

# Get Your Bombs Off Our Lawn

The Arms Industry and the University of Liverpool

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**Written by members of Liverpool Friends of Palestine  
with support from the Campaign Against Arms Trade**

**October 2015**

*“The blood of little children and of strong men is dripping from your very  
roof-beams...”* (Jack London, **The Iron Heel**, 1908)

# Introduction

Students and staff are concerned and frustrated by the University of Liverpool's blanket refusal to disclose details of financial and research links with arms companies. A Freedom of Information request submitted in December 2014 yielded no answers, with the University claiming damage to their commercial interests and information given in confidence as grounds for their silence. The UCU branch has endorsed and strengthened the FOI request, and may appeal against the decision.

Although the University declined to comment, information in the public domain indicates extensive military-related research, involving major arms companies, the Atomic Weapons Establishment, Ministry of Defence and NATO, including development work on combat drones. This report draws on University web pages, the Research Excellence Framework, the Engineering and Physical Sciences Research Council (EPSRC), the CORDIS database of EU grant funding, UK government publications and Freedom of Information responses on military exports, the mainstream press and trade journals, a previous report "Study War No More" concerning the period 2001-2006, Stockholm International Peace Research Institute (SIPRI) data and Campaign Against Arms Trade information on specific companies.

But so what? In a free discussion, one might ask:

- *Is it consistent with intellectual honesty and transparency for the University to conceal the information that, in the public interest, is required to consider these issues more fully?*
- *Is it in the best interests of students and staff that University research contracts are so heavily tilted towards the arms industry?*
- *How does the University cater for science and engineering students who do not wish to have any involvement with the military in general or with arming Israel in particular?*
- *Should the University be able to hide the implications of its own research or the involvement of its partners in human rights abuses and war crimes?*
- *Who decides which funding strands and collaborations are legitimate to pursue?*
- *Who benefits from those close links with the arms industry?*
- *What efforts have staff made to develop projects without military involvement, or to seek alternative funding using the same skills and academic and technical expertise?*
- *How can students influence what they are being taught if they do not know about their tutor's and department's links with the arms industry?*
- *Does academic freedom include the freedom to view and consider University finances?*

More questions were raised in the UCU Branch resolution, which requested:

- *all guidance/legal documents used in establishing the University of Liverpool's position and policy development in relation to military related/funded research.*
- *detail on what ethical processes currently exist in relation to military related/funded research.*

Here, we simply provide some relevant facts in the hope they may provoke an open and informed discussion, the first step towards finding answers. Other universities also have extensive military

connections and questions could be posed there, but we ask them about this University because we are citizens of Liverpool. The Campaign Against Arms Trade (CAAT) and Fellowship of Reconciliation (FoR) pamphlet “Study War No More” (2007) <sup>1</sup> is an excellent guide, with online data <sup>2</sup> covering the period 2001-2006. Our report updates and expands this material for Liverpool.

This story is not new, and the wider context of military encroachment as Universities which faced funding pressures turned to the private sector and knowledge became a commodity, was examined by Scientists for Global Responsibility in the report “Soldiers in the Laboratory” (2005) <sup>3</sup>.

For example, the Blair government's White Paper “Our competitive future: building the knowledge-driven economy ” (Department of Trade and Industry 1998) launched a fund to encourage universities to work more ‘effectively’ with business. By 2003 the Council for Science and Technology, appointed by the Prime Minister, included Euan Baird, Chairman of Rolls Royce; Alec Broers, former Vice- Chancellor of Cambridge and advisor to the BAE Virtual University Strategy; and Chris Evans, founder and director of 12 biotechnology companies.

As Chris Langley wrote in the SGR report<sup>4</sup>

“A variety of complex and interlocking changes which have occurred in the UK and elsewhere in the industrialised world in the last fifteen to twenty years have set the stage for the privatised university. Here research portfolios are increasingly dominated by industrial liaison of various kinds and commercial agendas are often imported wholesale into the university domain...

“Many would argue that increased reliance on industry; the redirection of research effort towards practical or applied subjects in both teaching and research; the proprietary treatment of research outcome with commercial interest in secrecy overriding the public interest in free, accessible and shared knowledge; all compromise ‘academic freedom’...”

The material considered here also stretches back to the 1990s, and includes projects which may now have ended. However, the University of Liverpool's entanglement with the arms industry continues, and probably includes aspects we have not identified.

Our original intention was to discover what relations there may be between the University and the horrors inflicted on Gaza through the ongoing illegal siege, repeated attacks and invasions. But the two-way arms trade with Israel is part of the global arms industry, whose roles at the University of Liverpool became the focus.

This report was written by Greg Dropkin in collaboration with David Hookes, members of Liverpool Friends of Palestine<sup>5</sup>, affiliated to the Palestine Solidarity Campaign.<sup>6</sup> Special thanks to Ian Prichard (CAAT<sup>7</sup>), Chris Langley, and David Whyte for comments on an earlier version.

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1 <http://www.studywarnomore.org.uk/documents/studywarnomore.pdf>

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3 [http://www.sgr.org.uk/ArmsControl/Soldiers\\_in\\_Lab\\_Report.pdf](http://www.sgr.org.uk/ArmsControl/Soldiers_in_Lab_Report.pdf)

4 *ibid.* p.20

5 <http://www.liverpoolfriendsofpalestine.co.uk/>

6 <http://www.palestinecampaign.org/>

7 <https://www.caat.org.uk/>

# Contents

Some company profiles.....	1
Arms trade with Israel.....	7
University of Liverpool.....	13
Military Education Committee.....	13
School of Engineering.....	14
Centre for Autonomous Systems Technology.....	15
Institute for Risk and Uncertainty.....	15
School of Electrical Engineering.....	16
Computer Science.....	17
School of Management.....	17
Centre for Engineering Dynamics.....	17
AgustaWestland Liverpool Advanced Rotorcraft Centre.....	17
Structural Dynamics.....	18
Computational Fluid Dynamics Laboratory.....	18
Finance: Endowment and Pension Funds.....	25
Finance: Engineering & Physical Sciences Research Council (EPSRC).....	27
Finance: EU funding.....	37
Conclusions.....	41

## Appendices

- 1 Freedom of Information request and University response
- 2 Liverpool UCU Branch resolution and UCU national policy
- 3 Companies applying for UK Military List export licences, end-user Israel
- 4 North West Aerospace Alliance members with military links

# Some Company Profiles

Some key firms involved in military production are introduced here. Each has links with the University, briefly highlighted and italicised. Details of these roles are explored in later sections. The Campaign Against Arms Trade<sup>[1]</sup> has extensive information on hundreds of firms, including a Company Map<sup>[2]</sup>. Through Freedom of Information requests, CAAT also obtained UK government data on applications for military export licences.<sup>[3]</sup>

## Arms Companies in order of appearance

**AgustaWestland (Finmeccanica)**

**Airbus**

**BAE Systems**

**Caterpillar**

**Ferranti Technologies (Elbit)**

**GE Aviation**

**Hewlett-Packard**

**Honeywell**

**IBM**

**Magellan**

**National Instruments**

**Qinetiq**

**Rolls-Royce**

**Siemens**

**Teledyne**

## Atomic Weapons Establishment (AWE)

**DSTL**

**AgustaWestland:** *directly involved through the AgustaWestland Liverpool Advanced Rotorcraft Centre and as a partner in EPSRC and EU funded projects at the University.* Originally Westland Helicopters, AgustaWestland is now owned by the Italian arms giant Finmeccanica<sup>[4]</sup>, the world's 9<sup>th</sup> biggest arms company,<sup>[5]</sup> which owns 25% of shares in MBDA Missile Systems.<sup>[6]</sup>

Italian tax police are probing suspected corruption, including slush funds and fake invoices, in a Finmeccanica sale of helicopters to Algeria.<sup>[7]</sup> Separately, Panama is seeking to cancel a €180 million deal with Finmeccanica for radars, helicopters and digital maps over allegations of kickbacks to the former Panamanian president.<sup>[8]</sup>

UK military export licence applications by AgustaWestland totalled 41 in 2013 (with end-

users Algeria, Belgium, Estonia, Latvia, Lithuania, Netherlands, Poland, Russia, Ukraine, France, Germany, Greece, Italy, Spain, Israel, Malaysia, Cyprus, Egypt, Oman, Saudi Arabia, Turkey, India, US).

AgustaWestland components exported to the US are incorporated by Boeing in Apache helicopters sold to Israel.<sup>[9]</sup> T129 attack helicopters, purchased by Turkey, have been deployed and reportedly used recently to attack the Kurdistan Workers' Party (PKK).<sup>[10]</sup>

**Airbus:** *directly involved as a research partner, with EPSRC and EU funded projects, and cited by the School of Management as a career prospect.* Airbus, previously called EADS, is the 2nd largest arms producer in Europe and the 7th largest in the world.<sup>[11]</sup> It is a joint French, German and Spanish company. Business activities include Eurocopter (now Airbus Helicopters),<sup>[12]</sup> MBDA (missiles and missile systems)<sup>[13]</sup> and Eurofighter - a joint venture with BAE and Finmeccanica.<sup>[14]</sup> Airbus products include fighter jets, artillery systems, missiles (via MBDA) and helicopters.<sup>[15]</sup> Markets include authoritarian regimes such as Saudi Arabia, the UAE and Kazakhstan.<sup>[16]</sup> In 2012 the Serious Fraud Office opened an investigation into a subsidiary GPT Special Project Management, after allegations of bribes to Saudi Arabian officials to win a communications contract for the Saudi National Guard.<sup>[17]</sup> The Eurocopter Panther is in service with the Israeli Air Force on maritime patrol.<sup>[18]</sup> MBDA, in which Airbus holds a 37.5% stake, had 40 applications for UK military export licences in 2013.

**BAE Systems:** *directly and extensively involved as a research partner, with project funding from EPSRC and EU (through the Aircraft Research*

Association,<sup>[19]</sup> involving Airbus, BAE Systems, Dowty Rotol, and Westland), and participating in NATO collaborations at the University. BAE's Head of Electromagnetics in Military Air & Information was appointed a Visiting Professor at the University in 2012.<sup>[20]</sup> BAE Systems is the world's 3<sup>rd</sup> largest arms producer.<sup>[21]</sup> Its portfolio includes fighter aircraft, warships, tanks, armoured vehicles, artillery, missiles and small arms ammunition. BAE's arms are sold indiscriminately around the world. The company has military customers in over 100 countries and around 95% of its sales are military.<sup>[22]</sup> In 2004, following media exposure, the UK's Serious Fraud Office began investigating BAE deals with Saudi Arabia, South Africa, Tanzania and the Czech Republic. However, the pivotal Saudi strand was stopped in 2006 following political intervention by Tony Blair (after pressure by the Saudi government and BAE).<sup>[23]</sup> In 2010, the US Department of Justice agreed a plea bargain with BAE. The company was sentenced to pay a \$400 million criminal fine.<sup>[24]</sup> In March 2011, some of the 200 Tactica armoured vehicles sold to Saudi Arabia<sup>[25]</sup> were used to suppress pro-democracy protests in Bahrain.<sup>[26]</sup> BAE-supplied Tornado and Typhoon jets are used by Saudi Arabia to strike Houthi rebels in Yemen.<sup>[27]</sup> A 100% owned BAE subsidiary, Rokar International,<sup>[28]</sup> supplies components to Israeli F-16s.<sup>[29]</sup> BAE made 135 applications for UK military export licences in 2013.

BAE has also participated in the EU funded OPARUS project which aims "to elaborate an open architecture for the operation of unmanned air-to-ground wide area land and sea border surveillance platforms in Europe".<sup>[30]</sup> Other project members include Dassault, EADS (now Airbus), Israel Aerospace Industries, and Thales. Previously, BAE participated in the EU funded UAV-NET, [UAV denotes Unmanned Aerial Vehicle, a.k.a. drone] a "civilian thematic network" coordinated by Israel Aircraft Industries with other network members including Alenia, EADS, ONERA and Thales.<sup>[31]</sup>

See also the **Arms trade with Israel** section below.

**Caterpillar:** cited by the School of Management as a career prospect. See **Arms trade with Israel** for some details of its military role.

**Ferranti Technologies:** indirectly, and possibly directly involved in the GAMMA programme and the Virtual Engineering Centre through membership of the North West Aerospace Alliance. Ferranti Technologies is 100% owned by the Israeli military corporation Elbit Systems,<sup>[32]</sup> ranked 35<sup>th</sup> in the world,<sup>[33]</sup> which supplies drones to the Israeli Air Force.<sup>[34]</sup>

Ferranti Technologies was formerly part of Ferranti, the UK military electronics giant which collapsed after acquiring the US company International Signal & Control.<sup>[35]</sup> In 2007 Finmeccanica acquired part of Ferranti Defence Systems while Elbit Systems bought Ferranti Technologies.<sup>[36]</sup> Ferranti Technologies applied for 4 UK military export licences in 2013, to Romania and Israel.

Another Elbit 100% subsidiary, UAV Engines Ltd (UEL)<sup>[37]</sup> supplies engines for the UK Watchkeeper drone<sup>[38]</sup> deployed in Afghanistan<sup>[39]</sup> alongside Hermes 450 drones leased from Elbit.<sup>[40]</sup> UEL had 5 applications for licences to export engines to Israel in 2013 along with one for electronic equipment and another 52 for exports to other countries. A Guardian investigation in 2009 found UEL supplied engines identical to those used in Israeli drones,<sup>[41]</sup> and UK gov't ministers were unable to deny these engines had been used in drones attacking Gaza<sup>[42]</sup> though the company claimed they were for onward export from Israel. In January 2015 a trial of protestors collapsed when UEL refused to supply details of their export licences.<sup>[43]</sup>

**GE Aviation:** directly involved (via GE Dowty) with the Flight Simulation and Control programme. GE is the world's 23<sup>rd</sup> largest arms producer even though military sales comprise only 3% of its total sales.<sup>[44]</sup> Its GE Aviation subsidiary produces commercial and military jet engines, avionics, electric power and mechanical systems for aircraft. It describes itself as "the leading provider of jet and turboprop power for military aircraft" and "a leading supplier of

integrated systems and technologies for combat aircraft, military transport, helicopters, land vehicles and unmanned aerial vehicles (UAVs)".<sup>[45]</sup> GE Aviation applied for 80 UK military export licences in 2013, mainly in categories which include combat and other military aircraft, electronic warfare and navigation equipment.

