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Inadvertently Arming China?

The Chinese military complex and its potential exploitation of scientific research at UK universities

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Summary

- This report draws attention to the little-analysed but pervasive presence of Chinese military-linked conglomerates and universities in the sponsorship of high-technology research centres in many leading UK universities and in their research relationships. In the cases where this is historic, these relationships and exchanges ended very recently.
- In many cases, these UK universities are or have been unintentionally generating research that is sponsored by and/or may be of use to China's military conglomerates, including those with activities in the production of Weapons of Mass Destruction (WMDs), including intercontinental ballistic missiles (ICBMs) as well as hypersonic missiles, in which China is involved in a new arms race and seeks 'massively destabilising' weaponry.
- Much of this research is entirely based at UK universities, while other research outputs include cooperation with researchers in China, often at the military-linked universities or companies sponsoring the UK research centre.
- Many of the research projects will have a civilian use, and UK-based researchers will be unaware of a possible dual use that might lead to a contribution to China's military industries.
- This report illustrates how over half of the 24 Russell Group universities and many other UK academic bodies have or have had productive research relationships with Chinese military-linked manufacturers and universities.[1] Much of the research at the university centres and laboratories is also being sponsored by the UK taxpayer through research councils, Innovate UK, and the Royal Society.
- This should be seen in the context of China's stated aim to equal the US military by 2027; and to use advanced military technology to leapfrog the US by 2049, the centenary of the founding of the People's Republic of China (PRC).
- Beijing's strategy of 'civil-military fusion' means an integration of military and civilian industry and technology intended to give the People's Liberation Army (PLA) a leading edge in adapting emerging technologies. We suggest that the existence of this strategy makes any claim to be able to reliably cooperate only with the civil branches of Chinese military-linked companies and universities less credible.
- This report analyses the relationships that up to 15 UK universities have established with 22 Chinese military-linked universities as well as weapons suppliers or other military-linked companies. Many of these Chinese universities are deemed 'Very High Risk' by the Australian Strategic Policy Institute (ASPI).
- This report includes statements from the UK institutions analysed: we are determined to be as fair to them as possible, and, provided they responded to our enquiries, the position of each is represented to the fullest extent possible. We have

[1] This includes, in very limited cases, researcher/s and/or teaching fellow/s at one or more of the constituent colleges of these universities, who are not employed by the university, but merely by a constituent college of that university, and where their research is carried out independently of either the college or university.

also told those institutions we did not hear from that we will update the online version of this report to the fullest extent possible, if and when they contact us.

- Again in the interests of accuracy and fairness, we state here that a number of UK institutions took issue with our analyses. We have duly included their comments and reiterate that even so, in our view there remains the danger that research, which is carried out in good faith, may be co-opted and exploited by the Chinese military.
- We also wish to make clear that none of the academics, researchers, or other staff whose research at UK universities or centres is discussed in this report are accused of knowingly assisting the development of the Chinese military, of knowingly transferring information to that end, or of committing any breach of their university regulations. Nor are they accused of any other wrongdoing, or breach of national security, or any criminal offence.
- Sponsorship of high-technology research in UK universities covers areas such as:
    - Metals and alloys;
    - Aerospace physics and hypersonic technology;
    - Ceramics, piezoelectrics and rare earths;
    - Drones and radars;
    - Shipbuilding;
    - Data science, AI, and facial recognition; and
    - Robotics (land, sea and space).

Conclusions

China has a long history of weapons sales to regimes that carry out grievous human rights abuses including Iran, Syria, Burma and North Korea. In addition, China's development of a surveillance state is already leading to systematic human rights abuses, with its treatment of the Uighur minority described as genocide.

The methods by which the UK monitors and controls Chinese involvement in UK university research are, we suggest, inadequate. The companies sponsoring UK-based research centres include China's largest weapons manufacturers, including producers of strike fighter engines, ICBMs, nuclear warheads, stealth aircraft, military drones, tanks, military-use metals and materials, and navy ships.

At its simplest, for the UK government and taxpayer to fund and assist the technological development and possibly the force-projection capabilities of the military of the People's Republic of China is not in the British national interest.

This is a picture of 'strategic incoherence'. China is demonstrating rapid technological-military development and growing force-projection capabilities. To risk financing and enabling these developments suggests a lack of strategic coordination.

This points to the need for a strategic reassessment for new rules for scientific research with PRC universities and companies, some of which should be applied directly to the UK's research councils and universities, while some may require legislation. Other rules are needed for scientific research in wider potentially sensitive scientific fields generally and in universities in particular.

Recommendations

The UK government should:

- List all those Chinese military-linked companies and institutions that it wants to bar from sponsoring science research in UK universities and from research cooperation in general;
- List those entities it wishes to prevent making inward investments generally into the UK. This has been the practice of the US government and looks set to continue with the new administration;
- Initiate a public audit of UK universities' sponsorship policies to establish the total Chinese funding of UK technology research and establish new rules for universities themselves, as well as for UKRI, Innovate UK, the Royal Society, and research councils. Combined with an 'entities list', this may be best placed in new legislation dealing with research and Chinese military-linked organisations specifically, or authoritarian states generally;
- Set up a new government organisation similar to the Committee on Foreign Investment in the United States (CFIUS), whose role would include monitoring and assessment of university sponsorship;
- While it is important to preserve academic freedom, the government should more deeply assess whether some of what is currently deemed 'basic scientific research', or research with findings in the public domain, may have possible dual-uses in sanctioned countries including China, and where approval for research centres may have allowed projects which are exposed to this risk to take place;
- Further review the Academic Technology Approval Scheme (ATAS), to better control entry to the UK of international students (apart from exempt nationalities) whose research may create risks in certain sensitive subjects; and
- Reassess the areas of scientific research that can be carried out by public research institutions and/or in which research findings can be publicly released.

These measures should form part of an urgent reassessment of the security implications of the so-called 'Golden Era' policies towards China and the strategic assumptions that underpinned them.

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Introduction: The context of Chinese military expansionism and civil-military fusion

Beijing has recently declared that China aims for the People's Liberation Army (PLA) to be on a par with the US military by 2027. This would have deep and far-reaching consequences for security for the UK, other democracies, and UK allies.

The rapid technological development of the PLA should also be set against the wider background of the increasingly hawkish strategy of and strategic thinkers around President Xi Jinping, as well as the authoritarian entrenchment of the state in China. Scholars have described Xi's adherence to the concept of the '100-year marathon', a strategic attempt to become a global hegemony by 2049, the centenary of the founding of the People's Republic of China (PRC).[2] Research and development in next-generation military technology should be understood in this strategic context.

Since the late 1990s, defectors have referred to new military technologies under development by the PLA for use 'beyond Taiwan'. The aim, discussed by senior Chinese military figures, is to use advanced military technologies to leapfrog the United States in particular.[3] This includes the capacity to launch devastating pre-emptive strikes or counter-attacks aimed at destabilising enemy forces' radar systems, orbital satellites, and command and control systems, including through the possible use of unconventional weapons and electronic warfare.

This is underway amidst apparent ongoing confusion in British strategic thinking. While UK taxpayers fund research at universities that risks contributing to the development of China's military, the UK's R&D spending on its own defence is anaemic: Volkswagen alone spends more on R&D than the entire UK defence sector.

Driving the Chinese growth in military technology is the mandated integration and joint development of military and civilian technology sectors, or 'civil-military fusion', which Beijing hopes will give the PLA a leading edge in adapting emerging technologies in order to utilise them for military purposes, across technological fields.[4] This means it is especially difficult to know that research for an apparently civilian business unit of a military-linked Chinese conglomerate, or for an apparently civilian-oriented department of a military-backed university, will not ultimately be put to military use.

China has a long history of weapons proliferation to unstable, authoritarian regimes that systematically abuse human rights, a challenge which may be growing. China has supplied military materiel to the Syrian regime throughout the Syrian civil war; it has routinely supplied Burma with materiel including FN-6 surface-to-air missiles,[5] 107mm surface-to-

[2] Pillsbury, M. (2015). *The Hundred-Year Marathon: China's Secret Strategy to Replace America As the Global Superpower*. St Martin's Griffin.
[3] https://www.iiss.org/blogs/research-paper/2018/12/emerging-technology-dominance
[4] https://www.iiss.org/blogs/analysis/2020/05/china-civil-military-innovation
[5] https://asiatimes.com/2019/11/chinas-mobile-missiles-on-the-loose-in-myanmar/

surface rockets,[6] JF-17 aircraft,[7] armoured vehicles,[8] and possibly drones.[9] In Afghanistan, Chinese weapons consistently make their way to the Taliban, including surface-to-air missiles and anti-aircraft guns.[10] Chinese entities and companies are believed to have been involved in nuclear proliferation to Pakistan, Iran and North Korea.[11]

China's military force-projection capacity is growing, and its military committing more resources to researching highly-destabilising materiel, such as directed-energy weapons and hypersonic missiles. China's development of a surveillance state is already leading to systematic human rights abuses.

The findings of this report do not detract from the value of the international scientific collaboration in which British universities participate and frequently lead, including with Chinese nationals, and should not be used to cast suspicion on Chinese researchers in the UK. However, that the Chinese military is liable to exploit some of the scientific research at UK universities that we describe, research which is often also sponsored by the UK taxpayer, demonstrates a lack of strategic coordination that is against the British national interest.

NB: None of the academics, researchers, or other staff whose research at UK universities or centres is discussed in this report are accused of knowingly assisting the development of the Chinese military, of knowingly transferring information to that end, or of committing any breach of their university regulations. Nor are they accused of any other wrongdoing, or breach of national security, or any criminal offence. In some cases, research may be used solely for non-military ends; the purpose of the examples mentioned in this report is not necessarily to demonstrate that they risk being used for military purposes, but in some cases that the research may simply help improve the business or academic position of a PRC military-linked conglomerate or institution; where research may be put to use by the military of the PRC or organisations which are linked to it, we assume that researchers in the UK will have carried out this research without intending this to happen. Furthermore, none of the UK universities, institutes or funding bodies mentioned in this report are accused of knowingly contributing to the development of China's military or its military industries, as we believe that these universities have developed the sponsorship and research relationships we describe in good faith and in the belief that their scientific outputs will have purely civil ends.

The purpose of this report is simply to draw attention to the risk that UK research may be exploited by the Chinese military in a way the researchers could never have envisaged. It is our belief that shedding light on this risk is unquestionably a matter of pressing and vital

[6] *Ibid*.
[7] https://thediplomat.com/2014/06/burma-to-purchase-chinese-pakistani-jf-17-fighter-jets/
[8] https://www.burmalibrary.org/en/armed-and-dangerous-myanmars-military-goes-shopping
[9] https://thediplomat.com/2016/06/is-myanmar-using-armed-chinese-drones-for-counterinsurgency/
[10] https://www.telegraph.co.uk/news/worldnews/1562148/Chinese-weapons-reaching-the-Taliban.html
[11] https://www.nonproliferation.org/wp-content/uploads/npr/102paul.pdf

public interest. (See also Nota Bene in Chapter 3.) We have initially published this in online form only to provide more opportunity for possible corrections.

Chapter overview

Chapter 1 of the report will consider the Chinese military-linked institutions and companies sponsoring the research centres in UK universities, and with whom researchers at these centres are or have been cooperating.

We have derived this listing from the compilation and risk rating carried out by the Australian Strategic Policy Institute (ASPI), and especially by Alex Joske, whose analysis of cooperation between the Chinese military nexus and western universities first drew attention to some of the university centres we discuss; in many respects this constitutes an extension of that work.

This report analyses the centres' research outputs and their possible uses for military materiel, while bringing to light other UK research centres that have not been discussed before.

In Chapter 2, we describe the UK university-based research centres of concern, outlining their Chinese sponsorship relationships, with examples of where UK taxpayer funding is contributing to these projects, and discuss their specific research outputs.

Chapter 3 analyses the technological themes we discern in the research and relates these themes to possible military use generally and the interests of China in particular. Chapter 4 describes the relevant rules in the UK, including for exports and information covered by military and dual-use export control lists, UK research governance, and the US approach to Chinese military-linked companies and institutions. We then offer conclusions and recommendations.

Highlights: Significant UK university relationships

Our investigations and analyses suggest the following:

Imperial College London

Imperial has at least four research centres sponsored by major Chinese weapons suppliers.

One of Imperial's sponsors is developing China's next-generation stealth fighters, for which engine research has been a major challenge. It recently described a major breakthrough in turbine blades that also happened to be in an area of research one of its subsidiaries has sponsored at its Imperial centre.

The firm also sponsors composites research at Imperial, including carbon fibre-reinforced plastic (CFRP), a radar-absorbing stealth material that is receiving 'ever more attention from the arms industry'. Imperial researches other types of composite that, in other applications, appear to be used in strike fighters.

Summary of response from Imperial College London[12]

"In the limited instances where we receive sponsorship from Chinese companies, this is for fundamental scientific research. For example, our work to develop lightweight strong glass… has a wide range of potential scientific and commercial applications in many sectors worldwide. We do not conduct any classified research. Imperial conducts its own due diligence prior to any sponsorship arrangement. We also work closely with the Export Controls Joint Unit and other relevant UK government agencies. All relationships with third parties are subject to prior and continued review.

Our research outputs, which are in the public domain and routinely published in leading international journals, are good for science, innovation and the UK's global influence. Science is a global endeavour, and we are proud to work with our peers in academia and industry all over the world."

[12] Where these have been received, fuller responses are available below.

Cambridge University

Beijing has said that exchanges between Cambridge and NUDT will 'greatly raise the nation's power [in] high-precision navigation'.[13] One scientist who is a teaching fellow at a constituent college of Cambridge (though, like many fellows at Cambridge, not employed by the university directly) is also a Distinguished Visiting Professor at NUDT. He has researched with a scholar in the PRC whose other work includes studies of high-altitude nuclear detonation.

Summary of response from Cambridge

"The Cavendish Laboratory does not have, nor has ever had, any projects, research grants or contracts with NUDT or other military institutions in China. There was an MoU between the groups, but this never led to any formal research funding, lapsed in 2018 and has not been renewed."

Manchester University

Manchester University has provided China's main nuclear inter-continental ballistic missile (ICBM) conglomerate with a UK taxpayer-subsidised research centre. One member of staff's research has been funded by the EPSRC and includes drones and air-breathing hypersonic vehicles, including a study on improved manoeuvrability with a Chinese military-linked university; a recent paper illustrates missiles moving towards the same target. One Manchester lab sponsored by a major Chinese weapons firm produces research on drone swarms.

A Manchester researcher from the PRC investigates ceramic coatings for hypersonic vehicles with a major military laboratory at China's Central South University. Manchester states this has possible 'defence purposes', and one of the papers presenting the findings calls these ceramics 'desirable for applications [in] defence sectors'. When in military use, hypersonic missiles travel at over Mach 5, with manoeuvrability that renders target-prediction impossible. An Obama-era official has called them 'leader-killers'. The EPSRC has helped fund research, by scholars from the PRC, on air-breathing hypersonic vehicles. Images from

[13] Citing China's Ministry of Education: https://web.archive.org/web/20200831235735/http://www.gesie.org/news/Center/2017-09-22/925.html and https://www.aspi.org.au/report/picking-flowers-making-honey

China in November 2020 showed what appeared to be a 'potentially air-breathing and nuclear capable' hypersonic missile attached to a military plane manufactured by one of Imperial's Chinese sponsors.

Another member of staff at Manchester has researched an aluminium alloy with staff at a Chinese military-linked laboratory which has separately been funded by the National Defense Program of China for research into the same alloy.

Summary of response from Manchester

"We value our connections with China as an important part of the UK's extensive international trade and cultural links. All such interactions have to be based on government guidance and regulation… We take all necessary measures to assure ourselves that our research is not used beyond its agreed application. Typically, the results of collaborative research are published in the open, publicly accessible scientific literature, as is the norm for research conducted at the University.

The cases given in the Civitas report were either for research collaborations or for visiting researchers to undertake projects in University of Manchester laboratories. All current projects mentioned in the Civitas report went ahead after assessment and approval by the Export Control Joint Unit (ECJU).

We can confirm that all due diligence and processes are in place to allow academics and the University to question the potential of their research and only engage with external entities within the legal remits of the export control legislation as assessed by the ECJU. Our current due diligence addresses and ensures that no controlled information is exported outside the UK without the appropriate licence in place. The University continues to work closely with the ECJU and government agencies to ensure that we are fully compliant with policies and protocols around export of materials, information and data."

Birmingham University

Birmingham states that its practice of collecting internet users' data to predict online behaviour in cooperation with Baidu (called 'China's Google' but under US sanctions for military connections) is 'controversial'. Another project, sponsored by US-sanctioned companies including Chinese military jet manufacturers, will allow 'end-users' to 'transfer technologies to their supply chain'.

Strathclyde University

Strathclyde hosts another UK university laboratory sponsored by China's leading ICBM manufacturer whose fields include drone 'swarming technology'. A separate Strathclyde

centre, for image processing, is backed by Chinese military-linked universities as well as the Royal Society. Strathclyde researchers have cooperated with PRC institutions on research including 'person re-identification' in camera networks (for 'learning deep features').

Summary of response from Strathclyde

"The collaboration agreement referred to between the University of Strathclyde and the China Academy of Launch Vehicle Technology (CALT) focused on mechatronics research contributing to the UK-China Flagship Challenge program project SmartFarm, with the aim of developing more efficient and sustainable approaches to farming and food production. It used AgriRover – a device for testing soil quality based on technology previously developed for use in exploration on Mars – as a key prototype. A demonstration of AgriRover was made in a farm in Beijing and an export control license was secured from the UK Government Export Control Joint Unit before the demonstration… Openly published research is by definition available to researchers over the entire world. The university supports, and has contributed to, work of UUK and CPNI on Trusted Research to ensure that checks and balances are embedded across our systems."

University of Kent

Kent's centre has cooperated with Huawei as well as researching numerous fields, including radars and Global Navigation Satellite System (GNSS).

