**UK TRADE AND INVESTMENT**

# REPORT ON INWARD INVESTMENT IN THE UNMANNED AERIAL VEHICLE INDUSTRY

**FINAL REPORT**

**Presented by**

**International Consultancy Group Ltd.**

**October 2008**

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## EXECUTIVE SUMMARY

The global Unmanned Aerial Vehicle (UAV) market is made up of an extensive range of craft, from very small hand-launched vehicles to strategic UAVs the size of passenger aircraft. Although referred to as 'UAVs' in common parlance, these vehicles are perhaps better considered as integrated systems incorporating the aircraft itself, a communications and control system, and a payload dependent on the objective of the mission.

The current market is primarily military, with UAVs recently seeing action in theatres of war including Kosovo, Afghanistan, and Iraq. The incipient civil market for unmanned vehicles includes an array of potential applications relating to emergency services, public security, and commercial sectors such as communications, media, and inspection services. However, this market is at present in a very early stage of development, and most civil UAV applications are at the experimental stage.

The global UAV industry is dominated by the United States, which leads in both development and production of systems as well as defence procurement of UAVs. The UK ranks fourth in development and production, rivalled mainly by key competitors Israel and France. Although it currently produces a small number of systems, the Japanese UAV industry is significant in terms of the size of companies interested in the technology, and because it is the only country where civil applications of UAVs have become in any way routine.

The size of the global UAV market is relatively small compared to other sectors of the aerospace industry. The global market for all types of system is estimated to be approximately $31 billion over the next 10 years, with civil systems accounting for around $2 billion during this period. The UK share of this market is estimated to be $1.8 billion over the next 10 years.

The industry will require significant technical advances if applications are to realize true commercial potential. The development of intelligent autonomous systems and 'sense-and-avoid' technology would be a major step towards enabling UAVs to share unrestricted airspace with manned aircraft. At the same time, the regulatory environment relating to civil UAV flight is becoming more well-defined thanks to efforts by both European and UK agencies to define these requirements.

The future development of the UAV sector will require substantial input from research organisations, and UK academic institutions and companies are well-placed to participate in progressing the capabilities of the industry. University researchers are active in the majority of key technologies enabling UAV development, and have good collaborative links with industry. The UK government has also aided industry development through part-funding the ASTRAEA programme dedicated to addressing a range of technical UAV issues. The UK's competitive position is further strengthened by the Parc AberPorth technology park in west Wales, a dedicated UAV facility with support for both technology development and test flights.

As a target for inward investment, the UAV industry should be regarded as a long-term proposition. The size and nature of the UK market are likely to make it difficult for investors to see the market as an adequate commercial proposition at this time. However, it may be possible to overcome these constraints by focusing on enabling technologies with a range of applications equally relevant to other UK industry sectors. Serious approaches to the Japanese market should also be considered, as major Japanese companies have a long-term focus on this industry sector, and may be interested in extending their experience in European markets through the UK.

**UK TRADE AND INVESTMENT**

# REPORT ON INWARD INVESTMENT OPPORTUNITIES IN THE UNMANNED AERIAL VEHICLE INDUSTRY

## 1. Introduction

Unmanned aerial vehicles (UAVs) are defined as airborne craft, either remotely controlled or autonomous, which may be used for surveillance, intelligence gathering, or combat strike missions. The definition necessarily displays a military bias since most UAV applications to date have been focused on combat situations in which it is either too dangerous or not practical to utilize a manned mission.

In professional circles there is some debate about the precise range of technologies that can be described by the term 'UAV'. Although some types of radio-controlled systems where human intervention is essential are accepted to be included in this market, the consensus is that small model planes intended for recreational purposes are excluded from the definition. Defining UAVs solely by weight and size is equally problematic, since the advent of micro-UAVs indicates that very small high-spec systems are likely to find both military and commercial applications. A critical feature of UAVs is in part one of autonomy: the UAV is ideally capable of carrying out predetermined tasks without the need for constant human control.

UAVs may also be known as 'unmanned aircraft systems' (UAS), a term originally instituted by the US Department of Defense to encompass not only the vehicles themselves but the ground control and data communications systems that require to be integrated with the craft in order to achieve full functionality. Although this term is gaining wider acceptance in the professional community, it is still often used interchangeably with 'UAV' to describe unmanned airborne craft and systems in general.

This report was commissioned for the purpose of studying UAV markets and capabilities in the UK with a view to establishing the viability and, if feasible, the potential sources of inward investment in the sector. For the purposes of the project, the term 'UAV' will be applied to unmanned aerial vehicles and their associated systems unless otherwise specified.

This report is focused specifically on aerial vehicles and related systems and does not address market or technology issues arising from autonomous ground or marine systems, although some technology developments discussed below may be applicable to such systems.

## 2. The Shape of the UAV Sector

*UAV Systems*

Although the basic definition of a UAV is straightforward, the industry itself is much more complex than the term would indicate. This sector is characterized by a very diverse range of craft that is constantly being developed and refined. The situation is further complicated by the fact that a UAV is, in truth, better understood as an integrated system in two senses. First of all, the vehicle itself is only fully functional when it is integrated with a ground control/launch system, makes use of a communications system to transmit data and receive instruction, and carries a payload determined by the task required of the craft.

Additionally the UAV requires a power source, which is generally a battery of some type, but solar operated craft are in the experimental stage. Propulsion is either by means of jet engines or propellers. Vertical take-off and landing (VTOL) technologies are also utilised, so the UAV effectively functions as a small helicopter.

Secondly, successful development of a UAV requires the integration of disparate technologies that are very unlikely to be the province of a single organisation. The capability requirements for UAV development are extensive. Examples of the types of technology integrated into advanced UAV systems include:

- Sensor development
- Sensor exploitation
- Communications and control systems
- Artificial intelligence
- Robotics
- Electro-optics
- Mechanics
- Aeronautics
- Materials (composites, ceramics)
- Embedded systems

*Types of UAV*

The methods of classifying different types of UAV are highly variable and depend to some extent on the purposes for which the craft are being categorized, as well as the professional point of view of the individual assembling the descriptions. Even then descriptive categories can be deceptive, as the craft can vary dramatically in size and capability. At the top end of the scale the Eitan, developed by Israel Aircraft Industries, is reported to have the wingspan of a Boeing 737. Its operation is apparently aerodynamically similar to than of a traditional manned aircraft.

At the opposite end of the spectrum the Nano Air Vehicle, developed by AeroVironment with funding from DARPA in the US, weighs less than 10 grams and is 7.5 centimetres long. The tiny UAV flies by moving its wings, a new development in propulsion technology. As a very recent development the practical applications of this miniaturized craft are unclear, but it represents the cutting edge of technologies defining the ever-widening parameters of unmanned flight.

The table below provides a guide to the vast range of sizes and capabilities found in modern UAVs. Essentially, smaller craft are only able to carry a restricted power supply, which in turn affects their maximum range and endurance, while larger craft are able to support much longer forays.

**Classification of UAVs/UAS**

| Category | Range (km) | Altitude (meters) | Endurance (hours) |
|---|---|---|---|
| **Tactical** | | | |
| Micro | <10 | 250 | 1 |
| Mini | <10 | 150 to 300 | <2 |
| Close range | 10 to 30 | 3,000 | 2 to 4 |
| Short range | 30 to 70 | 3,000 | 3 to 6 |
| Medium range | 70 to 200 | 5,000 | 6 to 10 |
| Medium range endurance | >500 | 8,000 | 10 to 18 |
| Low altitude deep penetration | >250 | 50 to 9,000 | 0.5 to 1 |
| Low altitude long endurance | >500 | 3,000 | >24 |
| Medium altitude long endurance | >500 | 14,000 | 24 to 48 |
| **Strategic** | | | |
| High altitude long endurance | >2000 | 20,000 | 24 to 48 |
| **Special Purpose** | | | |
| Unmanned combat aerial vehicle | approx. 1,500 | 10,000 | approx. 2 |
| Lethal | 300 | 4,000 | 3 to 4 |
| Decoy | 0 to 500 | 5,000 | <4 |
| Stratospheric | >2000 | >20,000 to >30,000 | >48 |
| Exo-stratospheric | TBD* | >30,000 | TBD |
| Space | TBD | TBD | TBD |

*to be developed

*Source: UVS International*

It should be noted that the final three categories of UAV are currently aspirational.  Stratospheric and exo-stratospheric Ukases are in development, while space-related craft are still at the conceptual stage.  In none of these cases do there exist craft capable of flying.

*Military Applications of UAVs*

Traditionally, UAVs have been tasked with what are known in military parlance as 'dull, dirty, and dangerous' missions, sparing human pilots many difficult and unpleasant tasks.  Military UAVs are the most high-profile unmanned vehicles currently in operation, largely due to their deployment in recent theatres of war including Kosovo, Afghanistan, and Iraq.

A principal military application for UAVs is reconnaissance and surveillance, which includes intelligence gathering activities as well as target acquisition and verification to support human decision-making.  Such activities are collectively referred to under the acronym ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance).  Payloads can include a variety of sensors or cameras to capture data and transmit it back to ground control. Although this is most popularly associated with concepts such as spying out the location of enemy combatants, such craft have been used for diverse purposes such as evaluating terrain before an attack, and for nuclear-biological-chemical detection.

UAVs can also take a more proactive role in the battlefield.  Used for the detection of mines and explosives, the vehicles may be tasked with detonation where feasible.  UAVs may also be used for seeding an area with sensors, which may then be remotely monitored.  Other military roles include search and rescue support for downed pilots, and the delivery of emergency medical supplies or survival kits to personnel otherwise inaccessible.

Even more aggressively, UAVs can be supplied with a weapons payload and targeted on enemy installations.  Unmanned Combat Aerial Vehicles (Caves) eliminate the need to potentially endanger a human pilot while enabling the forces to strike deep within enemy territory.  This would seem to be an ideal application for an unmanned craft, but the effectiveness of this approach is limited by the lack of flexibility inherent in existing technology.  Nevertheless, UCAVs are currently in use to a limited degree in combat situations.

*UAVs in Civil and Commercial Applications*

The continued enhancement of the surveillance and combat capabilities of military UAVs has prompted the identification of a host of non-military applications for this technology.

Non-military uses for UAVs essentially fall into two categories.  The first may be described as civilian applications pertaining to public security and emergency services, including police and rescue services, coastguards, border surveillance, fire management agencies, fisheries protection, or management of Exclusive Economic Zones.

Most existing non-military applications of UAV technology fall into this category, although they are still primarily in the experimental or demonstration stage. During the 2007 forest fires in California, the U.S. Forest Service tested a UAV (built by General Atomics) equipped with a thermal-imaging sensor developed by NASA with the aim of gaining an improved understanding of the movement and behaviour of a large-scale fire. Although the test was deemed to be carried out successfully, the USFS intends to retain its reliance on manned flights for the foreseeable future, with its capabilities augmented by the imaging technology. UAVs have also been used to patrol the US – Mexican border for illegal immigrants, but this occurs at the cost of having to ban other civil aircraft for a radius of several hundred miles due to safety issues.

