.

Needless to say this nomenclature is not yet widely adopted although there is a growing use of the term 'RPAS'

New definitions added to ICAO Annex 2 with amendment 43 (2012)

Command and control link (C2). The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight.
Detect and avoid. The capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action.
Operator. A person, organization or enterprise engaged in or offering to engage in an aircraft operation.
Note. In the context of remotely piloted aircraft, an aircraft operation includes the remotely piloted aircraft system.
Remote pilot. A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.



1. Generally designated 'kite-balloon'.
2. 'Float' or 'boat' may be added as appropriate.
3. Includes aircraft equipped with ski-type landing gear (substitute 'ski' for 'land').
4. For the purpose of completeness only.

Table 1. Classification of aircraft.

Remote pilot station. The component of the remotely piloted aircraft system containing the equipment used to pilot the remotely piloted aircraft.
Remotely piloted aircraft (RPA). An unmanned aircraft which is piloted from a remote pilot station.
Remotely piloted aircraft system (RPAS). A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links and any other components as specified in the type design.
RPA observer. A trained and competent person designated by the operator who, by visual observation of the remotely piloted aircraft, assists the remote pilot in the safe conduct of the flight.
Visual line-of-sight (VLOS) operation. An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft.

Annex 7 Amendment 6 (6th Edition) November 2012

Remotely piloted aircraft (RPA). An unmanned aircraft which is piloted from a remote pilot station.

The Northrop Grumman X-47B Unmanned Combat Air System (UCAS) demonstrator conducts a touch and go landing on the flightdeck of the aircraft carrier USS George H W Bush *(CVN 77) on 17 May 2013, marking the first time any unmanned aircraft has completed a touch and go landing at sea.* Northrop Grumman/US Navy.