Summary of response from the University of Kent

"We do not comment on individual members of staff. However, we can confirm that we have a PhD project funded by Huawei for the novel design of antennae for civilian-specific smart phones. All results to date have been published by IEEE, a reputable US-based journal for engineering studies. We have also applied for open access to these papers, which will improve their availability. The antennae group does not have collaborations with any military-linked universities in China.

"The University of Kent respects all UK trade restrictions. We follow government guidelines and cooperate with the UK authorities."

Warwick Manufacturing Group (WMG)

WMG trained one of the pioneers of China's ICBM programme in 1983 and is a partner of China's main ICBM-developing conglomerate today. WMG says that its priorities 'align closely with the main priorities of the State Council's plan', boasting that its '[taught] courses have been of benefit to a wide range of organisations [including weapons giant]

China North Industries Corporation' (aka Norinco, whose other customers include Zimbabwe). WMG staff have researched with an alloys supplier to the Chinese military, and a military-linked university in high energy-density polymer nanocomposites: this research stated that 'functional polymer composites are attracting interest [for] high power weapons.'

Summary of response from WMG

"All of the University's research is governed by research ethics governance and export control regulations. The research you refer to is in fact, at our university, to use polymer-based nanocomposites to develop sustainable and environmentally friendly fully biodegradable plastics. The content of the courses that we run for Chinese companies are all three week long taught modules on a number of aspects of management and not any form of research."

Southampton University

Harbin Engineering University, supervised by the PLA Navy, says its joint centre with Southampton in naval architecture has helped it move into a 'world class' position. A Southampton researcher has investigated very large floating structures (VLFS) with at least two Chinese military-affiliated institutions. VLFS bases would allow improved sea and air power projection into disputed waters.

Summary of response from Southampton

"As an international university, Southampton has many active collaborations with research colleagues from China producing work which has the potential to create wide-ranging societal benefits… our collaboration with Wuhan University of Technology has mainly focused on efficient shipping and safety including reducing emissions and improving navigational safety. The 'High Performance Ship Technology Joint Centre' collaboration [came] to an end in September 2017. Additionally the partnership with Harbin is an education programme with undergraduate modules offered there replicating the same offered in Southampton. We proactively manage and regularly review our collaborative relationships with the wide range of domestic and international partners with whom we work to ensure they are appropriately aligned to our strategic objectives and governance policies. In managing our partnerships and collaborations, we also closely monitor and follow UK Government advice on both international matters and on University-business relationships."

Queen Mary University of London (QMUL)

QMUL calls itself 'very honoured' to have a large joint research centre with Northwestern Polytechnic University, an institution which says it is 'devoted to improving and serving the national defence science and technology industry.'[14] One of the centre's PRC-based Chief Scientists is an authority on aero engines who has been funded by China's National Defense Technology Foundation for Scientific Research. Another has advertised his interests in modern strike fighters and hypersonic missiles.

Cranfield University at Shrivenham

Cranfield is home to Cranfield Defence and Security, a secure military site whose partners include the Atomic Weapons Establishment (AWE). A researcher at Cranfield's Centre for Electronic Warfare, Information and Cyber (CEWIC) has researched automated camera surveillance of people showing physical symptoms of stress with counterparts in China who acknowledge Chinese state project-funding, but Cranfield have stated that: 'in academia, papers can be published independently from paid project work and can be part of an individual's academic scholarly output'. The Cranfield researcher is an expert in Electro-Optics and has been a visiting professor at Nanchang HangKong University, where optoelectrics is a designated area of military research.

Summary of response from Cranfield

"…As can be seen from the order of the authors, [the researcher at Cranfield] was a minor contributor to the paper [above]. His role was mainly focused on providing peer advice for the writing of good scientific papers.

"[He] was not paid to work for Nanchang Hangkong University during his time as an employee of Cranfield. The Visiting Professor title was an honorary title. [He] rejects in the strongest terms any suggestion his research has links with the Chinese military [and] has had no funding from Chinese companies or organisations for his research.

"Shrivenham is not owned or run by Cranfield. The University is an academic provider supplying postgraduate education."

[14] *Ibid*.

Glasgow University

Glasgow has established a joint college with a major military-backed PRC university whose collaborations include with a Chinese nuclear warhead manufacturer, the Chinese Academy of Engineering Physics.

Heriot-Watt University

One Heriot-Watt researcher from the PRC cooperated with a researcher affiliated with Harbin Engineering University on research entitled *Snoopy: Sniffing your smartwatch passwords via deep sequence learning*, where UK taxpayers funded research into a password-breaking tool with a leading Chinese military-linked university which is under US sanctions, known to specialise in information security, and whose staff have been charged with espionage. The research speculates: 'in the wrong hands, Snoopy can potentially cause serious leaks of sensitive information'.

One researcher has been funded by UK defence groups to work on MIMO Radar. She has researched radar-jamming with China's military-linked Key Laboratory of Radar Imaging and Microwave Photonics, including *Target Tracking While Jamming by Airborne Radar for Low Probability of Detection*, which discussed stealth aircraft avoiding detection.

Response from Heriot-Watt

"Heriot-Watt University is a global university with an international academic community that takes part in world leading, multi-national research across many diverse areas. As with all universities, and as a charitable organisation, any research carried out, authored or co-authored by any member of Heriot-Watt University staff is publicly available and complies with all regulations and laws regarding national security and intellectual property… we believe this report to be without merit."

University of Surrey

Surrey has partnered with the China Academy of Space Technology (CAST), a subsidiary of CASC, to develop 5G technology. Its parent company is a major part of China's nuclear weapons programme. This formal relationship appeared after Max Lu became Vice Chancellor. Theresa May subsequently appointed Lu to the Council for Science and Technology; he also sits on the boards of UKRI, the National Physical Laboratory and Universities UK, giving him considerable potential influence over UK research funding.

Summary of response from Surrey

"The University of Surrey's world-leading 5G Innovation Centre conducted this research into the role of satellites in maximising the potential of 5G service roll-out. The research was led by Professor Barry Evans, who is a leading authority on satellite-based technologies in telecommunications. We partner with many different companies, government agencies and other bodies to drive this work to ensure the full potential of 5G technologies are realised. Telecommunications technologies are global in nature and scope, and our work contributes to defining and developing 5G standards and protocols internationally – and forms part of a large body of research on this topic publicly available worldwide… in compliance with all relevant British Government guidance and legislation, we are playing our part in both advancing the sum of human knowledge and delivering a global Britain."

Some of the PRC companies sponsoring and involved with research have civilian business lines, although in some cases production for the PRC military constitutes the majority of their business. Where conglomerates are also civilian-oriented, the interests of their military-linked businesses often overlap with the research carried out in the centres these conglomerates sponsor.

Glossary

AA: Aluminium alloy
AAID: Aerosol-assisted ion deposition
ACMT: Advanced Conventional Military Technology
AEA: Adversarial Erasing Attention
AECC: Aero Engine Corporation of China
AI: Artificial intelligence
AHV: Air-breathing hypersonic vehicles
AM: Additive manufacturing
ASRI: Aircraft Strength Research Institute (subsidiary of AVIC)
ATAS: Academic Technology Approval Scheme
AVIC: Aviation Industry Corporation of China
BAMTRI: Beijing Aeronautical Manufacturing Technology Research Institute (former name of MTI, below)
BATRI: Beijing Aircraft Technology Research Institute (subsidiary of COMAC)
BIAM: Beijing Institute for Aeronautical Materials (subsidiary of AECC)
BIS: Bureau of Industry and Security, Department of Commerce (US)
BIT: Beijing Institute of Technology
BUAA/Beihang: Beijing University of Aeronautics and Astronautics
BWC: Biological and Toxin Weapons Convention
CAF: Creep age forming
CALT: China Academy of Launch Vehicle Technology (subsidiary of CASC)
CASC: China Aerospace Science and Technology Corporation
CCP: Chinese Communist Party
CETC: China Electronics Technology Group Corporation
CFRP: Carbon fibre-reinforced plastic
CGM: Control Momentum Gyroscopes
CGWIC: China Great Wall Industry Corporation
CNN: Convolutional neural network
CNT: Carbon nanotube
COMAC: Commercial Aircraft Corporation of China
CQU: Chongqing University
CQUT: Chongqing University of Technology
CRISPR: Clustered regularly interspaced short palindromic repeats
CSSC: China State Shipbuilding Corporation
CSU: Central South University
CVD: Chemical vapour deposition
DARPA: Defense Advanced Research Projects Agency (US)
DIT: Department for International Trade (UK)
DMU: Dalian Maritime University
DNN: Deep neural networks
DOD: Department of Defense (US)
EPSRC: Engineering and Physical Sciences Research Council (UK)
ETPE: Energetic thermoplastic elastomers
FAI: First Aircraft Institute (subsidiary of AVIC)
FAST: Fast light alloys stamping technology

FLR: Fuzzy label regularisation
FML: Fibre-metal laminate
FP: Formal Partnership
FSS: Frequency selective surface
GNSS: Global Navigation Satellite System/s
GPS: Global Positioning System
HDPE: High-density polyethylene
HEFCE: Higher Education Funding Council for England
HEU: Harbin Engineering University
HfC: Hafnium Carbide
HIT: Harbin Institute of Technology
HUST: Huazhong University of Science and Technology
ICBM: Intercontinental Ballistic Missile
IDSS: Intelligent decision supporting systems
LPD: Low probability of detection
MIMO: Multiple Input Multiple Output
MSS: Ministry of State Security
MTCR: Missile Technology Control Regime
MTI: Manufacturing Technology Institute (subsidiary of AVIC)
NELA: Northeast Light Alloy Company
NCHU: Nanchang HangKong University
NJU: Nanjing University
Norinco: China North Industries Corporation
NPU/NWPU: Northwestern Polytechnic University
NUAA: Nanjing University of Aeronautics and Astronautics
NUDT: National University of Defence Technology (China)
PEEK: Poly ether-ether ketone
PDS: Passive detection system
PLA: People's Liberation Army
PRC: People's Republic of China
PZT: Lead zirconate titanate
QMUL/QMES: Queen Mary University of London/Queen Mary Engineering School
Re-ID: Re-identification
RFID: Radio frequency identification
RPV: Remotely Piloted Air Vehicles
SAR/ISAR: Synthetic-aperture radar/inverse synthetic-aperture radar
SASAC: State-owned Assets Supervision and Administration Commission
SASTIND: State Administration for Science, Technology and Industry for National Defence
SIPRA: China-Scotland Signal Image Processing Research Academy
SLV: Satellite Launch Vehicles
SOE: State-owned enterprise
TPUN: Thermoplastic polyurethane elastomer nanocomposites
UAV: Unmanned aerial vehicle
UESTC: University of Electronic Science and Technology of China
UHF: Ultra-high frequency
UHSS: Ultra-high strength steel
UHTC: Ultra-high temperature ceramics

UWB: Ultra-wide band
USV: Unmanned submersible vehicle
UUV: Unmanned underwater vehicle
VLFS: Very large floating structures
WA: Wassenaar Arrangement
WMD: Weapons of Mass Destruction
WHUT/WUT: Wuhan University of Technology
WMG: Warwick Manufacturing Group

NB: For individuals, name order (whether given name or surname is first) is written as provided on the material studied.

Chapter 1: Chinese military-linked and funded universities and companies

We have adapted the Australian Strategic Policy Institute (ASPI's) risk ratings and background materials to build a list of the relevant Chinese institutions and companies involved in scientific research with UK universities (adding some universities and institutes that do not appear in the ASPI system). We regard ASPI's university tracking as the most comprehensive research carried out into China's universities' military links; no other institute has its reach. We first outline the relevant Chinese universities and research institutions, then companies. Where applicable, we provide ASPI's risk and security rating of each institution and the UK universities with which they are associated. It is notable that these universities include many of the 'Seven Sons of National Defence', a group of leading Chinese universities with especially close ties to the military. While some of the Chinese universities below are officially under civilian administration, some are official military universities, and almost all have extensive military research activities. The paper also discusses some universities in China which are not considered military-linked or funded and which do not appear in this list.

Key for associations with UK universities

FP = Formal partnership or cooperation in other formal project (expired or ongoing)

R = Research cooperation generally, co-authored papers, shared researchers or teachers including with constituent colleges of the relevant universities, staff or student visits, or joint training (expired or ongoing)

Universities and research institutions

Army Engineering University of the PLA

The leading education and research institution of the PLA Ground Force, with 11 'key military laboratories'.[15] Its research fields include communications and electronic information science; combat engineering and support science; weapons systems engineering; missile engineering and explosives; radar engineering; unmanned systems

[15] https://unitracker.aspi.org.au/universities/army-engineering-university/ and https://www.scmp.com/news/china/science/article/2172141/chinas-brightest-children-are-being-recruited-develop-ai-killer in *Ibid*.

engineering; flight vehicle design and engineering; and electrical engineering and automation.[16]

Links or associations

- ASPI rating: Very high risk.
- UK research connections or cooperation between staff: Imperial (R).

Beijing Institute of Technology (BIT)

BIT is one of a cluster of elite defence universities known as the Seven Sons of National Defence, and one of just fourteen institutions allowed to grant PhDs in weapons science.[17] It has launched a programme to train elite high school students in intelligent weapons systems.[18]

BIT chairs the B8 Cooperation Innovation Alliance, a weapons research group of eight institutions.[19] It has produced China's first light tank, two-stage solid sounding rocket and low-altitude altimetry radar.[20] It states that it carries out 'world-class research on several areas of missile technology', including 'precision strikes, high damage efficiency, manoeuvre penetration, long-range suppression, and military communications systems and counter-measures'.[21] No Chinese institution has produced more military patents; BIT's designated 'disciplines with defence characteristics' [22] include artillery, communication and information systems, control engineering, and aircraft design.[23]

Selected defence laboratories

- State Key Laboratories of Vehicle Transmission; Science and Technology on Materials under Shock and Impact; Mechatronical Engineering and Control (with Norinco Group's 212 Research Institute, aka Xi'an Mechanical & Electric Institute); Explosion Science and Technology;
- Key Laboratory of Fundamental Science for Advanced Machining and of Electronic Information Technology in Satellite Navigation, Ministry of Education;
- Science and Technology on Electromechanical Dynamic Control Laboratory;
- Fundamental Science on Vehicular Power System Laboratory;
- Fundamental Science on Multiple Information Systems Laboratory; and

[16] https://unitracker.aspi.org.au/universities/army-engineering-university/
[17] https://unitracker.aspi.org.au/universities/beijing-institute-of-technology/
[18] *Ibid*.
[19] *Ibid*.
[20] *Ibid*.
[21] https://web.archive.org/web/20180816213622/http://www.bit.edu.cn/gbxxgk/gbxqzl/xxjj/index.htm in *Ibid*.
[22] In all cases, these may not be exhaustive.
[23] https://web.archive.org/web/20190816013340/http://www.bit.edu.cn/gbkxyj/gbxkjs/97886.htm in *Ibid*.

- Micro-structure Fabrication Technology Research and Application Center for Science Technology and Industry for National Defense.[24]

Links or associations

- US ban on students.
- ASPI rating: Very high risk. Top Secret security credentials.[25]
- UK research connections or cooperation between staff: Manchester (R).

Beijing University of Aeronautics and Astronautics (aka Beihang, BUAA)

Another of the Seven Sons, Beihang is a leading institution for research on military aircraft, stealth technology, and nuclear science. It has a cooperation agreement with ballistic missiles manufacturer China Aerospace Science and Technology Corporation (CASC).[26] Designated defence research areas include navigation guidance and control, biomedical engineering, and nuclear energy science.[27]

Selected defence laboratories

- National Key Laboratory of Aero-thermodynamics of Aero-engines; Science and Technology on Aircraft Control; Reliability and Environmental Engineering Technology;
- National Laboratory for Computational Fluid Dynamics;
- Key Laboratory of Fundamental Science for National Defense-Novel Inertial Instrument & Navigation System Technology; and
- National Defence Key Discipline Laboratory of Trusted Network Computing Technology or Key Laboratory of National Defense Science and Technology for Trusted Network Computing Technology.[28]

Links or associations

- US ban on students. On US and Japan End User Lists.
- ASPI rating: Very high risk. Top Secret security credentials.
- UK research connections or cooperation between staff: Swansea, WMG, Scottish universities or groups (R).

[24] *Ibid*.
[25] Security credentials are also based on ASPI's rating, which is derived from the level of access granted by the Chinese government itself.
[26] https://unitracker.aspi.org.au/universities/beihang-university/
[27] *Ibid*. inc. https://web.archive.org/web/20190816021802/http://physics.buaa.edu.cn/info/1097/1244.htm
[28] *Ibid*.

Central South University (CSU)

CSU has a long history of strategic military research, including for China's first atomic bomb and intermediate-range ballistic missile.[29] Today, military research specialisms include aviation, metals, heat-resistant materials for aero and rocket engines, and guidance and control technology. SASTIND has committed to developing CSU military research, including its Military Industry Technology Research Institute and School of Aeronautics and Astronautics.[30] It has a cooperation agreement with the China Academy of Launch Vehicle Technology (CALT). CSU was the first university to receive a weapons production license.[31]

Selected defence laboratories

- National Key Laboratory of Science and Technology for National Defence on High-strength Structural Materials;
- State Key Laboratory for Powder Metallurgy; and
- National Defense Discipline Laboratory for Detection, Guidance and Control Technology.[32]

Links or associations

- ASPI rating: High Risk. Secret security credentials.
- UK research connections or cooperation between staff: Cambridge, WMG (R).

Chongqing University (CQU)

CQU is accredited to conduct classified research. Since 2016, an agreement with SASTIND 'advance[s] military-civil fusion' at the university.[33] CQU carries out staff exchanges with China Aerospace Science and Technology Corporation (CASC) and researches communication and information systems.

Selected defence laboratories

- Defense Key Disciplines Lab of Novel Micro-nano Devices and System Technology (which 'accepts students working on biochemical microsystems, micro-energy devices and systems along with new kinds of micro-nano devices').[34]

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[29] https://unitracker.aspi.org.au/universities/central-south-university/
[30] https://web.archive.org/web/20190606005331/http://news.csu.edu.cn/info/1003/80531.htm in https://unitracker.aspi.org.au/universities/central-south-university/
[31] http://archive.fo/kjBmI in *Ibid*.
[32] *Ibid*.
[33] https://web.archive.org/web/20190731043940/http://news.cqu.edu.cn/newsv2/show-14-6345-1.html in https://unitracker.aspi.org.au/universities/chongqing-university/
[34] *Ibid*.