Police forces have also shown an interest in applying UAV technology to law enforcement. In Miami, Dade County police are seeking approval from the Federal Aviation Administration to fly a small, 14-pound UAV over both urban areas and the Everglades National Park in a bid to provide tactical support to officers on the ground. In the UK, Strathclyde police tested a prototype mini-UAV in late 2007 to assess its support capabilities for mountain and marine rescue operations. The vehicle was grounded in early 2008 after technical difficulties, and although the police denied that the vehicle actually crashed they have stated that they prefer to wait for the availability of a full-scale craft before committing themselves to bringing such a UAV into service.

The second category pertains to more purely commercial uses of UAV technology, where UAVs are currently used on a small scale for limited applications relating to meteorological research, observation of volcanoes and other geological features, or crop spraying. However, a vast array of potential commercial applications has been identified to include:

- Agriculture (monitoring soil condition, erosion, or biodiversity, crop spraying, or management of range herds)
- Atmospheric, environmental, meteorological, or oceanographic monitoring
- Communications relay
- Delivery services
- Disaster relief (identifying relief requirements and possibly delivering rapid short-term aid)
- Geological inspection and assessment
- Imagery and mapping
- Media (flexible filming of sports matches or large-scale events, film production)
- Power and pipeline monitoring
- Structural inspection and surveying
- Traffic monitoring

Because of the industry's enthusiasm for applying UAVs to commercial markets, a critical focus of the industry at this time is the potential for, and technical issues related to, the migration of UAVs from military to civil airspace. These developments are proceeding on several fronts. In December 2007, Eurocontrol (European Organisation for the Safety of Air Navigation) released a set of specifications detailing the requirements UAVs should meet in order to be allowed to operate in civil airspace. Essentially, the document specifies that UAVs must demonstrate ability to meet the same standard of separation from other air traffic as that required by conventional aircraft. The specifications are innovative insofar as the industry is not yet able to meet these demands, but will be expected to use them as guidance in the development of future systems. The specifications are not mandatory, but Eurocontrol believes that they are likely to be adopted by most member states to facilitate harmonious integration of unmanned systems into European airspace.

In the UK the Civil Aviation Authority oversees the guidelines for UAV operation. This is governed by the CAP722 regulations, originally issued in May 2002, in which the principles governing the operation of manned civilian aircraft are extended to UAVs. These include the need for the UAV system to be certified as airworthy, and for organisations involved in the design, manufacture, operation, and maintenance of civil UAVs to be approved for the purpose. At present both military and civilian operators must apply to the CAA on a case-by-case basis when they wish to conduct test flights.

Future UAV regulation is likely to be tied to the size and capability of vehicles. European Aviation Safety Agency legislation specifies that, with exceptions for research and police purposes, national regulation will only apply to systems weighing less than 150 kilograms. Operation of heavier systems will be governed by EASA regulations.

The CAA is recognised worldwide to have taken a proactive approach to addressing regulatory and safety issues of operating UAVs in civilian airspace. Given the technical problems discussed below it is difficult for the organisation to progress UAV operation any more swiftly, but the CAA's attitude is seen to be both positive and constructive.

## 3. Market Structure

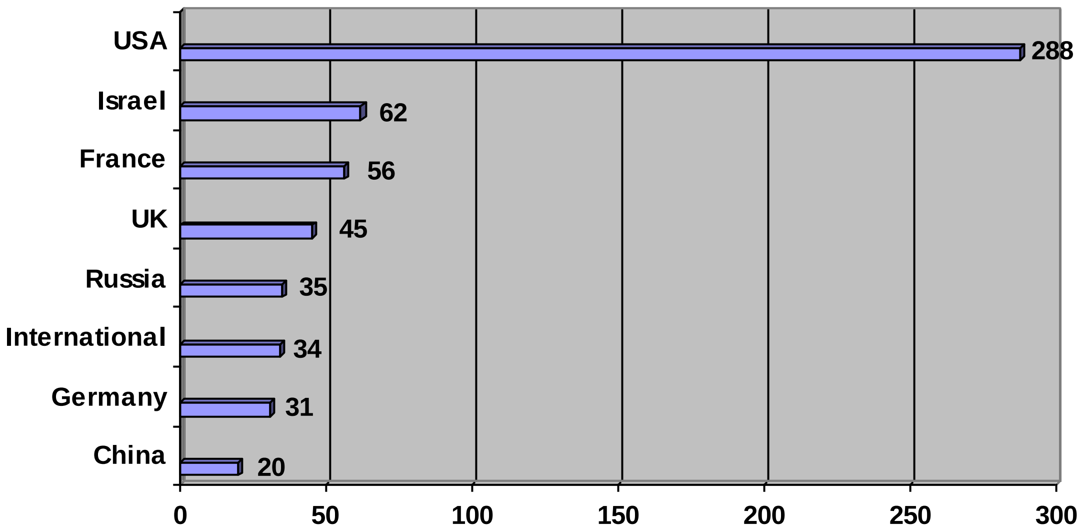
The UAV market is heavily defence-oriented and will continue to be so for the foreseeable future. Defence applications for the technology are well understood and can be further extended in combat situations where there is greater freedom of operation and fewer concerns about conflict with inhabitants of the battlefield.

The market for civilian and commercial UAVs is often enthusiastically described as ‘limitless’, reflecting the plethora of potential applications identified, as well as claims that many tasks could be performed more effectively or at reduced expense through investment in UAV technology. Civilian market growth is currently restricted by a number of technical issues detailed in the chapter below.

There is a school of thought that argues that UAV technology will never be applied successfully to civil markets. At a conference at the Royal Aeronautical Society, an anonymous aerospace industry executive told a *New Scientist* journalist that the technical and regulatory issues are too complex, and the consequent risks to the public too high, for the craft to be accepted in civil airspace.[1] In this view the UAV industry is pushing hard for market extension without possessing the capability to adequately manage such as transition.

The UAV industry is at present heavily focused in the United States, where significant defence expenditure has supported a thriving R&D and production community. The chart below shows key national participants in the market according to the level of system development. The chart refers to the number of discrete vehicle types or systems, rather than unit production.

**Number of Unmanned Aerial Systems in Production or Development by Country, 2007**




*Source: UVS International*

In 2007 a total of 789 unmanned aerial systems were in production or development worldwide. Unsurprisingly the USA leads the industry by a huge margin, and Israel is also aggressively developing and deploying a wide range of UAVs which are principally used for domestic military purposes. The UK features as major market participant, ranked fourth according to number of systems in development or production.

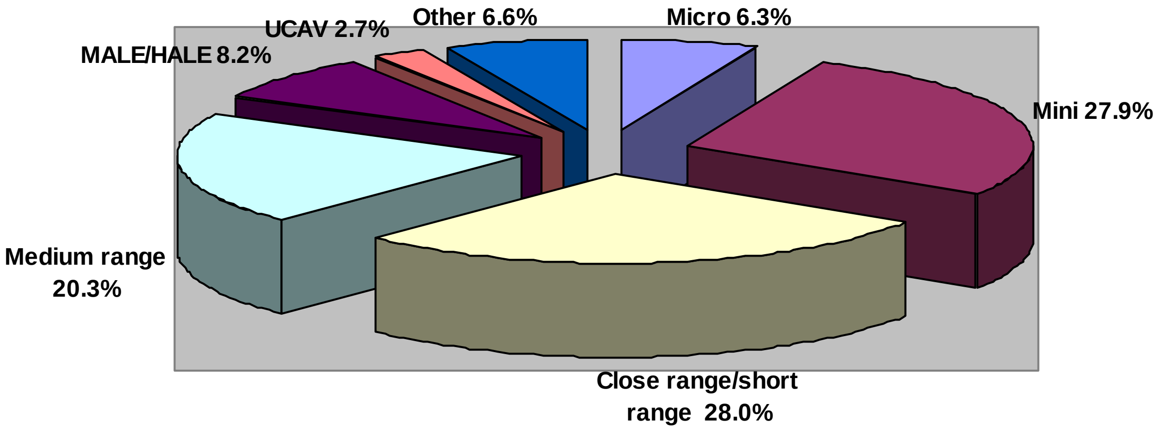
A few nations are notable for the significance of their presence in the industry, rather than the number of systems developed. Australia has a small but very active UAV sector, as well as important academic research capabilities. Canada has only three systems currently in development, but regional industry associations in eastern Canada are heavily promoting the area as an excellent location for UAV development and testing. The strong base of aerospace companies in Canada also provide materials, components, and sub-systems with direct relevance to UAV development, and the industry association hopes that these subcontractors might attract larger system developers to the country.

Japan has a handful of individual developers of the technology, but these include major companies such as Fuji Heavy Industries and Yamaha Motors, who are already marketing systems, and Hitachi, Mitsubishi, and Sony, who have a very early-stage research interest in the technology. In terms of applications the country has been at the forefront of deploying UAVs for commercial purposes, including crop spraying, monitoring potential volcano and landslide activity, aerial seeding of forests, and identifying and spraying for insects attacking commercial forests. Yamaha has sold over 2000 small unmanned helicopters for these types of applications, apparently mostly for domestic use.

Japan also has a long-term plan for sector development which accords with their overall industrial strategy for increasing their global presence in aircraft and space markets. The Defense Ministry's Technical Research and Development Institute has identified UAV technology as an area to be addressed by domestic R&D, reducing the need to acquire such systems from the US.

The type and size of UAVs in development and production is shown in the following chart. Although large military systems receive a great deal of press coverage, most systems are in fact at the small to medium end of the scale. While this does indicate some increased focus on smaller systems suitable to commercial environments, it is also indicative of a developing military interest in small, agile UAVs that are simultaneously more cost-effective, flexible at short ranges, and can be lost in conflict without endangering entire missions.