**Hewlett-Packard:** *directly involved with the Computer Science dept and the School of Electrical Engineering, cited by the School of Management as a career prospect.* HP is the world's 37<sup>th</sup> biggest arms firm.<sup>[46]</sup> Through the Defence Growth Partnership HP has influence on the UK government.<sup>[47]</sup> See also **Arms trade with Israel.**

**Honeywell:** *directly involved with Computer Science.* Honeywell's military products include systems for tanks, combat aircraft and engines for the General Atomics MQ-9 Reaper,<sup>[48]</sup> a drone deployed by the RAF<sup>[49 50]</sup> (now in use over Syria).<sup>[51 52]</sup> It is the 18th largest arms company in the world, with 12% of its sales being derived from arms and provision of services to the military.<sup>[53]</sup> It applied for 107 UK military export licences in 2013, to Abu Dhabi, Finland, Germany, India, Indonesia, Israel, Italy, South Korea, Oman, Pakistan, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, and Turkey. It holds a 2012 contract for engines supplied to Israel's military training fleet.<sup>[54]</sup> Honeywell UK applications for Military Export Licences to Israel (6 in 2013) are classed as ML9a1: "Vessels" (surface or underwater) specially designed or modified for military use, regardless of current state of repair or operating conditions, and whether or not they contain weapon delivery systems or armour, and components therefor specially designed or modified for military use;

**IBM:** *directly involved with Computer Science.* As reported in "Study War No More", the International Technology Alliance (ITA) was launched in 2006, as the Ministry of Defence and US Department of Defense chose an IBM-led consortium to undertake a new joint government / industry advanced technology

partnership exploring secure wireless and sensor networks. According to Dr Thomas H. Killion, U.S. Army Chief Scientist, the ITA will allow "the best in our industry and university communities on both sides of the Atlantic" to focus "on the scientific enablers of net-centric warfare."<sup>[55]</sup> Current research to "enhance US and UK capabilities to conduct coalition warfare"<sup>[56]</sup> includes "relevant human, social, and cultural considerations to provide insight and perspective on human-level issues".<sup>[57]</sup>

**Magellan Aerospace:** *indirectly, and possibly directly involved in the GAMMA programme and the Virtual Engineering Centre through membership of the North West Aerospace Alliance.* Produces tail-assemblies for the F-35A Lightning II (Conventional Take Off and Landing variant)<sup>[58]</sup> under contract with BAE Systems, a principal member of the Lockheed Martin-led F-35 industry team.<sup>[59]</sup>

**National Instruments:** *directly involved with the School of Electrical Engineering.* National Instruments is a US company with extensive aerospace / arms work<sup>[60]</sup> including military communications<sup>[61]</sup> and electronic warfare.<sup>[62]</sup> It holds contracts with Lockheed-Martin<sup>[63]</sup> including test equipment for the F-35 Joint Strike Fighter<sup>[64]</sup>; Thales<sup>[65]</sup>; BAE<sup>[66]</sup>; Boeing<sup>[67]</sup>; and Airbus<sup>[68]</sup>. It carries out work on UAVs<sup>[69]</sup> and submarines.<sup>[70]</sup>

**Qinetiq:** *directly involved with the School of Engineering, with EPSRC and EU funded projects, and with the School of Management.* QinetiQ is the 6th largest UK arms company having been privatised from the MoD in 2001.<sup>[71]</sup> The company are "experts in defence, aerospace and security"<sup>[72]</sup> and a "world leading" supplier of military robotics.<sup>[73]</sup> International customers include the Saudi Ministry of Interior.<sup>[74]</sup> It applied for 11 military export licences in 2013, to Canada, France, Germany, Israel, Italy, Malaysia, Portugal, Sweden, and Turkey. Corporate Watch explains "Most of QinetiQ's work is still based on military applications -- weapons, guidance systems, military aircraft technology etc. From this, it branches out into



surveillance and security technologies (including some of the technologies being considered for use in ID cards), communications and high-tech materials, including nanotechnology and 'energetic materials' (i.e. explosives)."<sup>[75]</sup>

**Rolls-Royce:** *directly involved with the School of Engineering and the Institute for Risk & Uncertainty, and possibly indirectly through the North West Aerospace Alliance, with funding from EPSRC and EU grants.* Rolls-Royce produces military aircraft engines, naval engines and cores for nuclear submarines. Despite arms comprising only 26% of its total sales, it is still the world's 17th largest arms company.<sup>[76]</sup> It has military aircraft engines in service with "160 customers in 103 countries".<sup>[77]</sup> In March 2014, India's anti-fraud agency began an investigation into alleged corruption in a deal to supply India with engines for its Hawk aircraft.<sup>[78]</sup> Rolls-Royce applied for 23 UK military export licences in 2013.

**Siemens:** *directly involved with Computer Science, and possibly indirectly through the North West Aerospace Alliance, and as a beneficiary of EPSRC-funded research in the School of Engineering.* Siemens produces naval technology,<sup>[79 80 81]</sup> and has a contract with BAE for software used in Trident submarine development.<sup>[82]</sup>

**Teledyne:** *possibly indirectly involved through the North West Aerospace Alliance.* Teledyne has extensive aerospace and military electronics interests.<sup>[83]</sup> It made 130 applications for UK military export licences in 2013, including 16 to Israel, mainly concerning military electronics.

**Atomic Weapons Establishment (AWE):** *directly funds University research.* AWE is the scientific body responsible for UK nuclear weapons production, maintenance,

decommissioning and development. As reported in the booklet *Atoms for Peace?* by the Nuclear Information Service and MEDACT,<sup>[84]</sup> Liverpool is one of over 50 Universities which have received AWE funding, revealed through Freedom of Information requests to the Ministry of Defence. In the period surveyed, the University received £236,346 in 2010, £36,293 in 2011, and £69,992 in the first six months of 2012.

AWE is 1/3 owned by the US company Lockheed Martin, the world's largest arms company, 1/3 by the UK firm Serco, and 1/3 by the US firm Jacobs. Press reports in 2006 revealed AWE's attempts to circumvent nuclear testing treaties by developing a new "Reliable Replacement Warhead".<sup>[85]</sup> According to Matrix Chambers, this may be a material breach of the Nuclear Non-Proliferation Treaty.<sup>[86]</sup> By continuing to possess and make new nuclear weapons, Britain is failing to comply with its obligations to disarm under the nuclear Non-Proliferation Treaty (NPT) signed in 1968. The Trident replacement programme to build a new generation of nuclear deterrents is set to cost the UK taxpayer £100bn over 50 years, as estimated by Greenpeace<sup>[87]</sup> (and CND).<sup>[88]</sup>

**DSTL:** *directly involved through Flight Simulation and Technology Engineering, the Centre for Engineering Dynamics, and Computational Fluid Dynamics, with funding from EPSRC.* The UK government **Defence Science and Technology Laboratory** is an agency of the Ministry of Defence, covering all military research apart from nuclear weapons.<sup>[89]</sup> Priority areas include Command, Control, Communication, Computers, Intelligence, Surveillance and Reconnaissance, Weapons, and Platform Systems. DSTL is currently launching a competition for industry and academia to investigate new techniques and methods to provide military context of cyber activities.<sup>[90]</sup>

## Notes to Company Profiles

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# Arms trade with Israel

Any pretence that research and development of military and security equipment is simply about peacekeeping in a violent world, falls away when considering Palestine and repeated Israeli attacks on Gaza and the Lebanon. One starting point is “Operation Protective Edge” in July-August 2014, with UN statistics showing 2220 Palestinian deaths, of whom 1492 were civilians,<sup>[1]</sup> while Israel suffered 71 fatalities, of whom 4 were civilians. The International Criminal Court is beginning to consider whether actions on either side during this period constitute war crimes.<sup>[2]</sup>



**Palestinians inspect a home destroyed in an Israeli air strike in the central Gaza Strip on 9 July 2014**  
*Ashraf Amra / APA images*

In February, the acclaimed international human rights lawyer Raji Sourani, Director of the Palestinian Centre for Human Rights, spoke at the University of Liverpool. A PCHR press release<sup>[3]</sup> issued on 30 July 2014 documented how, in the previous 24 hours alone, 102 Palestinians, 98 of whom were civilians, including 31 children and 18 women, were killed, and 580 were wounded. Overnight, Israeli tanks shelled a UN shelter for forcibly displaced civilians in Jabalya refugee camp. 15 civilians were killed and dozens of others wounded. The Gaza Power Plant was completely

paralysed and electricity supplies were cut off in large areas. Israeli warplanes bombed and destroyed a 4-storey apartment building in the centre of Khan Yunis, killing 32 people in 4 families, including 15 children.

The Amnesty International report “Families Under the Rubble” investigated 8 massive attacks on civilian high-rise buildings in Gaza. For example: <sup>[4]</sup>

On Sunday 20 July 2014, at approximately 7.50pm, following the evening prayer, an

Israeli aircraft dropped a bomb on the three-storey home of the Abu Jame' family in Abu Safar, an area near the al-Zanneh neighbourhood of Bani Suheila, east of Khan Yunis. The attack led to the killing of 25 members of the Abu Jame' family – 19 children, five women and one man – and Ahmad Sahnoud, a member of the al-Qassam Brigades, Hamas' armed wing, who was in the vicinity of the house at the time. Only three members of the family who were in the house at the time survived the attack: Bassam Ahmad Abu Jame', Tawfiq Abu Jame' and three-year-old Nour Abu Jame'.

The house, which was attacked without prior warning, was completely destroyed. A fieldworker supporting Amnesty International's work visited the site five days afterwards and photographed the huge crater created by the bomb. A military advisor supporting Amnesty International's work confirmed that the damage was consistent with that which would be caused by a large air-dropped bomb...

Tawfiq Abu Jame' was sitting in his apartment at the dinner table with his wife and children when the house was attacked right after the call to prayer.

*“After the Maghreb prayer, we were sitting together about to break our fast. We drank water, and then suddenly, something hit us, without any warning. I passed out and when I woke up again. I found myself in the hospital. I was injured all over my body. I asked them [family members in the hospital] what had happened and, at first, they told me everyone was fine. Ten minutes later they said that my mother had died. Then, they told me that my wife was killed. And, then, that the entire family was dead, except for me.”*

The Defense for Children International report “Operation Protective Edge, A War Waged on

Gaza's Children”<sup>[5]</sup>, documents the young lives ripped apart by the onslaught in 2014.

On 22 June 2014 a UN Commission of Inquiry published its report<sup>[6]</sup> on the slaughter in Gaza which began on 6 July 2014. Khuza'a, in southern Gaza, was one of many areas to come under ferocious attack. As the UN Commission reported, Khuza'a's only clinic suffered repeated Israeli air strikes on 23 and 24 July. One of the doctors recounted:

*“They targeted the clinic with three rockets from drones. There were at least 25 or 30 explosions in the neighbourhood. The attacks on the clinic continued also on the 24th. Our clinic was deprived of the most basic provisions to treat patients. [...] and in all this there was no communication or warnings. We were just attacked.”*

*“About thirty people in total were killed, and several more injured in these attacks. They were mostly children and women. None of them were combatants. Among them was my brother who was killed before my own eyes. He was hit during that attack and collapsed... It was the most painful experience of my life, being a doctor and not being able to save my brother's life.”*

The attacks on Khuza'a had previously intensified on 22 July, “carried out for the most part from the air, by F16s and drones. Tanks in and around Khuza'a were also firing intensely. The clinic was overflowing...”

Ambulances were blocked from entering Khuza'a to evacuate the wounded, or held up at checkpoints.

Elbit's Hermes 450 drone is established as a “workhorse” of the Israeli military.<sup>[7]</sup> On 12 Aug 2014 Defense News reported commanders crediting Elbit drones for “delivering added operational value”.<sup>[8]</sup>

Israel is also a major exporter of “field tested” weapons. Indeed, Elbit's share price rose 6.1% in July 2014, anticipating fresh orders on the back of the slaughter.

To understand how the international and UK arms trade fuels these atrocities, a good starting point is the new War on Want / CAAT / Palestine Solidarity Campaign report “Arming Apartheid”.<sup>[9]</sup>

What role is played by companies involved with the University of Liverpool? The key weapons deployed repeatedly in Gaza are F-16 fighter-bombers, Apache attack helicopters, weaponised drones, militarised bulldozers, tanks and artillery. The economic siege is also imposed from the sea. Each of these aspects of Israel's repeated military assaults and continuing siege involves companies active at the University of Liverpool.

### **F-16**

At least two companies directly involved with the University (BAE and GE Aviation) also supply components for Israeli F-16s. Lockheed-Martin, who supply the planes, are involved with Sci-tech Daresbury, a National Science and Innovation Campus including the University of Liverpool alongside major corporations.<sup>[10]</sup>

Israel's F-16s were exported from the US by Lockheed-Martin. However, as acknowledged by the then Foreign Sec David Miliband in Parliament on 21 April 2009, “British made components for F16s have been exported to the United States where Israel was the ultimate end-user. These licences covered components for head-up displays, head-down displays and enhanced display units.”<sup>[11]</sup> As reported in Air Forces Monthly, June 2004 “selected combat aircraft in the F-16I fleet (delivered to the Israel Defence Force) [were] equipped with BAE Systems EDU HUD”.<sup>[12]</sup> On 22 July 2002, Israel carried out a “targeted assassination” in Gaza City,<sup>[13]</sup> killing 9 children and 6 adults, as it later emerged.<sup>[14]</sup> On 23 July, the then Foreign Sec Jack Straw told the Commons “...the contract between British Aerospace and Lockheed Martin for the supply of head-up displays is of long standing. So it is perfectly possible—I do not happen to know—that such equipment, licenced by previous Administrations or indeed by this Administration, was incorporated in that equipment... Particularly over the past five years, all defence industries have become much more

transnational—in our case, transatlantic—and what we are doing is part of a transatlantic assembly line.”<sup>[15]</sup>

BAE's wholly-owned subsidiary Rokar has its HQ in Jerusalem.<sup>[16]</sup> Rokar is involved in the upgrade of F-16s through the F-16 ACE program, involving “close collaboration between Israeli defense industries, the cooperation of Lockheed Martin the F-16 original manufacturer and the assistance of the Israeli Ministries of Defense and Finance”.<sup>[17]</sup> Rokar supplies Electronic Countermeasures including chaff and flares for use on F-16s and other military aircraft.<sup>[18]</sup>

GE Aviation supplies engines for 126 F-16s in the Israeli fleet.<sup>[19]</sup> When GE signed an agreement with a subsidiary of Israel Aircraft Industries in 1999, the company proclaimed “The agreement reflects the strong level of industrial cooperation between General Electric Company (GE) and the Israeli defense industries. This commitment was reinforced by GEAE President Mr. Jim McNerney during recent meetings with leaders of the Ministry of Defense, Israeli Air Force (IAF), and local defense industries... GE has established more than \$700 million in industrial cooperation with Israeli companies in the 1990s-exceeding by about 50% its commitments based on contracts with the Israeli government... GEAE engines power most of the front-line fighter aircraft and helicopters of the IAF, and are competing for the engines for new IAF fighter aircraft now under consideration. GE is offering its new F110-129 engine, the most advanced version of the F110 engine.”<sup>[20]</sup>

### **Apache**

AgustaWestland, directly involved with the University, has exported components for Apache attack helicopters supplied to Israel, as divulged by Boeing, the supplier.<sup>[21]</sup> Boeing themselves appear to have a limited role at the University. AgustaWestland and Airbus incorporate Spike missiles supplied by the Israeli arms firm Rafael, in helicopters for sale worldwide.<sup>[22 23]</sup>

The AgustaWestland licence application for military exports to Israel in 2013 is classed as ML10a, denoting *Manned "aircraft" and "lighter-than-air vehicles", and specially designed components therefor*. In 2012 there were 4 AgustaWestland applications re Israel, classed as ML4b1, covering:

*bomb handling equipment; CBW munitions disposal; chaff; decoy flares; explosive ordnance disposal; guided missile decoy rounds and equipment; military devices for initiating explosives; military firing sets; mine clearing / countermeasures / detection / handling / hunting / laying / sweeping; missile jamming; air defence systems; man portable air defence systems; munitions; guided missile decoying / detection / jamming equipment; guided missile detection equipment.*

In 2010 there was one Westland application re Israel, classed as ML11a (*Electronic equipment specially designed or modified for military use and specially designed components therefor*).

### **Drones**

As a member of the North West Aerospace Alliance, Ferranti Technologies may be involved with the University via the Virtual Engineering Centre and the GAMMA programme. Ferranti, profiled above, is wholly owned by Elbit Systems, an Israeli arms company.<sup>[24]</sup> The War on Want report *Killer Drones*<sup>[25]</sup> is an overview of Israeli military drones up to December 2013 (prior to the attacks on Gaza in July-Aug 2014), with extensive details of Elbit's role. See also *Israel and the Drone Wars*,<sup>[26]</sup> by Drone Wars UK, and for the wider context *Back from the Battlefield*,<sup>[27 28]</sup> by Statewatch and Drone Wars UK.

During the 2014 attacks Elbit UAVs (drones) were heavily deployed, including the shoulder-launched Skylark,<sup>[29]</sup> the new Hermes-900 and the Hermes-450<sup>[30]</sup>.

Ferranti applied for a licence for military exports to Israel in 2013, coded ML10a (*Manned "aircraft" and "lighter-than-air vehicles", and specially designed components therefor*).

### **Bulldozers**

Caterpillar is cited by the University's School of Management as a career prospect. Caterpillar D9 bulldozers, sold to Israel under the US Foreign Military Sales program,<sup>[31]</sup> have been used extensively in Israeli attacks on Gaza and Lebanon, and in the demolition of Palestinian homes in the occupied West Bank.<sup>[32]</sup> In 2006 the Church of England voted to divest its shareholding in Caterpillar.<sup>[33]</sup> The continuing role of Caterpillar and other suppliers of heavy machinery is detailed in a 2014 report "Facts on the Ground"<sup>[34]</sup> by the Israeli research organisation Who Profits from the Occupation.<sup>[35]</sup> Caterpillar Shrewsbury applied for 4 UK licences for military exports to Israel in 2013, all classed as ML6a (*Ground "vehicles" and components therefor, specially designed or modified for military use*).