Links or associations

- ASPI rating: Medium Risk. Secret security credentials.
- UK research connections or cooperation between staff: Nottingham (R).

Chongqing University of Technology (CQUT)

CQUT is a member of the B8 Cooperation Innovation Alliance. Having been under the oversight of a major weapons manufacturer, it is linked to Norinco and China South Industries Group, the country's largest weapons manufacturers, collaborating on research with other military companies.[35]

Links or associations

- ASPI rating: Medium Risk. Secret security credentials.
- UK research connections or cooperation between staff: Exeter (R).

Dalian University of Technology (School of Naval Architecture)

Supervised by SASTIND, Dalian takes part in classified defence research and cooperates with the PLA Navy.[36] It participates in the China Innovation Alliance of the Graphene Industry (a civil-military fusion research programme), and the National Defense Technology Industry Nuclear Power Technology Innovation Center.[37]

Links or associations

- ASPI rating: Medium Risk. Secret security credentials.
- UK research connections or cooperation between staff: Scottish universities or groups (R).

Harbin Engineering University (HEU)

One of the Seven Sons and supervised by the PLA Navy, HEU pioneered China's first experimental submarine and focuses on navy ships and armaments. HEU states that it is

[35] https://unitracker.aspi.org.au/universities/chongqing-university-of-technology/ inc. http://archive.fo/xfgKM
[36] https://web.archive.org/web/20190623221913/http://www.gs.xinhuanet.com/news/2018-08/02/c_1123210706.htm in https://unitracker.aspi.org.au/universities/dalian-university-of-technology/
[37] *Ibid*.

involved in 'most' naval submarine, undersea weapon, and warship research programmes[38] and is a centre for aircraft carrier and 'high tech weapons' research, nuclear engineering, stealth technology, naval architecture, underwater acoustics, information security, and nuclear reactor engineering.[39] [40] Since 2012, HEU employees have been implicated and convicted in espionage and illegal military exports cases in various countries, including for ballistic missile technology.

Selected defence laboratories

- National Key Laboratory of Underwater Acoustic Technology;
- National Defense Key Laboratory of Underwater Vehicles Technology;
- Multi-hull Ship Technology Key Laboratory of Fundamental Science for National Defense;
- Coatings Analysis and Detection Center (jointly with PLA Navy); and
- Energetic materials (such as explosives) (jointly with the Chinese Academy of Engineering Physics, a nuclear warhead research organisation).[41]

Links or associations

- US ban on students. On US Entity List.[42]
- ASPI rating: Very high risk. Security credentials: Top Secret.
- UK research connections or cooperation between staff: Southampton (FP), Cranfield at Shrivenham, Scottish universities or groups (R).

Harbin Institute of Technology (HIT)

One of the Seven Sons of National Defence, HIT has a joint research centre with ballistic missile manufacturer China Aerospace Science and Technology Corporation (CASC).[43] Its specialisms include robotics, aviation, nuclear technology, electronic propulsion and thrusters, and biomedicine. A US-China Security and Economic Review Commission report

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[38] https://web.archive.org/web/20190520053551/http://pnec.hrbeu.edu.cn/2016/1229/c3349a122303/page.htm in https://unitracker.aspi.org.au/universities/harbin-engineering-university/

[39] https://web.archive.org/web/20190520053551/http://pnec.hrbeu.edu.cn/2016/1229/c3349a122303/page.htm in https://unitracker.aspi.org.au/universities/harbin-engineering-university/

[40] https://web.archive.org/web/20190520053551/http://pnec.hrbeu.edu.cn/2016/1229/c3349a122303/page.htm in https://unitracker.aspi.org.au/universities/harbin-engineering-university/

[41] https://www.federalregister.gov/documents/2020/06/05/2020-10869/addition-of-entities-to-the-entity-list-revision-of-certain-entries-on-the-entity-list in https://unitracker.aspi.org.au/universities/harbin-engineering-university/

[42] These companies are the subjects of sanctions by either the US Dept. of Defense or Dept. of Commerce.

[43] https://web.archive.org/web/20190517054529/http://news.hit.edu.cn/2008/1201/c1990a49048/page.htm in https://unitracker.aspi.org.au/universities/harbin-institute-of-technology/

named HIT as one of four universities focused on information warfare-applicable research.[44] missile research deemed 'contrary to national security and foreign policy interests' led to US sanctions.[45]

Selected defence laboratories

- National Defence Key Laboratories of Micro and Small-Scale Spacecraft Technology; Satellite Laser Communications Technology; and Spaceflight Space Structure and Control Technology;
- National Key Laboratory of Science and Technology on Advanced Composites in Special Environments; and
- Information Countermeasures Technology Research Institute.[46]

Links or associations

- US ban on students. On Japan's End User and US Entity Lists.
- ASPI rating: Very high risk. Security credentials: Top Secret.
- UK research connections or cooperation between staff: Swansea, Southampton (R).

Huazhong University of Science and Technology (HUST)

Supervised by SASTIND, HUST military research includes shipbuilding, image processing, navigation technology, engineering, electronics, materials, lasers and directed-energy weapons. Cooperation between HUST and China's military industries includes AI and imaging for weapon systems. Some research students are sponsored by China's nuclear warhead manufacturer.[47]

Selected defence laboratories

- State Key Lab of Multi-spectral Image Information Processing Technology (under HUST's Institute of Pattern Recognition and Artificial Intelligence);
- China Aerospace Pattern Recognition Technology Research Institute;
- Ministry of Education Key Laboratory of Functional Materials for Electronic Information;
- Key Laboratory of Gravity Navigation of Ministry of Education; and

[44] https://nsarchive2.gwu.edu//NSAEBB/NSAEBB424/docs/Cyber-066.pdf?_ga=2.30462079.1319451064.1567722102-1036413872.1567722102 in *Ibid*.
[45] https://www.latimes.com/archives/la-xpm-2009-jun-03-me-espionage-trial3-story.html ; https://fas.org/irp/ops/ci/chung071609.pdf in *Ibid*.
[46] *Ibid*.
[47] http://archive.fo/QEVhF in https://unitracker.aspi.org.au/universities/huazhong-university-of-science-and-technology/

- Research centre on vibration damping and isolation (jointly with the Academy of Aerospace Solid Propulsion Technology (AASPT) of CASC (AASPT develops ballistic missiles and carrier rockets).[48]

Links or associations

- ASPI rating: Very high risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Cambridge (R), Birmingham (FP).

Nanchang HangKong University (NCHU)

NCHU is supervised by SASTIND, with numerous links to military aircraft manufacturer AVIC.[49] 'Optoelectric and laser technology' is among the research areas at NCHU designated 'national defence key disciplines'.[50]

Selected defence laboratories

- National Defense Key Disciplines Laboratory of Light Alloy Processing Science and Technology; and
- Aeronautical Science and Technology Key Laboratory of Aeronautical Testing and Evaluation Technology (jointly with AVIC).[51]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Cranfield at Shrivenham (R).

Nanjing University of Aeronautics and Astronautics (NUAA)

One of the Seven Sons, NUAA is a specialist aerospace research institution with relationships with military aerospace manufacturers AVIC and AECC. It is home to China's national helicopter defence laboratory and is implicated in US aerospace technology theft.[52] Defence

[48] *Ibid*.
[49] http://archive.fo/tejLA in https://unitracker.aspi.org.au/universities/nanchang-hangkong-university/
[50] https://web.archive.org/web/20190731222931/http://www.nchu.edu.cn/rcpy/yjsjy In *Ibid*.
[51] *Ibid*.
[52] https://www.bbc.co.uk/news/resources/idt-sh/Looking_for_Chinas_spies; https://web.archive.org/web/20190523015338/http://cepe.nuaa.edu.cn/2017/0924/c2842a49983/page.htm in https://unitracker.aspi.org.au/universities/nanjing-university-of-aeronautics-and-astronautics/

research fields include nuclear science, aeronautical propulsion, guidance and control technology, and microwave and millimetre wave systems and components.[53]

Selected defence laboratories

- State Key Laboratory of Helicopter Drive Technology;
- Ministerial Key Discipline Laboratory of Advanced Design Technology of Aircraft; and
- Ministry of Education Key Laboratory of Radar Imaging and Microwave Photonics.[54]

Links or associations

- US ban on students.
- ASPI rating: Very high risk. Security credentials: Top Secret.
- UK research connections or cooperation between staff: Cranfield at Shrivenham, Swansea, Scottish universities or groups (R).

National University of Defense Technology (NUDT)

NUDT is China's leading military-affiliated research institution, under direct supervision by the powerful Central Military Commission.[55] Research specialisms include hypersonic missiles, drones and drone swarms, radars, navigation and quantum physics. NUDT developed the Tianhe-2A supercomputer. Defector testimony indicates that its 'Intelligence Center' is involved in political interference outside the PRC.[56]

Selected defence laboratories

- State Key Laboratories of New Ceramic Fibers and Ceramic Matrix Composites; Complex Electromagnetic Environment Effects on Electronics and Information System;
- National Laboratory of Science and Technology on Automatic Target Recognition;
- National 863 Plan Laser Gyroscope Key Laboratory; and
- Science and Technology on Scramjet Laboratory.[57]

Links or associations

- On Japan's End User List (for missile development) and US Entity List (for importing equipment from the US for potential nuclear weapons use).
- ASPI rating: Very high risk.

[53] *Ibid*. inc. https://web.archive.org/web/20190819055420/http://msc.nuaa.edu.cn/3297/list.htm
[54] *Ibid*.
[55] https://unitracker.aspi.org.au/universities/national-university-of-defense-technology/
[56] https://www.auliving.com.au/zh-tw/201911/132010.html in *Ibid*.
[57] *Ibid*.

- UK research connections or cooperation between staff: includes Cambridge, Swansea, Scottish universities or groups (R).

Northwestern Polytechnical University (NPU, NWPU)

One of the Seven Sons and specialising in aviation, space and naval technology. Its UAV laboratory manufactures military drones though a subsidiary. NPU is implicated in the illegal export of anti-submarine warfare technology from the US.[58] It researches electromagnetic field and microwave technology, space biology, and detection, guidance and control technology.

Selected defence laboratories

- Fundamental Science on Aircraft Structural Mechanics and Strength Laboratory
- State Key Laboratories of UAV Special Technology; Underwater Information and Control (jointly with China Shipbuilding Industry Corporation's 705 Institute, which may be another name for the National Defense Key Laboratory of Torpedo Guidance Technology);[59] and
- Science and Technology on Thermostructural Composite Materials Laboratory.[60]

Links or associations

- US ban on students. On Japan End User List and US Entity List.
- ASPI rating: Very high risk. Security credentials: Top Secret.
- UK research connections or cooperation between staff: includes QMUL (FP); Bristol, Scottish universities or groups (R).

Shanghai Jiaotong University (SJTU) (School of Naval Architecture)

Supervised by SASTIND, SJTU's School of Naval Architecture, Ocean & Civil Engineering cooperates with military corporations CSIC and CASC and the PLA Navy.[61] SJTU is linked to Unit 61398, a PLA cyber-espionage unit implicated in cyber-warfare against the US.[62]

Selected defence laboratories

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[58] https://web.archive.org/web/20181103131242/https://www.justice.gov/usao-ma/pr/chinese-national-allegedly-exported-devices-military-applications-china in https://unitracker.aspi.org.au/universities/northwestern-polytechnical-university/
[59] http://archive.fo/uBnWI in *Ibid*.
[60] *Ibid*.
[61] https://web.archive.org/web/20190710033455/http://naoce.sjtu.edu.cn/mtjj/5005.html and https://web.archive.org/web/20190710033521/http://naoce.sjtu.edu.cn/chanxueyan.html in https://unitracker.aspi.org.au/universities/shanghai-jiaotong-university/
[62] *Ibid*.

- Defense Key Disciplines Laboratory of Ship Equipment Noise and Vibration Control Technology.[63]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Southampton (R).

Southeast University

Under a joint construction agreement with SASTIND, a report for the US-China Economic and Security Review Commission identified the university as involved in training hackers.[64] Its electronic specialisms underpin military research laboratories in navigation and underwater acoustics, research in information sensing and diversion, the university having hosted staff from the PLA Navy's Submarine Academy.[65] Strategic cooperation agreements include with missile developer China Aerospace Science and Industry Corporation and subsidiaries of military electronics conglomerate China Electronics Technology Group Corporation (CETC).[66] [67]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Scottish universities or groups (FP).

Tianjin University

Supervised by SASTIND, Tianjin is a Ministry of State Security (MSS) centre whose research includes communication and information engineering.[68]

Selected defence laboratories

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[63] *Ibid*.

[64] https://web.archive.org/web/20190906063010/https://nsarchive2.gwu.edu//NSAEBB/NSAEBB424/docs/Cyber-066.pdf?_ga=2.35247585.1319451064.1567722102-1036413872.1567722102 in https://unitracker.aspi.org.au/universities/southeast-university/

[65] http://archive.fo/kcl93 in https://unitracker.aspi.org.au/universities/southeast-university/

[66] https://web.archive.org/web/20190506013011/https://www.seu.edu.cn/2018/1010/c17406a242399/page.htm in *Ibid*.

[67] *Ibid*.

[68] https://web.archive.org/web/20190707051754/https://sinosphere.blogs.nytimes.com/2015/05/22/tianjin-university-defends-chinese-scientists-indicted-by-u-s/ in https://unitracker.aspi.org.au/universities/tianjin-university/

- Key Laboratory of Micro-Optical-Electro-Mechanical System Technology.[69]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Scottish universities or groups (FP).

University of Electronic Science and Technology of China (UESTC)

Founded in 1961, UESTC is one of China's oldest military-linked universities. Under joint SASTIND-China Electronics Technology Group Corporation (CETC) supervision,[70] and with programmes in microwaves, anti-jamming, and military-use materials, its military electronic outputs are used in missiles, aircraft carriers and aircraft, such as the JF-17 fighter. Staff associated with UESTC have founded at least one AI firm involved in surveillance in Xinjiang.[71]

Selected defence laboratories

- National Anti-interference Communication Technology Laboratory;
- Fundamental Science on EHF [Extremely High Frequencies] Laboratory; and
- Strong Radiation Laboratory (jointly with the Chinese Academy of Engineering Physics, China's main nuclear warhead research institution, leading to the US government giving UESTC Entity listing as a 'proxy for China's nuclear weapons programme'; originally a National 863 Plan laboratory).[72][73]

Links or associations

- On Japan's End User List (for chemical weapons development) and US Entity List.
- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Scottish universities or groups (FP).

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[69] https://unitracker.aspi.org.au/universities/tianjin-university/

[70] http://www.moe.gov.cn/s78/A08/gjs_left/s7187/s7189/201403/t20140313_165432.html ; http://archive.fo/nhxS5 in https://unitracker.aspi.org.au/universities/university-of-electronic-science-and-technology-of-china/

[71] https://www.aspistrategist.org.au/the-company-with-aussie-roots-thats-helping-build-chinas-surveillance-state/ in https://unitracker.aspi.org.au/universities/university-of-electronic-science-and-technology-of-china/

[72] http://archive.fo/rVagW ; https://web.archive.org/web/20130502184604/http://www.rd.uestc.edu.cn/content/89. in *Ibid*. Named for its March 1986 founding, this programme was intended to stimulate high-tech industries and was inspired by Ronald Reagan's Strategic Defense Initiative.

[73] *Ibid*.

University of Science and Technology, Beijing (USTB)

USTB is a specialist in steel and other metals and materials.[74]

Selected defence laboratories

- Key Laboratory of Corrosion and Protection;
- Atmospheric and Environmental Effects and Protection Joint Laboratory (with Norinco's 59th Research Institute: includes explosives and stealth technology); and
- Joint Research and Development Center (with CETC's 13th Research Institute: focuses on semiconductor research).[75]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: WMG (R).

Wuhan University of Technology (WHUT, WUT)

WHUT researches military engineering and advanced composite materials for weapons in formal cooperation with the PLA Air Force,[76] as well as ship design.

Selected defence laboratories

- Key Laboratory of High-Performance Ship Technology; and
- PLA Air Force-WHUT Air Defence Engineering and Protective Technology Research Institute.[77]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Southampton, Birmingham (FP).

[74] http://archive.fo/QnTQO and https://web.archive.org/web/20190310061400/http://www.ustb.edu.cn/xxgk/xxjj/index.htm in https://unitracker.aspi.org.au/universities/university-of-science-and-technology-beijing/
[75] https://web.archive.org/web/20180522072302/http://adma.ustb.edu.cn/about.asp?fid=150 ; http://archive.fo/FNn00 and http://archive.fo/svKtf in *Ibid*.
[76] http://archive.fo/u9Kgv in https://unitracker.aspi.org.au/universities/wuhan-university-of-technology/
[77] https://web.archive.org/web/20190722043237/http://www.wutnews.net/politics/news.aspx?id=61013 in https://unitracker.aspi.org.au/universities/xidian-university/

Xidian University

Supervised by SASTIND and defence electronics manufacturer CETC and a partner of the PLA signals intelligence unit,[78] Xidian is a research base for radar, antennas, electronic countermeasures, pattern recognition and intelligent systems.[79] It claims an 'unbreakable bond with secret intelligence work since its beginning'.[80] Xidian's Mobile Internet Security Talent Recruitment Base (also known as the National 111 Project for Mobile Security)[81] has recruited foreign scholars and is directed by a PLA Navy major general.

Selected defence laboratories

- National Laboratory of Radar Signal Processing;
- National Key Laboratory of Antennas and Microwave Technology (jointly with China Electronics Technology Group Corporation's 14th Research Institute, a centre of anti-stealth research on the US Entity List);[82]
- National Key Discipline Laboratory of Wide Band-gap Semiconductor; and
- Key Laboratory of High-Speed Circuit Design and EMC [Electro-magnetic Compatibility].[83]

Links or associations

- ASPI rating: Very high risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Kent (R).