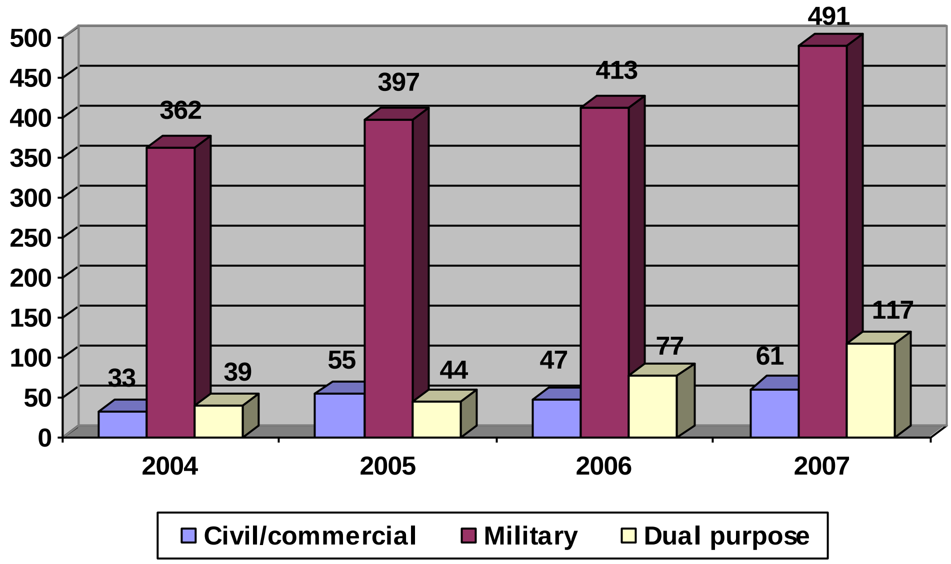
**UAV production and development by category, 2007**




*Source: UVS International*

The following chart contrasts the civil and military applications of UAVs in current production and development. It does not include systems used for further research and development purposes. The graph clearly shows that the industry is still dominated by military technologies, while civil and commercial applications are making incremental progress. It also suggests the role that military technology is likely to play helping to build craft suitable for commercial exploitation.

**Applications of UAV Systems, 2004 – 2007**




*Source: UVS International*

*Market Value*

For the purposes of understanding and quantifying the market, it is most useful to consider UAVs from the combined point of view of functionality and capability. This yields a categorization that is descriptive of a current situation in which most UAVs are deployed for military purposes; the separate segmentation of civil and commercial UAVs underlines that fact that these craft, while conceptually related to military UAVs, represent an entirely different market opportunity that is still at an early stage.

Market value is best understood by assessing the number and value of actual vehicles in production, broadly classified into discrete categories. Although supporting technologies are essential, procurement is dependent on integration into larger platforms.

The following chart shows forecast vehicle production through 2017. A distinction is made between the military market segments as compared to the civil UAV market, which is forecast to develop gradually over ten years, but remain at a much lower level.

**UAV Production Forecast by Vehicle Type, 2008 – 2017 (units)**

| Vehicle type | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mini UAV** | 1,806 | 1,985 | 1,965 | 1,885 | 620 | 885 | 2,415 | 2,370 | 2,120 | 1,951 |
| **Tactical UAV** | 269 | 328 | 292 | 358 | 268 | 303 | 304 | 230 | 213 | 144 |
| **Naval UAV** | 1 | 6 | 6 | 38 | 27 | 40 | 48 | 50 | 55 | 59 |
| **MALE UAV** | 43 | 51 | 63 | 105 | 91 | 84 | 86 | 73 | 57 | 62 |
| **HALE UAV** | 7 | 8 | 13 | 11 | 16 | 13 | 17 | 14 | 19 | 27 |
| **UCAV** | 3 | 1 | 2 | 4 | 1 | 1 | -- | 6 | 5 | 11 |
| **TOTAL** | **2129** | **2379** | **2341** | **2401** | **1023** | **1326** | **2870** | **2743** | **2469** | **2254** |
| **Civil UAV** | 307 | 307 | 317 | 317 | 345 | 375 | 372 | 389 | 427 | 475 |

*Source: Teal Group*

The value of production reflects the same situation, with civil market values still amounting to less than 10% of military market size over ten years. The values of the various segments also reflect that relative cost of UAV systems. The market will see a preponderance of smaller systems at a lower value, in contrast to the smaller number of high-value, long-range endurance craft with more strategic applications.

**Market Value of UAV Production, 2008 – 2017 ($ millions)**

| Vehicle type | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mini UAV** | 50.8 | 57.2 | 59.5 | 56.1 | 60.4 | 52.7 | 54.6 | 53.0 | 68.2 | 71.6 |
| **Tactical UAV** | 418.5 | 430.0 | 744.5 | 848.0 | 674.5 | 561.5 | 517.5 | 726.5 | 665.0 | 310.0 |
| **Naval UAV** | 40.0 | 40.0 | 75.0 | 259.5 | 199.5 | 305.0 | 367.5 | 373.0 | 401.5 | 422.5 |
| **MALE UAV** | 351.0 | 470.0 | 801.0 | 939.0 | 1,081.0 | 1,032.0 | 1,140.0 | 726.0 | 588.0 | 668.0 |
| **HALE UAV** | 525.0 | 675.0 | 1,105.0 | 845.0 | 1,010.0 | 1,270.0 | 1,195.0 | 1,090.0 | 1,300.0 | 1,580.0 |
| **UCAV** | 200.0 | 200.0 | 105.0 | 75.0 | 330.0 | 30.0 | -- | 60.0 | 300.0 | 430.0 |
| **TOTAL** | **1585.3** | **1872.2** | **2890.0** | **3022.6** | **3355.4** | **3251.2** | **3274.6** | **3028.5** | **3322.7** | **3482.1** |
| **Civil UAV** | 120.0 | 120.0 | 195.0 | 220.0 | 235.0 | 254.0 | 227.0 | 237.0 | 261.0 | 241.0 |

*Source: Teal Group*

Regional production is once again dominated by the US, which generally accounts for one-third to one-half of global UAV production. The apparent strength of the Middle East market is largely due to Israel and it significant industry sector, although Turkey and Iran also feature as producers in this region.

The European and Asian markets are roughly comparable in size with the Asian region showing slightly higher production in many years. This is due to both the Japanese commitment to UAV development and the growing interest in the technology in China.

### UAV Production by Region, 2008 – 2017 (units)

| Region | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| **USA** | 1,448 | 1,688 | 1,499 | 1,437 | 189 | 267 | 1,772 | 1,722 | 1,747 | 1,787 |
| **Europe** | 368 | 409 | 385 | 301 | 283 | 403 | 572 | 655 | 492 | 174 |
| **Middle East** | 150 | 88 | 197 | 386 | 98 | 178 | 171 | 110 | 109 | 23 |
| **Asia** | 419 | 463 | 558 | 554 | 687 | 788 | 662 | 604 | 542 | 679 |
| **Other** | 51 | 38 | 19 | 40 | 111 | 65 | 65 | 41 | 6 | 66 |
| **TOTAL** | **2,436** | **2,686** | **2,658** | **2,718** | **1,368** | **1,701** | **3,242** | **3,132** | **2,896** | **2,729** |

*Source: Teal Group*

The US again leads the world in value of production. The value of the Middle East market is a reflection of the Israeli capability in the production of smaller, short-range vehicles.

### Value of UAV Production by Region, 2008 – 2017 ($ millions)

| Region | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| **USA** | 1,025.0 | 1,395.0 | 1,960.0 | 2,000.0 | 2,105.0 | 2,035.0 | 1,865.0 | 1,765.0 | 2,095.0 | 2,060.0 |
| **Europe** | 200.4 | 183.4 | 325.7 | 308.5 | 470.4 | 655.2 | 697.6 | 761.9 | 623.9 | 566.3 |
| **Middle East** | 186.4 | 136.2 | 425.9 | 429.9 | 492.4 | 280.4 | 266.4 | 43.0 | 122.0 | 448.0 |
| **Asia** | 283.7 | 225.3 | 292.4 | 451.9 | 478.6 | 510.6 | 609.8 | 625.6 | 718.8 | 613.0 |
| **Other** | 9.8 | 52.3 | 81.0 | 52.3 | 44.0 | 24.0 | 62.8 | 70.0 | 24.0 | 35.8 |
| **TOTAL** | **1,705.3** | **1,992.2** | **3,085.0** | **3,242.6** | **3,590.4** | **3,505.2** | **3,501.6** | **3,265.5** | **3,583.7** | **3,723.1** |

*Source: Teal Group*

# 4. Key Drivers of the UAV Sector

## Technology Assessment

*Performance improvements*

In terms of current applications for UAVs, certain performance improvements are sought in order to enhance the flexibility of the craft to better carry out existing tasks. Major performance issues are detailed below.

- *Availability of bandwidth*

Radio frequency communication is utilised by UAV systems to send data to and receive commands from ground control systems. In areas with a crowded spectrum, and particularly in battlefield situations, problems of interference are becoming more common. UAVs do not have a dedicated portion of the spectrum allotted to them although, paradoxically, model aircraft do have an official allocation.

Frequency allocation is a major issue for the communications industry in general, and a greater use of UAVs in any context will exacerbate these difficulties. This problem is not expected to be resolved any time soon: in 2007 the World Radio Communication Conference did not progress the issue of frequency release and the next conference does not take place until 2011, although the problem of frequency allocation for UAVs is on the agenda for this meeting. However, competition from wireless telecoms providers is expected to be fierce, as these service providers also have burgeoning requirements for bandwidth.

Insufficient bandwidth is also expected to constrain the development of civil UAV applications in the near term. In one sense the issue is out of manufacturers' hands, although efforts have been made to improve the situation through greater application of data compression techniques. It may also be possible to address this problem through a more innovative use of autonomous systems, as outlined below under 'Projected Technology Requirements'.

- *Combat readiness*

UCAVs carrying weapons payloads are currently in use. However, their capabilities are somewhat limited and they do not have the flexibility or autonomy to operate as independent combat units, and it is in this field that performance improvements are now required if UCAVs are to display a step-change in battlefield capabilities.

At present, targets may be destroyed in a more traditional manner either by cruise missiles or by manned aircraft carrying a weapons payload.

Although generally accurate, missiles are expensive, must operate on a point-to-point basis, and cannot be redirected in flight. Piloted aircraft are more flexible, but are even more expensive and run the additional risk of loss of personnel.

In order to provide an appropriate replacement for existing attack capabilities, UCAVs must have well-developed autonomous systems allowing them to stack in-air while awaiting target acquisition and subsequently deliver their payloads (and return successfully) with minimal operator input. Improved agility and manoeuvrability are also required to access difficult targets and prevent the UCAVs from becoming artillery targets in their own right.

- *Communication issues*

Data encryption for communications between the UAV and its ground control system are regarded as essential for combat purposes, but civilian emergency services are also likely to require some level of secure communication. The MoD believes that existing encryption standards are sufficient for military purposes, but data security issues may arise with the smaller and less complex UAVs used for civil and commercial applications. This is in part because the larger and more complex the level of data transfer required, the greater the power demand on the UAV. This in turn increases the size of the payload, affecting performance of the craft, and this problem can become acute with very small UAVs.

Within the industry, it is believed that the problem of encryption may be most usefully addressed by improving the autonomous capabilities of the UAV. In this scenario, a craft with a greater capacity for independent action will not rely so heavily on data links for command-and-control purposes, obviating the need for complex encryption, and it is likely that issues of communication security will develop along these lines in future.

**Projected technology requirements**

Extending the capabilities of and hence the market for UAV technology is heavily dependent on the development and consequent integration of new technology, much of which is proceeding at the research stage.

