UNMANNED AERIAL VEHICLES

This extract covers a miscellany of aerospace subjects starting with UAVs and concluding with Richard Branson's Virgin Orbit company which filed for bankruptcy in 2023 following the failed satellite launch earlier this year.

A UAV is an aircraft without a human pilot on board and is a component of an unmanned aircraft system (UAS) which includes a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy, either under remote control by a human operator, or autonomously by onboard computers. Compared to crewed aircraft, UAVs were originally used for missions "too dull, dirty or dangerous" for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural, and other applications, such as policing and surveillance, product deliveries, aerial photography, infrastructure inspections, smuggling, and drone racing. Civilian UAVs now vastly outnumber military UAVs.

UAVs typically fall into one of six functional categories (although multi-role airframe platforms are becoming more prevalent):

- Target and decoy – providing ground and aerial gunnery targets that simulate an enemy aircraft or missile.
- Reconnaissance – providing battlefield intelligence.
- Combat – providing attack capability for high-risk missions.
- Logistics – delivering cargo.
- Research and development – to improve UAV technologies.
- Civil and commercial – agriculture, aerial photography, data collection, etc.

Vehicles can be categorized in terms of range/altitude:

- Hand-held 2,000 ft (600 m) altitude; about 2 km range.
- Close 5,000 ft (1,500 m) altitude; up to 10 km range.
- NATO type 10,000 ft (3,000 m) altitude; up to 50 km range.
- Tactical 18,000 ft (5,500 m) altitude; about 160 km range.
- MALE (medium altitude, long endurance) up to 30,000 ft (9,000 m); over 200 km.
- HALE (high altitude, long endurance) over 30,000 ft (9,100 m); indefinite range.
- Supersonic (Mach 1–5) or hypersonic (Mach 5+) 50,000 ft (15,200 m) or suborbital altitude; range over 200 km.
- Orbital low earth orbit (Mach 25+).
- CIS Lunar Earth-Moon transfer.
- Computer Assisted Carrier Guidance System (CACGS) for UAVs.

Manned and unmanned aircraft of the same type generally have recognizably similar physical components. The main exceptions are the cockpit and environmental control system or life support systems. Some UAVs carry payloads (such as a camera) that weigh considerably less than an adult human, and as a result can be considerably smaller. Additionally, those that carry heavy payloads such as weaponized military UAVs are still lighter than their manned counterparts with comparable armaments.

Small civilian UAVs have no life-critical systems, and can thus be built out of lighter but less sturdy materials, and can use less robustly tested electronic control systems. For small UAVs the quadcopter design has become popular (and see below on flying car designs). Miniaturization means that less-powerful propulsion technologies can be used that are not feasible for manned aircraft, such as small electric motors and batteries.

Control systems for UAVs are often different from manned craft. For remote human control, a camera and video link almost always replace the cockpit windows; radio-transmitted digital commands replace physical cockpit controls. Autopilot software is used on both manned and unmanned aircraft.

In the military sector, American Predators and Reapers are made for counter-terrorism operations and war zones in which the enemy lacks sufficient firepower to shoot them down. They are not designed to withstand anti-aircraft defences or air-to-air combat. In 2013 the chief of the US Air Combat Command stated that current UAVs were "useless in a contested environment" unless crewed aircraft were there to protect them. A 2012 Congressional Research Service (CRS) report speculated that, in the future, UAVs may be able to perform tasks beyond intelligence, surveillance, reconnaissance and strikes; the CRS report listed air-to-air combat ("a more difficult future task") as a possible future undertaking. The Department of Defense's Unmanned

Systems Integrated Roadmap FY2013-2038 foresees a more important place for UAVs in combat. Issues include extended capabilities, human-UAV interaction, managing increased information flux, increased autonomy and the development of UAV-specific munitions. DARPA's project of systems of systems, or General Atomics' work may augur future warfare scenarios, the latter disclosing Avenger swarms equipped with High Energy Liquid Laser Area Defense System (HELLADS). The global military UAV market is dominated by companies based in the United States and Israel. By sale numbers, the US held over 60% of military market share in 2017. Four of the top five military UAV manufactures are American: General Atomics, Lockheed Martin, Northrop Grumman and Boeing, followed by the Chinese company CASC. Israel mainly focuses on small surveillance UAV system and, by quantity of drones, Israel followed by the USA are the principal exporters of UAVs; the United Kingdom followed by India are the principal importers. General Atomics is the dominant manufacturer with the Global Hawk and Predator/ Mariner systems product-lines; the RAF has selected the new General Atomics Protector to replace its fleet of Predators.