Zhejiang University

Zhejiang University is an MSS-funded cyber research centre and a base for military-focused research into automation and manufacturing. The university participates in China's National Defense Technology Industry Nuclear Power Technology Innovation Center. Zhejiang University has been implicated in espionage charges in the US.[84]

Selected defence laboratories

[78] https://web.archive.org/web/20190531021509/http://leixieyuan.xidian.edu.cn/gywm/gsgk.htm in *Ibid*.
[79] https://unitracker.aspi.org.au/universities/xidian-university/
[80] https://web.archive.org/web/20190531024544/https://news.xidian.edu.cn/info/1002/34263.htm in *Ibid*.
[81] https://mis.xidian.edu.cn/html/team/overseas/2017/0306/5.html in *Ibid*.
[82] https://www.globalsecurity.org/military/world/china/cetc-14.htm; According to Xinhua News Agency: 'As the birthplace of China's radar industry, the 14th is known as the 'eye of the three armed forces and the heavy weapon of the country.' Today, the performance of China's multi-type radar products has reached the world's leading level…. [it] has successfully developed China's first quantum radar system'.
[83] https://unitracker.aspi.org.au/universities/xidian-university/
[84] https://unitracker.aspi.org.au/universities/zhejiang-university/

- Key Laboratory of High-Performance Embedded Computing.[85]

Links or associations

- ASPI rating: High Risk. Security credentials: Secret.
- UK research connections or cooperation between staff: Scottish universities or groups (FP).

Companies

Aero Engine Corporation of China (AECC)

The Aero Engine Corporation of China (AECC) was created from the Aviation Industry Corporation of China (AVIC, below) in 2016, with AVIC retaining a stake and Commercial Aircraft Corporation of China (COMAC, also below) another shareholder.[86] AECC is one of China's leading civilian and military aviation engine manufacturers, and it appears that this includes attack helicopters and ground attack aircraft.[87]

Links or associations

- Under US DOD sanctions as a 'Chinese military company' (specific sanctions also apply separately to subsidiaries and former subsidiaries such as Skyrizon).[88]
- UK research connections or cooperation between staff: Imperial, Manchester (FP).

Beijing Institute for Aeronautical Materials (BIAM)

An AECC subsidiary, the Beijing Institute for Aeronautical Materials (BIAM) develops and manufactures advanced materials for civilian and military use: BIAM researchers are reported as working on military helicopters, including graphene armour, and other military fields.[89]

Links or associations

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[85] https://web.archive.org/web/20190721232058/http://www.cbeis.zju.edu.cn/index.php/About/details.html?id=1 in *Ibid*.

[86] https://web.archive.org/web/20171127182732/http://www.guancha.cn/Industry/2016_06_13_363868.shtml in https://unitracker.aspi.org.au/universities/aero-engine-corporation-of-china/

[87] *Ibid*.

[88] https://ua.usembassy.gov/chinas-skyrizon-added-to-u-s-commerce-department-military-end-user-list/

[89] https://www.defenseworld.net/news/23505#.YCCIPuj7RPY

- Under US DOD sanctions as a 'Military End User'.
- UK research connections or cooperation between staff: Imperial, Birmingham, Manchester (FP).

Aviation Industry Corporation of China (AVIC)

China's leading civilian and military aviation supplier, AVIC supplies the PLA Air Force with the J-20 fifth generation stealth fighter jet,[90] among many other military systems. AVIC has dozens of subsidiaries. Research subsidiaries involved with UK universities include:

- AVIC First Aircraft Institute (FAI), responsible for designing the new PLA Air Force stealth strategic bomber[91];
- AVIC Aircraft Strength Research Institute (ASRI); and
- AVIC Manufacturing Technology Institute (MTI). Formerly the Beijing Aeronautical Manufacturing Technology Research Institute (BAMTRI), MTI is reported to include laser weapons research. [92]

Links or associations

- Under US DOD sanctions as a 'Chinese military company'.
- UK research connections or cooperation between staff: Imperial (FP), Nottingham (FP); Scottish universities or groups (R).

China Aerospace Science and Technology Corporation (CASC)

China Aerospace Science and Technology Corporation (CASC) and some of its subsidiaries are leading suppliers of missiles, carrier rockets, military satellites and precision-guided weapons, and as leading players in China's nuclear weapons programme are involved in international nuclear proliferation. One subsidiary, China Great Wall Industry Corporation (CGWIC), has a history of proliferation to Iran.[93]

In December 2020, CASC entered into an agreement with the China State Shipbuilding Corporation (CSSC) to integrate advanced weaponry into naval projects to 'jointly build a world-class military, aerospace power, maritime power, manufacturing power, and science and technology power.'[94] CASC is involved in developing autonomous technology and

[90] https://thediplomat.com/2018/03/chief-engineer-of-chinas-alleged-stealth-fighter-vows-new-capabilities-for-aircraft/ in https://unitracker.aspi.org.au/universities/aviation-industry-corporation-of-china/
[91] https://www.globaltimes.cn/content/1204238.shtml
[92] https://nationalinterest.org/blog/buzz/china-developing-airborne-laser-weapon-113546
[93] https://www.nti.org/learn/facilities/50/
[94] https://www.janes.com/defence-news/news-detail/china-shipbuilding-casc-sign-deal-on-military-technologies

unveiling the D3000 unmanned oceanic combat vessel in 2017 for anti-submarine and surface combat, which is expected to be deployed in the South China Sea.[95].

Links or associations

- Under US DOD sanctions as a 'Chinese military company'.
- UK research connections or cooperation between staff: Manchester (FP), WMG (FP).

China Academy of Space Technology (CAST)

The China Academy of Space Technology (CAST, also known as the 5th Academy of CASC)[96] is a CASC subsidiary.

Links or associations

- On Japan's End User List.
- UK research connections or cooperation between staff: Surrey (R).

China Academy of Launch Vehicle Technology (CALT)

A CASC subsidiary, the China Academy of Launch Vehicle Technology (CALT) develops ICBMs[97] and produces the Long March series of rockets with dual civilian and military use. In October 2020, the Long March 2C rocket propelled three Yaogan 30 military signals intelligence satellites 370 miles into Earth's orbit. These test electronic eavesdropping equipment and help the Chinese military track US and other deployments.[98]

In 2020, China launched the Long March-11 launch vehicle from a merchant vessel in the Yellow Sea.[99] As the leading manufacturer of China's ICBMs, through the 1990s CALT produced the Dongfeng 5 (DF5), a silo-based ICBM with an effective 7,456 mile-range and equipped with a 1-3 MT nuclear warhead, able to strike targets across western Europe and the mainland US. In 2015, CALT upgraded the Dongfeng to the DF5B, equipped with multiple independent re-entry vehicle (MIRV) warheads, allowing separate strikes from one missile. In 2017, CALT tested the DF5C, able to carry 10 MIRV warheads.[100]

Links or associations

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[95] https://www.uscc.gov/sites/default/files/Research/Jane's%20by%20IHS%20Markit_China's%20Advanced%20Weapons%20Systems.pdf

[96] https://unitracker.aspi.org.au/universities/china-aerospace-science-and-technology-corporation/

[97] https://fas.org/nuke/guide/china/contractor/calt.htm

[98] https://spacenews.com/china-launches-latest-trio-of-yaogan-30-remote-sensing-satellites/

[99] https://www.nasaspaceflight.com/2020/05/long-march-11-launches-out-of-xichang-for-the-first-time/

[100] https://www.globalsecurity.org/wmd/world/china/calt.htm; https://spaceflightnow.com/2020/10/26/china-launches-three-military-spy-satellites/;

- Under US DOD sanctions as a 'Chinese military company'.
- UK research connections or cooperation between staff: Imperial (FP), Scottish universities or groups (FP).

Beijing Institute of Astronautical Systems Engineering

The Beijing Institute of Astronautical Systems Engineering is a CALT subsidiary whose research includes reusable boosted vehicles for military requirements and refers to supersonic flight and large angle of attack, citing studies on long-range missiles.

Links or associations

- Under US DOD sanctions[101] through CALT.[102]
- UK research connections or cooperation between staff: Scottish universities or groups (R).

China North Industries Corporation (Norinco)

China North Industries Corporation (Norinco) is a Chinese state-owned defence conglomerate with vast size and reach.[103] Norinco is involved in China's nuclear weapons programme and in arms proliferation, including to North Korea. It also supplies the PLA, the PLA Navy and PLA Air Force with systems and weapons from assault rifles to battle tanks and UAVs.[104] Since 2003, Norinco has been subject to three separate rounds of US sanctions in relation to transferring ballistic missile technology to Iran, and has supplied the Venezuelan dictatorship with armoured personnel carriers, used against unarmed opposition demonstrations in 2017 which led to 72 civilian deaths.[105] Norinco collaborates with leading Chinese universities, including providing direct supervision to Xi'an University of Technology.

Links or associations

- Under US DOD sanctions as a 'Chinese military company'.
- UK research connections or cooperation between staff: WMG (R).

[101] These can include specific licencing requirements
[102] https://www.wisconsinproject.org/u-s-entity-list-annotated-china-section/
[103] https://ipisresearch.be/publication/working-paper-china-north-industries-group-corporation/
[104] *Ibid*.
[105] https://www.scmp.com/news/world/americas/article/2098924/venezuela-defends-purchase-chinese-riot-control-gear-after-more

Commercial Aircraft Corporation of China (COMAC)

Commercial Aircraft Corporation of China (COMAC) is a state-owned aircraft manufacturer. Focused on civilian airliners, China's Ministry of Industry and Information Technology nonetheless calls it a defence industry conglomerate,[106] and China's main military aircraft manufacturer AVIC (above) holds a 10 per cent stake. Senior staff at the Central Military Commission have described their interest in converting civilian planes to military uses during inspections of COMAC jets.[107]

Links or associations

- Under US DOD sanctions as a 'Chinese military company'.
- ASPI rating: Very high risk.
- UK research connections or cooperation between staff: Imperial, Birmingham (FP).

Northeast Light Alloy Company (NELA)

Harbin-based Northeast Light Alloy Company (NELA) was China's first aluminium-magnesium alloy producer. It appears to be primarily a supplier to China's military, with reports stating that 60 per cent of its products are sold to China's armed forces.[108]

Links or associations

- UK research connections or cooperation between staff: WMG (R).

Shougang Group

Shougang Group (formerly Shougang Corporation) is a state-owned steel and metals conglomerate based in Beijing. Shougang acquired thirteen military factories in 1988.[109] Subsidiaries such as Shougang Guiyang Special Steel Company describe a manufacturing role (in the 'national defence and military industry').[110]

Links or associations

- UK research connections or cooperation between staff: Imperial (FP); WMG (R).

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[106] http://archive.md/5MKh1 in https://unitracker.aspi.org.au/universities/commercial-aircraft-corporation-of-china/
[107] *Ibid*.
[108] http://m.futuresmag.com/2007/07/24/chinalco-may-acquire-northeast-light-alloy
[109][109] http://sro.sussex.ac.uk/id/eprint/118/1/Shougang.pdf
[110] https://www.shougang.com.cn/en/ehtml/IronSteelIndustry/20170329/829.html

Chapter 2: UK university research centres and their specialist fields

We analyse formal research centres, partnerships, relationships or groups in UK universities which are funded, supported and/or jointly established with and by Chinese military-linked institutions or companies, as well as other UK university centres of concern. In each case, none of the academics or researchers whose research at UK universities or centres discussed in this report are accused of knowingly assisting the development of the Chinese military, of knowingly transferring information to that end. Following each description, we refer to the relevant technological themes in Chapter 3.

For the avoidance of any doubt, we reiterate our Nota Bene of page 8. We do not accuse any individual academic or researcher, or other university representative or employee, of any wrongdoing. Rather, we highlight the risks inherent in the ties these UK research centres, partnerships, relationships or groups have established. To adapt Neil Armstrong: *research is creating new knowledge* – but, in our view, that research is insufficiently protected and in danger of being exploited.

UK-based university research centres, partnerships, relationships and groups

Imperial College London and the Beijing Institute for Aeronautical Materials (BIAM)

Imperial College London appears to have established more research centres with Chinese military companies than any other UK university.[111]

- *Imperial Centre for Materials Characterisation, Processing and Modelling (BIAM is a subsidiary of the Aero Engine Corporation of China (AECC))*

This BIAM-sponsored Centre is managed by a researcher from the PRC.[112] The BIAM Centre carries out research for aerospace, including in aeronautical materials, lithium-ion batteries, and aircraft windshields. Research includes superalloy micromechanics, solid-state lithium batteries, and fatigue performance of nickel-based (Ni-based) single-crystal superalloys. In 2019, the Centre received as a visitor the Chairman of AECC itself.[113]

One example of superalloys research may be especially worth noting. A major priority for AECC, parent company of BIAM, has been the ability to produce the engines for the next-

[111] https://www.aspi.org.au/report/china-defence-universities-tracker
[112] https://www.imperial.ac.uk/avic-design/people/zhusheng-shi/
[113] https://www.imperial.ac.uk/biam-imperial/events/

generation Chinese stealth fighter jets used by the PLA Air Force and PLA Navy.[114] One critical aspect of this has been the need to develop two of the most important components in advanced engines: single-crystal superalloy turbine blades and powder metallurgy superalloy turbine disks.

In August 2020, a researcher at the Centre published the paper *Micro-mechanisms of cyclic plasticity at stress concentrations in Ni-based single crystal super-alloy*[115] with researchers based at BIAM in Beijing. Its abstract reads:

> 'Single-crystal superalloys are high-temperature materials used for turbine blades in jet engines. Fatigue damage can pose a major threat to the integrity of such components in operation. Traditionally… fatigue behaviour [has] been studied by investigating cyclic plasticity in the bulk of the material… however, such investigation may not contribute to the understanding of the alloy's fatigue behaviour, since plastic micro-strains are confined to regions near stress raisers… The investigation of local cyclic plasticity at stress concentrations promises [to] provide new insight into fatigue crack initiation in Ni-based superalloys.'

One award-winning research project from 2019 at the Centre involved investigating single crystal superalloys within turbine blades to develop jet engines. Imperial recently announced a breakthrough with some fanfare:

> 'Congratulations… He has won the 1st prize in the 'Electron Microscopy – Physical Sciences' category in the International Scientific Imaging Competition 2019 supported by the Royal Microscopical Society, a contest of the best scientific images obtained by microscopists from all over the world.'

The title of the research was *The building blocks of jet engines*. The BIAM Centre at Imperial describes this as:

> 'Cuboidal Ni3Al precipitates (edge length ~400 nm) in a Ni-based single-crystal superalloy. These precipitates are the source of the outstanding strength of superalloys at high temperatures, enabling the operation of turbine blades in the extreme environments within jet engines. The sample (provided by BIAM) was etched to reveal the precipitates.'[116]

Chen Xiangbao, vice-president of BIAM, told Chinese news outlets in 2017 that it 'will not take a long time for our fifth-generation combat plane to have China-made engines… We are able to develop the two most important components in an advanced engine – the single

[114] https://www.pm-review.com/chinas-j-20-stealth-fighter-jet-engines-incorporate-powder-metallurgy-superalloy-turbine-disks/
[115] https://www.researchgate.net/publication/343953306_Micro-mechanisms_of_Cyclic_Plasticity_at_Stress_Concentrations_in_a_Ni-Based_Single-Crystal_Superalloy
[116] https://web.archive.org/web/20191014012546/http:/www.imperial.ac.uk/biam-imperial

crystal superalloy turbine blades and powder metallurgy superalloy turbine disks', adding that the main remaining challenge 'is mass production'.[117]

According to recent statements by the PLA Air Force, the next-generation J20 fighter will have no need of the Russian engines originally planned for the new stealth jet, and the 'domestically built' WS-10C engine will be preferable.[118] Since 2017, it has been frequently reported that AECC, the parent company of the sponsor of this Imperial laboratory, has been developing "domestically produced engines featuring single crystal superalloy turbine blades" for China's J-20 stealth fighter engines.[119]

Having long had to reverse-engineer US and Russian jet engines, AECC may be moving closer to being able to produce next-generation stealth fighter jet engines for the Chinese military.

See technological themes:

1. Alloys of aluminium, titanium and other metals.
7. Drones and lithium-ion batteries.

Imperial College London and the Aviation Industry Corporation of China (AVIC)

- *The AVIC Centre for Structural Design and Manufacturing*

Imperial describes its AVIC Centre for Structural Design and Manufacturing as 'promoting world leading scientific research into aircraft design and manufacturing technologies.' A report at King's College London found that research sponsored by AVIC at Imperial used high-velocity gun systems which are 'relevant for nuclear weapons development'.[120]

The centre cooperates with the AVIC Aircraft Strength Research Institute (ASRI); Manufacturing Technology Institute (MTI) and First Aircraft Institute (or FAI, which is designed China's latest bombers).[121] It carries out research into materials science, manufacturing techniques and structural integrity, which Imperial states is for 'safer, lighter and more efficient air transportation facilities.' According to Imperial, the institutes' 'knowledge of metals, polymers and composites and experience with design, manufacture, testing and inspection combines well with Imperial's capabilities on fundamental research.'[122]

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[117] https://www.ainonline.com/aviation-news/defense/2017-06-20/new-chinese-fighters-tap-russian-us-technology

[118] https://www.scmp.com/news/china/military/article/3116826/chinas-next-gen-j-20-stealth-fighter-jettisons-russian-engine

[119] https://www.pm-review.com/chinas-j-20-stealth-fighter-jet-engines-incorporate-powder-metallurgy-superalloy-turbine-disks/

[120] Scott, E. at al. *Catalogue of Case Studies on Intangible Technology Transfers from Universities and Research Institutes*. King's College London, September 2020. https://www.kcl.ac.uk/alpha/assets/pdfs/itt-case-studies.pdf; https://kclpure.kcl.ac.uk/portal/files/135803068/itt_case_studies.pdf

[121] https://www.globaltimes.cn/content/1204238.shtml

[122] https://www.imperial.ac.uk/avic-design/

This centre also employs a researcher from the PRC as its manager. His research through the Centre includes Aluminium-Zinc-Magnesium alloys and aging, strength of Aluminium-Copper-Lithium alloys and the aluminium alloys (AA) 7050 and 6082.[123]

Researchers include a Chinese professor whose research with AVIC staff includes a corpus on aluminium alloys (such as AA7050), and CDRX-based material models. His paper, *A CDRX-based material model for hot deformation of aluminium alloys*[124] was authored with AVIC researchers, including from the FAI, and dealt with alloy AA5052. Another Imperial scholar from the PRC has published widely on alloys, including aluminium alloy AA6082.[125]

Researchers from the PRC include one whose research covers ballistic tests, the geometry of projectiles and thermoplastic composites,[126] and another whose research aims to enable the 'massive production of aluminium alloys' for aerospace.[127] One researches 'strength assessment and modelling for thick CFRP [carbon fibre reinforced plastic] composite laminates'. In May 2020, listing himself as a researcher at the First Aircraft Institute, he co-published *An explicit–implicit combined model for predicting residual strength of composite cylinders subjected to low velocity impact*[128] with a researcher at the Army Engineering University of the PLA.