It should be noted that 'integration' is key to market expansion: isolated improvements in aeronautics or communications are useful insofar as they enhance the performance of the overall system in complex and demanding environments. Next-generation technology requirements are also heavily dependent on the regulatory framework that develops around UAV access to unrestricted airspace. As such regulations are in a rudimentary stage of development, it will be some time before it is clear which technical solutions respond best to these requirements.

Key projected technology requirements are as follows:

- *Intelligent autonomous systems*

The greatest challenge to the UAV industry today is the development of UAV systems that can properly be described as autonomous: in other words, the vehicles can carry out tasks with minimal or no operator input, and are able to gather data, make decisions about potential actions, and execute tasks without direct human oversight. Autonomy could also be extended to encompass launching, landing, and refuelling.

UAV autonomy dispenses with the heavier personnel requirements of existing systems. At present a team of several skilled operators is required to keep a UAV airborne and on-task, and the ability of one individual to oversee several vehicles at once would render this unnecessary. This in itself would help to extend the range of applications that could make use of UAVs.

Simon Jewell, Strategic Business Development Director for BAE Systems, suggests that autonomous systems could also be utilized to address the increasingly pressing problems of bandwidth. Programmes facilitating the intelligent capture and analysis of images would supersede the current need to collect and transmit large amounts data required for quality video imagery. He has also pointed out that, once developed to a sufficiently high level, intelligent autonomous systems are likely to have applications beyond the military or UAV field.

- *Sense-and-avoid*

A specific aspect of intelligent autonomy is the requirement for what is commonly called 'sense-and-avoid' technology. This refers to the ability of the UAV to deploy collision avoidance techniques with regard to either manned or unmanned aircraft, environmental obstacles such as mountains, trees, or buildings, or poor weather conditions that could adversely affect performance. By sensing their presence and taking appropriate evasive action, whether this involves a change of flight path or, in extreme cases, self-destruction, the UAV is prevented from damaging either nearby objects or itself. This is of course of critical importance to the process of getting the vehicles accepted as rightful inhabitants of unrestricted airspace, as a single serious accident could severely curtail further commercial development.

Given the sheer range of craft size and capability within the UAV market, a single comprehensive solution is unlikely to address the requirements of all vehicles. It is more likely that some form of modular solution could be developed, utilizing various obstacle-sensing and avoidance techniques that could be combined as needed. Broadly speaking, solutions are likely to be either cooperative, relying on active communication between UAVs and other aircraft or traffic management systems, or non-cooperative, where the UAV is dependent on its own systems for sensing and evading danger.

Progress in this field is heavily dependent on the coordination of both technical and regulatory efforts. The definition of an Equivalent Level of Safety (ELOS), which will provide a means of comparing the safety of UAV flights with those of manned aircraft, is an initial step towards defining safety requirements and assessing technical solutions, but this work is in an early stage with Eurocontrol leading discussions. Although major manufacturers are claiming advances in the development of sense-and-avoid technologies, the UK CAA has reportedly had no applications for UAV flights utilizing such capabilities.

- *Swarming capability*

Swarming refers to the ability of a group of networked UAVs to reliably and flexibly act in tandem to achieve an objective. Swarming has immediate military applications in terms of sending fleets of UAVs to perform cooperative reconnaissance or combat missions.

A key element in swarming technology is the development of software enabling UAVs to respond without controller input to behaviour within the group. Much research has focused on data-link derivatives, but some interest has been directed more novel approaches such as digital pheromone emission. Ultimately the goal is to create a swarm capable of initiating its own communication network and making group decisions about how best to carry out a task.

- *Integration of communications systems*

An area that is currently not well understood is the manner in which UAV command and control systems will be integrated with other control and communication systems. This applies to both larger battle command systems found in future theatres of conflict, and communications systems in civil environments, including air traffic control and emergency service command structures.

The push for greater UAV autonomy has direct implications for its integration into wider systems. At present it is unclear how a human operator would be placed to monitor and override a UAV decision, or how a UAV would identify and handle conflict within a wider communication system. The problem will become especially pertinent in commercial markets if individual UAVs or swarms controlled by different operators are required to interact with one another.

## Constraints on technology development and adoption

The technology requirements and performance improvements detailed above do in themselves represent major constraints on the development and adoption of UAV technology, particularly for civil and commercial applications. Additional market-related constraints exist that will challenge market development, particularly on the civil and commercial fronts.

- *Programme coordination*

A near- to medium-term constraint on technology development is the commitment to and coordination of military UAV research programmes. Academic research on relevant themes is proceeding with funding from both governments and private industry, and a sizeable body of this research addresses the issues outlined above. However, longer-term investment in new technology is hindered to some extent by the cost of the enterprise: prosecution of military action in Afghanistan and Iraq is already making heavy demands on defence budgets, leaving limited resources available for new programmes.

The acquisition and management of military UAV programmes further complicates the situation. Ellen Purdy of the Pentagon's procurement office observes that the US Department of Defense lacks a truly coherent vision regarding practical issues of UAV development.[2] Although the DoD has a long-term plan for the adoption and integration of UAV technology in battles zones, the Air Force and Army are still debating which branch of the forces should oversee development of the Predator-based UAV being acquired by both.

Furthermore, Purdy points out that the speed of development itself means that technical problem-solving is not always systematic. While some development issues such as sense-and-avoid systems receive a great deal of attention others, including the identification and development of alternative modes of communication between UAVs and ground control systems to avoid overcrowded radio spectra, have not been addressed to the same extent. Finally, Purdy observes that the industrial base addressing unmanned system requirements is not fully mature. Although there are a sizeable number of prime contractors capable of large-scale systems integration, second- and third tier contractors supplying components are often in short supply.

- *Cost*

Perhaps the greatest constraint on the adoption and extended use of UAV technology is the cost of developing, acquiring and operating such systems. For combat purposes, a multi-million pound UAV may well be justifiable in terms of improved intelligence gathering and reduced risk to serving personnel, but for commercial purposes a comparatively low-cost vehicle of proven effectiveness will be essential.

- *Defence-focused industry*

To date the development of UAVs has largely been the preserve of defence companies accustomed to working with the procurement agencies of defence departments and other government bodies. Under these circumstances awareness of the differing requirements of and methods of working with commercial customers is not always well-developed. For example, it may prove more advantageous for commercial organisations to lease UAVs for specific projects or to seek other innovative ways of acquiring and financing such technology, but as yet there has emerged no flexible alternative to straightforward purchase and operation.

- *Entrenched competition in civil markets*

In order to find acceptability in civil and commercial markets, UAVs must not only overcome any direct cost constraints but must also demonstrate a clear cost-benefit advantage over existing technologies. This mainly means replacing human operators with vehicles that perform at least as well as humans. Even when UAVs have greater autonomous capabilities and become more cost-effective, there are likely to be management and process difficulties around converting from human to autonomous systems. In the short to medium term, this is likely to slow the uptake of UAV technology on a commercial basis.

- *Privacy and civil liberties*

Although this issue is not widely debated at present, public perceptions of the impact of UAVs on personal privacy are very likely to become a focus of debate as these technologies find new applications. There is currently no legislative framework, nor indeed any informal guidelines, relating to the manner in which UAVs might be deployed for civil purposes or how the information gathered by them might be used.

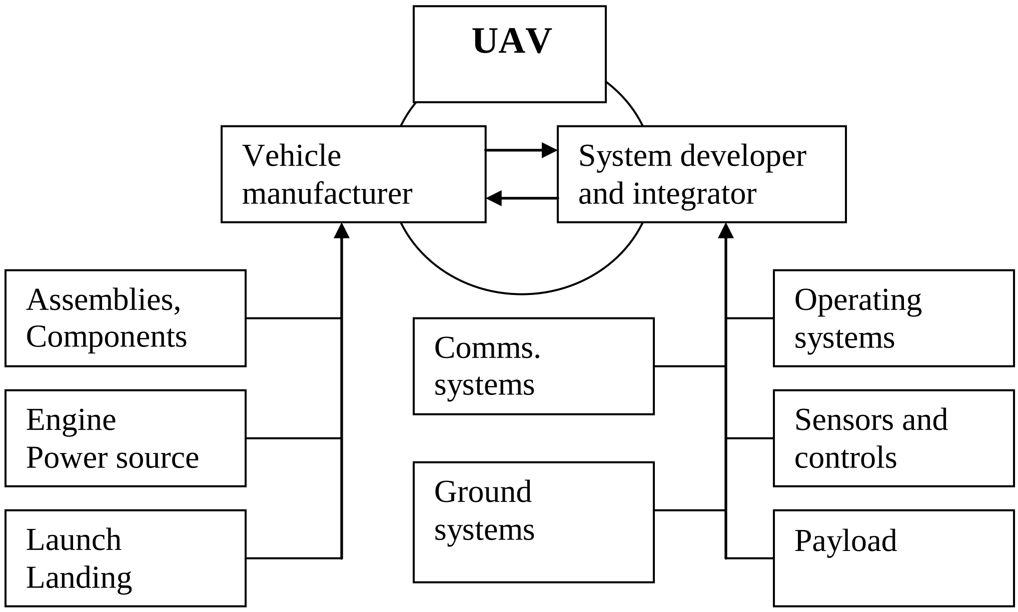
The UAV industry itself does not appear to be proactive in foreseeing and forestalling potential public disquiet regarding the use of such technology. The issue is not at the top of the agenda right now, but it must be observed that there is a risk of the industry inadvertently finding itself in a position similar to that of Monsanto and its genetically-modified crops, where unprecedented (and indeed unexpected) public outcry severely constrained the development of the UK market for such crops.

## 6. Supply Chain

The supply chain in the UAV industry in many ways resembles the common defence prime-contractor structure in which a major systems integrator will take responsibility for programme management and secure appropriate subcontracting capabilities.

The complex nature of the UAV system, coupled with the fact that high-end technology is still being developed and refined even as UAVs are being built, has resulted in the evolution of a partnership-based model.  Two or three prime contractors with specialist capabilities manage different aspects of the programme and cooperate on system integration.  The diagram below illustrates the supply chain for a high-specification UAV.

**UAV Industry**
**Outline Supply Chain**




*Source:  ICG Ltd.*

## 6. Major Global Market Participants

The following companies are key participants in the development, production, and integration of UAV systems. With a few exceptions, these companies do not have an exclusive focus on UAVs, but are active in the wider aerospace and defence industries. UAVs usually form a very small part of their business as an extension of existing activities and capabilities. Additional companies with a specific focus on UAVs do exist, and they are often focused on mini- or micro-vehicles, but these are small companies with limited resources and they do not influence the global industry.

UK companies will be profiled in a separate section.