### **Tanks**

Teledyne Continental Motors supplied the engines for Israeli Merkava Mark III (used in Gaza 2014).<sup>[36]</sup> Caterpillar contributed a track system for the Merkava Mark IV.<sup>[37]</sup>

### **Artillery**

The BAE wholly owned Israeli subsidiary Rokar, mentioned earlier for its role in F-16 upgrades, also produces a guidance system for artillery shells which "increases effectiveness while reducing collateral damage".<sup>[38]</sup>

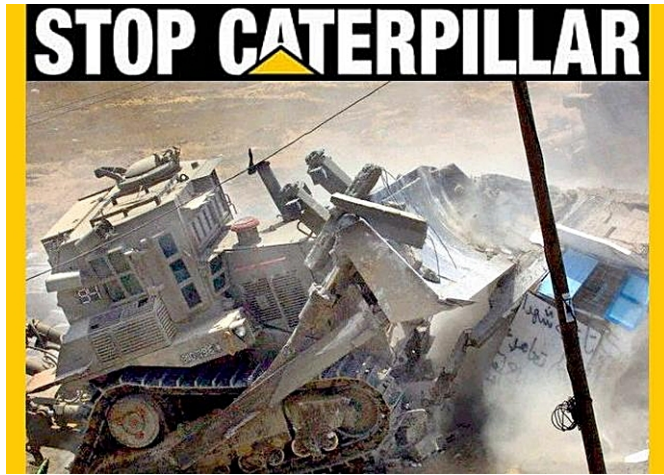
### **Computers**

Hewlett Packard is directly involved with the University. As detailed by the Israeli research organisation Who Profits from the Occupation, Hewlett Packard supplies computer systems to the Israeli Ministry of Defense and the Israeli Prison Service.<sup>[39]</sup> It also supplies biometric monitoring at checkpoints along the apartheid wall. In June 2014 the US Presbyterian Church voted to divest from Hewlett-Packard along with Caterpillar and Motorola due to their role in the Occupation.<sup>[40]</sup>

The various company profiles and details of the military trade do not, by themselves, show what roles are being played at the University.

Perhaps companies which build nuclear weapons or supply components to armed drones, attack

helicopters, F16s or military bulldozers could just be saving the planet in Liverpool. Let's find out.





## Notes to Arms trade with Israel

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# University of Liverpool

The University website gives some information about links with government and the military. The parts of the University involved in arms-industry related work include at least the Military Education Committee, the School of Engineering, Centre for Autonomous Systems Technology, School of Electrical Engineering, Computer Science Dept., and the School of Management. We begin with a short review of their military links, and then consider the Centre for Engineering Dynamics (in the School of Engineering) in more detail.<sup>[1]</sup>

Units within the academic structure have a variety of relationships with the arms industry. Projects may be directly commissioned by the Ministry of Defence or under military auspices, e.g. NATO led work on combat drones. They may be funded by or carried out in partnership with an arms company, e.g. BAE (95% of whose sales are military). They may involve partnership with companies like Airbus engaged in both civil and military production, for research with applications in both fields. Or they may be apparently civilian projects, whose technology can be adapted by the partners for military use, as with AgustaWestland. The University also co-funds 3 or 4 year PhD bursaries (CASE studentships) with arms companies such as Airbus or BAE.<sup>[2 3]</sup> We consider any project involving a company which is active in the military industry, to be worth examining.

For their part, arms companies use their working relationships with the University of Liverpool as a badge of honour, openly recognising the value they derive. For example, AgustaWestland proclaims online that its relationship with University of Liverpool – in particular the Centre of Excellence in Computational Fluid Dynamics (CFD), flight mechanics and simulation - provides “opportunities for professors and creative students to dedicate research to specific ‘live’ projects, which in turn benefits the company.”<sup>[4]</sup>

## Military Education Committee

Like other Universities with an Officer Training Corps, Liverpool has a Military Education Committee whose terms of reference are:<sup>[5]</sup>

- (a) To receive annual reports from the University Royal Naval Unit, the University Officers' Training Corps and the University Air Squadron on their work and to forward such reports with any appropriate comments to the University Student Experience Committee.
- (b) To act as a liaison between the University and Her Majesty's Forces in matters of military education and to offer support and encouragement to the Commanding Officers of the three Service Units, as may appear advisable.
- (c) To organise lectures, seminars and other events relating to matters of Service interest.
- (d) To consider and advise upon such matters in the field of military education as may be referred to the Committee by the University.

The current members include 6 serving military officers and 2 retired paratroopers along with University staff, at least one of whom, Dr M White, appears to be actively engaged in projects with the arms industry whilst others, T Dray (of John Moores Univ) and Ms A Chambers (UCLAN), are concerned with employment prospects for graduates. The Secretary of the Liverpool MEC is Dr Paul Redmond, Director of Employability & Educational Opportunities at the Student Services Centre.

The MEC belongs to the Council of Military Education Committees COMEC which communicates directly with the Ministry of Defence.<sup>[6]</sup> COMEC recently published a paper by Lord David Owen entitled “Reshaping the British Nuclear Deterrent”.<sup>[7]</sup> The former Foreign Secretary was also Chancellor at the University of Liverpool 1996-2009.

The actual functioning of the Liverpool MEC is not shown, so there is no public information on

the Committee's work. By contrast, the 2014 Annual Report of the University of Sheffield Military Education Committee is available online<sup>[8]</sup> while the University of Aberdeen publishes minutes of its MEC<sup>[9]</sup> and the University of Strathclyde MEC has a website.<sup>[10]</sup>

It is unclear why the Liverpool MEC fails to report publicly on its activities, or how it may consider decisions on education, research, collaboration with industry, or funding from UK government or other sources.

### **School of Engineering**

The School of Engineering<sup>[11]</sup> lists “some of the organisations that work closely with us, as research partners and / or in the design, development and delivery of our programmes”, ranging from BAE Systems to the Ministry of Defence, and including AgustaWestland, Rolls-Royce, and Airbus.<sup>[12]</sup> As profiled above, these arms companies are major exporters, and the School has much wider involvement with the industry.

The **Flight Simulation and Technology Engineering** group within the school “is currently funded or supported by a variety of sources including the European Commission, the Engineering and Physical Sciences Research Council, BAE Systems, AgustaWestland, Eurocopter, GE Dowty, DSTL, the Civil Aviation Authority, United States Army and the Regional Growth Fund. The group has secured over £10 million of funding to date.”<sup>[13]</sup>

Research is conducted in several centres.

The **Centre for Engineering Sustainability**<sup>[14]</sup> is concerned with climate change and declining natural resources, renewable energy sources and sustainable materials. However the Centre works with the Institute for Risk & Uncertainty<sup>[15]</sup> (see below) which in turn collaborates with industrial partners including Rolls Royce, Airbus, the National Nuclear Laboratory, EDF Energy, national and international police forces, i.e. the military, nuclear, and security sectors.<sup>[16]</sup>

The **Centre for Materials and Structures**<sup>[17]</sup> includes work on Nanostructured functional materials, structural materials and mechanics for optimum structural design, explosion resistance and impact loading, and materials degradation at high temperatures. The Centre participates in the EPSRC Centre for Innovative Manufacturing in Laser-based Production Processes,<sup>[18]</sup> whose industrial partners include Airbus, AWE (the Atomic Weapons Establishment), BAE, GE Aviation, and Rolls Royce (all profiled above)

The **Centre for Engineering Dynamics**<sup>[19]</sup> includes work on aerodynamics, flight dynamics and flight simulation, with clear links to the defence industry. The Centre states “Much of this cutting edge work is undertaken in partnership with major industry names”. It mentions research on Nonlinear Flexibility Effects on Flight Dynamics and Control of Next-Generation Aircraft<sup>[20]</sup> with project partners Airbus Operations, BAE Systems, DSTL and Qinetiq (all profiled above) . More details of research within the Centre for Engineering Dynamics are discussed below.

The **Virtual Engineering Centre (VEC)**,<sup>[21]</sup> based at Daresbury,<sup>[22]</sup> is a public-private partnership<sup>[23]</sup> established in 2010 with the University of Liverpool, the UK government Science and Technology Facilities Council,<sup>[24]</sup> BAE Systems,<sup>[25]</sup> Morson Projects, and the North West Aerospace Alliance. **Sci-Tech Daresbury**<sup>[26]</sup> includes business collaboration with IBM and Lockheed Martin.<sup>[27]</sup>

BAE is profiled above. Morson is an engineering recruitment and project management company. It proclaims “At Morson, we supply exceptional personnel across military and civilian projects... we pride ourselves on our involvement with some of the world’s most prominent Aerospace and Defence organisations.”<sup>[28]</sup>

The North West Aerospace Alliance “represents approximately 25% of the UK aerospace industry with over 220 member companies and a combined turnover in excess of £7 Billion”.<sup>[29]</sup> Members supplying the defence sector and/or

applying for military export licences include Airbus, BAE Systems, Ferranti Technologies, Magellan Aerospace, Rolls-Royce, Siemens, and Teledyne (all profiled above).<sup>[30]</sup> A fuller table of NWAA members with military connections is shown in an Appendix.

## **Centre for Autonomous Systems Technology (CAST)**

CAST<sup>[31]</sup> is concerned with programmable robots acting autonomously without human intervention. Such robots include Unmanned Aerial Vehicles (UAVs or drones), such as the BAE Systems Taranis,<sup>[32 33]</sup> capable of semi-autonomous flight, and the Mantis<sup>[34 35]</sup> which is designed to pilot itself. CAST operates through the Virtual Engineering Centre (VEC) with inputs from the depts of Computer Science, Electrical Engineering & Electronics, Engineering, Law, Philosophy, and Psychology, along with the VEC.



One theme of CAST research is Autonomous Systems Architectures,<sup>[36]</sup> whose web page has a photo of a drone. One research strand is the GAMMA Programme,<sup>[37]</sup> “created to ask that, given that the intelligent vehicles and systems will exist – and remotely operated systems already do, how can they be used most effectively and how can the UK benefit most from that market?” Its lead partners include BAE Systems, the North West Aerospace Alliance (NWAA), Universities of Manchester, Lancaster, Salford, Liverpool, UCLAN, Liverpool (including the Virtual Engineering Centre), National Nuclear Laboratories Limited, with further support from Lancashire County Council.

Another CAST theme Cooperation and Coordination,<sup>[38]</sup> concerns collective activity by robots. Research includes the “Robotic Autonomy Simulation Lab (RASL)” which

operates through the Virtual Engineering Simulation Laboratory (VESL),<sup>[39]</sup> which in turn states “Developed collaboratively with BAE Systems, VESL provides an open access environment for systems integration and support. Current projects include the evaluation of UAV [i.e. drone] mission performance and supporting the certification process of UAVs.” VESL is part of the Virtual Engineering Centre.

The web page of a third CAST theme Verification and Validation<sup>[40 41]</sup> shows the drone photo again, and projects include UAV Certification, which aims to answer the question “once systems can make their own decisions then how can we be sure that such autonomous systems will do what we require and will act safely and legally?”, unintended irony given BAE's involvement in the previous two themes.

A fourth CAST theme Autonomous Robotics<sup>[42]</sup> includes a project on Verifiable Ethics whose link, perhaps symbolically, is broken.<sup>[43]</sup>

The final CAST theme Autonomy in Aerospace<sup>[44]</sup> shows the drone photo yet again, mentions the GAMMA Programme,<sup>[45]</sup> and refers to “more autonomous vehicles for both civil and military search and surveillance applications.” Projects include Ship-Board Launch and Recovery of an Unmanned Autonomous Air System, again with a broken link. This topic is of interest to naval forces.<sup>[46 47 48 49]</sup>

## **Institute for Risk and Uncertainty**

Hosted through the Faculty of Science and Engineering, the interdisciplinary Institute for Risk and Uncertainty<sup>[50]</sup> describes itself as “dedicated to helping people and organisations create a safer world”. Some of its academic and industrial partners have military connections. The Institute works with the Logic and Computation group<sup>[51]</sup> within Computer Science which in turn collaborates with the Centre for Autonomous Systems Technology (see above) and with BAE Systems and Airbus. The Institute itself names Airbus and Rolls-Royce as industrial partners.<sup>[52]</sup> Without giving details, the

Institute mentions recent industrial collaborations with partners including Airbus, Dynamore, LMS, MMI, and the Ural Works of Civil Aviation, each of which engages in military work.<sup>[53]</sup>

Airbus is profiled above.

Dynamore markets the engineering simulation software LS-DYNA<sup>[54]</sup> for civil and military use.<sup>[55]</sup> LS-DYNA was originally developed at the US nuclear weapons lab Lawrence Liverpool National Laboratories.<sup>[56]</sup> Its forerunner, DYNA3D was created in order to simulate the impact of the Full Fusing Option (FUFO) or "Dial-a-yield" nuclear bomb for low altitude release.<sup>[57]</sup>

LMS, now owned by Siemens,<sup>[58]</sup> is an engineering simulation tool with applications in fields including military transport,<sup>[59]</sup> military standards testing,<sup>[60]</sup> and an Airbus military helicopter.<sup>[61]</sup>

MMI has civil and military clients in the UK, US and overseas,<sup>[62]</sup> and engages in military aircraft design projects.<sup>[63]</sup>

The Ural Works of Civil Aviation<sup>[64]</sup> is a Russian company which produces drones, one of which was recently shot down over Ukraine.<sup>[65]</sup>

*Lugansk News Today*



The drone uses an Israel Aerospace Industry design, produced under an agreement signed in October 2010.<sup>[66]</sup>

Details of collaboration between the Institute for Risk and Uncertainty and these partners are not shown.

## School of Electrical Engineering

The Intelligence Engineering and Industrial Automation Research Group<sup>[67]</sup> is concerned with computational intelligence, systems control and analysis, information processing and management; and their applications to industrial and engineering systems. An e-Automation Laboratory has been established in partnership with National Instruments. The Lab is described in the University Guide in relation to wind turbines and is supported by National Grid plc.<sup>[68]</sup> National Instruments (profiled above) uses the National Grid as a case study for its LabVIEW system of e-automation.<sup>[69]</sup> But LabVIEW is also used in military communication<sup>[70]</sup> and the Lockheed Martin F-35 fighter programme,<sup>[71]</sup> and National Instruments has extensive military contracts, as profiled above.

The School's current pilot project on Global Navigation Satellite Systems with BAE Systems is funded through Innovate UK (formerly the Technology Strategy Board).<sup>[72]</sup> The proposal states "For navigation systems suitable for the installation on either small vehicles or individual soldiers the challenges are to make an affordable antenna with a small physical size and high sensitivity... The project will be led by BAE Systems Advanced Technology Centre (ATC) who have over 50 years experience in antenna design, navigation techniques and electromagnetic (EM) simulation. ATC develops technologies for BAE Systems product units (Military Air, Maritime and Land Systems) and so is well placed to bring a military systems perspective, environmental qualification and exploitation route to the GNSS solution. MoD is currently funding ATC to design both wideband antennas and antennas manufactured using conducting textiles. ATC will be supported by Liverpool University..."

Research into cyber-security is undertaken in partnership with Hewlett-Packard, funded by an

EPSRC grant: Bayesian Analysis of Competing Cyber Hypotheses.<sup>[73]</sup> The research aims to use mathematical techniques to identify the source of cyber security threats. The proposal explains “Additionally, we see links to “transnational organised crime” (cyber-crime is lucrative and widespread) as well as “Terrorism” (state-sponsored cyber-warfare is increasing) and “Ideologies and beliefs” (anti-establishment hacktivists, eg Anonymous, are also resorting to cyber-attack to express their views)... in the 1970s, the CIA developed a technique, “Analysis of Competing Hypotheses” which encourages analysts and decision makers to avoid the pitfalls that can be associated with intelligence analysis.”