Other fields include the reinforcement technology z-pin, which the website states is currently seen in F/A-18 E/F aircraft; Composite Sandwich Structures (includes CFRPs, Glass-Fibre-reinforced polymers, 3D woven and co-woven fabrics); Al-Li alloy components using new forming technologies; Additive Manufactured Products (to be provided by BAMTRI); Microstructures and Properties of Transient Liquid Phase Bonding Joint of Single Crystal Alloy (widely used for turbine blades in aero engines); and Microstructure and mechanical properties of Ti6Al4V alloy joints and other titanium alloys.

Investigation at King's College London has drawn attention to two other pieces of Imperial research that it states will 'certainly be of interest for military aircraft designers, as well as in civilian applications'. These were 'Structural Integrity Assessment of Additive Manufactured Products'[129] and 'Impact testing of laminated glass and composites',[130] which used a high-velocity gun system 'relevant for nuclear weapons development'.[131] (In 2015, Charles Clover

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[123] https://www.imperial.ac.uk/avic-design/people/zhusheng-shi/
[124] https://www.sciencedirect.com/science/article/pii/S0749641920301364
[125] https://www.imperial.ac.uk/people/liliang.wang
[126] https://www.imperial.ac.uk/avic-design/people/mr-jun-liu/
[127] https://www.imperial.ac.uk/avic-design/people/qinmeng-luan/
[128] https://www.sciencedirect.com/science/article/abs/pii/S0263822320302063
[129] http://www.imperial.ac.uk/avic-design/projects/mti-fai/structural-integrity-assessment/ in Scott, E., Peel, R., Ruechardt, F., & Mitchell, N. (2020). Catalogue of Case Studies on Intangible Technology Transfers from Universities and Research Institutes: Revised edition. King's College London https://www.kcl.ac.uk/alpha/assets/pdfs/itt-case-studies.pdf; https://kclpure.kcl.ac.uk/portal/files/135803068/itt_case_studies.pdf.
[130] http://www.imperial.ac.uk/avic-design/projects/mti-fai/impact-testing-oflaminated-glass-and-composites/ in *Ibid*.
[131] International Atomic Energy Agency, *Communication Received from the Permanent Mission of Switzerland to the International Atomic Energy Agency regarding Certain Member States' Guidelines for Transfers of Nuclear-related Dual-use Equipment, Materials, Software and Related Technology* in *Ibid.*

at the *Financial Times* (as well as King's College London) have also reported links between AVIC's MTI/BAMTRI and Iran's missile programme).[132] [133]

Imperial states the centre 'supports fundamental, non-classified research into new materials and manufacturing methods'.[134] According to Charles Clover and King's College London, it 'conducted due diligence on AVIC before signing the agreement' and liaised with the UK Export Control Organisation (now the Export Control Joint Unit).[135]

See technological themes:

1. Alloys of aluminium, titanium and other metals.
5. Composites, nanocomposites, polymers, laminates and related technologies.

Imperial College London and the Beijing Aircraft Technology Research Institute (BATRI)

- *The COMAC-Imperial Research Centre for Wing Technology of Commercial Aircraft*

(BATRI is a subsidiary of the Commercial Aircraft Corporation of China (COMAC))

The Commercial Aircraft Corporation of China (COMAC) has AVIC as a major shareholder. This Centre's project areas include:

- Al-Li alloys (applying the creep age forming (CAF) process used to manufacture large aerospace panels like wing skins to produce panels with these alloys;
- Aircraft transonic flutter (computational prediction of aeroelastic instabilities);
- Optimisation for 3D-printed structures; and
- Stamp forming of composites (research into composite materials such as carbon fibre-reinforced poly ether-ether ketone (PEEK), a radiation-resistant material in demand for military aircraft).

See technological themes:

1. Alloys of aluminium, titanium and other metals.
3. Aerospace physics.

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[132] Charles Clover, 'UK universities under scrutiny over China ties,' *Financial Times*, 24 June 2015, https://www.ft.com/content/af5ea60e-1578-11e5-be54-00144feabdc0. The US Department of Commerce in 2014 listed BAMTRI and other Chinese companies 'for their roles in supplying Iran's ballistic missile program'. Also in https://www.kcl.ac.uk/alpha/assets/pdfs/itt-case-studies.pdf

[133] https://www.kcl.ac.uk/news/uk-universities-under-scrutiny-over-china-ties

[134] Charles Clover, 'UK universities under scrutiny over China ties,' *Financial Times*, 24 June 2015, https://www.ft.com/content/af5ea60e-1578-11e5-be54- in https://www.kcl.ac.uk/alpha/assets/pdfs/itt-case-studies.pdf.

[135] *Ibid*.

Imperial College London and the China Academy of Launch Vehicle Technology (CALT)

- *UK-China Advanced Structure Manufacturing Technology Laboratory*

The laboratory, sponsored directly by nuclear ICBM supplier CALT (above), is now little-mentioned in the public domain.[136] However, one engineer from the PRC at Exeter, has remained a Research Fellow of the Laboratory between 2017 and 2020. This researcher has published in the last two years on *Finite element analysis of interaction of laser beam with material in laser metal powder bed fusion process*[137] and *Evaluation of low cycle fatigue performance of selected laser melted titanium alloy Ti-6Al-4V*[138] (studying selective laser melting to make parts from this alloy, which separately is widely used in military aircraft; studies by others of low cycle fatigue resistance for Ti6Al4V have noted its possible use in rocket engine cases).[139] The researcher published these papers with researchers at Chongqing University of Posts and Telecommunications, Chongqing University, and Chongqing University of Technology.

Another researcher studied at the Laboratory, where his research was funded by CALT.[140] His research includes publications on the fast light alloys stamping technology (FAST) process for martensitic steel, springback for high strength aluminium alloys, and ultra-high strength steels.[141] His co-authors for this research include another PRC researcher at Imperial's AVIC Centre for Structural Design and Manufacturing (above).[142]

See technological themes:

1. Alloys of aluminium, titanium and other metals.
2. Steels.

Imperial College London and Shougang Group

- *Shougang-Imperial Lab for Lightweight Steel Based Systems for Impact Resistant Automotive Applications*

Imperial has also established a research centre with the major Chinese steel-making SOE Shougang. Although Shougang is a giant conglomerate and most of its manufacturing is for

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[136] Discussed in https://www.aspi.org.au/report/china-defence-universities-tracker

[137] https://www.researchgate.net/publication/325084564_Finite_Element_Analysis_of_Interaction_of_Laser_Beam_with_Material_in_Laser_Metal_Powder_Bed_Fusion_Process

[138] https://www.researchgate.net/publication/336063004_Evaluation_of_Low_Cycle_Fatigue_Performance_of_Selective_Laser_Melted_Titanium_Alloy_Ti-6Al-4V

[139] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7215716/

[140] Not to be confused with the medical researcher of the same name.

[141] https://www.researchgate.net/profile/Yuhao_Sun4

[142] https://www.researchgate.net/publication/342357420_Characterization_of_Thermomechanical_Boundary_Conditions_of_a_Martensitic_Steel_for_a_FAST_Forming_Process

civil use, the conglomerate also supplies large volumes of steel to the military and some of this laboratory's research may risk having dual-use applications. Research includes fibre metal laminates (FMLs), a class of lightweight structural materials that separately is of considerable interest to military industries. Defence-applicable research into FMLs elsewhere has included their capacity to improve the mechanical properties of CFRP, a material being researched by the centres above at Imperial and of increasing interest for stealth jets.[143]

See technological themes:

2. Steels.
5. Composites, nanocomposites, polymers, laminates and related technologies.

Response from Imperial College London

A spokesperson for Imperial College London said: "These claims completely mischaracterise the true nature of our sponsorship arrangements.

"In the limited instances where we receive sponsorship from Chinese companies, this is for fundamental scientific research. For example, our work to develop lightweight strong glass [per the KCL reference you note] has a wide range of potential scientific and commercial applications in many sectors worldwide. We do not conduct any classified research.

"Imperial conducts its own due diligence prior to any sponsorship arrangement. We also work closely with the Export Controls Joint Unit and other relevant UK government agencies. All relationships with third parties are subject to prior and continued review.

"Our research outputs, which are in the public domain and routinely published in leading international journals, are good for science, innovation and the UK's global influence. Science is a global endeavour, and we are proud to work with our peers in academia and industry all over the world."

…

"The project between Imperial and Shougang Research Institute of Technology in paragraph 2 aims to evaluate the possibility of stamping FMLs into lightweight panel components for automotive body structures (to replace current heavy steel components). This would help with passenger car energy saving and CO2 reduction."

[143] https://www.imperial.ac.uk/avic-design/projects/cfrp-laminates/

University of Cambridge and National University of Defense Technology (NUDT)

Memorandum of Understanding (MoU) with the National University of Defense Technology (NUDT) (now expired)

A Memorandum of Understanding (MoU) which expired in 2018 existed with NUDT, arguably China's most elite military-linked university. Cambridge states that this was 'signed in the wake of the UK… government's encouragement to create a "golden decade" for the UK-China relationship. That MoU produced no research, no collaborations, no funding and has been expired for three years.'

The National University of Defense Technology (NUDT) says the opportunities given by Cambridge will 'greatly raise the nation's power in the fields of national defence, communications [and] anti-jamming for imaging and high-precision navigation'.[144]

Cambridge has stated that the MoU produced no research with NUDT. Meanwhile, research was produced by a Bye-Fellow of Gonville and Caius, a constituent college of Cambridge, who was not directly employed or paid by the university itself, following the signing of the MoU (however this was not related to the MoU and the fact that this followed an MoU is purely coincidental).

This Bye-Fellow, whose employment at Gonville and Caius is simply in a teaching capacity and whose research we assume to be carried out independently, has cooperated on research with Xianwen Ran of NUDT.[145]

Ran is described online as a 'Doctor of Theology' at NUDT, but his own recent papers (not in cooperation with the Bye-Fellow at Gonville and Caius) include:

- In July 2020, *Theoretical model of radial scattering velocity of fragments of the reactive core PELE Projectile*[146] (the PELE projectile is a 'new type of armor-piercing warhead [whose] more obvious fragmentation effect… solves the problem of insufficient after-effects');
- *Simulation Study on Jet Formability and Damage Characteristics of a Low-Density Material Liner*[147] ('[The] warhead is an effective weapon against the ERA (explosive reactive armor')); and

[144] Citing China's Ministry of Education: https://web.archive.org/web/20200831235735/http://www.gesie.org/news/Center/2017-09-22/925.html and https://www.aspi.org.au/report/picking-flowers-making-honey

[145] https://www.researchgate.net/profile/Xianwen_Ran

[146] https://www.researchgate.net/publication/343130439_Theoretical_Model_of_Radial_Scattering_Velocity_of_Fragments_of_the_Reactive_Core_PELE_Projectile

[147] https://www.researchgate.net/publication/322261757_Simulation_Study_on_Jet_Formability_and_Damage_Characteristics_of_a_Low-Density_Material_Liner

- In December 2019, *A method to optimize the electron spectrum for simulating thermo-mechanical response to x-ray radiation*[148] ('The X-ray pulse originating from high altitude nuclear detonation (HAND) is mainly soft X-ray and its intensity is high enough [to] lead to severe thermo-mechanical deformation of unpenetrated material… It is possible to simulate [this] using the optimized electron spectrums').

The effects of high-altitude nuclear blasts and potentially devastating electro-magnetic pulses (EMP) are reported to be areas of high strategic interest to the Chinese military.[149]

The Bye-Fellow who is Ran's research partner in separate fields has stated that he is an 'Associate member of the Cavendish Laboratory', a 'Research Fellow at Imperial College London', and a 'Distinguished Visiting Professor of NUDT' (his CV lists this position as having been from 2014 to 2017, however, at the time of writing, his online profile stated that this continues).[150] He remains a High-Level Foreign Talent, a position awarded by Beijing (this 'comes with a long-term visa'), having been awarded membership of the '1000-Talent plan' in 2015. He remains a Distinguished Visiting Professor of China's Central South University (he states that at CSU he carries out 'research with engineers on better transportation systems and vehicles'). Before 1996, he was also a Fellow at the US defence research base Los Alamos National Laboratory, run by the Department of Energy.

According to Clive Hamilton and Mareike Ohlberg, the Thousand Talents Plan exists to bring scientific expertise and knowledge to China, primarily by returning PRC nationals:

> 'The US Department of Energy… has been heavily targeted to this end… According to one report, "so many scientists from Los Alamos have returned to Chinese universities and research institutes that people have dubbed them the 'Los Alamos club'".'[151]

There is no suggestion that this professor has engaged in any illicit knowledge transfer from Los Alamos or elsewhere, however. We refer to this to make the point, as with the other scientists whose work is mentioned in this report, that there may at times be a danger of the future co-opting of research against their intentions for dual-use purposes.

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148 https://www.researchgate.net/publication/338205287_A_Method_to_Optimize_the_Electron_Spectrum_for_Simulating_Thermo-Mechanical_Response_to_X-ray_Radiation

149 Pillsbury, M. (2015). *The Hundred-Year Marathon: China's Secret Strategy to Replace America As the Global Superpower*. St Martin's Griffin.

150 https://www.imperial.ac.uk/people/r.blumenfeld#:~:text=Rafi%20Blumenfeld%20is%20a%20Research,member%20of%20the%20Cavendish%20Laboratory%2C

151 Stephen Chen, 'America's hidden role in Chinese weapons research', *South China Morning Post*, 29 March 2017. In *Hidden Hand: Exposing How the Chinese Communist Party Is Reshaping the World*. Simon and Schuster.

Ran has published with him as recently as June 2020 (*Sink-rise dynamics of horizontally oscillating active matter in granular media: Theory)*[152] and in September 2016, *Vertical dynamics of a horizontally-oscillating active object in a 2D granular medium.*[153]

Other NUDT scholars include an expert in nanoporous aerogels and their use in high-performance light absorption and thermal insulation, who was a visiting academic fellow at Cambridge in 2019, joining the hybrid nanomaterials engineering group. [154] Elsewhere, these types of materials have wide potential dual-use applications, including in projectile coatings such as for hypersonic missiles.

See technological themes:

5. Composites, nanocomposites, polymers, laminates and related technologies.
6. Ceramics, piezoelectrics and rare earth coatings.

Response from the University of Cambridge

"Cavendish Laboratory: The Cavendish Laboratory does not have, nor has ever had, any projects, research grants or contracts with NUDT or other military institutions in China. There was an MoU between the groups, but this never led to any formal research funding, lapsed in 2018 and has not been renewed."

The Bye-Fellow "is not an employee of the University and he does not work on any research grant or contract involving the Cavendish Laboratory. He is a Bye-Fellow at Gonville & Caius College, where he teaches Physics to students for up to six hours per week during term time. The University and Colleges are separate legal and financial institutions."

"The report attempts to link the University to military research through [the] Bye-Fellow at Gonville & Caius, whose only link to the University is that he teaches physics at one college six hours per week. He is not employed by the University, he is not funded by the University. He has no research at the University. He is not collaborating on any research at the University."

The nanoporous aerogels expert "was a visitor at the Cambridge Graphene Centre (CGC) in 2019 [and] was invited under normal academic procedures because he has expertise in aerogels which the CGC didn't have at the time (i.e. he had expertise that Cambridge wanted, not the other way around). [He] did not carry out any experiments, did not have access to laboratories and did not attend group research meetings during his time at the University. The CGC now have two students working on aerogels which began after his departure. Their work is not in collaboration with NUDT."

[152] https://arxiv.org/abs/2006.04160
[153] https://www.researchgate.net/publication/307862085_Vertical_dynamics_of_a_horizontally-oscillating_active_object_in_a_2D_granular_medium
[154] https://www.nanoengineering.eng.cam.ac.uk/people

Cambridge also describes links to NUDT as “non-existent”.

Manchester University and the China Aerospace Science and Technology Corporation (CASC)

- *Sino-British Joint Advanced Laboratory on Control System Technology*

This joint laboratory focused on advanced control systems, but had plans to ‘move beyond Control Systems into other aspects of Aerospace Science’. Manchester states that the laboratory closed in 2018,[155] but its Chinese director states that he still leads the laboratory.[156]

The China Aerospace Science and Technology Corporation (CASC) is central to China’s space programme and, through its subsidiary the China Academy of Launch Vehicle Technology (CALT) is the main ballistic missile supplier to China’s nuclear weapons programme (CALT also researches technologies such as missile launchers and spaceplanes). In common with many of the facilities we describe, this means Manchester University has provided China’s main nuclear ICBM conglomerate with a research facility subsidised by the UK taxpayer.