**AAI Corporation**
www.aaicorp.com

AAI is a wholly owned subsidiary of Textron Inc, and an operating unit of Textron Systems Corporation, with a primary focus on the development of tactical unmanned aircraft systems for the defence industries. The company develops and manufactures a wide range of UAVs within which its key military vehicle is the PQ 7B Shadow 200 while the Aerosonde small UAS is manufactured by a subsidiary, Aerosonde Pty (Australia), primarily for use with NASA and the National Oceanic Atmospheric Administration for hurricane research.

The company has overseas subsidiaries in the UK (ESL Defence Ltd.) as well as in Australia, and employs over 2,500 people and generates annual revenues of almost $ 600 million.

**AeroVironment Inc.**
www.avinc.com

AeroVironment is a US-based corporation that supplies a range of small UAS (unmanned aerial systems) mainly for close-to-home paramilitary and civil use such as border, pipeline and utility asset monitoring. Its products include Raven, Dragon Eye, Swift, Puma and Wasp UAVs. The company is also a world leader in UAV product development focused on High Altitude Long Endurance (HALE) and small/micro segments including packaged UAV, VTOL and hovering UAV, and the Global Observer HALE system.

The company is based in Monrovia, California and had sales close to $200 million in 2007.

**The Agent Oriented Software Group**
www.agent-software.com

Based in the US, AOS is a world leader in the development of software supporting decision-making capabilities for autonomous and semi-autonomous systems. The UAV market is one of the leading applications for these systems, which are also supplied to the wider defence and space industries and utilized in the support of decision-making regarding oil production. The company's European headquarters are in Cambridge, UK.

**Aurora Flight Sciences**
www.aurora.aero

Aurora develops and supplies high altitude UAVs for a range of scientific tasks and is currently involved with NASA in developing a programme based on the Golden Eye UAV. The company is also developing Orion HALL (high altitude, long loiter) UAV capable of flying missions approaching four days at altitudes exceeding 65,000 feet. Aurora's Tactical Systems Group develops military-focused UAVs including the backpackable Golden Eye 50 and Excalibur. The company is based at Bridgeport, West Virginia.

**The Boeing Company**
www.boeing.com

Boeing and the Insitu Group supply a low-cost, long-endurance autonomous UAV, ScanEagle, that can remain on station for more than 15 hours. The machine is launched using a pneumatic wedge catapult , is guided via GPS and its on-board flight control system, and is retrieved by a sky-hook that hangs from a pole. ScanEagle is based on Insitu's Seascan miniature robotic aircraft and draws on Boeing's systems integration, communications and payload technologies.

Headquartered in Chicago, Illinois, the company is the world's leading aerospace organisation and manufactures a wide range of vehicles and systems including commercial and military aircraft, electronic and defence systems, missiles, satellites, launch vehicles and advanced information and communication systems. It also operates NASA's Space Shuttle and International Space Station.

**Elbit Systems**
www.elbitsystems.com

Elbit Systems develops and supplies a wide range of turnkey UAV systems to domestic (Israeli) and international markets, working in partnership with other major defence manufacturers including Thales Group. Its Hermes system, which is the baseline for the UK Watchkeeper programme, consists of a range of UAVs for MALE and high end tactical missions, while the Skylark series is designed for close range mission activity.

The company, based in Tel Aviv, develops, manufactures and integrates advanced high performance electronic and electro-optic systems for customers worldwide, both independently and in close co-operation with partners. International subsidiaries include Vision Systems LLC (VSI), based in San Jose, California and jointly owned with Rockwell Collins, and UAV Tactical Systems Ltd, a UK company in which Thales has a 49% share. This company is primarily focused on the Watchkeeper programme.

**EADS (European Aeronautic Defence and Space Corporation)**
www.eads.net

EADS supplies a range of UAV products to customers worldwide. The SIDM MALE system is based on the Eagle 1 UAV developed jointly by EADS and IAI. The system is an autonomous medium altitude system capable of operating in the ISTAR roles as well as other focused missions. Its CL 289 URAV (unmanned reconnaissance aerial vehicle) has been deployed by the French and German armed forces since the 1990s, and is a fast flying tactical drone providing short reaction and rapid response times. The Tracker UAV system is designed for both civil and military use and can be hand-launched, and is focused on over-the-hill reconnaissance and surveillance roles. The Scorpio is a lightweight, multi-purpose VTOL UAV system offering maximum flexibility in operating conditions.

EADS is a global leader in aerospace, defence and related services with its major subsidiaries including Airbus, Eurocopter, and Atrium (space). Sales revenues in 2007 exceeded € 39 billion.

**EMT**
www.emt-penzburg.de

EMT is based in Germany and develops and manufactures a wide range of UAVs including mini and micro systems as well as larger tactical models. Current products include the Luna tactical UAV, the Fancopter micro drone and the Aladin mini drone, while models in development include the Mikado (micro) and the X13 (tactical).

The company was founded in 1978 and is a certified aviation company and supplier of air vehicles and aviation equipment.

**General Atomics**
www.ga.com

General Atomics Aeronautical Systems Inc is an affiliate company of General Atomics that specialises in the development and manufacture of UAVs and associated systems. The I-GNAT systems provide long endurance and large payload capacities, taking off and landing conventionally on any hard surface. The series includes the I-GNAT ER/Sky Warrior Alpha which is a multi-mission ISR designed for military applications. The Predator and Predator B are further, larger evolutions of the I-GNAT series.The company also manufacturers the all-altitude Mariner UAV for global maritime surveillance.

**Israel Aerospace Industries Ltd (IAI)**
www.iai.co.il

IAI-MALAT is a global leader in UAV-based solutions with a track record of completing over 350,000 operational flight hours on four continents. The company supplies a range of UAVs including:

- Heron. Strategic MALE UAVs with a versatile all-weather capability on multi-mission, multi-payload platforms.
- I-View. A new generation of tactical UAV systems offering three platform sizes and designed for simple operation.
- Searcher Mk 11. Advanced UAV systems providing day and night real-time imagery data.
- Bird Eye 400. An affordable mini UAV system providing over-the-hill reconnaissance.
- MOSQUITO. A micro UAV system designed for providing real-time imagery in restricted urban areas.
- Hunter. Multi-role fully redundant UAV system enabling special missions based on customer payloads.
- Ranger. A joint manufacture with Swiss RUAG Aerospace.

IAI is a global leader in the development of both military and commercial aerospace technology, evolving from its early days as a single-customer operation supplying Israel's Ministry of Defence to its current worldwide status. Sales in 2006 totalled US2.8 billion.

**Insitu**
www.insitu.com

Insitu UAVs are lightweight ISR-equipped systems using catapult launch and skyhook retrieval. The Scan Eagle UAV for military and homeland security application was developed jointly with Boeing, based on Insitu's Insight UAV platform. The same platform was used for the development of the Georanger, designed specifically for geophysical surveys. The Integrator UAV is the company's next generation addition to the Insight platform family but provides improved payload capacity and ease of integration.

Based in the US, Insitu was a pioneer in the UAV market and specialises in the design, development and manufacture of high performance, low cost systems for Intelligence, Surveillance and Reconnaissance (ISR).

**Northrop Grumman**
www.northropgrumman.com

A US-based defense contractor, Northrop Grumman supplies the Global Hawk UAV, which has a duration of over 36 hours and a range of 13,500 nautical miles. Onboard sensors provide high-quality imagery both at high altitude and in adverse weather conditions. The company has a presence in global defence and technology markets, providing innovative systems, products and solutions in information and services, electronics, aerospace and shipbuilding.

**Proxy Aviation Systems**
www.proxyaviation.com

Proxy supplies two main UAVs, Skyraider and Skywatcher, to the US military market. The Skyraider is an optically piloted vehicle which can be flown either manned or unmanned. The machine is constructed of lightweight composite materials and undertakes missions requiring MALE characteristics and ISR operations, carrying a heavy payload. The company also supplies a distributed management system (SkyForce) for control of multiple UAVs.

Proxy is based in Germantown, Maryland, was founded in 2003 and is focused on the development of UAVs and control systems primarily for military applications.

**Rheinmetall AG**
www.rheinmetal.com

Rheinmetall is a major German engineering firm with a presence in automotive, general engineering, and defence markets. The company is Germany's centre of competence for unmanned air vehicles, but its capabilities also extend to autonomous ground vehicles and related systems. The tactical KZO UAV is a reconnaissance vehicle capable of both surveillance and targeting, and the company claims to supply similar craft to civilian markets for border patrols and pipeline inspections.

**SAGEM Defense Securite**
www.sagem-ds.com

Part of the French Safran Group, Sagem is a leading European defence company focused on avionics and defence optronics. The company claims to be the European leader in UAV systems as the developer of the Sperwer group of UAVs, a medium-range tactical UAV carrying a payload of optronic sensors.

**Schiebel Corporation**
www.schiebel.com

Schiebel manufactures and supplies the Camcopter S-100 AUV system that comprises a compact helicopter aerial vehicle designed to operate with a variety of payloads. The S-100 is a vertical take-off and landing vehicle (VTOL) which can be programmed to operate an autonomous mission or operate with manual control. The vehicle is stabilised using a redundant Inertial Navigation System while navigation is accomplished using a redundant GPS system. The Schiebel Camcopter family started development in the early 1990s and has supplied both military and Coastguard requirements over the period.

The Schiebel Group was founded in Vienna in 1951 and focuses on the development, testing and production of state-of-the-art mine detection equipment and the Camcopter range of UAVs. Its international markets include military, civil and humanitarian sectors.

**Swift Engineering Inc.**
www.swiftengineering.com

Swift engineering manufactures the Killer Bee UAV. The system is fully autonomous and runway independent, and can be transported by Humvee and operated by two men. The company operates in partnership with major aerospace defence firms including Northrop Grumman and Raytheon. Founded in the US in 1983, Swift's core competencies as a race car manufacturer include composite engineering and rapid development from concept to production.

## Key Events

UAV developers and related suppliers exhibit at most major aerospace and defence exhibitions worldwide, including those that are dedicated to air and land warfare systems in general. Increasingly, conferences and seminars addressing issues relating to the future of air traffic and transport also include UAV-related discussions.

The list provided below identifies conferences and exhibitions with a specific focus on UAV technologies and modes of deployment. Limited US activity reflects the prevalence of DoD-related industry meetings, which are not covered below.

## Europe

**Unmanned Air Vehicle Systems Conference**
30 March-1 April 2009
University of Bristol, Department of Aerospace Engineering
Queen's Building
University Walk
Bristol BS8 1TR
Tel: +44 117 928 9764
www.aer.bris.ac.uk/uavs/index.html

**ParcAberporth Unmanned Systems**
25 – 26 June 2008 (dates for 2009 not yet announced)
ParcAberporth
Ceredigion, Wales
This is the premier UK event including both conference presentations and demonstrations of UAV technology.

**Farnborough International Airshow**
19 – 25 July 2010
Farnborough, Hampshire GU14 6FD
Tel: +44 1252 532 800
In 2008 the Airshow featured a dedicated UAV pavilion organised by the Association for Unmanned Vehicle Systems International (AUVSI).