General Atomics Protector

The civilian drone market is dominated by Chinese companies. Chinese drone manufacturer DJI alone had 74% of civilian-market share in 2018 with $11 billion forecast global sales in 2020. DJI is followed by Chinese company Yuneec, US company 3DRobotics and French company Parrot. As of March 2018, more than one million UAVs (878,000 hobbyist and 122,000 commercial) were registered in the U.S. The civilian UAV market is relatively new compared to the military one. Companies are emerging in both developed and developing nations at the same time. Many early stage start-ups have received support and funding from investors as is the case in the United States, and by government agencies as is the case in India. Some universities offer research and training programs or degrees. Private entities also provide on-line and in-person training programs for both recreational and commercial UAV use.

Consumer drones are also widely used by military organizations worldwide because of the cost-effective nature of the consumer product. In 2018, Israeli military started to use the DJI Mavic and Matrice series of UAV for light reconnaissance missions since the civilian drones are easier to use and have higher reliability. It is predicted the global UAV market will reach US$21.47 billion, with the Indian market touching US$885.7 million, by 2021. Illuminated drones are beginning to be used in night-time displays for artistic and advertising purposes.

The US Aerospace Industries Association reports that large cargo and passenger drones should be certified and introduced over the next 20 years. Sensor-carrying large drones first, then short-haul, low altitude freighters outside cities from 2025; long-haul cargo flights by the mid-2030s, and then passenger flights by 2040. Spending should rise from a few hundred million dollars on research and development in 2018 to $4 billion by 2028 and $30 billion by 2036.

Example commercial UAVs

Finally, to finish with a look at the future which is being developed now, the BAE Systems Taranis is a British demonstrator programme for unmanned combat aerial vehicle (UCAV) technology, under development primarily by the defence contractor BAE Systems Military Air & Information. The aircraft, which is named after the Celtic god of thunder, first flew in 2013. An unmanned warplane, the Taranis is designed to fly intercontinental missions, and will carry a variety of weapons, enabling it to attack both aerial and ground targets. It will use stealth technology, giving it a low radar profile, and it will be controllable via satellite link from anywhere on Earth. An operational derivative of the Taranis is expected to enter military service circa 2030.

BAE Systems' Taranis on introduction

And if you are wondering what the Lockheed Martin Skunk Works are up to (the team that built the fastest air-breathing and manned aircraft ever, the SR71) here's a peep at the SR72!

The Lockheed Martin SR-72 is an hypersonic UAV concept intended for intelligence, surveillance and reconnaissance. Lockheed Martin privately has proposed it as a successor to the retired Lockheed SR-71 Blackbird.

In June 2017, Lockheed Martin announced that the SR-72 would be in development by the early 2020s and is to top Mach 6. Executive Vice President Rob Weiss commented that "We've been saying hypersonics are two years away for the last 20 years, but all I can say is the technology is mature and we, along with DARPA and the Services, are working hard to get that capability into the hands of our war fighters as soon as possible."

In January 2018, Lockheed Martin Vice President Jack O'Banion gave a presentation that credited the advancements in additive manufacturing and computer modelling, stating that it would not have been possible to make the airplane five years ago; 3D printing allows a cooling system to be embedded in the engine.

In November 2018, Lockheed Martin stated that a prototype of the SR-72 was scheduled to fly by 2025. The aircraft will also be capable of firing hypersonic missiles.

TRANSPORT AIRCRAFT

Another very important element of military aviation is the transport aircraft, both fixed and rotary wing, and their many derivatives. In the transport role they are used to airlift troops, weapons and other military equipment to support military operations.

Transport aircraft can be used for both strategic and tactical missions, and are often diverted to civil emergency relief missions. Fixed-wing transport aeroplanes are defined in terms of their range capability or tactical airlift to reflect the needs of the land forces which they most often support. Strategic airlift occurs between military theatres, tactical within them. Some aircraft are capable of both, a good example being the Boeing C-17 Globemaster III.

Boeing C17 Globemaster III

Examples of tactical airlift aircraft are the Lockheed Martin C-130J Super Hercules, and the Airbus 400M Atlas which has a strategic capability and, in terms of size, is positioned between the C-17 and the C-130J.