The ICENITE<sup>[74]</sup> project to optimise the structure of cables in bundles used in large platforms such as aeroplanes and ships, involves BAE (the project lead) and Bombardier.<sup>[75]</sup> BAE will lead on Optimisation of Installed Architectures for Electromagnetic Performance. BAE is interested in the Electromagnetic Environment (EME) for the design of aircraft carriers, as shown in the LinkedIn profile of their Queen Elizabeth Class EME Lead.<sup>[76]</sup>

Atomic Weapons Establishment (AWE) involvement in the Dept includes the Fusion Doctoral Training Network (see EPSRC section below).

## Computer Science

The Computer Science Department lists “some of the industrial organisations that fund and take part in our research and education programmes”,<sup>[77]</sup> including companies with military interests: BAE Systems, Hewlett-Packard, Honeywell, IBM, Siemens. Departmental research into Market Based Control of Complex Computational Systems<sup>[78]</sup> was undertaken in partnership with BAE Systems, Hewlett-Packard, BT and IBM, with EPSRC funding. The Computer Science intranet explains “The project aimed to adapt ideas from economics to the design and management of complex distributed computer systems, such as those used in fleets of self-guided aircraft...”<sup>[79]</sup> [i.e.

drones]. A profile of one graduate of the dept mentions his work for BAE Systems on the Astute Class Nuclear Submarine programme.<sup>[80]</sup>

## School of Management

The School of Management postgraduate courses include an MRes<sup>[81]</sup> whose Career Prospects page mentions work experience placements with Airbus, Caterpillar, and Hewlett-Packard. The same firms are mentioned as career prospects for the Entrepreneurship MSc.<sup>[82]</sup>

The School of Management operates Knowledge Platforms, one of which is Operations and Supply Chain Excellence. A current research project is **Management & Measurement of Service Delivery Arrangements, UK Ministry of Defence / Qinetiq funding £121,000 2014-2017.**<sup>[83]</sup> The project aims to support service delivery arrangements and reduce the risk associated with the uncertainty of delivery outcomes. Details are not shown, but the MoD is concerned with these issues for the provision of defence equipment.<sup>[84]</sup>

## Centre for Engineering Dynamics

We now look in more detail at some projects within the Centre for Engineering Dynamics, with military spin-off or direct military applications.<sup>[85]</sup>

### AgustaWestland Liverpool Advanced Rotorcraft Centre

The AWLARC is a joint project between the School of Engineering and AgustaWestland, developing “computational fluid dynamics software to simulate the flow of air around helicopters, with the aim of optimising and increasing the efficiency of these versatile machines.” When the then Business Secretary Vince Cable visited in 2012,<sup>[86]</sup> Head of UK research at AgustaWestland Jim Godman said: “We are very proud of the work that we are doing with Liverpool and Dr Cable’s visit was a great opportunity to share with him the programmes we are developing. We also discussed other Liverpool partnership work, such as the Technology Strategy Board funded-project to enhance the performance of tilt-rotors and

work to introduce active trailing edge flaps on helicopter blades.”

There have been 3 grants from the Technology Strategy Board (now Innovate UK):

**HiPerTilt**<sup>[87]</sup> - Innovative Aerodynamic Design Solutions for High-Performance Tiltrotor Aircraft

£1,373,240; Apr 13 - Mar 16.

HiPerTilt led by AgustaWestland with the University of Liverpool and Bristol will develop world leading aerodynamic models, processes, techniques and new designs/products integral to the design and development of next generation tilt-rotorcraft in the UK.

**Rotorcraft Technology Validation Programme**<sup>[88]</sup>

£5,825,000; Apr 10 - Mar 14

The Rotorcraft Technology Validation Programme (RTVP) is a collaborative 4-year programme to flight-demonstrate world-leading UK helicopter technologies; active rotors, active Vibration Management Systems (VMS) and Condition Based Maintenance (CBM).

**Rotor Embedded Actuator Control Technology (REACT)**<sup>[89]</sup>

£4,471,530; Mar 08 - Mar 13

...groundwork towards developing future generation flight trialed active rotor technology. Involved are The University of Bristol (power electronics), University of Liverpool (Computational Fluid Dynamics) and the University of Leicester (controls and algorithms). AgustaWestland is examining the manufacturing implications, operational capabilities, performance potential, flight safety, and control issues of the activated blade.

All these projects have civilian applications, but AgustaWestland is a major defence exporter (profiled above). As the Innovate UK data for the RTVP programme states, “**Once these technologies are validated they will be developed and embodied throughout the entire range of AW helicopters**”.<sup>[90]</sup> That is, civilian platforms and academic collaboration are being used to develop and test technologies intended for civil and military markets.

## Structural Dynamics

The Structural Dynamics Research Group within the Centre for Engineering Dynamics has worked with AWE. This includes research into the AWE-MACE, carried out jointly by engineering staff in Liverpool, Tehran, and at Aldermaston. The MACE (Modal Analysis Correlation Exercise) is an unclassified structure from the Atomic Weapons Establishment at Aldermaston UK, having joints representative of those in a nuclear warhead.<sup>[91]</sup> The research was funded by the EPSRC and published with permission of the Ministry of Defence and the Atomic Weapons Establishment (AWE-Aldermaston).

## Computational Fluid Dynamics Laboratory

The CFD lab<sup>[92]</sup> hosts NATO research into Unmanned Combat Aerial Vehicles (UCAV), as designed for *drone wars*,<sup>[93]</sup> including funding from BAE Systems and the Technology Strategy Board (now Innovate UK) with other related projects funded by the EU.

1. The Research Excellence Framework REF2014<sup>[94]</sup> data for General Engineering at the University of Liverpool refers to NATO involvement:<sup>[95]</sup>

Major collaborations include:

NATO Scientific working group AVT-113 measured/computed the vortical flow on an unmanned air vehicle model. The group, including NASA, Boeing, BAE SYSTEMS, German Aerospace Centre (DLR), produced journal publications (including Badcock#3) and an international conference. Liverpool was a significant contributor to the computations and organisation of this activity, and the follow-on AVT-161 and 201. The Liverpool PhD student (Vallespin) was a co-recipient of the NATO Scientific Achievement Award 2012 for the outcomes of AVT-161.<sup>[96]</sup>

**AVT-113**<sup>[97]</sup> was a NATO programme running from 2004 to 2007, with researchers from 11 countries including the UK and US, entitled Understanding and Modeling Vortical Flows to Improve the Technology Readiness Level for Military Aircraft, involving computations on a complete fighter aircraft (F-16XL). A paper by Prof. Ken J. Badcock as part of AVT-113 describes calculations at the CFD Laboratory cluster.<sup>[98]</sup>

**AVT-161**<sup>[99]</sup> was a NATO programme running from 2008 to 2011, entitled Assessment of Stability and Control Prediction Methods for NATO Air & Sea Vehicles, whose aim was “To assess the state-of-the-art in computational fluid dynamics methods for the prediction of static and dynamic stability and control characteristics of military vehicles in the air and sea domains”, including Unmanned Combat Air Vehicles (UCAV).

**AVT-201**<sup>[100]</sup> is a NATO programme 2012-2015 including 11 countries and NASA, whose final report is yet to appear. Entitled Extended Assessment of Reliable Stability & Control Prediction Methods for NATO Air Vehicles, it concerns the application of Computational Fluid Dynamics to the design of Unmanned Combat

Aerial Vehicles (UCAV) using a prototype military drone, known as SACCON (Stability and Control Configuration), originally designed by EADS-Military Air Systems (EADS is now renamed Airbus).<sup>[101]</sup>

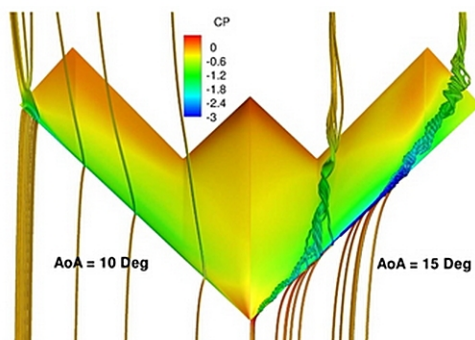
A research paper for the June 2014 Conference of the American Institute of Aeronautics and Astronautics, by D.J. Kennett (School of Engineering), G. Hoholis (CFD lab) and K.J. Badcock (Head of the School of Engineering and the CFD lab) is entitled “Numerical Simulation of Control Surface Deflections over a Generic UCAV Configuration at Off-design Flow Conditions”.<sup>[102]</sup> It concerns detailed modelling of SACCON. The acknowledgements state

This research has been supported by BAE SYSTEMS and the Technology Strategy Board as part of the Simulation at Off-Design Conditions (SimOD) group. Special thanks is also extended to the AVT-201 team members for their efforts in obtaining CFD and experimental data, and also for their subsequent discussions and advice.

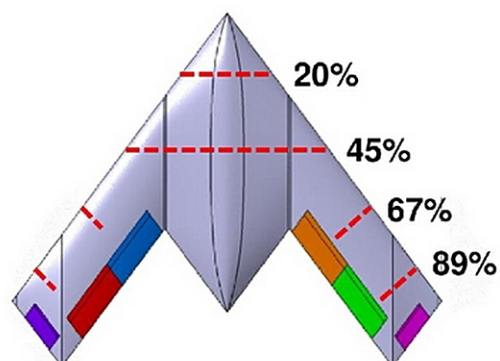
The CFD lab website mentions the paper in its page on **Flow Simulation at Off-Design Conditions**.<sup>[103]</sup>

## Results

Click on the following images to enlarge the view.



SACCON flow physics at alpha 10 and 15 degrees.



SACCON control surface and pressure coefficient slice location.



Other research topics in the CFD lab include:

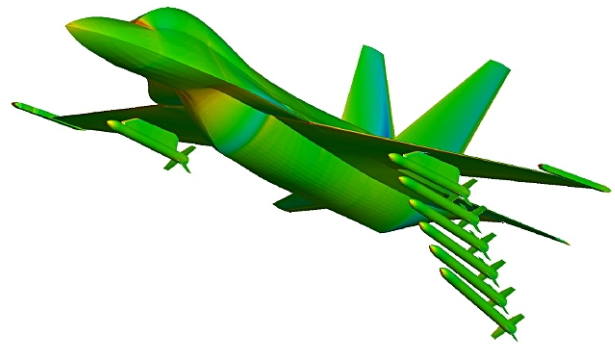
**Vortical Flows**, work on stability of fighter aircraft, carried out within the framework of international working groups - Thales JP12.15, NATO AVT-080, NATO AVT-113 and NATO AVT-161. Publications include Vortical Flow Prediction Validation for an Unmanned Combat Air Vehicle Model (AVT-161),<sup>[104]</sup> Validation of Vortical Flow Predictions for a UCAV Wind Tunnel Model,<sup>[105]</sup> Comparison of DES and URANS for Unsteady Vortical Flows over Delta Wings (AVT-80, AVT-113).<sup>[106]</sup>

**Buffet Control of Transonic Wings**,<sup>[107]</sup> funded through the EU FP-7 project BUCOLIC (see below). At first sight, the project concerns civilian passenger aircraft. However, it is carried out jointly with the Aircraft Research Association, comprising Airbus, BAE Systems, Dowty-Rotol (now Dowty, part of GE Aviation), and AgustaWestland. Buffet and transonic roll-off (wing drop) are current issues for military aircraft designers.<sup>[108 109]</sup>

**FlexFlight Project**,<sup>[110]</sup> partnered with Airbus UK, BAE Systems, DSTL, QinetiQ (all profiled above) and sponsored by the EPSRC. “The project will develop a systematic approach to flight control system (FCS) design for very flexible or very large aircraft, of the type being considered for low-environmental-impact air transport and for long-endurance unmanned operations.” Amongst the recent presentations cited, An Adaptive Aeroelastic Control Approach by using Nonlinear Reduced Order Models<sup>[111]</sup> concerns a flexible UAV (drone) model, and Reduction of Nonlinear Models for Control Applications<sup>[112]</sup> shows this model was developed at the DSTL by Peter Hopgood, the Aircraft Structures Lead within the Air and Weapons Systems Department.<sup>[113]</sup> An animated version is shown on a FlexFlight page in a section headed “DSTL Unmanned Aerial Vehicle (UAV)”.<sup>[114]</sup>

### **Meshless Preprocessor and Solver**,<sup>[115]</sup>

partnered with BAE Systems and sponsored by the EPSRC. The project report refers to simulations in which missiles are dropped from the Open Source Fighter (itself based on publicly available data for the F-16).



pressure: 0.3 0.42 0.54 0.66 0.78 0.9 1.02 1.14 1.26 1.38 1.5

“A three-dimensional store release from an aircraft can be seen in the Open Source Fighter<sup>[116]</sup> test case below... For the first time step all of the bodies are touching; but for the subsequent steps the store geometry has separated, and the meshless method allows us to simulate this movement as the store descends.”<sup>[117 118]</sup>

The **Computational Aeroelasticity**<sup>[119]</sup> page refers repeatedly to the “Open Source Fighter”, further described under the ECERTA programme funded via EU FP-6.<sup>[120]</sup>

**Fluidic Control of Aircraft**,<sup>[121]</sup> partnered with BAE Systems and sponsored by the EPSRC, states “Initial validation using the SACCON configuration will be done to ensure that the correct flow features are modelled, particularly the flow breakdown over the wings at high angles of attack. The fluidic devices will then be applied to the SACCON to determine their performance throughout manoeuvres and also compare them to conventional control surfaces.” As discussed above, SACCON is a prototype military drone originally designed by EADS-Military Air Systems.

**Computational Flight Dynamics**,<sup>[122]</sup> partnered with Airbus and sponsored by the EPSRC. The page describes modelling applied to the NACA 0012 aerofoil, a helicopter blade section studied by the MoD.<sup>[123]</sup> One of the conference papers listed, Requirements for Computer Generated

Aerodynamic Models for Aircraft Stability and Control Analysis, concludes “Future work will involve identifying examples relevant to UCAV configurations arising from leading edge vortex dynamics”.<sup>[124]</sup> UCAV are Unmanned Combat Aerial Vehicles (armed drones), as above.



**photo: Activestills.org.** A Palestinian youth stands on the roof of a destroyed house September 4, 2014 in Shuja'iyya neighborhood, east of Gaza city, which was heavily attacked during the Israeli offensive.

## Notes to University of Liverpool

- [1] <http://www.liv.ac.uk/>
- [2] <http://www.jobs.ac.uk/job/AEI719/phd-case-studentship-with-airbus-uk/>
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# Finance:

## Endowment and Pension Funds

Whilst direct funding of University projects by arms companies is hidden from view, there is some public information on endowment and pension fund investment, finance from the Atomic Weapons Establishment (see above), the Engineering and Physical Sciences Research Council grants and EU funding streams (see next sections).

Currently, the University is conducting a review of endowment funds held on trust.<sup>[1]</sup> The University has its own pension scheme, the University of Liverpool Pension Fund. The Statement of Investment Principles is not a public document, but is available to members of the scheme on request.<sup>[2]</sup>

In July 2008 information was obtained through a Freedom of Information request by CAAT.<sup>[3]</sup> At that time, both the non-academic staff pension fund and the endowment fund included arms companies:

UK arms company shareholdings\*:  
 BAE Systems £1,629,450 (+ £5,250)  
 Rolls Royce £283,670 (+ £3,150)  
 VT Group £2,022,443 <sup>[4]</sup>

US arms company shareholdings\*:  
 Boeing £3,150  
 General Dynamics £2,100  
 General Electric £55,650  
 Lockheed Martin £2,100  
 Northrup Grumman £1,050  
 Raytheon £1,050

\*Most UK arms company shares were [as of July 2008] held directly, with the BAE Systems and Rolls Royce shares, and a minority of the VT Group shares, held via the non-academic staff pension fund. Most VT Group shares were held via the endowment portfolio. The University also

held shares in BAE Systems and Rolls Royce indirectly via pooled funds. All US arms company shareholdings were held indirectly via pooled funds.