One of the academics involved in establishing the laboratory is the Dean of the Faculty of Engineering and Physical Sciences, who joined a CASC delegation at an agreement signing ceremony (in 2013 he was also a Guest Special Professor of Wuhan University on a ‘World-Renowned Scientist Lecture Tour’.)[157]

The director is a control systems expert, some of whose research at the laboratory has been EPSRC-funded and includes UAVs. His research on control systems technologies covers attitude control for rigid spacecrafts, formation flying for UAVs, and air-breathing hypersonic vehicles.[158] One of his recent papers at Manchester, from 2018 (‘Robust Cooperative Guidance Law for Simultaneous Arrival’), includes a diagram that appears to show different missiles, or rockets, moving towards the same target.[159]

[155] https://web.archive.org/web/20191203090318/http://www.aerospace.manchester.ac.uk/our-research/sino-british-control-lab/ In https://www.aspi.org.au/report/china-defence-universities-tracker
[156] https://www.research.manchester.ac.uk/portal/zhengtao.ding.html
[157] https://www.research.manchester.ac.uk/portal/en/activities/wuhan-university(f0e62519-2f53-4455-a369-930eeb231d36).html
[158] https://www.research.manchester.ac.uk/portal/en/researchers/zhengtao-ding(f87d35e0-a98b-4835-a0db-10debfccbbee).html
[159] https://www.research.manchester.ac.uk/portal/files/65368508/2018TCST_Preprint.pdf

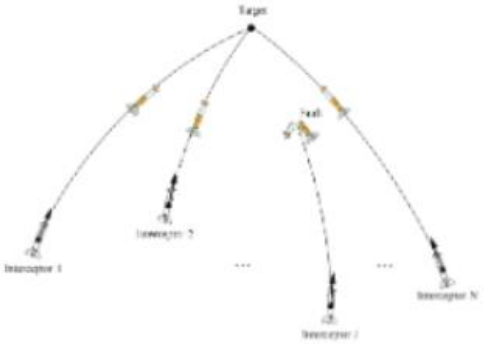

Fig. 2. N to 1 robust simultaneous arrival scenario.

We make following assumptions throughout this brief.

Assumption 1: The speed of each interceptor is constant but may not be the same as that of other interceptors.

See technological themes:

3. Aerospace physics.
4. Hypersonic technology.
7. Drones and lithium-ion batteries.

Manchester University and the Beijing Institute for Aeronautical Materials (BIAM)

- *BIAM-University of Manchester Graphene Aerospace Materials Centre*
- *BIAM-University of Manchester Technology Centre*
- *BIAM is a subsidiary of the Aero Engine Corporation of China (AECC)*

In 2017, Manchester launched two centres with the Beijing Institute for Aeronautical Materials (BIAM). They were opened at an event attended by staff from the Chinese consulate in Manchester, where Manchester's council leader described 'another vote of confidence in Manchester' which will 'further strengthen ties between Manchester and China.'[160]

The Graphene Aerospace Materials Centre researches graphene in composites, ceramics, and other aerospace materials. It is led by a professor from the PRC at Manchester's Department of Materials.[161]

The BIAM-University of Manchester Technology Centre develops, processes and tests advanced materials for aero engines. Its director at Manchester is another professor from

[160] https://www.manchester.ac.uk/discover/news/graphene-partnership-could-deliver-lighter-planes/
[161] https://www.royce.ac.uk/rolls-royce-chair-in-advanced-coating-technology/

China, also of the Department of Materials and who researched at BIAM before coming to the UK. His research is focused on the corrosion control of light alloys, including AA6082, 7010, 2055, 2099-T83 and AZ31B magnesium alloy-titanium joints.[162]

In 2020, a researcher affiliated with the Technology Centre published research on AA7150[163] with researchers at the defence laboratory the State Key Laboratory of Powder Metallurgy, Central South University (CSU) and Huazhong University of Science and Technology (HUST). Previous research by others at CSU on AA7150 has received direct sponsorship by the National Defense Program of China.[164]

See technological themes:

1. Alloys of aluminium, titanium and other metals.
5. Composites, nanocomposites, polymers, laminates and related technologies.

Response from the University of Manchester

"We value our connections with China as an important part of the UK's extensive international trade and cultural links. All such interactions have to be based on government guidance and regulation.

"The University carries out due diligence on all research collaborations informed by the latest information and guidance. We have a clear intellectual property policy which all our researchers, overseas and domestic, must adhere to as part of their professional contracts.

"We take all necessary measures to assure ourselves that our research is not used beyond its agreed application. Typically, the results of collaborative research are published in the open, publicly accessible scientific literature, as is the norm for research conducted at the University.

"The cases given in the Civitas report were either for research collaborations or for visiting researchers to undertake projects in University of Manchester laboratories. All current projects mentioned in the Citivas report went ahead after assessment and approval by the Export Control Joint Unit (ECJU).

"We can confirm that all due diligence and processes are in place to allow academics and the University to question the potential of their research and only engage with external entities within the legal remits of the export control legislation as assessed by the ECJU. Our current due diligence addresses and ensures that no controlled information is exported outside the UK without the appropriate licence in place. The University continues to work closely with the ECJU and government agencies to ensure that we are fully compliant with policies and protocols around export of materials, information and data."

…

[162] https://www.research.manchester.ac.uk/portal/xiaorong.zhou.html
[163] https://www.sciencedirect.com/science/article/abs/pii/S1003632620653602
[164] https://www.sciencedirect.com/science/article/abs/pii/S100363262065405X

"A collaboration and a separate visitor from NUDT were approved by ECJU.

"Agreements with China Aerospace Science and Technology Corporation (CASC) and Beijing Institute of Aeronautical Materials (BIAM) were terminated in 2018 and 2020, respectively. The web page of Professor Zhengtao Ding is out of date and will be updated to reflect these changes.

"A collaboration with Central South University (CSU) was approved by ECJU."

University of Strathclyde and the China Academy of Launch Vehicle Technology (CALT)

- *Space Mechatronic Systems Technology (SMeSTech) Laboratory*

Strathclyde's SMeSTech Laboratory is another UK university partnership for ICBM manufacturer CALT. Involved in research into mechatronic systems, satellites and other fields, Strathclyde does not mention CALT's involvement on its website (simply 'international funding').

One of the laboratory's EU-funded projects[165] on data fusion 'effectively combine[s] the data acquired by sensors used onboard satellites [and] other space vehicles' with broad applications 'on earth and in space'.

One associated Chinese professor in mechatronic systems technology has published across many related fields, including on 'UAV swarming technology' (for oil and gas facility inspection). His research includes *A new system design method for space launch vehicles*[166] and *MOSAR: modular spacecraft assembly and reconfiguration demonstrator*.[167] He has researched calcium phosphate[168] (for standard medical purposes; however his co-authors include researchers at China's military-linked Northwestern University). Other publications include on the manufacturing of oxidation-resistant coatings (types used for alloys and superalloys).[169]

His research into *A new system design method for space launch vehicles*[170] was with researchers at the Beijing Institute of Astronautical Systems Engineering, a subsidiary of CALT. This Institute appears to be based at 1 South Dahongmen Road, Beijing. It appears that so is the Aerospace Research Institute of Materials & Processing Technology, another CALT subsidiary, whose first director Yao Tongbin was 'awarded the A-Bomb, H-bomb and

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165 https://www.strath.ac.uk/engineering/designmanufacturingengineeringmanagement/thespacemechatronicsystemstechnologylaboratory/datafusionforspacerobotics/

166 https://www.researchgate.net/publication/274992821_A_new_system_design_method_for_space_launch_vehicles

167 https://pureportal.strath.ac.uk/en/publications/mosar-modular-spacecraft-assembly-and-reconfiguration-demonstrato

168 https://www.researchgate.net/profile/Xiu-Tian_Yan/2

169 https://www.researchgate.net/profile/Xiu-Tian_Yan/2

170 https://www.researchgate.net/publication/274992821_A_new_system_design_method_for_space_launch_vehicles

First Satellite Medals'.[171] The Beijing Institute has published studies of launch vehicles for hypersonic vehicles that refer to 'military requirements', the need for 'large angle of attack', and missile flight control.[172] [173] [174] [175]

Another Chinese researcher at Strathclyde is a graduate of Beihang and is based, like the colleague above, in the Robotics and Automation Systems Group that includes SMeSTech. The group's specialisms include electronic and power systems and orbital robotics. The PhD research he supervises includes multiple autonomous systems (to 'improve [their] capabilities, such as surveillance, target acquisition and tracking, etc').[176] After Beihang, he received his PhD in 2008 in robotics and autonomous systems from the School of Computer Science and Electronic Engineering at the University of Essex (the School has also established a joint double degree programme aimed at Chinese students with NWU[177]). The School of Naval Architecture at China's 'Dalian University' (in reality 'Dalian University of Technology') also states that it has established a 'joint training agreement' with the University of Strathclyde.[178]

See technological themes:

3. Aerospace physics.
7. Drones and lithium-ion batteries.
9. Shipbuilding.
10. Data science, AI, recognition and facial recognition.
11. Robotics (land, sea and space).

Response from the University of Strathclyde

A spokesperson for the University of Strathclyde said: "International research collaboration plays an important role in finding solutions to global challenges, from sustainable farming and future energy systems, to protecting health.

"The collaboration agreement referred to between the University of Strathclyde and the China Academy of Launch Vehicle Technology (CALT) focused on mechatronics research contributing to the UK-China Flagship Challenge program project SmartFarm, with the aim of developing more efficient and sustainable approaches to farming and food production. It used AgriRover – a device for testing soil quality based on technology previously developed for use in exploration on Mars – as a key prototype. A demonstration of AgriRover was

[171] http://www.jeccomposites.com/directory/aerospace-research-institute-materials-process
[172] https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9045021
[173] http://www.aerospacechina.org/CN/article/downloadArticleFile.do?attachType=PDF&id=264
[174] https://www.isodarco.it/courses/beijing92/beijing92_part.pdf
[175] http://www.aerospacechina.org/CN/article/downloadArticleFile.do?attachType=PDF&id=264
[176] https://pureportal.strath.ac.uk/en/persons/erfu-yang
[177] https://www.essex.ac.uk/news/2017/09/11/success-of-new-joint-degree-programme-between-essex-and-northwest-university-in-china
[178] http://vehicle.dlut.edu.cn/English/Programs_and_Degrees/School_of_Naval_Architecture.htm

made in a farm in Beijing and an export control license was secured from the UK Government Export Control Joint Unit before the demonstration.

"All of our research collaborations are open and transparent, and are subject to due diligence. Our scientific outputs are in the public domain, and are published openly in leading journals and websites.

"All of our research is undertaken in accordance with our Research Code of Practice and its guidance on research integrity with the core elements of honesty; rigour; transparency and open communication; and care and respect. Any transfer of materials is subject to UK Government legislation on export control. All relationships with third parties are subject to prior and continued review.

"Openly published research is by definition available to researchers over the entire world. The university supports, and has contributed to, work of UUK and CPNI on Trusted Research to ensure that checks and balances are embedded across our systems."

Birmingham University and the University of Science and Technology China (USTC), Wuhan University of Technology (WUT), BIAM, COMAC and Huazhong University of Science and Technology (HUST)

Birmingham University cluster:

- *USTC-Birmingham Research Institute in Intelligent Computation and its Applications*
- *Wuhan University of Technology-Birmingham Joint Key Laboratory for Intelligent Machines*
- *Efficient Manufacturing for Aerospace Components Using Additive Manufacturing, Net Shape HIP and Investment Casting (EMUSIC)*

Over the last decade, Birmingham has created a cluster of research partnerships with Chinese companies and institutions leading to potentially dual-use (potentially military- or surveillance-applicable) research.

The Director of the USTC-Birmingham Research Institute in Intelligent Computation and its Applications is a computer scientist with a PhD from USTC.[179] The Institute has two areas of focus: adaptive optimisation, and advanced data analysis and mining. The second area, the Institute states, is 'controversial', involving the collection of internet users' data to predict online behaviour. The group is 'engaged with Baidu [China's closest equivalent to Google but which, like COMAC, is now under US DOD sanctions as a 'Chinese military company'] to take this information one step further and consider predictions connected to browser pathways.'

[179] https://www.cs.bham.ac.uk/~xin/

In 2013, Birmingham and Wuhan University of Technology established the Wuhan University of Technology-Birmingham Joint Key Laboratory for Intelligent Machines. Although Birmingham makes no public mention of the laboratory, according to WUT it includes intelligent decision supporting systems (including AI with autonomous control technology) and carbon fibre-reinforced plastics (CFRP).[180][181]

Birmingham is also the coordinator of the Efficient Manufacturing for Aerospace Components USing Additive Manufacturing, Net Shape HIP and Investment Casting (EMUSIC), an EU-China project to develop aerospace component manufacturing (such as additive manufacturing (AM)); Near Net Shape Hot Isostatic Pressing (NNSHIPping); and of Ti-alloy investment casting.

The project 'will allow the end-users to decide whether to transfer the technologies to their supply chain'. Chinese partners include BIAM, the COMAC Shanghai Aircraft Design and Research Institute, the Institute of Metal Research (IMR), and Huazhong University of Science and Technology (HUST). Birmingham has stated that its involvement with BAMTRI/MTI in the project ended before the Chinese institute was added to a US watch list,[182] but Birmingham continues to use its name in their material.[183]

See technological themes:

1. Alloys of aluminium, titanium and other metals.
5. Composites, nanocomposites, polymers, laminates and related technologies.
10. Data science, AI, recognition and facial recognition.

University of Nottingham and ACAE (the Commercial Aircraft Engine Company)

- *University of Nottingham University Innovation Centre (UIC)*

Nottingham's agreement with ACAE (i.e. the Commercial Aircraft Engine Company, which it describes as an AVIC subsidiary,[184] although AVIC remains a shareholder in AECC) provided a £3 million three-year package of support for 'civil aerospace research projects in the UIC', including impact damage on composite materials and thermal barrier coatings to 'improve the performance of engine components such as turbine blades, which have to operate in

[180] http://imul.whut.edu.cn/en/about/
[181] http://imul.whut.edu.cn/en/team/lecturer/201402/t20140221_111923.htm
[182] https://www.kcl.ac.uk/alpha/assets/pdfs/itt-case-studies.pdf
[183] https://www.birmingham.ac.uk/generic/emusic/about/participants.aspx
[184] https://www.nottingham.ac.uk/research/groups/composites-research-group/research/mechanical-and-failure/avic-nottingham-university-innovation-centre.aspx

very high temperatures'.[185] ACAE has sponsored around 20 of its staff to study at Nottingham.[186]

The ACAE-UIC primarily works with the university's Composites Research Group. The executive director of the UIC looked forward to 'further enhanc[ing] our understanding of composite materials and thermal barrier coatings'. On his visit to launch the UIC, ACAE R&D Director Dr Victor Wang called it a 'historic moment' for his company. UIC staff have researched polymer nanocomposites with Chongqing University, including 3D-woven composite T-joints and related areas.[187]

One individual associated with the UIC is now at UCL, but formerly 'research director of University Innovation Centre in Aero Engine with AVIC'.[188] While at Nottingham, her team invented a novel Aerosol-Assisted Ion Deposition (AAID) process and, according to her website, developed nanocomposite coatings with unique physical and chemical properties: 'The method is being exploited to put sub-micron/micron thick high performance polymeric coatings on steels'. She has also developed nanocomposite coatings for tribological applications, ceramic coatings and next generation multifunctional films for deicing, antifogging and anti-lightning applications in aerospace.'[189] Choy has worked closely with 'leading research institutions and industrial companies to exploit [AAID] technologies [and] novel coating materials.' These include defence companies Rolls-Royce, QinetiQ and DSTL, implying a potential for dual-use.[190]

See technological themes:

5. Composites, nanocomposites, polymers, laminates and related technologies

Response from the University of Nottingham

A University of Nottingham spokesperson said: "The research agreement with the Commercial Aircraft Engine Company (ACAE) ended in 2017 and was specifically designed for civil aerospace applications in large passenger aircraft. All international research agreements are constructed fully in line with government legislation, including export control regulations, and subjected to rigorous internal research security, integrity and ethical procedures, as well as our own Research Code of Conduct and Export Control Policy."

[185] https://www.nottingham.ac.uk/research/groups/composites-research-group/research/mechanical-and-failure/avic-nottingham-university-innovation-centre.aspx
[186] https://www.nottingham.ac.uk/research/groups/composites-research-group/research/mechanical-and-failure/avic-nottingham-university-innovation-centre.aspx
[187] https://www.nottingham.ac.uk/research/groups/composites-research-group/research/mechanical-and-failure/avic-nottingham-university-innovation-centre.aspx
[188] https://iris.ucl.ac.uk/iris/browse/profile?upi=KLCHO01
[189] https://iris.ucl.ac.uk/iris/browse/profile?upi=KLCHO01
[190] https://iris.ucl.ac.uk/iris/browse/profile?upi=KLCHO01

University of Strathclyde and Beijing University of Aeronautics and Astronautics (and larger group in Scotland and China)

- ***China-Scotland Signal Image Processing Research Academy (SIPRA)***
- *Linked universities in China: National Laboratory of Pattern Recognition, Beijing University of Aeronautics and Astronautics (Beihang), Southeast University, Tianjin University, Zhejiang University, University of Electronic Science and Technology of China (among others).*

SIPRA was founded in 2008 by a group of Chinese and Scottish universities. It studies signal/image processing and its applications in communications, aerospace and other fields. SIPRA seeks 'close cooperation [with] industry in China and Scotland.'[191]

SIPRA's founder is at Strathclyde.[192] His research with counterparts in China includes person re-identification in camera networks. His paper *Adversarial erasing attention for person re-identification in camera networks under complex environments* states:

> 'Person re-identification (Re-ID) in camera networks under complex environments has achieved promising performance using deep feature representations. However, most approaches usually [ignore] features from non-salient parts of pedestrian, which results in an incomplete pedestrian representation. In this paper, we propose a novel person Re-ID method named Adversarial Erasing Attention (AEA) to mine discriminative completed features using an adversarial way… original pedestrian images are used to train the basic network [to] extract global and local deep features.'[193]

With his colleagues, this researcher received a Royal Society grant for *Fuzzy multilayer clustering and fuzzy label regularization for unsupervised person reidentification*:

> 'Unsupervised person reidentification has received more attention due to its wide real-world applications… we propose a novel method named fuzzy multilayer clustering [which] learns a new feature space using a multilayer perceptron for clustering in order to overcome the influence of complex pedestrian images…' [194]

One co-author was from an institute not mentioned among SIPRA partners, the State Key Laboratory for Management and Control of Complex Systems, Institute of Automation, Chinese Academy of Sciences (this co-author is also a graduate of NPU). SIPRA has received visits from China's National Laboratory of Pattern Recognition and a Vice-President of the Chinese Academy of Sciences. SIPRA members based at Strathclyde have visited NPU to cooperate on a funding application; one discussed cooperation at Beihang; and as a SIPRA member, another Scotland-based Chinese scholar has visited Beihang for research. SIPRA's founder has delivered 'a number of keynote lectures' to the University of Electronic Science

[191] https://www.china-scotland-sipra.org/
[192] https://www.stir.ac.uk/people/257402
[193] https://ieeexplore.ieee.org/document/9043556
[194] https://ieeexplore.ieee.org/document/8704867

and Technology (UESTC); another SIPRA-affiliated scholar has visited Beihang's Joint Research Laboratory in Cognitive Signal Image Processing to discuss research applications[195] and has researched pedestrian detection with the State Key Laboratory of Management and Control for Complex Systems, the School of Artificial Intelligence, and the Center for Excellence in Brain Science and Intelligence Technology of the Chinese Academy of Sciences.[196] [197]

See technological themes:

3. Aerospace physics.
7. Drones and lithium-ion batteries.
9. Shipbuilding.
10. Data science, AI, recognition and facial recognition.