Airbus A400M

And their Conversions

Specific military transport and commercial aircraft have been adapted to a variety of other roles. Using the RAF as an example, in addition to the A400M and C-130J which can be adapted for many roles, the Voyager is a multi-role tanker/ transport aircraft based on the Airbus A330.

In the realm of Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) there is: the E-3D Sentry (airborne early warning & control) derived from the Boeing 707 airframe and under consideration for replacement by an EASA-equipped platform; the Sentinel R1 (airborne battlefield & ground surveillance) based on the Bombardier Global Express airframe and adapted by Raytheon; RC-135W Rivet Joint (electronic surveillance) based on the Boeing C-135 Stratolifter airframe; and the Boeing P-8A Poseidon (anti-submarine & anti-surface warfare) developed from the Boeing 737 Next Generation. In addition, with civilian adaptions in mind, there is the Embraer Phenom 100 operating in a training role.

Boeing E-3D Sentry

Bombardier/Raytheon Sentinel R1

RC-135W Rivet Joint

Boeing P-8 Poseidon

Embraer Phenom 100

Finally, with training in mind, whilst not a civilian conversion, the Hawk, first developed by Hawker Siddeley in 1974 and now produced by BAE Systems, is one of the most successful advanced jet trainers and lightweight multi-role combat aircraft with over 1,000 built in many variations and sold to18 operators around the world. It is due for replacement by the RAF circa 2030.

BAE Systems Hawk in Red Arrows livery

ROTARY WING

Transport helicopters are operated in assault, medium and heavy classes. Air assault helicopters are usually the smallest, and are designed to move an infantry squad or section and their equipment.

Helicopters in the assault role are generally armed for self-protection both in transit and for suppression of the landing zone. This armament may be in the form of door gunners, or the modification of the helicopter with stub wings and pylons to carry missiles and rocket pods. For example, the Sikorsky S-70, fitted with the External Stores Support System, and the ***Hip E*** variant of the Mil Mi-8.

Medium transport helicopters are capable of moving up to a platoon of infantry and of being able to transport towed artillery or light vehicles either internally or as underslung loads. Unlike the assault helicopter they are usually not expected to land directly in a contested landing zone, but are used to reinforce and resupply landing zones taken by the initial assault wave. Examples include the unarmed versions of the Super Puma, and CH-46 Sea Knight.

Heavy lift helicopters are capable of lifting up to 80 troops and moving small armoured fighting vehicles (usually as slung loads but also internally); these helicopters operate in the tactical transport role in much the same way as small fixed wing turboprop aircraft. The lower speed, range and increased fuel consumption of helicopters are more than compensated for by their ability to operate virtually anywhere. Examples are the CH-47 Chinook and Mil Mi-26.

Boeing CH-47 Chinook

Staying with military helicopters a few moments longer, they are employed in a multitude of roles, some being converted transport aircraft, some being specifically built for the role. Examples of the former are: search & rescue; medical evacuation; airborne command post; observation; airborne early warning; and anti-submarine warfare. The classic example of the latter is the attack helicopter.

AgustaWestland AW101 with 'Crowsnest' radar deployed

Boeing AH-64E with Longbow radar to enable 'nap of the earth' flying

Civil aviation is one of two major categories of flying, representing all non-military aviation, both private and commercial. Most of the countries in the world are members of the International Civil Aviation Organization (ICAO) and work together to establish common standards and recommended practices for civil aviation through that agency.

Civil aviation includes two major elements: scheduled air transport, including all passenger and cargo flights operating on regularly scheduled routes; and general aviation (GA), including all other civil flights, private or commercial. Although scheduled air transport is the larger operation in terms of passenger numbers, GA is larger in the number of flights. In the U.S., GA carries 166 million passengers each year, more than any individual airline, though less than all the airlines combined. Since 2004, the US Airlines combined have carried well over 600 million passengers each year.

COMMERCIAL AVIATION

Commercial aviation includes most or all flying done for hire, particularly scheduled services on airlines; and private aviation includes pilots flying for their own purposes (recreation, business meetings, etc.) without receiving any kind of remuneration. All scheduled air transport is commercial, but general aviation can be either commercial or private. Normally, the pilot, aircraft, and operator must all be authorized to perform commercial operations through separate commercial licensing, registration, and operation certificates.