Endowment Funds Invested (all shares) £105m  
 Arms shares as % of total investments 2.7

### USS pension fund

Academic staff are also eligible to join the University Superannuation Scheme,<sup>[5]</sup> which publishes full details of the Statement of Investment Principles,<sup>[6]</sup> the top 100 equity investments,<sup>[7]</sup> and a list of all equity investments.<sup>[8]</sup>

USS Equity investments currently include

name	value	rank
BAE Systems	£117.1m	26
Siemens	£70.2m	78

and, without showing value or rank

Babcock International<sup>[9]</sup>  
 Finmeccanica (own AgustaWestland, see profile)  
 Honeywell International (see profile)  
 Raytheon<sup>[10]</sup>

along with banks and insurance companies with heavy investments in the arms trade, including **HSBC, with £299.3m, ranked 2; Barclays, with £117.4m, ranked 24; and Lloyds, with £105.9, ranked 36.**<sup>[11]</sup>

## Notes to Finance: Endowment and Pension Funds

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# Finance: Engineering & Physical Sciences Research Council

Much of the arms-related University research is funded through the Engineering & Physical Sciences Research Council, the main UK government agency for funding research and training in engineering and the physical sciences.<sup>[1]</sup> At least 50 EPSRC grants, worth over £30 million (not all for Liverpool), involve the University with arms companies and, in some cases, have direct military applications. We begin with the participation of arms companies and Liverpool academics in the Panels which award grant funding, and with BAE involvement in the EPSRC Peer Review College.

## Proposal Processing Panels

Grant applications are awarded through Panels, some of which involve representatives of the arms industry alongside University of Liverpool academics.

### Active Aircraft Full Proposals

Date of Panel: 26 February 2007

Panel members include Professor K Badcock University of Liverpool, Dr T Slack Airbus Operations <sup>[2]</sup>

### Materials Prioritisation Panel

Date of Panel: 13 April 2007

Panel members include Professor PR Chalker University of Liverpool, Professor J Fernie AWE, Dr P Withey Rolls-Royce Plc <sup>[3]</sup>

### Early Careers Forum 2013 Call

Date of Panel: 21 November 2013

Panel members include Dr CJ Sutcliffe University of Liverpool, and Dr S Harris BAE Systems <sup>[4]</sup>

### EPSRC Physical Sciences Materials

Date of Panel: 09 September 2011

Panel members include Prof M Rosseinsky University of Liverpool, and Dr A Stove Thales Group

[Thales Group = QinetiQ, DLR, NLR, EADS and Alenia, see **International Exercises on Validation of Delta Wind Simulation** below] <sup>[5]</sup>

### Process Environment and Sustainability

Date of Panel: 16 June 2009

Panel members include Dr G Agnew Rolls-Royce Plc, and Professor RJ Poole University of Liverpool <sup>[6]</sup>

As of 22/10/2010 the EPSRC Peer Review College included 37 representatives of BAE.<sup>[7]</sup>

Dr M Allan BAE Systems

Advanced Technology Centre (ATC)

Mr MD Andrew BAE Systems Programmes & Support Performance Excellence

Dr JM Bagshaw BAE Systems ATC

Technology and Engineering Services

Mr S Barker BAE Systems ATC

Dr P Blanchard BAE Systems ATC

Mr C Boutle BAE Systems Integrated System Technology

Dr S Case BAE Systems

Mr N Colford BAE Systems ATC

Professor RL Cooke BAE Systems ATC

Mr AGT Cross BAE Systems

Dr A El-Fataty BAE Systems Programmes & Support Performance Excellence

Dr P Foote BAE Systems (Sowerby Research Centre)

Dr S Harris BAE Systems (Sowerby Research Centre)

Mr J Hinton BAE Systems (Sowerby Research Centre)

Mr S Johnston BAE Systems Military Air Solutions

Dr D Kells BAE Systems (Sowerby Research Centre)

Mr I Leaver BAE Systems Defence Ltd

Mr I MacDiarmid BAE Systems Warton Aerodrome

Dr JT Macklin BAE Systems ATC Communication & Information Systems Divi

Mr N Martin BAE Systems Avionics Management Ltd E and IS Platform Solutions

Dr S McCallum BAE Systems ATC

Dr I McKenna BAE Systems Naval Ships Unknown

Mrs C Moss BAE Systems ATC

Dr D Nicholson BAE Systems

Dr A J Parker BAE Systems ATC

Mr J Pinto BAE Systems ATC

Dr A Rezai BAE Systems (Sowerby Research Centre)

Dr N Sellars BAE Systems Military Aircraft

Dr D Standingford BAE Systems ATC ATC (Bristol)

Dr V Stanger BAE Systems ATC

Mr CD Utting BAE Systems

Dr NA Verhoeven BAE Systems ATC

Mr A Wake BAE Systems Military Air Solutions

Mr R Wallace BAE Systems Warton Aerodrome

Mr PJ Wardle BAE Systems

Integrated System Technologies

Professor C Warsop BAE Systems

Mr P Woods BAE Systems (Sowerby Research Centre)



EPSRC grants involving the University of Liverpool with the arms industry include:

## Drones

### New Foundational Structures for Engineering Verified multi-UAVs <sup>[8]</sup>

University of Oxford – Computer Science  
Partners: George Washington University, IBM, McGill University, University of Liverpool  
Starts: 01 June 2012 Ends: 31 May 2015  
Value (£): 636,718

In order to work autonomously, these systems need to be highly intelligent and rational so that they can become reliable... In a multi-UAV setting, they should additionally be able to communicate with each other to simplify their goals, to learn from each other's information, and to update and share their knowledge... In 1996, the Lockheed Martin/Boeing Darkstar long-endurance UAV crashed following what the Pentagon called a "mishap [...] directly traceable to deficiencies in the modelling and simulation of the flight vehicle" [a stealth unmanned reconnaissance plane].

### Advanced Aerodynamic Modelling for Flight Dynamics Applications <sup>[9]</sup>

School of Engineering  
Partners: BAE Systems  
Starts: 30 April 2006 Ends: 29 September 2009  
Value (£): 208,352

A dataset from the MoD will be used for initial validation of the CFD predictions, followed by a generic Hawk trainer model and concluding with the proposed FLAVIIR demonstrator vehicle.

(FLAVIIR was a project with 10 Universities coordinated by BAE to develop UAVs (drones)) <sup>[10 11 12 13]</sup>

### Market Based Control of Complex Computational Systems <sup>[14]</sup>

Computer Science  
Partners: BAE Systems, BT, Hewlett Packard, IBM  
Starts: 01 October 2004 Ends: 31 March 2010  
Value (£): 684,598

...our long-term goal is no less than Automated Mechanism Design (AMD), the automation of interaction mechanism design and the automation of strategy-selection for participants in distributed computational systems.

(The Computer Science intranet <sup>[15]</sup> explains "The project aimed to adapt ideas from economics to the design and management of complex distributed

computer systems, such as those used in fleets of self-guided aircraft..." - i.e. drones)

## Nuclear warhead engineering fission and fusion

### Linux Cluster for Structural Dynamics Research <sup>[16]</sup>

U of Liverpool School of Engineering  
Starts: 18 January 2005 Ends: 17 January 2008  
Value (£): 53,187

Current projects involve several large scale systems such as a whole Lynx helicopter (research funded by QinetiQ), a helicopter tail cone with Westland Helicopters, Rolls-Royce aero-engine casings, the MACE structure from AWE-Aldermaston and a Ford Focus body shell.

Research into the AWE-MACE <sup>[17]</sup> was carried out jointly by engineering staff in Liverpool, Tehran, and at Aldermaston. The MACE (Modal Analysis Correlation Exercise) is an unclassified structure from the Atomic Weapons Establishment at Aldermaston UK, having joints representative of those in a nuclear warhead.

### Modal Analysis System <sup>[18]</sup>

U of Liverpool School of Engineering  
Starts: 02 June 2003 Ends: 01 June 2006  
Value (£): 123,080

The Structural Dynamics Research Group are already involved with research projects involving several large systems including, Rolls-Royce aero-engine casings, the tail-cone from a Lynx helicopter, MACE (a missile-like structure) from AWE Aldermaston, and a Ford Focus body shell.

### Model structure determination VFII <sup>[19]</sup>

School of Engineering  
Project Partner: AWE  
Starts: 11 July 2001 Ends: 10 October 2001  
Value (£): 14,185

... The MACE (Modal Analysis Correlation Exercise) structure was purpose-built at AWE Aldermaston and will be available for the research.

### EPSRC Centre for Doctoral Training (CDT) in Nuclear Fission - Next Generation Nuclear <sup>[20]</sup>

U of Manchester, Chemistry  
Project Partners: AMEC, AREVA Group, AWE, EDF Energy, National Nuclear Laboratory Ltd, Nuclear Decommissioning Authority, Rolls-Royce Plc, Sellafield Ltd  
Starts: 01 April 2014 Ends: 30 September 2022  
Value (£): 5,181,479

The U of Liverpool investigator is Professor EA Patterson School of Engineering  
Next Generation Nuclear is a collaborative CDT involving the Universities of Lancaster, Leeds, Liverpool, Manchester and Sheffield, which aims to develop the next generation of nuclear research leaders.

#### **Fusion Doctoral Training Network** <sup>[21]</sup>

U of York, Physics  
Starts: 01 October 2009 Ends: 31 March 2012  
Value (£): 201,925

The Liverpool researcher is Professor JW Bradley, Electrical Engineering and Electronics.  
...With inertial fusion, the Orion laser facility is just coming on line at AWE Aldermaston...

#### **Materials for fusion & fission power** <sup>[22]</sup>

University of Oxford, Materials  
Project Partners: CEA - Atomic Energy Commission, EURATOM/CCFE, Rolls-Royce Plc  
The U of Liverpool researchers are Professor GJ Tatlock, Centre for Materials and Structures, and Dr A R Jones, Centre for Engineering Dynamics

## **Helicopters and Tilt-Rotor**

#### **A New Approach to Active Vibration Suppression** <sup>[23]</sup>

School of Engineering  
Project Partners: Westland  
Starts: 01 October 2007 Ends: 31 March 2011  
Value (£): 321,900  
Sector: Transport Systems and Vehicles  
The research will be carried out in close collaboration with engineering scientists from Westland Helicopters Ltd. Tests were carried out on the W30 airframe. (The W30 <sup>[24]</sup> is a dual civil-military helicopter)

#### **Optimising Handling Qualities for Future Tilt Rotor Aircraft** <sup>[25]</sup>

School of Engineering  
Partners: BAE Systems, DSTL, Eurocopter, National Aerospace Laboratory NLR, ONERA Salon-de-Provence Center  
Starts: 01 February 2005 Ends: 31 July 2008  
Value (£): 356,864  
One of the drivers to the improvement goals in safety and operational capability, set out in ACARE's Vision 2020, is the provision of improved flight HQs particularly in poor weather and reduced visual ranges. ACARE participants <sup>[26]</sup> include many

military aerospace companies....The Liverpool flight simulator will be the principal test facility...

#### **Active Control Concepts for Handling Qualities, Envelope Protection and Structural Load Alleviation** <sup>[27]</sup>

School of Engineering  
Project Partners: BAE Systems, Deutsches Zentrum fur Luft-und Raumfahrt, National Research Council of Canada, QinetiQ, TU Delft, Westland  
Starts: 1 September 2003 Ends: 31 March 2007  
Value (£): 512,365  
Sector: Aerospace, Defence and Marine  
More stringent criteria will be applied in the procurement and certification of future rotorcraft, civil and military, and better models and control systems will be part-and-parcel of this.

#### **Garteur AG12; Validation Criteria for Helicopter Real Time Simulation Models** <sup>[28]</sup>

School of Engineering  
Project Partners: QinetiQ  
Starts: 29 October 2002 Ends: 28 October 2004  
Value (£): 5,507  
Sector: Aerospace, Defence and Marine  
The group will involve helicopter and simulation specialists from DLR, ONERA, NLR, Eurocopter and Westland Helicopters, in addition to QinetiQ. The work Liverpool will bring to the Group will be conducted under EPSRC grant GR/R02603/01 - Adaptive pilot model for simulation fidelity assessment, which runs until September 2003... [develop] criteria for simulation fidelity which may be usable in requirements specifications for new training simulators for civil and military use.

#### **Inverse methods for vibration suppression using structural modifications** <sup>[29]</sup>

School of Engineering  
Project Partners: Westland  
Starts: 01 October 2001 Ends: 30 September 2004  
Value (£): 208,546  
Sector: Aerospace, Defence and Marine

#### **Model Structure Determination** <sup>[30]</sup>

School of Engineering  
Project Partners: Ford Motor Co, Rolls-Royce Plc  
Starts: 05 October 1998 Ends: 04 July 2002  
Value (£):148,183  
...tests on structures, including a Lynx helicopter (data and f.e. models provided by DERA)...  
(The Lynx is a multi-purpose military helicopter, <sup>[31]</sup> DERA <sup>[32]</sup> was the former Defence Evaluation and

Research Agency, which formed Qinetiq and DSTL in 2001)

## Aerodynamics

### **Nonlinear Flexibility Effects on Flight Dynamics and Control of Next-Generation Aircraft** [33]

U of Liverpool School of Engineering  
Project Partners: Airbus Operations, BAE Systems, DSTL, QinetiQ

Sector: Aerospace, Defence and Marine  
Starts: 01 April 2011 Ends: 31 March 2015  
Value (£): 264,622

Standard linear control design methods are inadequate for highly flexible aircraft... Fresh approaches to nonlinear FCS design are then required to control these systems... These methods will be exemplified in next-generation aircraft concepts that will be defined in discussion with end users. In fact, the project will benefit from a strong collaboration with major UK industrial partners, which will provide substantial technical inputs and support to the planned research activities. (see FlexFlight project with application to military drones, discussed above)

### **Nonlinear Active Vibration Suppression in Aeroelasticity** [34]

U of Liverpool Centre for Engineering Dynamics  
Starts: 01 February 2012 Ends: 31 July 2015  
Value (£): 424,647

The research will include an experimental programme using the low-speed wind tunnel as well as the development and application of CFD code in the transonic range. The latter will include a study of the XFR-1 (a long-range twin engine wide body aircraft) with nonlinearity/structural damage inserted by engineering scientists from Airbus UK, unknown to the Liverpool researchers.

### **Supercomputer Resources for the UK Applied Aerodynamics Consortium** [35]

U of Liverpool School of Engineering  
Starts: 17 December 2005 Ends: 16 August 2007  
Value (£): 15,397

A supercomputer consortium will be formed to make use of the new HPCx facility for research in applied aerodynamics... participation of groupings from the PUMA and rotor DARPs and the main consortia developing codes for Rolls Royce (Hydra) and WHL (HMB).

The UK Applied Aerodynamics Consortium carried out modelling including weapons bays and the Harrier. [36 37 38]

(see also PUMA DARP below)

### **International Exercises on Validation of Delta Wind Simulation** [39]

School of Engineering  
Starts: 01 October 2005 Ends: 31 January 2006  
Value (£): 4,023

Glasgow University is making the only CFD contributions from UK to three major international exercises on delta wing aerodynamics. The first is with THALES grouping (QinetiQ, DLR, NLR, EADS and Alenia) looking at free to roll delta wing calculations The second is with the NATO RTO AG80 grc delta wing aerodynamics which features NRC, NASA, USAF, NLR, KTH, ONERA, Bath and Dassault which is now comparing predictions for a 70 degree delta wing with detailed experimental data. The third group is organised by NASA and aims to validate predictions at flight Reynolds numbers for the F This grouping involves NASA, USAF, Lockheed-Martin, NLR, KTH and EADS. The proposal asks for a travel budget of 13240 to allow attendance and participation in projects meetings for the three exercises.

### **DARP: Unsteady Aerodynamics Prediction and Simulation for Airframe and Turbomachinery Applications (PUMA) DARP** [40]

Principal Investigator: Prof K Badcock (U of Liverpool)  
Partners: Airbus Operations, BAE Systems, Dept for Business, Innovation and Skills, Qinetiq, Rolls-Royce Plc  
Starts: 01 April 2003 Ends: 29 September 2005  
Value (£): 198,164

This project will extend the CFD based aeroelastic prediction tools to realistic aircraft geometries. (a project running concurrently at Loughborough University with the same commercial partners was entitled DARP: PUMA DARP: Unsteady CFD prediction of Vertical Landing Craft. [41] "The vertical landing phase of aircraft such as Harrier or F-35 Joint Strike Fighter is a highly unsteady, complex aerodynamic problem...

The key advance in this project has been the successful Large Eddy Simulation (LES) of a complete Harrier aircraft in ground effect using an unstructured CFD algorithm."