University of Kent

- *Communications Research Group*

The Communications Research Group researches 'advanced communications technologies and systems for high-frequency and/or high data-rate wireless systems operating from radio frequency (RF) to Terahertz (THz) frequencies'.[198]

Areas of research include space antennas, smart antennas, space-borne radars, phased arrays, MIMO (multiple input multiple output), antenna and radio propagation for 4G/5G/6G mobile communications, base station antennas, antennas for satellite communications, RF/microwave/millimetre-wave circuits and RF front ends, mobile communication systems, satellite communications, inter-satellite links, wireless power transfer, ultra-wide band (UWB) radars, GNSS reflectometry, synthetic-aperture radars, electromagnetic modelling and small satellites.

A leading figure in the group is a professor of RF/Microwave Engineering[199] and former visiting professor at NPU and Xidian University.[200] The group has been sponsored by Huawei to research 5G antenna technologies, which Kent says will 'produce more research impacts on the society'.[201] These include millimetre-wave antenna designs for 5G smartphones. The group is moving into intelligent antenna technologies for 6G.

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[195] https://www.china-scotland-sipra.org/academic-visits/
[196] https://www.sciencedirect.com/science/article/abs/pii/S1566253518304111
[197] SIPRA's other publications include *Improved sparse representation using adaptive spatial support for effective target detection in hyperspectral imagery* and *A novel SAR target detection algorithm based on contextual knowledge* (https://www.tandfonline.com/doi/abs/10.1080/01431161.2013.845924).
[198] https://research.kent.ac.uk/communications/
[199] https://research.kent.ac.uk/communications/people/
[200] https://www.kent.ac.uk/engineering-digital-arts/people/670/gao-steven
[201] https://research.kent.ac.uk/communications/antennas/?article=1012

Researchers have received EU, EPSRC and Royal Academy of Engineering grants.[202] Current projects include 'Adaptive multi-band small MIMO antennas for next-generation smart phones' (funded by Huawei), 'Low-cost THz wideband smart antennas design and fabrication using 3D Printing' (funded by EPSRC), and 'Low-Profile Ultra-Wideband Wide-Scanning Multi-Function Beam-Steerable Array Antennas' (EPSRC).

One began his career at the China Research Institute of Radio Wave Propagation (also known as the 22nd Research Institute of China Electronics Technology Group Corporation (CETC)).[203] [204] [205] CETC has said that the corporation's purpose is 'leveraging civilian electronics for the gain of the PLA'.[206] His recent publications include on MIMO arrays for 5G terminal applications,[207] [208] [209] published with a Xidian researcher who specialises in Antennas and Microwaves, a designated area of military research at the university where it is carried out jointly with CETC's 14th Research Institute, a centre of anti-stealth research under US Entity List sanctions.[210]

They also include MIMO antenna units, ultrawideband transmitarrays,[211] and Vehicle Global Navigation Satellite System.[212] Co-authors for the final paper include a phased array radar expert at NPU and a satellite and antennas expert at the National Key Laboratory of Antennas and Microwave Technology, a defence-funded laboratory at Xidian University. Some of these researchers joined him for *Millimetre-Wave Dual-Polarized Differently Fed 2-D Multibeam Patch Antenna Array.*[213]

See technological themes:

8. Radars, antennae and related technologies.

[202] https://www.kent.ac.uk/engineering-digital-arts/people/670/gao-steven His recent projects as principal investigator include 'Millimeter-wave intelligent array antennas for Ka-band satellite communications on the move', 'Advanced reflectarray antennas for space-borne synthetic aperture radars', and 'Gallium Nitride integrated millimeter-wave active phased array multi-beam transceivers for SATellites'.
[203] https://www.kent.ac.uk/engineering-digital-arts/people/670/gao-steven
[204] https://www.natureindex.com/institution-outputs/china/china-research-institute-of-radiowave-propagation-cetc22/5d5cca46d226a5a18642164b
[205] https://www.globalsecurity.org/military/world/china/cetc.htm
[206] Matthew Luce: 'A model company: CETC celebrates 10 years of civil-military integration' China Brief (Jamestown Foundation), vol 12, no. 4, 2012. In Hamilton, C. and Ohlberg, M. (2020). *Hidden Hand: Exposing How the Chinese Communist Party Is Reshaping the World*. Simon and Schuster.
[207] https://kar.kent.ac.uk/80233/
[208] https://kar.kent.ac.uk/80232/1/08930474.pdf
[209] https://ieeexplore.ieee.org/document/8930474
[210] https://www.bis.doc.gov/index.php/documents/federal-register-notices-1/2250-83-fr-37423-entity-list-final-rule-8-1-18/file in https://unitracker.aspi.org.au/universities/xidian-university/
[211] https://kar.kent.ac.uk/74195/
[212] https://ieeexplore.ieee.org/document/9186051
[213] https://ieeexplore.ieee.org/document/9106783

Response from the University of Kent

"We do not comment on individual members of staff. However, we can confirm that we have a PhD project funded by Huawei for the novel design of antennae for civilian-specific smart phones. All results to date have been published by IEEE, a reputable US-based journal for engineering studies. We have also applied for open access to these papers, which will improve their availability. The antennae group does not have collaborations with any military-linked universities in China.

"The University of Kent respects all UK trade restrictions. We follow government guidelines and cooperate with the UK authorities."

Warwick Manufacturing Group (WMG) and China Aerospace Science and Technology Corporation (CASC) and others

Warwick Manufacturing Group (WMG) appears to have had a longer relationship with Chinese military researchers than any other university centre in the UK.

WMG founder, Lord Kumar Bhattacharyya (1940-2019), founded Warwick Manufacturing Group at the University of Warwick in 1980, travelling to Beijing two years later on a high-level scientific mission. Within a 'three-decade relationship with the State Administration of Foreign Experts Affairs',[214] Bhattacharyya appears to have trained his first Chinese rocket scientist in 1983, inviting Liang Sili and a group of his associates from the Ministry of Aerospace Industry to train at WMG for six months. Liang had already been one of the leading figures in China's ICBM programme for some decades.

Liang, who died in 2016, was educated at universities in the US before returning to China in 1949, and soon became deputy director of the Research Office of Missile Control Systems, where he helped lead the 'Two Bombs, One Satellite' programme – which built China's first nuclear weapons. Liang helped design the Dongfeng (DF) 2A missile (which carried out China's first live rocket-launched warhead test in 1966); the DF 5 (China's first ICBM); and the Long March 2 and 3 rockets (developed by CALT, these were derived from the DF 5 and launched China into the space race with the first successful launch in 1975).[215] [216]

A *China Daily* interview with Bhattacharyya in 2018, 'WMG founder gave Chinese engineers the skills to soar',[217] explains how during Liang's stay in the UK, Bhattacharyya 'shared techniques and knowledge that contributed to the development and design of [the] control system for the Long March rocket'. After Liang returned to China, Bhattacharyya invited

[214] http://www.chinadaily.com.cn/a/201812/11/WS5c0f1f8ea310eff3032904d9.html
[215] https://www.scmp.com/article/430770/long-march-towards-space
[216] https://web.archive.org/web/20160423001300/http://www.qstheory.cn/science/2015-12/18/c_1117508301.htm
[217] http://www.chinadaily.com.cn/a/201812/11/WS5c0f1f8ea310eff3032904d9.html

another group of engineers to WMG in 1985. China's main ICBM developer, CASC, the parent company of CALT, cooperates with WMG today.

WMG, which has been cited in the UK Government's Lambert,[218] Wilson[219] and Witty[220] reviews of university-business collaboration as an international role model, makes no attempt to hide its position in China, boasting: '[s]everal billionaires on China's east coast owe their status, in part, to the skills they acquired on WMG programmes.'[221] WMG's cooperation with Beijing appears to have had an impact on China's military-industrial development. *China Daily* claims that, today, at least 1,900 WMG-trained Chinese engineers hold senior positions in areas such as defence and aeronautics, including in AVIC and CAST. Bhattacharyya became a Labour Peer in 2004 and was awarded the first ever National Rainbow Bridge Award at a ceremony in Beijing in 2015 for 'promoting the friendly cooperation between Chinese people and people from other countries'.[222] Xu Bingjin, President of the China-Europe Association for Technical and Economic Cooperation, commented that amid a 'critical shortage of scientific talents', Bhattacharyya trained 'excellent talents for Chinese industries of automobile, aviation, aerospace, transportation and national defence'. Bhattacharyya became an advisor to Margaret Thatcher in 1982.

Today, WMG has created bespoke programmes for executives at CASC and a long-term research partnership MoU with the University of Science and Technology, Beijing (USTB).[223] WMG continues much of Bhattcharyya's work: 'The Professor's regular visits to China, delivery of keynote lectures and development of strategic relationships, have aided us in fully understanding the country's evolving industry landscape', their material says.[224] Hailing his meetings with Vice Premier Madam Liu Yandong and Vice Premier Ma Kai, WMG seems keen to present itself as supporting the regime in Beijing, describing how 'China's State Council unveiled its new national plan in 2015, with a strong focus on manufacturing. ''Made in China 2025' [is] designed to transform China… into a manufacturing world power by 2049'. According to WMG, '[o]ur strengths and expertise align closely with the main priorities of the State Council's plan'.[225] Here, WMG repeats parts of the wording of an official announcement from China's State Council:

> ''Made in China 2025' is the first 10-year action plan designed to transform China from a manufacturing giant into a world manufacturing power… by the year 2049,

[218] https://globalhighered.files.wordpress.com/2009/09/lambert_review_2003.pdf
[219] https://www.gov.uk/government/publications/business-university-collaboration-the-wilson-review
[220] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/249720/bis-13-1241-encouraging-a-british-invention-revolution-andrew-witty-review-R1.pdf
[221] https://studylib.net/doc/12304862/wmg-in-china
[222] https://warwick.ac.uk/newsandevents/pressreleases/professor_lord_kumar_bhattacharyya_awarded_china146s_first_ever_national_rainbow_bridge_award__beijing_china_150_sunday_25th_october_20151/
[223] https://studylib.net/doc/12304862/wmg-in-china
[224] https://warwick.ac.uk/fac/sci/wmg/education/custom/china/
[225] https://warwick.ac.uk/fac/sci/wmg/education/custom/china/p2477_wmg_in_china_8pp_final_web.pdf

which will be the 100th anniversary of the founding of the People's Republic of China.'[226]

WMG explains that their 'courses have been of benefit to a wide range of organisations including…China North Industries Corporation' (Norinco). These incorporate 'creativity and innovation', 'supply chain management' and 'collaboration and partnerships'.[227] WMG has emphasised that these courses do not involve research.

Gordon Brown described how WMG's work shows how 'knowledge created in our universities can be transferred to make a difference in the real world', and Theresa May and Chancellor Philip Hammond visited in 2016, which Business Secretary, Greg Clark, credited as helping inspire UK industrial strategy: 'During all the time I've known Lord Bhattacharyya he's been a big champion for the West Midlands. [The Prime Minister] saw for herself what is possible. As a result, I think the industrial strategy has taken such a prominent position in the post-Brexit plan'.[228]

WMG receives millions of pounds annually from the Higher Education Funding Council for England (HEFCE). Its research groups currently cover themes including advanced propulsion, cyber security, nanocomposites, and steels processing. Technological areas include steels; cyber-security; alloy manufacturing; metal joint strength; and lithium-ion batteries. Papers include: *The influence of fatigue on the stiffness and remaining static strength of self-piercing riveted aluminium joints;*[229] *Effect of governing metal thickness and stack orientation on weld quality and mechanical behaviour of resistance spot welding of AA5754 aluminium;*[230] and *Corrosion-erosion resistance of Zn-Al co-cementation coatings on carbon steels in aqueous media.*[231]

One WMG researcher is a former member of Central South University. He has researched with Zhenbo He, an employee of the Northeast Light Alloy Company of Harbin (NELA).[232] [233] [234] NELA was China's first aluminium-magnesium alloy producer and appears to be primarily a supplier to the Chinese military: China-based media reports that 60 per cent of its products are sold to China's armed forces.[235]

[226] https://www.chinadaily.com.cn/bizchina/2015-05/19/content_20760528.htm
[227] https://warwick.ac.uk/fac/sci/wmg/education/custom/china/p2477_wmg_in_china_8pp_final_web.pdf
[228] https://www.coventrytelegraph.net/news/coventry-news/government-wants-coventry-jaguar-land-12952360
[229] https://www.sciencedirect.com/science/article/abs/pii/S0261306913008169
[230] https://www.sciencedirect.com/science/article/abs/pii/S0261306910006734
[231] https://www.researchgate.net/publication/232068566_Corrosion-erosion_resistance_of_Zn-Al_co-cementation_coatings_on_carbon_steels_in_aqueous_media
[232] http://silkroadst.ikcest.org/eds-r?routing=eds&eid=e46b3496f2baacb9696b9b7824fdc4c4d91c1d251f8be356e3cdc5769ff6b987c54d7e5b441999a14d3646d37f66395c2ebdb12c3d3eda89d68ff25f0808e3bef27eca4c787beacec9f2cb2894e07f26
[233] https://www.bloomberg.com/profile/company/NELALZ:CH
[234] http://www.alu.com.cn/enNews/NewsInfo_520.html
[235] http://m.futuresmag.com/2007/07/24/chinalco-may-acquire-northeast-light-alloy

Their papers include research on a high-strength alloy (*Effects of Sc and Zr microalloying additions on the microstructure and mechanical properties of new Al–Zn–Mg alloys*[236] and *Effects of Sc and Zr microalloying additions and aging time at 120 °C on the corrosion behaviour of an Al–Zn–Mg alloy)*.[237] Papers on alloys with others include *Microstructure, strength and irradiation response of an ultra-fine grained FeNiCoCR multi-principal element alloy*,[238] and Fe/Ni composites studies.

Another WMG expert from the PRC is a specialist in nanocomposites who researches with staff at Central South University (CSU).[239] She has researched with the defence-funded laboratory the State Key Laboratory of Powder Metallurgy at CSU in high energy density polymer nanocomposites.[240] Her research with this laboratory states that 'functional polymer composites are attracting interest [in] polymer based dielectric capacitors which are [among other uses] employed [in] high power weapons.'[241] Another researcher at WMG, formerly a project engineer at Changchun University of Science and Technology (Changchun's specialisms include 'military industry manufacturing and its automation'),[242] is an automation systems and digital manufacturing project engineer, whose research includes autonomous guided vehicles (for shop floor logistics).

WMG also has a close relationship with the University of Science and Technology Beijing (USTB) and Shougang Group,[243] focused on developing steel manufacturing through exploiting waste.[244]

See technological themes:

1. Alloys of aluminium, titanium and other metals.
5. Composites, nanocomposites, polymers, laminates and related technologies.

Response from WMG

"All of the University's research is governed by research ethics governance and export control regulations. The research you refer to is in fact, at our university, to use polymer-based nanocomposites to develop sustainable and environmentally friendly fully biodegradable plastics. The content of the courses that we run for Chinese companies are all

236 https://www.researchgate.net/publication/271560177_Effects_of_Sc_and_Zr_microalloying_additions_on_the_microstructure_and_mechanical_properties_of_new_Al-Zn-Mg_alloys

237 https://www.researchgate.net/publication/256690519_Effects_of_Sc_and_Zr_microalloying_additions_and_aging_time_at_120_C_on_the_corrosion_behaviour_of_an_Al-Zn-Mg_alloy

238 https://www.sciencedirect.com/science/article/abs/pii/S0925838820331601

239 https://pubmed.ncbi.nlm.nih.gov/31270524/

240 https://pubmed.ncbi.nlm.nih.gov/31270524/

241 https://pubs.rsc.org/en/content/articlelanding/2019/cs/c9cs00043g#!divAbstract

242 https://unitracker.aspi.org.au/universities/changchun-university-of-science-and-technology/

243 https://www.tandfonline.com/doi/abs/10.1080/03719553.2016.1259871

244 https://warwick.ac.uk/fac/sci/wmg/education/custom/china/p2477_wmg_in_china_8pp_final_web.pdf p.7

three week long taught modules on a number of aspects of management and not any form of research."