The Convention on International Civil Aviation (the "Chicago Convention") was originally established in 1944; it states that signatories should collectively work to harmonize and standardize the use of airspace for safety, efficiency and regularity of air transport. Each signatory country, of which there are at least 193, has a civil aviation authority (such as the CAA in the United Kingdom) to oversee the following areas of civil aviation:

- **Personnel licensing** - regulating the basic training and issuance of licenses and certificates.
- **Flight operations** - carrying out safety oversight of commercial operators.
- **Airworthiness** - issuing certificates of registration and certificates of airworthiness to civil aircraft, and overseeing the safety of aircraft maintenance organizations.
- **Aerodromes** - designing and constructing aerodrome facilities.
- **Air traffic services** - managing the traffic inside of a country's airspace.
- **Security**.

The principal commercial aircraft manufacturers are:

- Airbus, one of the world's leading aircraft manufacturers fulfilling half or more of the orders for airliners with more than 100 seats. With headquarters in Toulouse, France, the company employs about 52,000 people in 12 major sites around the world. Current airliner models are:
  - *A220 Family*
  - *A320 Family*
  - *A330 Family*
  - *A350XWB Family*
  - A380

Airbus A350XWB

- Boeing, the other major commercial airliner manufacturer, is headquartered in Chicago, USA. The company employs circa 158,000 people. Current airliner models are:
  - Boeing 737 Next Generation
  - Boeing 737 Max
  - Boeing 747-8
  - Boeing 767
  - Boeing 777
  - Boeing 777X
  - Boeing 787

Boeing 777-9X

- Bombardier, the world's third largest civil aircraft manufacturer in respect of business, regional and amphibious aircraft. The company is headquartered in Montreal, Canada, employing circa 32,500 people. Current regional jet models are:
  - CRJ550
  - CRJ700
  - CRJ 900
  - CRJ 1000

Bombardier CRJ 900

- Embraer, which has become one of the world's main aircraft manufacturers by focusing on specific market segments with high growth potential in commercial, defence and executive aviation, is headquartered in Sao Jose dos Campos, Brazil. The company employs over 17,000 people. Current regional jet models are:
  - E-Jets E2 Family
  - E-Jets Family
  - ERJ Family

Embraer E-Jets E2

- Tupolev is a Russian aerospace and defence company headquartered in Moscow employing around 18,000 people. Current commercial aircraft models are:
  - Tu 204 Family
  - TU 214 Family

TupolevTu-214

- Finally, we should not omit the Commercial Aircraft Corporation of China (Comac) which is a Chinese state-owned aerospace manufacturer established on 11 May 2008 and headquartered in Pudong, Shanghai. The company designs and manufactures large passenger aircraft with capacities of over 150 passengers in an effort to reduce China's dependency on Boeing and Airbus. The first jet to be marketed was the ARJ21 developed by China Aviation Industry Corporation I. It was followed by the C919 which made its maiden flight in 2017 and has attracted interest from Chinese airlines. The C919, which can seat up to 168 passengers, is meant to compete in the market for single-aisle jets dominated by the Airbus A320 and Boeing 737 series.

Comac C919

To conclude commercial aviation as earlier described, there are several companies currently producing appropriate turboprop aircraft. Examples are the: Antonov An-140; ATR 42 & 72; De Havilland Canada Dash 8; CASA/IPTN CN-235; Ilyushin Il-114; Xian Y-7.

ATR 72 series

GENERAL AVIATION

Turning now to General Aviation (GA), in the UK this has been defined as a civil aircraft operation other than a commercial air transport flight operating to a schedule, or military aviation. Although the International Civil Aviation Organization excludes any form of remunerated aviation from its definition, some commercial operations are often included within the scope of general aviation in the UK.

The sector operates business jets, rotorcraft, piston and jet-engined fixed-wing aircraft, gliders of all descriptions, and lighter than air craft. Public transport operations include business (or corporate) aviation and air taxi services, and account for nearly half of the economic contribution made by the sector. Other commercial GA activities are aerial work, such as surveying and air ambulances, and flight training which plays an important role in the supply of pilots to the commercial air transport (CAT) industry. Private flying is conducted for personal transport and recreation. It includes a strong vintage aircraft movement, and encompasses a range of air sports, such as racing, aerobatics, and parachuting, at which British teams and individuals have succeeded in international competitions.