**Paris Airshow**
15 – 21 June 2009
Le Bourget
Paris
http://www.paris-air-show.com/

**Eurosatory**
14 – 18 June 2010
Paris-Nord Villepinte
Paris
www.eurosatory.com

**UAS 2009 – Unmanned Aircraft Systems**
11th International Conference & Exhibition
9 – 11 June 2009
Paris
www.uas2009.org

## North America

**AUVSI's Unmanned Systems North America 2009**
10 – 13 August 2009
Washington Convention Centre
Washington DC
http://symposium.auvsi.org/

## Middle East

**The International Defence Exhibition & Conference (IDEX)**
22 – 26 February 2009
National Exhibition Centre
Abu Dhabi
UAE
http://www.idex2009.com/

## Asia Pacific

**UV Pacific 2008 (including Heli-Pacific conference and exhibition)**
27 – 29 May 2008 (dates for next show not yet announced)
Crowne Plaza Royal Pines Resort
Ross St, Ashmore, QLD 4214, Australia
Tel: +61 7 5597 1111
UK contact: +44 (0)1628 606995

## 7. UK Market Participation

### Market Background

Military procurement of UAV technology in the UK is of course managed through the Ministry of Defence. The principal end-user is the Army, in particular the Royal Artillery, who utilize the craft mainly for ISTAR-related activities. The tendency in the UK military is to seek upgrading, refinement and integration of existing technologies, rather than the introduction of entirely new systems. For example, the MoD is looking for enhanced data encryption from the Watchkeeper UAV as compared to its predecessor, the Hermes. Similarly, the MoD will require ground control systems that are interoperable with a range of UAVs instead of relying on a single proprietary system.

There is apparent resistance within the MoD to extensive procurement of UAV technology from US manufacturers. The reasons for this are not explicit, but it is likely to involve a desire to maintain some level of technical capability independent of the US. In any case, US defence contractors in the UK have expressed some frustration at lack of access to MoD UAV programmes.

### UK UAV Market Estimates

The Teal Group forecasts European UAV production at 4,000 units over a 10-year period to 2017, equating to 400 units per annum. The total value of 10-year production is estimated at $4.8 billion for Europe which equates to an average value per unit of $1.2 million. UK production is estimated at around 30% of total European production, which would produce a production value of $1.4 billion over 10 years, or $140 million per year using the same average value of $1.2 million per unit.

UK market forecasts are based on the information supplied by the Teal Group and broadly equate to known programmes in addition to other growth factors.

**Estimated UK market value including R&D and procurement, 2008 – 2017**
**($ millions)**

| Segment | Value 2008 – 2017 | Averge annual value |
|---|---:|---:|
| R&D | 450 | 45 |
| Procurement | 1,400 | 140 |
| **TOTAL** | **1,850** | **185** |

*Source: Teal Group/ICG Ltd.*

## Key UK Suppliers

The following are major UK participants in the UAV market.

**BAe Systems**
www.baesystems.com

BAE Systems is a leading contractor in the UK MOD's SUAV(E) Programme together with Qinetiq, Rolls-Royce and Smiths Aerospace. The programme is focused on addressing technology, systems and integration issues and is based on BAEs Raven UAV demonstrator programme, Nightjar 1 and 2 and other risk reduction programmes. The company's own UAV development programmes include Taranis, Corax, Raven and the Herti development.

BAE Systems is the third largest defence and aerospace company in the world and delivers a full range of products and services for land, naval and air forces, as well as advanced electronics and information technology solutions. Company sales revenues exceeded £15.7 billion in 2007. Principal locations for UAV development in the UK are BAe Systems Avionics in Rochester, and BAe Systems Air Systems, Warton, Lancashire.

**Cranfield Aerospace**
www.cranfieldaerospace.com

Cranfield Aerospace is a commercial spin-out from Cranfield University. With a corporate focus on general aerospace engineering, the company provides a range of research and development services to UAV manufacturers and prime contractors, including rapid prototyping, technology insertion, and full product development.

**Flight Refuelling Ltd.**
www.flight-refuelling.com

Flight Refuelling is part of Cobham Air Refuelling & Auxiliary Mission Equipment Division. The company specialises in aerial refuelling system, fluid systems, and air traffic control products. In the UAV market the company is a major subcontractor for the Phoenix UAV Surveillance and Targeting System (prime BAe Systems) with responsibility for the vehicle itself as well as the launcher and transport containers.

**QinetiQ Ltd**
www.qinetiq.com

QinetiQ supplies the ultra-lightweight Zephyr HALE (high altitude long endurance) UAV. Powered by solar power that is recharged by solar batteries during the day, this machine recently achieved a 54-hour flight to record the longest duration UAV flight in the world. The Zephyr is hand-launched and weighs only 30kg, with an 18 metre wingspan. The development programme is designed to permit long-endurance flights of up to three months.

The company is a leading UK-based international defence and security technology organisation that provides solutions, products and technologies to relevant government departments and agencies worldwide, as well as to major multinationals.

**Rolls-Royce**
www.rolls-royce.com

Better known for its jet aviation engines, Rolls-Royce is active in providing engines and propulsion systems for UAVs. These include traditional jet-type engines such as those for the Global Hawk system. The company also provides power for vertical take-off and landing UAVs, and its latest application is the Northrop Grumman Fire Scout in development for the US Army and Navy.

**Selex Sensors & Airborne Systems**
www.selex-sas.com

Part of the Finmeccanica group of companies, Selex is a major European defence contractor. The company has a key systems integration capability for UAVs, including sensors, airframes, control stations and communications networks. The OTUS and STRIX electrical mini UAS units are designed for short-range tactical support. Both are man-portable including the ground station. The ASIO system is a mini vertical take-off and landing unit specially designed for 'hover and stare' requirements to support forward scouting.

**Thales UK**
www.thalesgroup.com/uk

Thales UK is developing the UK's Watchkeeper tactical UAV surveillance system, which is the largest in Europe and provides capabilities in Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR). The system, valued at £700 million, comprises WK450 UAVs with an endurance of over 16 hours and is due to become operational in 2010. The company has a joint venture with Elbit Systems (Israel) based in Leicestershire to manufacture, support and upgrade tactical UAV subsystems for Watchkeeper and other UAV systems.

Thales UK is also involved in other UAV ventures, most notably teaming with Boeing and Qinetiq to undertake a series of tests with Boeing's Scan Eagle under the auspices of the UK's JUEP (Joint UAV Experimentation Programme).

The Thales Group is based in France and operates in over 60 countries worldwide, describing itself as a world leader in mission-critical information systems. The company generates almost 80% of its revenues outside France.

**Ultra Electronics**
www.ultra-electronics.com

A developer of tactical communications systems, sonar systems, and related information and network systems for land, sea, and air-based craft, Ultra are active in providing specialist systems for UAVs. These include high-integrity data links for UAVs and UCAVs, and data link modelling, analysis, and support for the Watchkeeper programme in the UK. In the US, Measurement Systems Inc. develops human-computer interface equipment for UAV control systems.

### Key Foreign Investors in UK UAV

Foreign investment related to UAVs in the UK is currently limited. In practice, most of the companies involved in the industry are present in the UK in a general defence contracting capacity, and their interest in participating in the UK UAV market is a small part of this wider objective.

| | | | |
|---|---|---|---|
| The Agent Oriented Software Group | USA | Cambridge | Software development |
| Airborne Systems | USA | Llangeinor, Wales | Parachutes, aerial delivery platforms, UAV recovery systems |
| Boeing | USA | Bristol | Development of ScanEagle ISR UAV |
| General Dynamics | USA | Newport | Control & communications systems |
| Lockheed Martin | USA | Farnborough | Control & communications systems |
| Northrup Grumman | USA | Fareham | Control & communications systems |

### UK Government Support

*ASTRAEA*

ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation and Assessment) is a UK programme focusing on the technologies, systems, facilities, and procedures for operating Unmanned Airborne Systems safely and effectively in UK airspace. The programme is part of a wider UK strategy to build on the strengths of the UK aerospace industry, supporting enhanced collaboration between industry, academia, and government bodies in order to deliver long-term economic growth and high-value jobs.

The programme is concentrated on establishing an operational environment in which UASs may be deployed routinely alongside civil manned flights without special restrictions or regulations. To achieve this, ASTRAEA comprises 16 projects covering vehicle technologies themselves, facilities required for UAV operation, and regulatory issues relating to safe operation. The projects are collaborative efforts between small groups of industry and academic stakeholders. A full list of programme stakeholders is presented below.

**ASTRAEA Stakeholders**

| Industry | Academia | Public Sector/Other |
|---|---|---|
| Agent Oriented Software<br>BAE Systems<br>EADS UK<br>Flight Refuelling<br>Qinetiq<br>Rolls-Royce<br>Thales | Bath University<br>Cranfield University<br>Lancaster University<br>Loughborough University<br>University of the West of England<br>University of Aberystwyth<br>University of Leicester<br>University of Sheffield | SBAC<br>UAVS<br>BERR (DTI)<br>Department for Transport<br>Ministry of Defence<br>Northwest Regional Development Agency<br>Scottish Enterprise<br>South East of England Development Agency<br>South West of England Development Agency<br>Welsh Assembly Government |

*Source: SEEDA*

The ASTRAEA programme is the first of its kind in Europe, and is expected to establish a basic framework for the safe, reliable, and efficient operation of UAVs in civilian airspace. Phase 1 of the programme runs from December 2005 to December 2008 and is focused on clarifying issues pertaining to the operation of UAVs in civilian airspace and pursuing relevant research and simulation activities. The first phase of the programme was funded to a level of £32 million, with approximately half the funds provided by public sector bodies and the remaining funding supplied by industry partners.

A proposed ASTRAEA Phase 2, with the objective of demonstrating flight capabilities in non-segregated airspace, has been suggested for start-up in 2009 or possibly early 2010. At present, no budget figure has been named and it is anticipated that a delay in approving public funding may occur; in this case it may be necessary for the major industry partners to assume greater responsibility for programme funding if ASTRAEA is to continue.

*FLAVIIR*

The FLAVIIR (flapless air vehicle integrated industrial research) project is a 5-year programme encompassing research and development into future UAV technologies. Jointly funded by BAE Systems and the EPSRC, the goal of the programme is 'to develop technologies for a maintenance free, low cost UAV without conventional control surfaces and without performance penalty over conventional craft'. The £6.2 million allocated to the programme is split between a three-year research phase followed by a two-year demonstration phase.

Managed by Cranfield University, the programme partners include the universities of Leicester, Liverpool, Manchester, Nottingham, Southampton, Swansea, Warwick, York, and Imperial College London. The project began in 2004 and, at its three-year review by BAE Systems, the teams were reported as having made significant advances in the realms of robustness and reliability of the craft, coupled with reduced complexity and cost of ownership.