## Pilot aids

### Prospective Sky-Guides: Developing Guidelines for Pilot Vision Aids <sup>[42]</sup>

Aerospace Engineering

Partner: BAE Systems

Sector: Aerospace, Defence and Marine

...new design guidelines for vision aids that use synthesised optical information... Industrial collaboration with BAE Systems will gradually apply technology and certification constraints to the research, thus guiding the academic work to practical fruition.

Starts: 19 May 2003    Ends: 18 May 2006

Value (£): 292,718

(The project is described as intended for civil aircraft applications, but BAE Head-Up Display <sup>[43]</sup> has been incorporated in F-16s <sup>[44]</sup>)

## Manufacturing techniques

### Tracking and Estimation Techniques for Phase Transitions in Complex Plasmas <sup>[45]</sup>

Electrical Engineering and Electronics

Project Partners: Max Planck Institutes (Grouped), QinetiQ

Starts: 01 April 2009    Ends: 31 March 2012

Value (£): 561,138

(Qinetiq interest in this area includes a process for producing nanomaterials <sup>[46]</sup> with military applications, including ignitors <sup>[47]</sup>)

### High Throughput Selective Laser Melting of Cellular Components <sup>[48]</sup>

U of Liverpool School of Engineering

Project Partners: Airbus Group (EADS), Integrated Heat Exchange, McLaren Group, MCP Equipment, Osprey Metals Ltd, ReaLizer GmbH, Southampton Photonics Ltd, Stryker Howmedica Osteonics

Starts: 01 October 2005    Ends: 30 September 2010

Value (£): 1,083,781

(Selective Laser Melting is a technique of Additive Manufacturing (AM) or 3D printing. "Additive manufactured parts are now utilized in aerospace, automotive, medical fields and also in consumer products and military... Large aerospace companies, such as Boeing, GE Aviation, and Airbus, are hard at work qualifying AM processes and materials for flight." <sup>[49]</sup>. "Whilst there is already a flourishing industry for making polymer parts on high-performance military aircraft, probably the greatest interest in this industry is for the direct metal fabrication systems. It is relatively easy for direct

metal AM systems to process titanium, which makes it ideal for incorporation into carbon composite aircraft designs" <sup>[50]</sup>)

### Novel Cellular Structures for Enhanced Impact Performance <sup>[51]</sup>

U of Liverpool School of Engineering

Project Partners: Airbus Group (EADS), Instron Ltd, MCP Equipment, Osprey Metals Ltd

Starts: 11 October 2005    Ends: 10 October 2008

Value (£): 244,214

The core structures will be manufactured using a revolutionary technique called selective laser melting (SLM). SLM is a layered manufacturing technique by which parts of high complexity can be built from metal powder in relatively short timescales.

### Innovative manufacturing technology research centre <sup>[52]</sup>

Engineering

Partners: BAE Systems

Starts: 01 July 2003    Ends: 31 March 2007

Value (£): 2,577,534

The manufacturing research group at the University of Liverpool seeks to attain excellence in manufacturing process and technology research through the establishment of an Innovative Manufacturing Technology Research Centre (IMTRC).

(BAE innovative manufacturing <sup>[53]</sup> projects include metal 3d printed parts for military jets <sup>[54]</sup> and internet for the battlespace <sup>[55]</sup>)

### Additional Management Support for the Liverpool IMRC in e-Business <sup>[56]</sup>

U of Liverpool Management School

Starts: 01 February 2005    Ends: 30 September 2007

Value (£): 152,745

Sector: Aerospace, Defence and Marine, Electronics, Transport Systems and Vehicles

Innovative Manufacturing Research Centre in e-Business was launched at the University of Liverpool in April 2002... Major industrial partners include Westland Helicopters, Airbus, Jaguar, Chiron Vaccines and Compuware who together have contributed almost 0.25m in cash and over 1m in in-kind support since the formation of the IMRC.

### Innovative Manufacturing Centre Proposal: Novel manufacturing processes for functional multilayer oxide thin films <sup>[57]</sup>

School of Engineering

Project Partners: SAFC Hitech

Starts: 01 July 2003      Ends: 31 July 2006  
Value (£): 296,731  
The outcomes of the project have been the subject of further development in EC (REALISE, FAME, SINANO and PULLNANO) and DTI programmes (COSMOS) which involved the industrial Partners Infineon, Philips, STMicroelectronics, ASM Microchemistry, Epichem (now SAFC Hitech) and Qinetiq.

**Innovative manufacturing technology research centre** <sup>[58]</sup>

School of Engineering  
Partner: BAE Systems  
Sector: Aerospace, Defence and Marine  
...All research programmes carried out within the IMTRC will be supported by leading edge national and international companies through close collaborative partnerships.  
Starts: 01 April 2002      Ends: 30 June 2003  
Value (£): 4,900,001

**MTP in Engineering applications of lasers** <sup>[59]</sup>

School of Engineering  
Partners: BAE Systems, Mersey Care NHS Trust, Metal Improvement Co Inc, Royal Mint (The)  
Starts: 08 June 2001      Ends: 31 March 2004  
Value (£): 463,930  
The training environment will be supported by our well-equipped laboratories and research experience gained in a substantial research project based on requirements of one of our industry sponsors.

**Laser forming of aerospace alloys - a direct fabrication technique** <sup>[60]</sup>

School of Engineering  
Partners: BAE Systems Rolls-Royce Plc  
The project will culminate in practical Laser Forming systems for further development by BAe and RR.  
Starts: 01 September 2000      Ends: 31 August 2003  
Value (£): 227,386  
Sector: Aerospace, Defence and Marine

**Laser engineering for manufacturing applications (LEMA - Integrated laser manufacture)** <sup>[61]</sup>

School of Engineering  
Partners: BAE Systems, BNFL, Delcam International plc, Pre Nexus Migration, Rolls-Royce Plc  
Starts: 13 May 1994      Ends: 12 October 1998  
Value (£): 543,414

**Laser Surface Processing** <sup>[62]</sup>

School of Engineering  
Project Partners: BNFL, Glacier Vandervell, Lumonics Ltd, Pre Nexus Migration, Rolls-Royce Plc  
Starts: 01 January 1996      Ends: 30 June 2000  
Value (£): 301,839

**Laser welding of airframe alloys** <sup>[63]</sup>

School of Engineering  
Partners: BAE Systems  
Starts: 01 October 1990      Ends: 30 September 1993  
Value (£): 96,685

**Sensors for control & automation of welding processes - control & integration** <sup>[64]</sup>

Electrical Engineering and Electronics  
Partners: BAE Systems, Optosci Ltd  
Starts: 01 October 2001      Ends: 30 September 2004  
Value (£): 64,413  
Sector: Aerospace, Defence and Marine  
Liverpool's expertise has come from involvement with the EPSRC IMI CEMWAM programme (both phases).

**IMI: Fusion welding process monitoring and control (CEMWAM II)** <sup>[65]</sup>

Electrical Engineering and Electronics  
Partners: Airbus Operations, BAE Systems, Bombardier, British Aluminium Ltd, Ministry of Defence (MOD), Rolls-Royce Plc, TWI Ltd  
Starts: 01 July 1999      Ends: 30 June 2002  
Value (£): 187,630  
Sector: Aerospace, Defence and Marine

**IMI: Fusion welding process monitoring and control (CEMWAM)** <sup>[66]</sup>

Electrical Engineering and Electronics  
Partners: BAE Systems, Bombardier, Rolls-Royce Plc  
Starts: 01 February 1996      Ends: 31 January 1999  
Value (£): 193,891

**IMI: Large scale laminated tooling for rapid manufacturing (LASTFORM)** <sup>[67]</sup>

School of Engineering  
Partners: Airbus Operations, BAE Systems, Bombardier, Pre Nexus Migration, Rolls-Royce Plc, Rover Ltd  
Starts: 01 February 1996      Ends: 31 October 1999  
Value (£): 189,887  
Sector: Aerospace, Defence and Marine

### **Cold Gas Dynamic Manufacturing** <sup>[68]</sup>

School of Engineering

Partners: BAE Systems BOC

Starts: 01 April 2001      Ends: 31 March 2002

Value (£): 900,163

The proposed research will investigate the application of the emergent surface coating technique of Cold Gas Dynamic Spraying (CGDS) in the development of a novel near net shape metal deposition process- Cold Gas Dynamic Manufacturing (CGDM)... Subsequent application specific technology development is expected to be carried out under In Demand prior to process industrialisation.

(Cold Spray technology <sup>[69]</sup> is used by the US Army)

### **The structure and evolution of copper-rich precipitates in ferritic steels and their role in hardening** <sup>[70]</sup>

Materials Science & Eng

Project Partners: Argonne National Laboratory, INSS Inc, Ricardo Group, Rolls-Royce Plc, University of California, Santa Barbara

Starts: 01 October 2002      Ends: 30 September 2005

Value (£): 243,710

The in-service hardening of nuclear reactor pressure vessels due to copper precipitation is of particular concern.

### **Networking: NESSPIOM-Network on enhanced semiconductor surface processing through in-situ optical monitoring** <sup>[71]</sup>

Advanced Materials & Surfaces (Res Cen)

Project Partners: Imperial College London, IQE (Europe) Ltd, Pre Nexus Migration, QinetiQ, Thomas Swan, Trinity College Dublin, University of Liverpool, University of Oxford, University of Sheffield, University of Wales, Cardiff, Wafer Technology Ltd

Starts: 01 October 1998      Ends: 30 September 2001

Value (£): 39,332

### **Interactive programmable feature recogniser (IPFR)** <sup>[72]</sup>

Manufacturing Eng & Industrial Mgt

Partners: BAE Systems, Delcam International plc, Pre Nexus Migration

Starts: 18 April 1994      Ends: 17 July 1996

Value (£): 97,252

## **Inspection**

### **An ultrasonic inspection system for analysing high-performance structures** <sup>[73]</sup>

U of Liverpool School of Engineering

Starts: 30 June 2007      Ends: 29 June 2010

Value (£): 78,460

...The ultrasonic inspection would be used in a large number of projects within the Department of Engineering. These projects benefit from the collaboration of a number of major companies and organisations including Airbus (Germany), Airbus (France), Astrium, Propex Fabrics, Gurit, Linpac, The Royal Mail and The Home Office.

### **DISTINGUISH: Detection of explosive substances by tomographic inspection using neutron and gamma-ray spectroscopy** <sup>[74]</sup>

Physics

Partners: BAE Systems, John Caunt Scientific Ltd, Manchester Airport Plc, NIS Ltd, Police Scientific Development Branch

Sector: Aerospace, Defence and Marine

Starts: 09 January 2006      Ends: 08 July 2009

Value (£): 169,231

### **SuperSTEM - the UK aberration-corrected STEM facility** <sup>[75]</sup>

School of Engineering

Starts: 15 September 2006      Ends: 14 September 2011

Value (£): 1,332,865

... a significant proportion of high level users from overseas as well as industrial users (e.g. Shell, IBM, AMD, Johnson-Matthey, Haldor Topsoe, Statoil, Qinetiq)

## **Risk & Uncertainty**

### **EPSRC and ESRC Centre for Doctoral Training in Quantification and Management of Risk & Uncertainty in Complex Systems & Environments.** <sup>[76]</sup>

School of Engineering

Partners: many, including IBM and Rolls-Royce

Starts: 01 October 2014      Ends: 31 March 2023

Value (£): 4,113,084

### **Bayesian Analysis of Competing Cyber Hypotheses** <sup>[77]</sup>

Electrical Engineering and Electronics

Partner: Hewlett Packard

Starts: 01 October 2014      Ends: 30 September 2016

Value (£): 189,699

Even the £650M in additional funding that accompanied the UK's Cyber Security Strategy is

dwarfed by the >£10B estimated annual cost of cyber-crime to the UK economy. Additionally, we see links to "transnational organised crime" (cyber-crime is lucrative and widespread) as well as "Terrorism" (state-sponsored cyber-warfare is increasing) and "Ideologies and beliefs" (anti-establishment hacktivists, eg Anonymous, are also resorting to cyber-attack to express their views).

...in the 1970s, the CIA developed a technique, "Analysis of Competing Hypotheses" which encourages analysts and decision makers to avoid the pitfalls that can be associated with intelligence analysis. This technique involves consideration of multiple candidate explanations for what is being observed.

## Communications

### **Developing theory for evolving socio-cognitive systems** <sup>[78]</sup>

School of Biological Sciences

Partner: Hewlett Packard

Starts: 01 November 2006 Ends: 30 September 2007

Value (£): 193,550

### **INGAAS: N materials for uncooled 1.3 um laser transmitters** <sup>[79]</sup>

University of Essex Computing and Electronic Systems

Starts: 01 January 2000 Ends: 31 May 2003

Value (£): 177,947

...bringing together expertise in materials science and device physics from the Universities of Liverpool and Essex. The project will involve significant input from Hewlett-Packard Ltd.

### **A SiGe on insulator technology for high-speed, low power mobile communications applications** <sup>[80]</sup>

Electrical Engineering and Electronics

Project Partners: Pre Nexus Migration, QinetiQ, University of Southampton, Zarlink

Starts: 01 June 1997 Ends: 30 November 2000

Value (£): 257,711

(Qinetiq interest in mobile communications includes contracts with the MoD <sup>[81]</sup>, and systems for drones <sup>[82]</sup> with military and civil applications.)

## Combustion

### **Development of Unified Flame Surface Density Based Reaction Rate Models for the LES of Turbulent Premixed Flames** <sup>[83]</sup>

U of Liverpool School of Engineering

Starts: 01 August 2009 Ends: 01 July 2011

Value (£): 137,051

In the UK, Ford as an IC engine manufacturer, and Rolls Royce and Siemens Plcs. as gas turbine manufacturers, have shown interest in the outcome of this work on RANS and LES modelling of premixed combustion

### **Theoretical Investigation Of Turbulent Combustion In Stratified Inhomogenous Mixtures Using Direct Numerical Simulation** <sup>[84]</sup>

School of Engineering

Starts: 01 August 2007 Ends: 31 July 2010

Value (£): 147,093

...Rolls-Royce as a gas turbine manufacturer will have interest in the outcome of this work concerning the fundamentals of turbulent stratified charge combustion

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# Finance: EU funding

The University has also received funding through EU grants awarded under the FP7 and FP6 programmes. Future EU funding will be through Horizon 2020. The overall budget and partners for projects involving the University with the arms industry is shown below. A search of CORDIS<sup>[1]</sup>, mainly focused on aerospace, identified 17 projects worth £131m including unidentified non-EU funds, although the University received only a portion, which is shown in more recent entries.

## **Transition Location Effect on Shock Wave Boundary Layer Interaction (TFAST) [2]**

2012-02-01 to 2016-01-31

Total cost: EUR 5 096 031,82

EU contribution: 3 567 790

UoL EU component: 124 187

Coordinator: Instytut Maszyn Przeplywowych im Roberta Szewalskiego Polskiej Akademii Nauk - IMP PAN

Participants include Rolls-Royce Deutschland<sup>[3]</sup>, Dassault Aviation,<sup>[4]</sup> the Office National D'Etudes et de Recherches Aerospatiales (ONERA<sup>[5]</sup>), and the Deutsches Zentrum Fuer Luft – Und Raumfahrt (DLR)<sup>[6 7]</sup>

TFAST funds CFD Flight Science projects,<sup>[8]</sup> including simulations with the V2C transonic aerofoil designed by Dassault Aviation

## **Buffet Control of Transonic Wings (BUCOLIC) [9]**

2013-10-01 to 2015-06-30

Total cost: EUR 1 269 375,04

EU contribution: 952 031,28

UoL EU component: 222 292,82

Coordinator: Aircraft Research Association (ARA)<sup>[10]</sup> (see profile BAE Systems)

The ARA (which received EUR 729 738,46) and UoL are the only participants. The project is outlined above as a research topic in the Computational Fluid Dynamics lab.

## **Novel Innovative Competitive Effective Tilt Rotor Integrated Project (NICE-TRIP) [11]**

2006-11-01 to 2014-11-30

Total cost: EUR 35 505 778,38

EU contribution: 18 999 049,98

UoL EU component: not shown

Coordinator: G.E.I.E. Vertair

Participants include AgustaWestland, Airbus, Selex (Finmeccanica), DLR, ONERA.