Of the 21,000 civil aircraft registered in the UK, 96 per cent are engaged in GA operations, and annually the GA fleet accounts for between 1.25 and 1.35 million hours flown. The single most common class of aircraft is the fixed-wing light aircraft associated with traditional GA, but the main area of growth over the last 20 years has been in the use of more affordable aircraft, such as microlights, amateur built aeroplanes, and smaller helicopters.

There are 28,000 Private Pilot Licence holders, and 10,000 certified glider pilots. Some of the 19,000 pilots who hold professional licences are also engaged in GA activities. Although GA operates from more than 1,800 aerodromes and landing sites, ranging in size from large regional airports to farm strips, over 80 per cent of GA activity is conducted at 134 of the larger aerodromes. The GA industry, which is around 7 per cent the size of its CAT cousin, employs 12,000 people, and contributes £1.4 billion to the UK economy.

GA is regulated by the Civil Aviation Authority (CAA), although until Brexit regulatory powers were being increasingly transferred to the European Aviation Safety Agency (EASA). The main focus is on standards of airworthiness and pilot licensing, and the objective is to promote high standards of safety. At the lighter end of the GA spectrum some regulatory authority is devolved to representative bodies, and gliding is in transition from a self-regulatory model to more formal governance by EASA. We must see what happens post-Brexit.

Airspace regulation necessary to protect an increasing number of CAT operations has reduced the area in which GA flights can be freely conducted. The growth in CAT is also making access to larger airports more difficult for the GA sector, and smaller aerodromes are vulnerable to closure and re-development for more profitable uses. The UK planning system has no remit to consider the national significance of GA public transport operations, and generally does not favour the development of smaller aerodromes catering to the GA market. The planning process has become a mechanism for addressing local aerodrome-related environmental issues which, particularly regarding noise, are the main subjects of public criticism levelled at GA.

The first aerodrome in the UK was established by the Aero Club at Muswell Manor on the Isle of Sheppey, and in May 1909 it was the venue of the first flight conducted in the country by a British pilot, John Moore-Brabazon. In 1910 the Aero Club was granted the Royal prefix, took responsibility for controlling all private flying in the UK, and started issuing the first British pilot's licences. The introduction of the de Havilland DH.60 Moth in 1925 revolutionised light aviation, and the Royal Aero Club, recognising the "vital necessity of promoting civil flying", formed the Light Aeroplane Club scheme. Between 1925 and 1939 around 60 flying clubs were started, and more than 5,000 pilots were trained.

De Havilland DH.60 Moth

During World War II civil aerodromes were taken over for military use, existing military airfields were expanded, and new ones were built. This resulted in a significant inventory of facilities becoming available after the war. Pre-war civil aerodromes, for example Sywell, were returned to civilian use. Surplus military airfields were closed, and in some cases, for example Beccles, subsequently re-opened as civil aerodromes. The Ministry of Civil Aviation was created to regulate all civil aviation in the UK, and this task remained the responsibility of government departments until the establishment of the independent CAA in 1972.

With an expanded infrastructure in place, GA became established after the war when manufacturers such as Cessna and Piper introduced light aircraft designed for the private market. The Cessna 172, developed from the late 1940s Cessna 170, was introduced in 1956, and became the world's best-selling single-engine aeroplane. Single piston-engine aircraft are still the most common class of aircraft in the UK GA fleet.

Cessna 172

The development of the Rogallo wing in the 1950s fostered the development of hang-gliding during the 1960s and 1970s. The 1960s also saw experiments with motorised hang gliders, but it was not until the 1970s that this blend of technologies started to mature, resulting in the birth of the microlight movement. Another milestone in the development of GA was the 1964 introduction of the Learjet 23. Although it was not the first business jet, it popularised corporate aviation, and established the personal jet as a whole new class of aircraft.

Example motorised hang glider

Learjet 23

Modern Sailplane

Typical recreational hot air balloons

And on a more serious note:

Bombardier CL-415 amphibious fire fighter

Newquay's civilian search & rescue helicopter

HRH Price William with his East Anglian Flying Ambulance

Hybrid Air Vehicles' Airlander 10

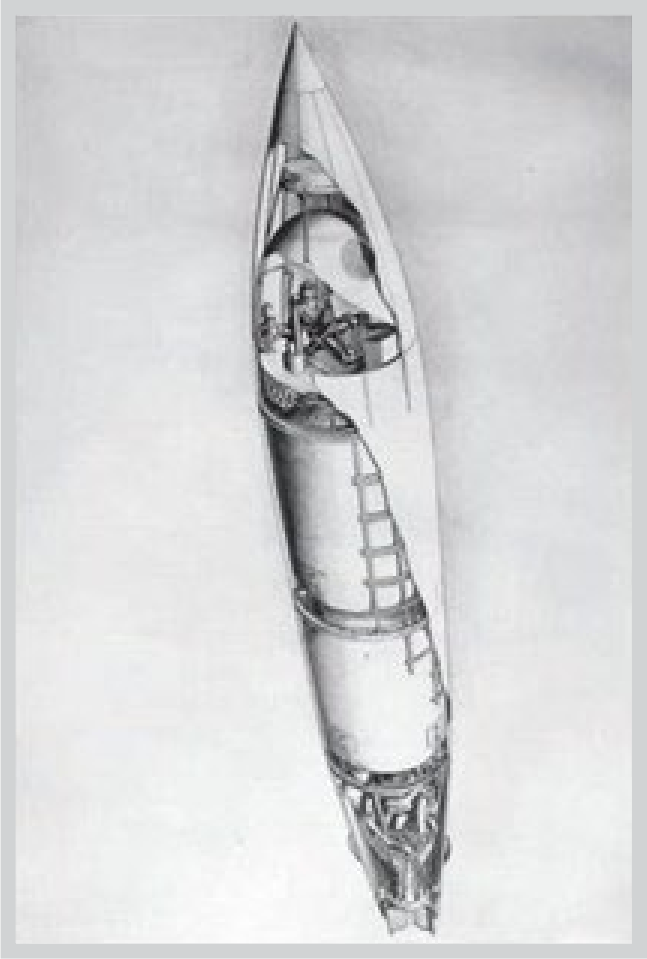
Finally, with a look to the future, many companies are now designing flying cars.

An Airbus modular self-flying prototype

THE FINAL FRONTIER

We turn now to the 'Final Frontier' – space. Focusing on the UK, scientific interest in space travel existed before WWII, particularly amongst members of the British Interplanetary Society (founded in 1933) whose members included Sir Arthur C. Clarke, author and conceiver of the geostationary telecommunications satellite. As with the other post-war space-faring nations, the British government's initial interest in space was primarily military. Early programmes reflected this interest. Much of the rocketry knowledge was obtained from captured German scientists who were persuaded to work for the British.

The British performed the earliest post-war tests of captured V-2 rockets in Operation Backfire, less than six months after the end of the war in Europe. In 1946 a proposal was made by Ralph A. Smith to fund a British crewed suborbital launch in a modified V-2 called Megaroc; this was, however, rejected by the Government. Nevertheless, the British space programme has always emphasized unmanned space research and commercial initiatives, it has never been government policy to create a British astronaut corps.



Megaroc

The first official British space programme began in 1952; and from 1957 British space astronomy used Skylark suborbital sounding rockets, launched from Woomera, Australia, which at first reached heights of 200 km (124 mi). In 1959, the first satellite programme was started, with the Ariel series of British satellites, built in the United States and the UK and launched using American rockets. The first British satellite, Ariel 1, was launched in 1962.

During the 1960s and 1970s, a number of efforts were made to develop a British satellite launch capability. A British rocket named Black Arrow did succeed in placing a single British satellite, Prospero, into orbit from a launch site in Australia in 1971. Prospero remains the only British satellite to be put into orbit using a British vehicle, so far.

Ariel 1

Black Arrow on its launch cradle

Prospero

From 1950 to 1985 the UK developed and launched several space rockets, as well as developing space planes. During this period the launcher programmes were administered in succession by the Ministry of Supply, the Ministry of Aviation, the Ministry of Technology and the Department of Trade and Industry. Development of a British launch system to carry a nuclear device occurred from 1950 onwards. Rockets were tested on the Isle of Wight and at RAF Spadeadam, Cumbria, and both tested and launched from Woomera in South Australia.

A major satellite launch vehicle was proposed in 1957 based on Blue Streak and Black Knight technology. This was named Black Prince, but the project was cancelled in 1960 due to lack of funding. Blue Streak rockets continued to be launched as the first stage of the European Europa carrier rocket until Europa's cancellation in 1972. The smaller Black Arrow launcher (previous page) was developed from Black Knight and was first launched in 1969 from Woomera. Falstaff, a British hypersonic test rocket, was launched from Woomera between 1969 and 1979.