*Worldwide Universities Network Intelligent UAV Group*
www.wun.ac.uk/iuav/index.html

The Worldwide Universities Network facilitates collaboration across a range of disciplines for both research and educational purposes. The research group for Intelligent Uninhabited Aerial Vehicles (IUAV) comprises individuals and small teams focused on projects including UAV power systems, navigation and control systems, and systems integration. UK universities are well-represented within the research themes. The project is also expected to greatly facilitate cooperation between US and UK researchers in particular.

The project leader is Professor Costas Soutis, Head of Aerospace Engineering at the University of Sheffield. Partners from the UK include:

- University of Bristol, Department of Aerospace Engineering
- University of Leeds, Faculty of Engineering
- University of Manchester, School of Mechanical Aerospace & Civil Engineering
- University of Sheffield, Department of Aerospace Engineering
- University of Southampton, Department of Engineering Sciences
- University of York, Electronic Engineering in the Department of Electronics

The Advanced Manufacturing Research Centre in Sheffield is also active in research relating to the Manufacturing research theme.

## UK Centres of Excellence

### Parc Aberporth

Originally a military airfield, the site became part of the Defence Evaluation Research Agency (DERA) and was used as a missile testing complex.
Parc Aberporth was officially launched as a UAV centre of excellence in 2004, incorporating testing and development capabilities for both military and civil UAVs. The technology park is next to West Wales Airport, and currently the site has the UK's only civil-licensed airfield approved for UAV flights.

The site comprises a technology park with space available for leasing or bespoke building. A specialist UAV support team is available to provide guidance on identifying appropriate UK-based expertise or to help manage financing issues. Technical guidance and support can also be provided, particularly in the field of practical UAV deployment. Financial assistance is available, including investment and loan opportunities.

In 2006, Qinetiq and West Wales Airport formed a partnership to establish the West Wales UAV Centre to provide guidance on UAV deployment to both military and civilian operators. In addition to providing advice on design, technical, and safety issues, the Centre will assist approved operators through the provision of specialist facilities for test flights. The objective of the Centre is to facilitate more widespread deployment of UAVs, moving beyond segregated airspace into more broadly-based applications.

### Academic research base

The UK possesses a major academic resource relating to basic research into key enabling technologies for UAVs.

**Aberystwyth University**
Old College
King Street
Aberystwyth SY23 2AX
Tel: +44 1970 623 111

Aberystwyth University has a range of expertise in UAV technology, including modelling and simulation of vehicle performance, novel navigation techniques for remote or hazardous environments, and interpretation and modelling of remotely-sensed data. The University collaborates with Boeing and Qinetiq in the development of UAVs for agricultural and environmental mapping. The craft, which have a three-meter wingspan, collect data from a range of sensors including hyperspectral cameras in order to monitor diverse parameters such as biodiversity, fertilizer requirements, or local pollution. Additionally, the Intelligent Robotics Group is active in research into 'aerobots', helium balloons with payloads guided by artificial intelligence. The aerobots are intended to provide surveying capabilities for a future Mars mission. The team is led by Dr. David Barnes.

**Cranfield University**
Defence College of Management and Technology (DCMT)
Shrivenham
Swindon SN6 8LA
Tel: +44 1234 750 111

DCMT is a partner in the ASTRAEA programme, in which its work is focused on the development of Collision Avoidance System algorithms governing the decision-making of multiple UAVs both within a swarm and in relation to other air traffic. Additional research interests within the College include systems for energy conservation for both UAVs and autonomous ground vehicles. There is also a specific focus on overcoming the challenges of operating UAVs in crowded urban environments where differing patterns of wind shear create problems of control and avoidance very different to those present in battlefield conditions.

**Lancaster University**
Bailrigg
Lancaster LA1 4YW
Tel: +44 1524 56201

Relevant research at Lancaster is focused primarily on issues of path planning and collision avoidance. This encompasses work in signal processing, optical sensor networks, and adaptive routing. This research is applied in the ASTRAEA programme, and the Principal Investigator for Lancaster is Dr. Plamen Angelov.

**University of Leicester**
University Road
Leicester LE1 7RH
Tel: +44 116 252 2522

UAV research is concentrated within the Department of Engineering. The university, in collaboration with three Indian institutions, was awarded a grant in 2007 by the UK-India Education and Research Initiative to develop novel control technologies for UAVs and micro-satellites used in rescue and disaster management scenarios. The team is led by Professor Ian Postlethwaite. Related research has been focused on the development of biologically-inspired sensor and control systems for chemical analysis required in environmental monitoring.

**Loughborough University**
Leicestershire LE11 3TU
Tel: +44 1509 263 171

Through its participation in ASTRAEA research at Loughborough focuses on system hazard identification and modelling, enabling a UAV to monitor its own state and perform an analysis of immediate and future capabilities. This research also encompasses autonomy hazard identification, enhancing the UAV's capability to identify, model, and react appropriately to potential hazards. This work is supervised by Professor Paul Chung. Relevant research at the university is also carried out by Professor John Andrews, Professor of Systems Risk and Reliability, who has interests in UAV flight and mission reliability modelling. Professor Michael Henshaw, Professor of Systems Engineering, organised the FLAVIIR research programme into UAV technology. The university is also developing a UAV lab to support research into navigation, flight control, and mission planning for UAVs.

**University of Sheffield**
Western Bank
Sheffield S10 2TN
Tel: +44 114 222 2000

Dr. Tony Dodd of the Department of Automatic Control and Systems Engineering is presently working on the development of a mini-UAV specifically for use in urban environments. The quad-rotor mini-UAV is designed to be more stable and manoeuvrable, as well as efficient in terms of power use. It is anticipated that the craft will have a very wide range of civil and commercial uses. Dr. Dodd is additionally active in the development of systems for autonomous control of multiple UAV platforms. A colleague, Professor Christian Boller of the Department of Mechanical Engineering, is also a leading researcher in the design of micro aerial vehicles.

**University of the West of England**
Bristol Institute of Technology
Frenchay Campus
Coldharbour Lane
Bristol BS16 1QY
Tel: +44 117 328 3156

The Bristol Institute of Technology, a faculty of the University, is the focus of UAV-related research. Activity in the field of mobile robotics is concentrated on developing systems able to function intelligently with minimal human intervention, and this work is actively applied to the UAV field.

**Bristol Robotics Laboratory**
DuPont Building
Bristol Business Park
Coldharbour Lane
Frenchay
Bristol BS16 1QD

Professor Chris Melhuish, Director
Tel:  +44 117 328 6334 (direct line to Dr. Melhuish)

The Bristol Robotics Laboratory is a collaborative venture operated by UWE Bristol University, and HEFCE, and research interests have many applications in the UAV sector.  The Laboratory is active in research relating to simultaneous location and mapping (SLAM), which enables a vehicle to explore and navigate territory while retaining its ability to find its way back to base.  The Laboratory is also conducting research into dynamic soaring modelled on the flight of the albatross, considered to be a means of overcoming endurance limitations of small UAVs.  This research is conducted by Dr. A.G. Pipe.  Further relevant research relates to control algorithms governing the swarming activity of flocks of flying autonomous robots.
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**UK UAV-related Clusters/Regional Centres**

The wide-ranging strengths of the aerospace and defence industries in the UK have supported the development of UAV capabilities throughout the country. As outlined above, academic research expertise in disparate elements of UAV-related technology exists at diverse locations throughout the UK. Industry-driven expertise, however, is heavily concentrated in specific geographic regions, and this is actively supported by relevant national government or regional development agencies.

*West Wales*

The west of Wales is the location of the Parc AberPorth technology park, identified above as the UK's key centre of excellence for the development and testing of UAV technology.  The nearby universities of Aberystwyth and Swansea are also active participants in industry research.

*Southeast England*

The South East of England Development Agency (SEEDA) is a stakeholder in the ASTRAEA programme, and its involvement in the UAV industry is driven by an aerospace strategy document prepared by the Farborough Aerospace Consortium on SEEDA's behalf.  SEEDA has been particularly interested in encouraging SMEs to become more involved in the UAV supply chain by working with and supplying to major industrial partners, and the agency reports that approximately 20 small companies became more closely involved in the industry under the aegis of ASTRAEA.  Key UAV industry participants in the region include Qinetiq, Selex Sensors & Airborne Systems and VTOL Technologies.

*Northwest England*

The North West Aerospace Alliance (NWAA) promulgated its most recent cluster strategy in 2007, in which it identified the non-military market for UAVs as a key growth segment with the aerospace industry. Major UK industry participants, including BAE Systems and Rolls Royce, are located in the region, and the North West Development Agency is an investor in the ASTRAEA programme. Although a depth of aerospace capability exists in the region, the NWAA assesses that academic and industry activities in this area are currently neither well-coordinated nor sharply focused. The association has developed an action plan to address these perceived weaknesses by initially encouraging cooperation between universities and private industry.

*Southwest England*

In addition to academic expertise based in Bath and Bristol, the southwest of England is home to a number of aerospace companies actively involved in UAV development. These include Rolls Royce in Bristol, Thales in Wells, and Flight Refuelling (part of Cobham Air Refuelling & Auxiliary Mission Equipment Division) in Wimbourne. The South West Regional Development Agency is an investing stakeholder in the ASTRAEA programme. As in other regions, a key objective of participation is to draw SMEs into the UAV supply chain, thereby strengthening the region's capabilities on a broader front.

## Networks and Trade Associations

**Unmanned Aerial Vehicle Systems Association (UAVS)**
The Granary
1 Waverley Lane
Farnham, Surrey GU9 8BB
Tel: +44 1252 732 577
www.uavsuk.com

UAVS is the UK trade association providing a focus of activity for organisations active in R&D, manufacture, testing, and operation of autonomous aerial systems, as well as related sub-systems and components. In addition to providing a locus for industry networking and information exchange, UAVS maintains contact with the UK government and international organisations to support and influence the development of a regulatory and legislative framework for UAV operation.

**Farnborough Aerospace Consortium**
The Silver Building, Ively Road
Farnborough Airport, Farnborough
Hampshire GU14 6XA
Tel: +44 1252 375 600
www.fac.org.uk

The Farnborough Aerospace Consortium has a specialist group dedicated to the promotion of UAV technologies in the region, and is particularly active in encouraging SMEs to collaborate on development projects with larger organisations. FAC has been particularly proactive in working with SEEDA to involve SMEs in the industry.

**Society of British Aerospace Companies (SBAC)**
Salamanca Square
9 Albert Embankment
London SE1 7SP
Tel: +44 20 7091 4500
www.sbac.co.uk

SBAC is the principle trade association for aerospace companies in the UK. The association has a special interest group relating to UAVs.