## **Control and Alleviation of Loads in Advanced Regional Turbo Fan Configurations (CLARET) [12]**

2012-01-28 to 2013-09-27

Total cost: EUR 450 379,2

EU contribution: 337 783,5

UoL participation ended

Coordinator: University of Bristol

Participants include ARA and Stirling Dynamics<sup>[13]</sup>

## **Aircraft and Rotorcraft Pilot Couplings - Tools and Techniques for Alleviation and Detection (ARISTOTEL) [14]**

2010-10-01 to 2013-09-30

Total cost: EUR 3 843 228,3

EU contribution: 3 003 652

UoL EU component: 440 488

Coordinator: Technische Universiteit Delft

Participants include ONERA.

## **Future Fast Aeroelastic Simulation Technologies (FFAST) [15]**

2010-01-01 to 2013-03-31

Total cost: EUR 3 659 130,49

EU contribution: 2 735 511

UoL EU component: 252 699

Coordinator: University of Bristol

Participants include DLR, Airbus Operations, Airbus Defence and Space.

UoL work on aeroelasticity is outlined as a research topic in the Computational Fluid Dynamics lab.

## **Centre of Excellence for Modern Composites Applied in Aerospace and Surface Transport Infrastructure (CEMCAST) [16]**

2010-04-01 to 2013-03-31

Total cost: EUR 3 659 130,49

EU contribution: 2 735 511

Coordinator: Politechnika Lubelska

The UoL is not listed as a participant, however Prof. Eann Patterson is mentioned in the Final Report.

## **Advanced Dynamic Validations using Integrated Simulation and Experimentation (ADVISE) [17]**

2008-12-01 to 2011-11-30

Total cost: EUR 2 787 115

EU contribution: 1 836 538

UoL EU component: not shown

Coordinator: Eidgenössische Materialprüfungs-

Undforschungsanstalt

Participants include Airbus

## **Simulating aircraft stability and control characteristics for use in conceptual design (SIMSAC) [18]**

2006-11-01 to 2010-07-31

Total cost: EUR 5 109 387

EU contribution: 3 282 343

UoL EU component: not shown

Coordinator: Kungliga Tekniska Hogskolan

Participants include Dassault, DLR, EADS (now Airbus), Swedish Defence Research Agency [19], Saab [20], Alenia Aeronautica (Finmeccanica) [21], ONERA.

SimSAC funds a CFD project within Flight Science Technology at the University of Liverpool. [22]

## **Generation of Advanced Helicopter Experimental Aerodynamic Database for CFD code validation (GOAHEAD) [23]**

2005-07-01 to 2009-12-31

Total cost: EUR 4 975 307

EU contribution: 2 999 152

UoL EU component: not shown

Coordinator: DLR

Participants include EUROCOPTER (now Airbus), ONERA, Agusta, Westland (now AgustaWestland), Cranfield University [24]

The Helicopter Multi Block solver (HMB) of Liverpool University was the only in-house code from the UK to be used in this project. [25 26]

## **Unsteady effects in shock wave induced separation (UFAST) [27]**

2005-12-01 to 2009-05-31

Total cost: EUR 3 837 018

EU contribution: 2 457 700

UoL EU component: not shown

Coordinator: Instytut Maszyn Przeplywowych im Roberta Szwalskiego Polskiej Akademii Nauk

Participants include EADS (now Airbus), ONERA. The Liverpool research was led by Prof G. Barakos.

## **Optimized Procedures and Techniques for IMprovement of Approach and Landing (OPTIMAL)[28]**

2004-02-01 to 2008-10-31

Total cost: EUR 42 293 707

EU contribution: 21 991 855

UoL EU component: not shown

Coordinator: Airbus Operations

The 24 participants include DLR, Eurocopter, Eurocopter Deutschland, ONERA, Thales Air Traffic Management, Thales Avionics, Thales Air Systems, GE Aviation Systems, Agusta, Northrop Grumman.

OPTIMAL funds were applied to modelling and simulation Flight Science projects. [29]

## **Detached Eddy Simulation for Industrial Aerodynamics (DESIDER)[30]**

2004-01-01 to 2007-06-30

Total cost: EUR 5 395 105

EU contribution: 3 170 548

Coordinator: European Aeronautic Defense and Space Company - EADS Deutschland

According to the Final Report, the UoL was linked to the project but not paid by it.

Participants include Alenia Aeronautica, Dassault, Eurocopter, Swedish Defense Research Agency, ONERA, DLR

## **Development of powerful free-electron masers for physical applications[31]**

2004-04-01 to 2007-03-31

Total cost: not available

EU contribution: EUR 108 000

UoL EU component: not shown

Coordinator: University of Tel-Aviv

Participants: Joint Institute for Nuclear Research (Moscow), Russian Academy of Sciences Institute of Applied Physics, University of Liverpool.

The project concerns "development of Free Electron Masers/ Lasers for physical and industrial applications." However, military applications include laser weapons. [32]

## **Active control technologies for tilt-rotor (ACT-TILT)<sup>[33]</sup>**

2001-11-01 to 2005-05-31

Total cost: EUR 6 799 917

EU contribution: 3 598 133

UoL EU component: not shown

Coordinator: EUROCOPTER

Participants include Agusta, Eurocopter Deutschland, Westland Helicopters. The project Objective stated “The application of this technology to rotorcrafts is still in its early days, with most of the on-going programmes being military.”

ACT-TILT funded Flight Science projects<sup>[34]</sup> including OHQTILT<sup>[35]</sup> which declared “Military missions will be included in the review and a new emphasis will be given to requirements for flight in degraded visual environments”.

## **Crashworthiness of aircraft for high velocity impact (CRAHVI)<sup>[36]</sup>**

2001-02-01 to 2004-04-30

Total cost: EUR 5 117 688

EU contribution: 2 887 959

UoL EU component: not shown

Coordinator: Airbus UK

Participants include Airbus Deutschland, Airbus Espana, Airbus France, DLR, ONERA

## **Rotorcraft handling, interactions and loads prediction (RHILP)<sup>[37]</sup>**

2000-03-01 to 2003-04-30

Total cost: EUR 2 280 056

EU contribution: 1 242 906

UoL EU component: not shown

Coordinator: Eurocopter

Participants include Eurocopter Deutschland, DLR RHILP, along with ACT-TILT, funded the OHQTILT project<sup>[38]</sup> which included military applications. The XV-15, featured on the Tilt-Rotor Model Library<sup>[39]</sup>, was a US military design.<sup>[40]</sup>

## Notes to Finance: EU funding

- [1] [http://cordis.europa.eu/home\\_en.html](http://cordis.europa.eu/home_en.html)
- [2] [http://cordis.europa.eu/project/rcn/101445\\_en.html](http://cordis.europa.eu/project/rcn/101445_en.html)
- [3] <http://www.rolls-royce.com/select-country.aspx#/our-contact/Germany>
- [4] <http://www.dassault-aviation.com/en/passion/aircraft/military-dassault-aircraft/>
- [5] <http://www.onera.fr/en/site-index/military-systems.html>
- [6] [http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10195/337\\_read-279/#/gallery/1464](http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10195/337_read-279/#/gallery/1464)
- [7] [http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10197/455\\_read-254/](http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10197/455_read-254/)
- [8] <http://www.liv.ac.uk/flight-science/cfd/tfast/>
- [9] [http://cordis.europa.eu/project/rcn/110476\\_en.html](http://cordis.europa.eu/project/rcn/110476_en.html)
- [10] <http://www.ara.co.uk>
- [11] [http://cordis.europa.eu/project/rcn/81483\\_en.html](http://cordis.europa.eu/project/rcn/81483_en.html)
- [12] [http://cordis.europa.eu/project/rcn/103152\\_en.html](http://cordis.europa.eu/project/rcn/103152_en.html)
- [13] <http://www.stirling-dynamics.com/aerospace/aircraft-we-ve-worked-on>
- [14] [http://cordis.europa.eu/project/rcn/96102\\_en.html](http://cordis.europa.eu/project/rcn/96102_en.html)
- [15] [http://cordis.europa.eu/project/rcn/93282\\_en.html](http://cordis.europa.eu/project/rcn/93282_en.html)
- [16] [http://cordis.europa.eu/project/rcn/93924\\_en.html](http://cordis.europa.eu/project/rcn/93924_en.html)
- [17] [http://cordis.europa.eu/project/rcn/88865\\_en.html](http://cordis.europa.eu/project/rcn/88865_en.html)
- [18] [http://cordis.europa.eu/project/rcn/81469\\_en.html](http://cordis.europa.eu/project/rcn/81469_en.html)
- [19] <http://www.foi.se/en/>
- [20] <http://saabgroup.com/about-company/organization/business-areas/>
- [21] <http://www.aleniaaermacchi.it/>
- [22] [http://www.liv.ac.uk/flight-science/cfd/aerodynamics\\_for\\_sim/data\\_driven\\_models/](http://www.liv.ac.uk/flight-science/cfd/aerodynamics_for_sim/data_driven_models/)
- [23] [http://cordis.europa.eu/project/rcn/75774\\_en.html](http://cordis.europa.eu/project/rcn/75774_en.html)
- [24] <http://www.cranfield.ac.uk/Research/About/Themes/Aerospace>
- [25] <http://www.sciencedirect.com/science/journal/12709638/19>
- [26] <http://www.liv.ac.uk/flight-science/cfd/helicopter-multiblock-code/>
- [27] [http://cordis.europa.eu/project/rcn/78484\\_en.html](http://cordis.europa.eu/project/rcn/78484_en.html)
- [28] [http://cordis.europa.eu/project/rcn/72811\\_en.html](http://cordis.europa.eu/project/rcn/72811_en.html)
- [29] <http://www.liv.ac.uk/flight-science/fs/fsms/optimal/>
- [30] [http://cordis.europa.eu/project/rcn/85509\\_en.html](http://cordis.europa.eu/project/rcn/85509_en.html)
- [31] [http://cordis.europa.eu/project/rcn/71780\\_en.html](http://cordis.europa.eu/project/rcn/71780_en.html)
- [32] <http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0470255609.html>
- [33] [http://cordis.europa.eu/project/rcn/60129\\_en.html](http://cordis.europa.eu/project/rcn/60129_en.html)
- [34] <http://www.liv.ac.uk/flight-science/fs/fshq/acttilt/>
- [35] <https://www.liv.ac.uk/flight-science/fs/fsac/hqtilt/>
- [36] [http://www.cordis.europa.eu/project/rcn/54244\\_en.html](http://www.cordis.europa.eu/project/rcn/54244_en.html)
- [37] [http://cordis.europa.eu/project/rcn/51693\\_en.html](http://cordis.europa.eu/project/rcn/51693_en.html)
- [38] <https://www.liv.ac.uk/flight-science/fs/fsac/hqtilt/>
- [39] [http://www.liv.ac.uk/flight-science/facilities/aircraft\\_tilt/](http://www.liv.ac.uk/flight-science/facilities/aircraft_tilt/)
- [40] <http://history.nasa.gov/monograph17.pdf>

# Conclusions

The information available from public sources does not fully answer the questions asked in the Freedom of Information request, later endorsed by the UCU branch. However, it does show a long-lasting, extensive and deep involvement of the University with the arms industry, whose scale came as a shock to us when researching this report.

There is almost certainly more to the story, and the fact that the University refused to answer any questions suggests that not all the relevant information is currently in the public domain. Allowing students and staff to understand the facts is one priority.

But now that we know the context includes work on combat drones and funding from the Atomic Weapons Establishment, we ask readers to begin to consider the questions raised in the Introduction. If significant sections of this community do not wish the University of Liverpool to be a research unit for and an investor in the arms industry, as it actually is, an open informed debate including strategies for arms conversion will be a good place to start. Here are some ideas and examples of non-military projects which could be developed at the University.

## Alternatives to Military Research

### Climate change

If we are to avoid runaway global warming it will be necessary to replace fossil fuels by renewable energy in the next few decades. This will mean a worldwide research effort to develop improved forms of renewable energy such as solar cells with better efficiencies; more efficient batteries to store renewable energy which is often from intermittent sources; solar-derived liquid and gaseous fuels for transport such as aircraft and shipping; better wind and water turbines from a micro- to macro-scale to harness solar energy and tidal power. Liverpool already has the Stephenson Institute for the development of solar PV science and technology, and an Oceanographic Institute for tidal and wave research.

### Renewable energy agricultural technology

Almost half the world's population still live as subsistence farmers. They also have the right to develop so they need access to energy and technologies that will improve the productivity of their labour and thus the quality of their lives. Many of these farmers practice a form of agro-ecological farming and thus they help to maintain biodiversity. If they are driven off the land by large-scale agribusiness corporations with their plantation mono-cultures, this will produce at least two disasters. Firstly, there will be a social disaster since the farmers and their families will end up in the slums of large cities;

and, secondly, an ecological disaster because of the loss of biodiversity due the poisoning of the land and water with pesticides, herbicides, and excessive use of artificial fertilisers. Avoiding this requires the development of renewable-energy driven agricultural technologies of appropriate scale. It would also involve a wide range of scientific and engineering expertise as well as contributions from the social sciences.

The Green New deal<sup>1</sup> proposed that we in the so-called advanced economies should help the farmers of the developing world to acquire the appropriate technologies to improve the productivity of their land and labour. It is in fact in our best interests that we do this.



A solar-powered shipping container shows imaginative thinking by the “Institut fuer Luft- und Kaeltetechnik (ILK)” (Institute for Air conditioning and Refrigeration)<sup>2</sup>. These containers can be used as pumping stations for

1 <http://www.greennewdealgroup.org/>

2 <http://www.ilkdresden.de>

water for drinking and for irrigation; medical cool rooms for storing medicines and carrying out medical procedures. They can also be used as school rooms with access to the internet; and field laboratories to support the development of improved seeds for crops, detection of plant diseases and their elimination. It would be possible to collaborate with German colleagues to develop the concept and increase the number of applications. If the containers are put into mass production then many really useful jobs will result.

### **A Centre for the Science and Technology for Sustainable Development (CSTSD)**

Liverpool University could take the lead in proposing such a centre in the North West. We could collaborate with the other 8-10 or so Universities as well as government laboratories, small and medium enterprises (SMEs), and social entrepreneurs. We could, in the first instance collaborate with African scientists and engineers to draw up a research and development program that would meet the requirements of communities in Africa. This would act as the inverse of the historical relationship of the North West with Africa,

namely, one of gross exploitation of human and natural resources through the slave trade and subsequent colonialism.

These are just a few possibilities but where could the money come from to fund these ambitious plans? In the first instance some government funds that are at present subsidising military research could be switched to support such proposals. But there is also a very large fund created under the Copenhagen Accord<sup>3</sup> on climate change in 2009. This fund is intended to help the developing world mitigate and adapt to climate change. It is expected to reach \$100bn by 2020. Already the UK government has set aside about £3.5bn for its contribution to this fund. Some of this money could also help to set up the Centre described above, as well as to carry out a pilot project for testing the usefulness of the solar-shipping containers in communities in Africa and elsewhere.

Of course if the Trident upgrade is cancelled then the very large sums of money released can be put to good use to create really useful jobs and, at the same time, help save the planet from heat-death and nuclear annihilation.

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There are many opportunities for research and development to replace military work on technologies for death and destruction. This is especially true in the fields of renewable energy and sustainable development. There is almost unlimited scope for collaboration with scientists and engineers from the developing world. Liverpool University can replace its current collaborations with arms companies, by research into science and technologies that help to produce a sustainable world based on cooperation and mutuality. In so doing it will become a magnet for students from all over the world who do not wish to be associated with a university whose academic work contributes to death and human suffering. They will be very enthusiastic about contributing to a sustainable, life-enhancing future for their own communities and helping to save our planet from a heat death.