Blue Streak

In 1960 the British Space Development Company, a consortium of thirteen large industrial companies, was set up by Robert Renwick to plan the world's first commercial communication satellite company. With Blue Streak Britain had the technology to make it possible, but the idea was rejected by the British government on the grounds that such a system could not be envisaged in the next 20 years (1961–81). (The United States set up COMSAT in 1963, resulting in Intelsat, a large fleet of commercial satellites; the first of Intelsat's fleet, Intelsat I (Early Bird) was launched in April 1965.) By 1972 UK government funding of both Blue Streak and Black Arrow had ceased, and no further government-backed British space rockets were developed. Other space agencies, notably NASA, were used for subsequent launches of UK satellites.

The official UK national space programme was revived in 1982 when the British government funded the HOTOL project, an ambitious attempt at a re-usable space plane using air-breathing rocket engines designed by Alan Bond. Work was begun by British Aerospace and Rolls-Royce, however, having classified the engine design as 'top secret' the government then ended funding for the project, terminating it.

Artist's impression of HOTOL (Horizontal Take Off & Landing)

In summary, UK satellite programmes from 1959 to date have been as follows:

- **1962 - 1979:** the Ariel programme developed six satellites, all of which were launched by NASA.

- **1971:** the last Black Arrow (R3) launched Prospero X-3, the only British satellite to be launched using a British rocket. Ground contact with Prospero ended in 1996.

- **1969 – 2012:** Skynet, a purely military programme, operating a set of satellites on behalf of the UK Ministry of Defence. Skynet provides strategic communication services to the three branches of the British Armed Forces and to NATO forces engaged on coalition tasks. Skynet is the most expensive single UK space project, although as a military initiative it is not part of the civil space programme.

- **1985 to date:** Surrey Satellite Technology Ltd (SSTL) was founded in 1985 out of research by Surry University into radio satellites following successful trials of commercial off the shelf components cumulating in the UoSat-1 test satellite which was launched with the help of NASA in 1981. It was the first modern reprogrammable small satellite and outlived its planned three-year life by a further five years. Since then the company has worked with numerous international customers to launch over 70 satellites. In April 2008 the university sold its majority share in the company to EADS Astrium. In 2020 SSTL commenced the creation of a telecommunications spacecraft for lunar missions which is planned to be completed in 2024.

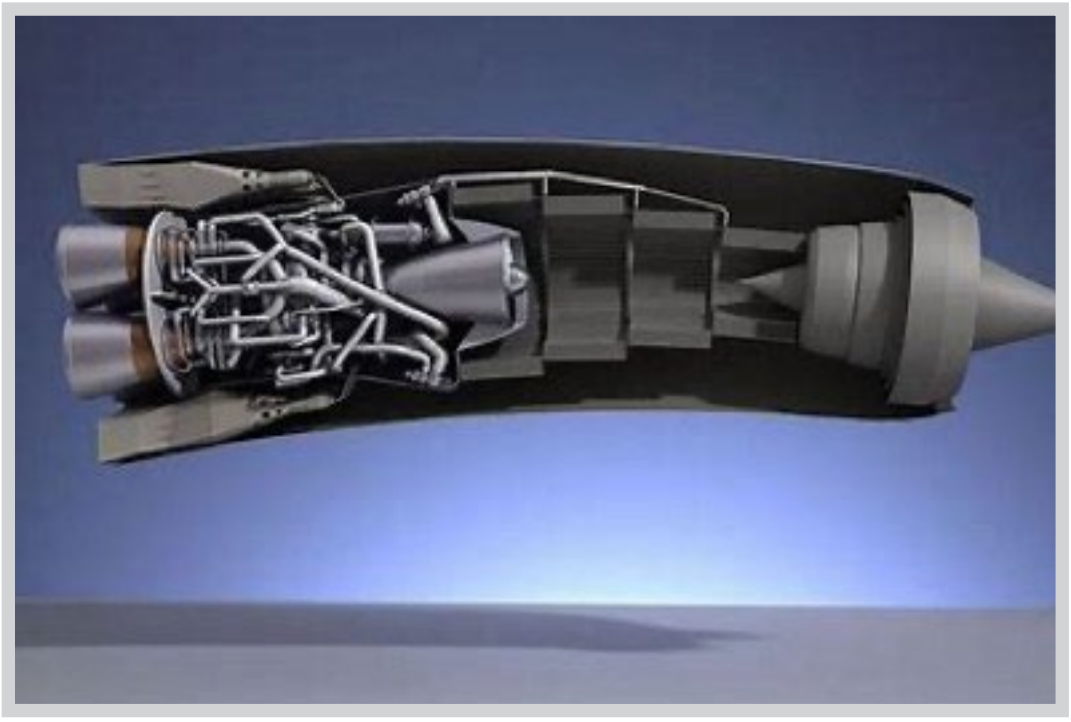
- **1988:** Zircon was the codename for a British signals intelligence satellite, intended to be launched in 1988, before being cancelled. During the Cold War the UK's Government Communications Headquarters (GCHQ) was very reliant on America's National Security Agency for communications interception from space. GCHQ therefore decided to produce a UK designed and built signals intelligence satellite, to be named Zircon, a code-name derived from zirconium silicate, a diamond substitute. Zircon's function was to intercept radio and other signals from the USSR, Europe and other areas. The satellite was to be built by Marconi Space and Defence Systems at Portsmouth Airport at which a new high security building had been built. It was to be launched on a NASA Space Shuttle under the guise of Skynet IV. Launch on the Shuttle would have entitled a British national to fly as a Payload Specialist, and a group of military pilots were presented to the press as candidates for 'Britain's first man in space'. Zircon was cancelled by Chancellor Nigel Lawson on grounds of its cost in 1987. The subsequent 'scandal' about the true nature of the project became known as the Zircon Affair.