**Skills, Training and Support**

Given the fact that the civil UAV market is currently in its early stages and existing government support is directed to primary research, there no current scope for skills training of the type identified in other industry sectors. Available support in the UK has largely been covered in other sections of the report. However, one regional network does exist to provide participants with a forum in which to discuss relevant issues.

**MARVIN Knowledge Network for Autonomous Systems**
Contact: Guy Horsley

This network, funded by SEEDA, is intended to provide a framework for the exchange of technical and market information and awareness relating to all types of autonomous system, including marine, land-based, and aerial. The longer-term aim of the network is to encourage companies and research institutions to collaborate on technical problem-solving with the aim of strengthening UK capabilities.

# 8. Opportunities for Inward Investment

## Advantages for UK Investment

*Research base*

The UK possesses a major academic resource in terms of ongoing research into many different aspects of UAV development. These institutions are experienced in collaborative research programmes with industry and other academic bodies. UK academics are also active on international programmes and recognised for their expertise.

*Centre of Excellence*

The ParcAberporth centre provides a competitive base for all types of UAV development, particularly late-stage test flights. This dedicated capability is not readily available in much of continental Europe, and sets the UK apart as a centre for integrated industry R&D.

## Barriers to UK Investment

Significant barriers exist to inward investment in the UK UAV industry.

*Market size and structure*

As outlined above, the overall UK UAV market size is relatively limited. Its heavy defence orientation makes entry difficult for new participants without strong partnerships with existing prime contractors.

*European technology development*

Significant national competition in UAV technology exists in Europe. France is a leader in UAV development, and Germany is aggressively pursuing smaller-scale yet sophisticated programmes with a goal of dramatically enhanced system autonomy. The German subsidiary of EADS is currently leading the Advanced UAV project, a tri-national cooperative programme between Germany, France, and Spain. Finland has also expressed an interest in joining the programme as a potential provider of data-link technology.

The Advanced UAV is intended to be a step forward from current technologies, as it is anticipated to comprise a standard airframe with a range of wing and payload options allowing the craft to be optimised for specific missions. The German defence procurement agency awarded a contract to EADS for this programme in late 2007, and the German air force regards the craft as a first step towards a high-performance unmanned air combat vehicle.

The UK pursues its own course of action in the development of UAV technology, and is largely uninvolved in European cooperative programmes. This may pose a challenge to attracting investment into the UK, as key competitor nations can demonstrate not only comparable levels of technology but may, through cooperative activity, offer enhanced access to the European UAV market as a whole.

*Atlantic competition*

Unsurprisingly, the UK is not the only country to have identified UAVs as a key future aerospace technology, nor is it alone in its desire to build on existing national strengths. Although the US can claim leadership in the sector by the sheer weight of development activity, significant competition is emerging around what can described as the 'Atlantic rim'. In Canada, a UAV Test & Coordination Centre has been set up at Goose Bay in Newfoundland, and a UAV Technology Development Park is in place in Nova Scotia. Both locations boast plenty of open space for flight testing, and also claim that extremes of weather encountered in the region make for robust testing conditions. The Canadian centres are positioning themselves as gateways to the North American market while simultaneously strengthening relationships with UAV developers in Europe, and a delegation from the UK recently visited the region.

Closer to home, the North European Aerospace Test (NEAT) range in northern Sweden offers facilities for the testing of all types of civil and defence craft, including UAVs. At 25,000 square kilometres the range is the largest in Europe, and as the surrounding area is almost entirely unpopulated it can be used for UAV demonstration flights as well as UCAV tests involving live firing. The facility has been established since the 1950's, and as a consequence attracts much testing activity from across Europe.

A newer facility has also emerged in Finland in 2005 - 2006. Robonic Ltd. Oy has established the Arctic Test UAV Flight Centre (RATUFC) in Kemijarvi, Finland, which again benefits from both open space and the capacity to subject craft to extreme temperatures in test flights. The newest generation of Sagem Sperwer UAVs have been tested on this site.

On a more positive note, the UK is recognized particularly by the Canadians as a major competitor in the sector, and both Parc AberPorth and Farnborough are identified as key locations for UAV development.

## Case Studies in Inward Investment

Given the military nature of the current UAV market and the fact that commercial markets are still in their infancy, traditional forms of inward investment in the sector are not well developed. Additionally, the development of UAV technology out of related aerospace materials and systems by companies already involved in defence and aerospace markets makes it difficult to identify investment as specific to UAV markets.

However, some specific investments are emerging as the market develops. Selex Sensors and Airborne Systems UK (Selex S&AS) established a flight test and trials facility at Parc AberPorth in 2006. The company's activity at AberPorth encompasses both UAV technology and payloads, particularly sensor systems and ground control stations. Selex had reportedly assessed sites elsewhere in Europe, but favoured the Welsh technology park because it offered a combination of flight test facilities and specialist technical support that is currently unique on the continent. An additional supporting factor was the proximity of MOD customers, who represent a major market for the company's systems.

In this context it is also appropriate to consider existing measures for international cooperation that are likely to set the scene for investment as markets mature. The Neuron programme is a useful case in point. Led by the French DGA defence procurement agency, the programme brings together expertise from six European countries:

- Dassault Aviation (France): Prime contractor, general design authority, flight controls, final assembly, static and flight testing
- Saab (Sweden): overall design, fuselage, avionics, fuel system, flight testing
- EADS Casa (Spain): wing, ground control station, data-link integration
- Alenia Aeronautica (Italy): weapon firing system, air data system, electrical system, flight testing
- RUAG Aerospace (Switzerland): wind tunnel tests, weapons carriage
- HAI (Greece): rear fuselage, tail pipe, systems integration bench

The programme's aims are threefold:

1. The first is to maintain and develop the skills of the participating European aerospace companies' design offices, which will not see any other new fighter programs before 2030 now that the Dassault Rafale, Eurofighter Typhoon, and F-35 Joint Strike Fighter projects are all complete or well underway.
2. The second goal is to investigate and validate the technologies that will be needed by 2015 to design next-generation combat aircraft.
3. The final aim is to validate an innovative cooperation process by establishing a European industry team responsible for developing next-generation combat aircraft.

Although these objectives refer clearly to requirements relating to combat aircraft, a spokesperson for prime contractor Dassault claims that the programme is in fact not military. As reported in Defense Industry Daily, a Dassault press release specifies that the programme is not about developing new weapons systems, but focused on proving the capabilities of systems to show that an unmanned craft can operate at the same high level as a manned craft.[3] Reading between the lines, it seems likely that the Neuron programme is intended to facilitate wider UAV operability through integrated partnerships modelled on defence contracts.

## 9. Conclusions and Next Steps

Making definitive statements about the direction of the UAV industry is both challenging and risky, as the sector is currently undergoing a simultaneous step-change in technology, regulatory environment, and market scope. Furthermore, development of the civil side of the industry will rely on the integration of a wide range of technologies from disparate organisations and a concomitant reorientation to a commercial point of view.

It should be noted that, as the military market for UAVs is driven by military applications and requirements, the development of a civil UAV market is equally dependent on applications and requirements. The regulatory framework is being put in place, but the market cannot develop to its full potential until significantly more substantial investment is made specific to civil applications together with the accompanying technologies.

### Key Conclusions

- The development of technology facilitating the safe operation of UAVs in non-restricted airspace is very dependent on the emerging regulatory framework. This in turn is proceeding slowly, and it is likely to be at least 5 – 7 years before rudimentary civil UAV flights are in any way routine in the UK or any European market.

- The current UAV market is heavily defence-focused and will remain so for the foreseeable future. Although the civil market is expected to grow significantly, it will do so from a very low initial base and the overall global market size will remain small in contrast to other segments of the aerospace industry.

- Although inward investment does take place within the defence industry itself, this is largely driven by upcoming contract opportunities or by the requirement to provide greater support to partners in-country. The UK MoD market for UAVs, is largely concentrated in the hands of companies such as Thales and BAe Systems. US contractors have had little success in gaining access to this market, and there is reported reluctance within the MoD to involve such companies closely in UAV programmes. Efforts to attract prime contractors to the UK on the strength of the domestic defence market are therefore unlikely to be fruitful. Defence subcontractors would need to secure appropriate partnerships with UK primes in order to participate in the market.

- The civil and commercial markets for UAVs are developing slowly, with short- to medium-term constraints relating to both technology and regulation. However, this is the right time to consider the UK's role in the global development of the UAV industry: competitor nations in both Europe and North America are funding programmes and projects to extend their own national capabilities, with a view to positioning themselves for the anticipated boom in new UAV applications once the commercial markets begin to take shape.

- The UK possesses a strong research base in many aspects of UAV-related technology. The potential for partnerships with these institutions may operate as an attraction to encourage establishment of UK R&D facilities.

- Market participants supplying sub-systems are more likely to find the UK an attractive market. However, many of these companies are active in a range of defence or aerospace activities and do not necessarily have a specific focus on UAVs. In any case the number of capable subcontractors is limited. For this reason it may be necessary to take a broader view of UK opportunities to attract some companies.

Effectively, the UK currently possesses a defence-focused UAV market that is likely to be difficult for new entrants to access, while the civil market is undeveloped. Under these circumstances it is difficult to identify a commercial rationale for encouraging foreign direct investment in the sector; however, it is equally difficult to argue that a market in an early stage of development is inherently unworthy of attention.

A useful paradigm for considering the most effective means of attracting inward investment is comparison with other market sectors that have undergone similar stages of development. For example, the nascent North Sea oil and gas industry was initially developed by attracting large oil majors, both domestic and foreign, to provide initial investment and this in turn encouraged smaller participants to provide supporting services. Similarly, the UK electronics industry was initially boosted by significant inward investment from large US and Japanese companies, which then supported the development of subcontract services. Although there has been a significant level of divestment from the UK, principally for reasons relating to the international market for electronic components, a reservoir of R&D and manufacturing capability and individual skills still exists to support other key UK industry sectors.

**Appendix A**

## Endnotes

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**Appendix B**

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**Appendix E**

## Industry Terminology and Acronyms

| | |
|---|---|
| ASTRAEA | Autonomous Systems Technology Related Airborne Evaluation and Assessment |
| ATM | Air traffic management |
| DARPA | |
| DoD | Department of Defense (USA) |
| EASA | European Aviation Safety Agency |
| ELOS | Equivalent Level of Safety |
| FLAVIIR | Flapless Air Vehicle Integrated Industrial Research |
| HALE | High Altitude Long Endurance |
| ISTAR | Intelligence, Surveillance, Target Acquisition and Reconnaissance |
| ITAR | Intelligence, Target Acquisition and Reconnaissance |
| MALE | Medium Altitude Long Endurance |
| MAV | Micro air vehicle |
| MoD | Ministry of Defence (UK) |
| UAS | Unmanned aircraft system |
| UAV | Unmanned aerial vehicle |
| UCAV | Unmanned combat aerial vehicle |
| VTOL | Vertical take-off and landing |