### **Another, non-military future is possible for Liverpool University!**

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<sup>3</sup> [http://unfccc.int/meetings/copenhagen\\_dec\\_2009/items/5262.php](http://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php)

## Appendix 1

# Freedom of Information Request and Response

Dear University of Liverpool,

16<sup>th</sup> December 2014

I am writing to request information on the investments, financial relationships the University of Liverpool holds in the arms trade (specifically, but not limited to BAE Systems, Rolls Royce, GKN, Smiths Group, Cobham, VT Group, General Dynamics, General Electric, Halliburton, L3 Communications, Northrup Grumman and Raytheon). Please include the following information:

- 1) The total amount, in pounds sterling, that the university has received in research funding from arms trade companies in the last five financial years. Details should be broken down for each company, year-by-year for the last five financial years.
- 2) The total amount, in pounds sterling, that the university has received in the form of industrial consultancy and industrial research fees from arms trade companies in the last five financial years. Details should be broken down for each company, year-by-year for the last five financial years.
- 3) The total amount, in pounds sterling, that the university has received in research funding from the Ministry of Defence over the last five financial years. Details should be broken down, year-by-year for the last five financial years.
- 4) The total amount, in pounds sterling, that the university has received in the form of industrial consultancy and industrial research fees from the Ministry of Defence over the last five financial years. Details should be broken down, year-by-year for the last five financial years.
- 5) A portfolio statement for the fund(s) our university has investments in. If you do not have a copy of this, please send me a list of the names of the fund(s) and the corresponding management companies. Details should be broken down, year-by-year for the last five financial years.
- 6) Please also confirm if any shares are held in arms trade companies as part of a pension fund or endowment, either directly or indirectly through an externally managed fund. Details should be broken down, year-by-year for the last five financial years.

I would wholeheartedly encourage the university to adopt an ethical investment policy that excludes the arms trade, and would appreciate it if you could tell me if this is something that the university is working towards.

Yours faithfully,

Sam Robinson



Dear Mr/Ms Robinson,

Thank you for your email of 16<sup>th</sup> December 2014 requiring information about arms trade investment, funding and shares at the University of Liverpool.

Although the University holds the information you requested, it will not supply it to you because this information is exempt under Section 41 (confidential data) and Section 43 (commercial interest) of the Freedom of Information Act (FOIA) and is therefore being withheld.

Section 41 of the FOIA allows information to be withheld if releasing it would constitute a breach of confidence. I am satisfied that disclosing this information would be an actionable breach of confidence. It is therefore exempt from disclosure in accordance with Section 41 of the FOIA.

The information contained in research funding agreements is “commercially sensitive” and the release of this information could harm the commercial interests of the University. You will be aware that Universities are now subject to Competition Law. Clearly any information about our investments and research contracts is covered by Competition Law restrictions.

The University believes that the requested information concerning this information is exempt from disclosure in accordance with Section 43 of the FOIA on the basis that disclosure could potentially prejudice the commercial interests of the University.

If you are not satisfied with the University’s response to your request, you may ask the University to review it. If you wish to do this, please write to the Freedom of Information Reviewer,, Legal, Risk & Compliance, The University of Liverpool, The Foundation Building, 765 Brownlow Hill, Liverpool, L69 7ZX (email [3][University of Liverpool request email]), enclosing a copy of your original request and explaining your complaint. Please include an address for correspondence.

If you remain dissatisfied with the handling of your request, you have a right to appeal to the Information Commissioner at:-

The Information Commissioner’s Office, Wycliffe House, Water Lane, Wilmslow, Cheshire, SK9 5AF.

Telephone: 08456 30 60 60 or 01625 54 57 45

Website: [4]www.ico.gov.uk

Yours sincerely,

Lesley Jackson

## Appendix 2

# UCU Branch and Congress Resolution

2 March 2015

Liverpool University and Colleges Union

## University involvement in arms-related research and development

“This branch is:

- Disturbed to hear that Liverpool University is involved in research and development (R&D) for the arms industry;
- Especially concerned to hear that it has been, and is currently involved in research on ‘drones’, otherwise known as unmanned aerial vehicles (UAVs).

We believe that:

- This research was originally part of the FLAVIIR program for R&D into military drones, which was part-funded by BAE Systems, 95% of whose sales are military-related;
- The GAMMA program of CAST (Centre for Autonomous Systems Technology) is also part-funded by BAE Systems and may well have applications to military drone development.

We understand:

- That there are serious questions of legality about the use of military drones outside a field of battle. The international lawyer, Prof Phillip Alston, UN Special Rapporteur on Extrajudicial, Summary, or Arbitrary Executions, in his report to the UN, said “Outside the context of armed conflict the use of drones for targeted killing is almost never likely to be legal.” Several thousand civilians are known to have been killed in Afghanistan, Pakistan, Yemen, and elsewhere by these illegal drone strikes;

We further believe:

- That it is most inappropriate for an institution of higher education and scholarship to become beholden to companies and institutions involved in death and destruction such as BAE Systems, which has also been accused of bribery and corruption by the UK government.

This branch therefore wishes:

- To join with students in a request, under the Freedom of Information (FoI) Act, for the university to reveal all of its involvement in military-related research and development.”

### **Amendments:**

1. To request all guidance/legal documents used in establishing the University of Liverpool's position and policy development in relation to military related/funded research.
2. To request detail on what ethical processes currently exist in relation to military related/funded research.

**Amendments were carried unanimously.**

**Motion 4 with amendments was carried unanimously.**

Proposed by: David Hookes

Seconded by: Sarah Mosedale

## **UCU congress 24 May 2015**

### **82 Trident replacement - UCU Scotland**

Congress notes that by our nature, educational unions should be intrinsically opposed to the production and use of nuclear weapons. Congress condemns the £100-130 billion (and increasing) costs of replacement of the trident system, with £4.2 billion to be spent before the decision for replacement is made, particularly at a time when funding cuts are being made in important public services, and education is underfunded. Congress deplores the risk to the population of nuclear weapons convoys moving warheads between Burghfield and Faslane.

Congress agrees that UCU should:

1. affiliate to CND
2. support anti-nuclear events organised by CND, SCND or coalitions such as Scrap Trident and the Scottish Peace Network
3. encourage members to join CND and take part in its activities
4. encourage campaigns of divestment in university research that leads to or encourages the production of weapons of mass destruction, or contributes in any way to the arms-trade.

**CARRIED**

## Appendix 3

# Companies applying for Military List export licences, with end-user Israel <sup>1</sup>

directly or *indirectly* involved with the University of Liverpool

## 2010-2013

ABSL POWER SOLUTIONS LTD	Conjay Collectors Ammunition Company Ltd
ACORN SURFACE TECHNOLOGY LIMITED	CONSOLITE TECHNOLOGY LIMITED
AEROFLEX LIMITED	CORUS UK LIMITED
AERONAUTICAL & GENERAL INSTRUMENTS LTD	COVESION LIMITED
<b>AGUSTAWESTLAND LIMITED</b>	Covesion Ltd
AMETEK AIRTECHNOLOGY GROUP LIMITED	CRANFIELD AEROSPACE LIMITED
AMI METALS UK LIMITED	David Hart Aerospace Pipes Ltd
ATLANTIC INERTIAL SYSTEMS LIMITED	deltra electronics ltd
AVOCADO RESEARCH CHEMICALS LIMITED	DOMO LIMITED
AVON POLYMER PRODUCTS LIMITED	DRUCK LIMITED
BABCOCK INTEGRATED TECHNOLOGY LIMITED	DYTECNA ENGINEERING LIMITED
<b>BAE SYSTEMS (OPERATIONS) LIMITED</b>	E2V TECHNOLOGIES (UK) LIMITED
BARDEN CORPORATION (UK) LIMITED	E2V TECHNOLOGIES (UK) LTD
BARDEN CORPORATION(U.K.)LIMITED(THE)	ELEY HAWK LIMITED
BARTINGTON INSTRUMENTS LIMITED	ELEY LIMITED
BRIMAR LIMITED	ESL DEFENCE LIMITED
BSC FILTERS LIMITED	EUROPEAN ANTENNAS LIMITED
C-MAC MICROCIRCUITS LIMITED	EW SIMULATION TECHNOLOGY LIMITED
CAPITAL INJECTION CERAMICS LIMITED	<b>FERRANTI TECHNOLOGIES LIMITED</b>
CARL ZEISS MICROSCOPY LIMITED	FINNING (UK) LTD.
CARL ZEISS NTS LIMITED	FIRST LIGHT LAMPS LIMITED
CARL ZEISS SMT LIMITED	FREUDENBERG NONWOVENS LP
<b>CATERPILLAR SHREWSBURY LIMITED</b>	<b>GE AVIATION SYSTEMS LIMITED</b>
CAV AEROSPACE LIMITED	Gill Research and Development Limited
CENTRONIC LIMITED	GKN AEROSPACE SERVICES LIMITED
CHELTON LIMITED	GRAPHIC PLC
CHEMRING ENERGETICS UK LIMITED	GUARTEL TECHNOLOGIES LIMITED
CHEMRING EOD LIMITED	HALE HAMILTON (VALVES) LIMITED
CIVIL DEFENCE SUPPLY LTD	<b>HONEYWELL CONTROL SYSTEMS LIMITED</b>
CLAYTON ENGINEERING LIMITED	HORSTMAN DEFENCE SYSTEMS LIMITED
COBHAM DEFENCE COMMUNICATIONS LIMITED	HYPERTAC LIMITED
COBHAM MAL LIMITED	INDEPENDENT FORGINGS & ALLOYS LIMITED

<sup>1</sup> <https://www.caat.org.uk/resources/company-licence-appls>

INNOVATIVE SENSOR DEVELOPMENTS LIMITED PRP OPTOELECTRONICS LIMITED  
 INSTRO PRECISION LIMITED **QINETIQ LIMITED**  
 JANKEL ARMOURING LIMITED QIOPTIQ LIMITED  
 JAYBEAM LIMITED RACAL ACOUSTICS LIMITED  
 KELVIN HUGHES LIMITED RAKON UK LIMITED  
 Keronite International Limited RAYTHEON SYSTEMS LIMITED  
 KINGFISHER s.r.o. Remploy.Limited  
 LAND ROVER EXPORTS LIMITED REPAIRCRAFT PLC  
 LAW ENFORCEMENT INTERNATIONAL LIMITED RF2M MICROELECTRONICS LTD  
**LOCKHEED MARTIN UK LIMITED** RF2M MICROWAVE LTD  
 M M MICROWAVE LIMITED ROCKWELL COLLINS UK LIMITED  
 M S INSTRUMENTS PUBLIC LIMITED COMPANY RTI EXTRUSIONS EUROPE LIMITED  
 MANROY ENGINEERING LIMITED SABRE COMPUTERS INTERNATIONAL LIMITED  
 MARSHALL SPECIALIST VEHICLES LIMITED SCHLEIFRING SYSTEMS LIMITED  
 MARTIN-BAKER AIRCRAFT COMPANY LIMITED SIGNATURE INDUSTRIES LIMITED  
 MEGGITT (UK) LIMITED Skylaunch Limited  
 MEGGITT AEROSPACE LIMITED Skylaunch Ltd  
 MEGGITT DEFENCE SYSTEMS LIMITED SMITHS DETECTION-WATFORD LIMITED  
 MESL MICROWAVE LIMITED SOUTH MIDLANDS COMMUNICATIONS LIMITED  
 MICRO-METALSMITHS LIMITED STOP-CHOC LIMITED  
 MIL POWER LIMITED SUREWAVE TECHNOLOGY LIMITED  
 MORGAN TECHNICAL CERAMICS LIMITED SYNECTIC SYSTEMS GROUP LIMITED  
 MPE LIMITED **TELEDYNE** DEFENCE LIMITED  
 NAVISTAR DEFENSE U.K. LIMITED THERMACORE EUROPE LIMITED  
 NICKWAKE LIMITED LIABILITY PARTNERSHIP TIMKEN UK LIMITED  
 OPTOMISE SYSTEMS LIMITED TMD TECHNOLOGIES LIMITED  
 OROLIA LIMITED TRAK MICROWAVE LIMITED  
 PALL EUROPE LIMITED TYCO ELECTRONICS UK LTD  
 PANDECT PRECISION COMPONENTS LIMITED UAV ENGINES LIMITED  
 PASCALL ELECTRONICS LIMITED ULTRA ELECTRONICS LIMITED  
 PBS INTERNATIONAL FREIGHT LIMITED UTM LIMITED  
 PENNY & GILES AEROSPACE LIMITED VESTGUARD UK LIMITED  
 PETONEX LIMITED VON ROLL UK LIMITED  
 PHOENIX OPTICAL TECHNOLOGIES LIMITED WALLOP DEFENCE SYSTEMS LIMITED  
 PLEXTEK LIMITED WARTSILA UK LIMITED  
 POLAMCO LIMITED WESCO AIRCRAFT EUROPE, LTD  
 POLARIS VISION SYSTEMS EU LIMITED **WESTLAND HELICOPTERS LIMITED**  
 PORVAIR FILTRATION GROUP LIMITED WILTSHIRE BALLISTIC SERVICES LIMITED  
 PREMIER ELECTRONICS LTD

## Appendix 4

# North West Aerospace Alliance members with military links <sup>1</sup>

**Addison Engineering** (parts for end users such as Airbus, BAE Systems, Rolls-Royce, Augusta Westland, Euro-Copter and Bombardier Shorts)

**Aegis Services** (Customer approval: BAE Systems)

**Aerospace Metallic Supply** (Customer approvals: AgustaWestland, BAE Systems, Bombardier, GKN)

**Airbus** (see profile)

**Aircelle** (part of Safran Group, which had 83 Military Licence (ML) export applications 2013)

**APPH** (ML export applications 2013 to India, Brazil, Indonesia, France)

**Assystem** (2013 ML export applicant - partner to the worlds largest industrial groups)

**BAE Systems** (see profile)

**Beldam Crossley** (4 ML export applications 2013, Poland, Colombia)

**Coleg Cambria** (Learning partnership with Airbus, Magellan Aerospace, Thomas Cook, Raytheon and Marshalls)

**Didsbury Engineering** (Eurofighter, F35, Hawk... tooling for many lifting applications on the Airbus and Boeing range of aircraft)

**EDM** (customers include Rolls Royce, Qinetiq, BAE Systems and Lockheed Martin)

**ELE Advanced Technologies** (working with Rolls Royce, Siemens, Honeywell, Avio SPA, Alstom, Pratt and Whitney, Man Turbo)

**Ferranti Technologies** (see profile)

**Ford Aerospace** (customers include AgustaWestland, Airbus, BAE Systems, Boeing, Bombardier, GKN)

**Group Rhodes** (over 40 machines have been installed on Rolls Royce and British Aerospace)

**James Fisher Aerospace** (supply of test and support equipment as well as non destructive testing of critical aerospace components for companies such as: Airbus/EADS, Safran Group, Rolls Royce, Boeing, Goodrich, GKN and BAE Systems)

**Lomas Engineering** (approved suppliers of tooling to the worlds leading aerospace companies such as Airbus, Boeing, BAE Systems, Lockheed Martin, Embraer, Bombardier)

**Magellan Aerospace** (see profile)

**Merc Engineering** (Supplying prolific industry-leaders such as GE, BAE Systems, Rolls-Royce and Cobham)

**Morson Projects** (complete design, development and manufacturing service to the worlds leading military and commercial aerospace organisations)

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<sup>1</sup> <http://www.aerospace.co.uk/media/76762/nwaa-member-directory-2014-2015.pdf>

**Oxley Group** (lighting capability in the air sector spans across rotary, fixed wing, fast jet and UAV aircraft.... As leading EMC specialists, we provide a range of products to remove unwanted electromagnetic interference on military and civil aircraft)

**Perfect Bore** (providing bores to customers such as Airbus, Rolls Royce, Messier Dowty, GE Aviation & BAE)

**Rolls-Royce** (see profile)

**Sheen Spark Ltd** (approvals from major OEMs including Rolls-Royce, MTU, Goodrich and Howmet)

**Siemens** (see profile)

**Sifco** (The SIFCO Process is approved by such companies as Rolls-Royce, Pratt and Whitney, Messier, Westland Helicopters, BAE Systems and Boeing)

**Surface Finishing Engineering** (Customer Approvals AgustaWestland, BAE Systems, GKN)

**Tata Technologies**

**Teledyne CML Composites** (see Teledyne profile)

**Washington Mills Electro Minerals** (Aerospace Approval including Rolls Royce and Pratt Whitney)