- **2018:** it was announced that the UK will not be affiliated with the European Space Agency's Galileo satellite system after Britain completes its withdrawal from the European Union. Instead, the UK Space Agency will operate an independent satellite system.

The British National Space Centre (BNSC) was established in 1985 to co-ordinate British government agencies and other interested bodies in the promotion of British participation in the international market for satellite launches, satellite construction and other space endeavours. BNSC was the third largest financial contributor to the General Budget of the European Space Agency (ESA), contributing 17.4% to its Science Programme and to its robotic exploration initiative, the Aurora programme. The UK decided not to contribute funds for the International Space Station on the basis that it did not represent value for money, neither did the UK take part in any crewed space endeavours during this period.

That said, the UK continued to contribute scientific elements to satellite launches and space projects. Unfortunately the British probe Beagle 2, sent as part of the ESA's Mars Express to study the planet Mars, was lost when it failed to respond; however, it has recently been found by NASA's Mars Reconnaissance Orbiter and it has been concluded that, while it did land successfully, one of the solar arrays failed to deploy blocking communication antenna.

In 2010 the UK government partnered with the ESA to promote a single-stage to orbit reusable spaceplane concept called Skylon. The design as developed by Reaction Engines Ltd, a company founded by Alan Bond after HOTOL was cancelled, is a hypersonic pre-cooled hybrid air-breathing rocket engine called SABRE (Synergetic Air Breathing Rocket Engine). Testing of the key technologies involved was successfully completed in 2012 allowing Skylon's design to advance from its research stage to the development stage. The first ground based engines tests were due to happen in 2020 and, if all goes well, unmanned test flights by 2025. The project has been financed by the UK Government, BAE Systems, Rolls-Royce, Boeing and a private investment consortium.



Reaction Engines' SABRE

Artist's impression of Skylon

In 2014 the UK government announced it would build a British commercial spaceport. Following a competition, five potential sites remained in 2015: Campbelltown Airport; Glasgow Prestwick Airport; Stornoway Airport; Newquay Cornwall Airport; Llanbedr Airport. In 2018 the UK Space Agency announced the Government would back the development of a spaceport at A'Mhòine in Sutherland, Scotland with launch operations being developed by Lockheed Martin and financial support from the UK Government and Highlands & Islands Enterprise. The goal is to start launches as soon as possible in the 2020s.

Artist's impression of a launch from Sutherland Spaceport

In addition, investigation continues into the siting of a 'horizontal launch' spaceport. This would see a modified aeroplane leave a British runway, climb to altitude somewhere over the ocean and then release a rocket that can put a satellite into orbit. A number of systems are presently in development. One that is particularly prominent is Sir Richard Branson's Virgin Orbit company that has signed a partnership with Newquay Council to operate out of Newquay Airport from 2021.

Virgin Orbit at 'Spaceport Cornwall'