University of Southampton and Wuhan University of Technology (WUT) and Harbin Engineering University (HEU)

- *High Performance Ship Technology Joint Center (Wuhan University of Technology and the University of Southampton)*
- *Southampton Ocean Engineering Joint Institute at Harbin (Southampton University with Harbin Engineering University)*

Southampton provides little information about its research laboratory the 'High Performance Ship Technology Joint Center' with Wuhan University of Technology, which according to Wuhan was established in 2012. Southampton says that 'researchers have set up… international joint laboratories [including] with Wuhan University of Technology on 'green ship technology''.[245]

One leading British professor is an instrumental figure at the Joint Center. According to Chinese media quoting Wuhan, in 2016 he was appointed 'a WUT Expert of [the] '1000 Foreign Talents Plan'' in a special ceremony in Wuhan. The 'CPC Central Committee' certified [he] had been recruited in the 'Recruitment Program of Global Experts' (also known as 'Thousand Talents Plan')'.[246] According to WUT, the professor "stated that WUT had reached domestic advanced level in laboratory construction and research of Naval Architecture'. In 2017, he attended 'a reception for foreign experts working in China in the Great Hall of the People in Beijing', hosted by Premier Li Keqiang.[247]

This professor is a leading figure in UK naval engineering, as a fellow of the Royal Academy of Engineering, Royal Society, and now a 'foreign academ[ician] of [the] Chinese Academy of Engineering and a strategic scientist of WUT' recruited under the 111 Programme. 'Under his support, WUT-UoS High Performance Ship Technology Joint Centre was established on September, 2012'.[248] He has carried out maritime engineering research with staff at PRC institutions, including Shanghai Jiaotong University's School of Naval Architecture[249] (which cooperates with military shipbuilders and the PLA Navy). His co-researchers at Southampton include an Emeritus Professor who is a graduate of NPU in Xian and a former researcher of the China Aeronautical Research Establishment in the same city, later a professor of Beihang.[250]

[245] https://www.southampton.ac.uk/engineering/research/centres/lrf-utc.page
[246] http://www.dongtinginn.com/t20170405_261372.shtml
[247] *Ibid*.
[248] *Ibid*.
[249] https://www.sciencedirect.com/science/article/abs/pii/S0889974616000037
[250] https://www.southampton.ac.uk/engineering/about/staff/jtxing.page#publications

One researcher at LRF UTC in Southampton[251] is a graduate of Dalian University of Technology, China, in Naval Architecture and Offshore Engineering, was awarded the WHC Nicholas Prize by the Royal Institution of Naval Architects. Her work includes analyses of as-welded S690 steels (including fracture toughness)[252]; she has also worked with WUT on ship propeller shaft vibrations,[253] and researched design improvement for very large floating structures (VLFS) (dealing with the hinge connectors called their 'weakest link').[254] Her associate research group is the national Centre for Advanced Tribology at Southampton (nCATS), a centre of expertise on corrosion whose projects include nanostructured coatings for aluminium alloys research. At Southampton, another scholar has researched triaxial weave fabrics including the wings of unmanned aerial vehicles (UAVs)[255] with a Beihang co-researcher.

The former scholar has researched with China-based researchers linked to organisations under sanction. One 2019 study, *Structural design of hinge connector for very large floating structures*,[256] included two authors from the China Ship Scientific Research Centre,[257] affiliated to China Shipbuilding Industry Corporation (CSIB),[258] one of China's leading military conglomerates.[259]

Southampton says even less about the Southampton Ocean Engineering Joint Institute at Harbin (JEI), a joint research laboratory of Southampton and Harbin Engineering University. JEI describes itself as the first China-UK maritime school, which has placed Harbin in a 'world class' position.

According to Harbin, JEI was launched in September 2020, and will develop the Chinese navy by offering 'undergraduate training in four undergraduate majors [including] Naval Architecture and Ocean Engineering'. However, Southampton states that the JEI came to an end in 2017.

See technological themes:

9. Shipbuilding.

[251] https://www.southampton.ac.uk/smmi/about/staff/yw4u14.page
[252] https://www.sciencedirect.com/science/article/abs/pii/S1350630719308799
[253] https://eprints.soton.ac.uk/411896/
[254] https://eprints.soton.ac.uk/434022/
[255] https://www.researchgate.net/publication/326011803_Optimal_design_of_triaxial_weave_fabric_composites_under_tension
[256] https://www.researchgate.net/publication/335789007_Structural_design_of_hinge_connector_for_very_large_floating_structures
[257] https://www.researchgate.net/publication/346078843_Structural_Design_of_Hinge_Connector_for_Very_Large_Floating_Structures
[258] https://www.marin.nl/jips/partners/china-ship-scientific-research-center
[259] https://unitracker.aspi.org.au/universities/china-shipbuilding-industry-corporation/

Response from the University of Southampton

"As an international university, Southampton has many active collaborations with research colleagues from China producing work which has the potential to create wide-ranging societal benefits. This research is publicly available having been peer-reviewed and published in reputable scientific journals.

For example, our collaboration with Wuhan University of Technology has mainly focused on efficient shipping and safety including reducing emissions and improving navigational safety. The 'High Performance Ship Technology Joint Centre' collaboration actually came to an end in September 2017.

Additionally the partnership with Harbin is an education programme with undergraduate modules offered there replicating the same offered in Southampton.

We proactively manage and regularly review our collaborative relationships with the wide range of domestic and international partners with whom we work to ensure they are appropriately aligned to our strategic objectives and governance policies. In managing our partnerships and collaborations, we also closely monitor and follow UK Government advice on both international matters and on University-business relationships."

Queen Mary University of London (QMUL) and Northwestern Polytechnic University (NPU)

- *NPU-QMUL Collaborative Partnership and Joint Research Centre*

Source: Prof Jihong Zhu, Northwestern Polytechnic University

Queen Mary University of London (QMUL) School of Engineering and Materials Science (SEMS) hosts the NPU-QMUL Collaborative Partnership. The universities signed an MoU for the plans during the September 2015 UK-China Education Summit, where Minister for

Universities and Science Jo Johnson and China's Minister of Education Yuan Guiren hailed the 'UK-China Strategic Framework in Education'.[260]

QMUL has praised NPU's 'particular strengths in aerospace and marine engineering',[261] and calls itself 'very honoured' to be working with NPU.[262] NPU describes itself as 'devoted to improving and serving the national defence science and technology industry.'[263] The Partnership includes the Queen Mary Engineering School (QMES) at NPU itself, which provides NPU students with Chinese-recognised degrees in materials science or polymers.

QMUL describes one of the leading figures in the Partnership, a senior QMES professor, as 'The Beloved Teacher' whose 'fundamental research has… led to new understanding of the strength of nano-structured materials.' He was invited to attend the first 'Belt and Road' Smart Education Summit Forum in Xi'an and, as QMUL puts it, he 'sows the seeds of friendship today [that] are bound to blossom all over the Eurasia[n] land in the future.'[264]

Probably no other British university seems so keen to be of use to Chinese geo-strategy. At the centre of the Partnership is the Joint Research Institute (JRI) of Advanced Materials and Structures (AMAS), launched in 2017 by both universities' presidents. According to QMUL, one of the purposes of the JRI 'is to serve the 'The Belt and Road' initiative of China'.[265] The JRI consists of five Research Centres,[266] each with two Chief Scientists, one at QMUL and one at NPU. All UK Chief Scientists have researched with NPU staff. The Centres are:

- Advanced Ceramic Materials. NPU Chief Scientist(s): Prof Feng Gao and Prof Kong Jie. Fields include advanced ceramic materials including piezoelectric materials.

Prof Kong Jie is a Dean of QMES; he is also its Party Branch Secretary and a guest professor of QMUL. He leads a province-level innovation team in polymers and is a national authority on space physics. His research, which includes major national projects for aero engines and gas turbines, has been funded by the National Defense Technology Foundation for Scientific Research of China.[267]

- Nano Energy Materials. NPU Chief Scientist: Prof Bingqing Wei. Fields include high-energy-density battery, supercapacitors, and other nano-energy materials.[268]

- Functional Polymers & Composites. NPU Chief Scientist: Prof Kong Jie (above). Fields include polymers and advanced polymer composites.

[260] https://www.gov.uk/government/news/uk-china-education-partnership-reaches-new-heights
[261] https://www.sems.qmul.ac.uk/china/
[262] https://www.sems.qmul.ac.uk/china/undergraduate/
[263] *Ibid*.
[264] https://www.sems.qmul.ac.uk/china/qmes/teaching/teacher/profandybushby/
[265] https://www.sems.qmul.ac.uk/china/research/
[266] https://www.sems.qmul.ac.uk/china/research/
[267] http://qm.nwpu.edu.cn/info/1131/1310.htm
[268] https://www.sems.qmul.ac.uk/china/research/

- Biomaterials and Engineering. NPU Chief Scientist: Prof Li Shang, an expert in the biological interactions of nanoparticles. Its areas are biomaterials, drug release and bioengineering.[269]

Material Structure Design and Optimization. NPU Chief Scientist: Prof Jihong Zhu. Its research fields include structure design and optimisation, and composites structure design.[270]

Before a recent edit, the website of NPU Chief Scientist Prof Jihong Zhu contained diagrams and pictures of modern strike fighters and hypersonic missiles (see pictures above).[271] Zhu supervises PhDs in structural optimisation (the subject of his Research Centre with QMUL), which according to his previous website could be applied to military aircraft, rockets, and hypersonic flying vehicles. His students include employees of the China North Industries Group and PLA Academy of Military Science, Beijing. QMUL staff at this Research Centre have been funded by the UK Technology Strategy Board (now Innovate UK).[272] [273]

See technological themes:

5. Composites, nanocomposites, polymers, laminates and related technologies.
6. Ceramics, piezoelectrics and rare earth coatings.

Other centres of concern

The following UK university research centres either lack direct Chinese sponsorship or have unclear connections to China, but the ways in which some of their defence-applicable research activities or other relationships could be exploited are a cause for concern.

Cranfield University at Shrivenham

Cranfield University at Shrivenham is home to Cranfield Defence and Security, a secure military site run in partnership with the UK Defence Academy, Ministry of Defence. Its strategic partners include BAE Systems, research councils, and the Atomic Weapons Establishment (AWE).

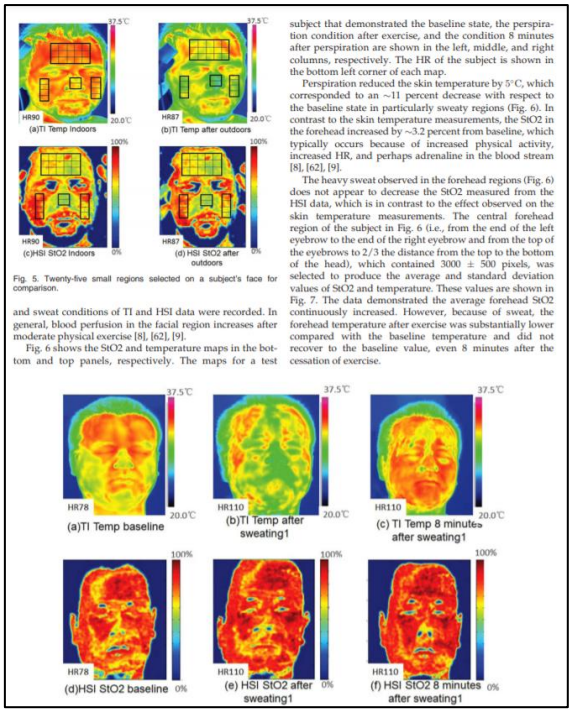
[269] *Ibid*.
[270] https://www.sems.qmul.ac.uk/china/research/
[271] http://teacher.nwpu.edu.cn/zhujihong.html
[272] https://www.sems.qmul.ac.uk/staff/v.v.toropov
[273] https://www.sems.qmul.ac.uk/staff/research/projects/v.v.toropov#previousfundedresearchprojects

One researcher based at Cranfield University at Shrivenham is an expert in defence sensors and nanotechnology and a member of the Centre for Electronic Warfare, Information and Cyber (CEWIC) at Cranfield. His research fields include topological and hyperspectral algorithm development for target detection in natural and urban environments; hyperspectral diffused optical tomography for target recognition in undersea environments; real time people tracking in multiple CCTV networks using colour constancy and tone compression; and automatic target recognitions using cortex-like machine vision.[274] His UK clients include the Home Office, the Centre for the Protection of National Infrastructure, EPSRC and Qinetiq. Yet he has also previously been Distinguished Professor in Remote Sensing, Nanchang HangKong University (which he also listed on his Cranfield webpage as a client). There is no suggestion that his research has any links with the Chinese military (see also our Nota Bene in the Introduction to this report). He is an expert in Electro-Optics, having joined Cranfield as a Senior Lecturer in the subject.[275] One of Nanchang HangKong University's designated 'national defence key disciplines' is optoelectrics (with laser technology).[276]

His papers in the last five years include:

- *Spatial spectral band selection for enhanced hyperspectral remote sensing classification applications* with a researcher at Dalian Maritime University, including analysis of satellite photo datasets;[277] and
- In 2014 *Detection of psychological stress using a hyperspectral imaging technique*[278] (image below). This paper appears intended to develop automated human camera surveillance techniques. Its authors included Tong Chen of Southwest University, Chongqing (but who the paper states 'was with' Cranfield), and another scholar, who the paper states was affiliated with Glyndwr University, Wrexham).

[274] https://www.cranfield.ac.uk/people/dr-peter-yuen-59015
[275] https://www.cranfield.ac.uk/people/dr-peter-yuen-59015
[276] https://www.cranfield.ac.uk/people/dr-peter-yuen-59015
[277] https://www.mdpi.com/2313-433X/6/9/87
[278] https://ieeexplore.ieee.org/document/6919328



This other scholar has researched fields including *Autofocus for ISAR imaging using higher order statistics,*[279] as well as other research on inverse synthetic aperture radar, including with staff of Nanjing University of Astronautics and Aeronautics, such as super-resolution imaging of (commercial) aircraft. His papers include *High-resolution 3-D imaging via multipass SAR* [280] ('a technique for combining multiple [synthetic aperture radar] images, acquired on flightpaths slightly separated in the elevation direction, to generate high-resolution three-dimensional imagery'). There is no suggestion that this work is connected with Cranfield.

At Cranfield, the defence sensors and nanotechnology expert's research also includes *Target recognitions in multiple-camera closed circuit television using colour constancy*[281] with researchers who were at the time Cranfield-affiliated but are now based in China.[282]

See technological themes:

10. Data science, AI, recognition and facial recognition.

[279] https://ieeexplore.ieee.org/document/4469250/
[280] https://www.researchgate.net/publication/3357683_High_resolution_3-D_imaging_via_multi-pass_SAR
[281] https://www.researchgate.net/publication/258808319_Target_recognitions_in_multiple-camera_closed-circuit_television_using_color_constancy
[282] https://www.sciencedirect.com/science/article/abs/pii/S0925231218311871#!

Response from Cranfield

"We operate at all times within the guidance and regulations issued by the UK Government on academic relations with international institutions.

"[The Cranfield researcher discussed] has had no funding from Chinese companies or organisations for his research.

"A number of [his] entries on his profile page are out of date. His relationship with Nanchang Hangkong University, for example, ended in 2015. His profile is currently being updated to amend these errors.

"Detection of psychological stress using a hyperspectral imaging technique was not funded by China… The lead Chinese academics did receive funding from the Chinese Ministry of Education for their project work. However, in academia, papers can be published independently from paid project work and can be part of an individual's academic scholarly output. [The Cranfield researcher] has received no funding from China for his research. As can be seen from the order of the authors, [he] was a minor contributor to the paper. His role was mainly focused on providing peer advice for the writing of good scientific papers.

"[He] was not paid to work for Nanchang Hangkong University during his time as an employee of Cranfield. The Visiting Professor title was an honorary title.

"The Visiting Professorships that [he] holds are for collaborative research in agricultural remote sensing.

"[He] rejects in the strongest terms any suggestion his research has links with the Chinese military.

"Nanchang Hangkong University is not a client of Cranfield University.

"[Regarding the researcher who has published on Autofocus for ISAR imaging using higher order statistics] There is no connection between [his] work and Cranfield or [its researchers] and this is rejected in the strongest terms. The papers referenced were published before [the Cranfield researcher] joined Cranfield University.

"Shrivenham is not owned or run by Cranfield. The University is an academic provider supplying postgraduate education."

University of Glasgow and the University of Electronic Science and Technology China (UESTC)

Glasgow College, UESTC

In 2016, the University of Glasgow and University of Electronic Science and Technology, China (UESTC) established a joint college in China called 'Glasgow College' of UESTC, offering joint Glasgow-UESTC graduate degrees in electronics, microelectronics and

communications. The relationship began in 2009 with a joint agreement to promote research.[283]

It is alleged UESTC is closely associated with China's nuclear weapons programme.[284] It has been added to the US Government's Entity List of organisations and institutions under sanctions, restricting the export of US technology.[285] It runs joint military laboratories with China's sole nuclear warhead manufacturer: the Chinese Academy of Engineering Physics.[286]

Heriot-Watt University and partners in Scotland and China

Heriot-Watt University is one of the institutions involved in research that includes Offshore Robotics for Certification of Assets (OrcaHub), launched in 2017 with UK government and UKRI R&D funding for Robotics and AI for Extreme Environments.[287] Among its co-investigators (outside Heriot-Watt) is an Assistant Professor who is a graduate of the Harbin Institute of Technology (HIT) and publishes widely with researchers at the Institute, including through major EPSRC funding for space robotics.[288] [289] [290] (HIT's military laboratories include the National Defence Key Laboratories of Micro and Small-Scale Spacecraft Technology,[291] and the university is sanctioned by Japan and the US). Another scholar, at Liverpool, has researched with the National University of Defense Technology, Changsha, on deep neural networks (DNNs).[292] [293]

At Heriot-Watt (although not necessarily within OrcaHub), the research of one Associate Professor in Robotics and Autonomous Systems 'focuses on robot perception, learning and long-term autonomy, and their applications in real-world, dynamic and complex environments.' [294] [295]

One of his recent papers, with the Harbin Engineering University, was entitled *Snoopy: Sniffing your smartwatch passwords via deep sequence learning*,[296] in which UK taxpayer-funded researchers demonstrated a password-breaking tool with a leading Chinese military-linked university which is on the US Entity List, whose designated research fields include

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[283] https://www.gla.ac.uk/schools/engineering/international%20partnerships/uestc/
[284] https://unitracker.aspi.org.au/universities/chinese-academy-of-engineering-physics/
[285] https://www.govinfo.gov/content/pkg/FR-2012-09-19/pdf/2012-22952.pdf in *Ibid*.
[286] *Ibid.*
[287] https://orcahub.org/
[288] https://www.research.ed.ac.uk/portal/zli33
[289] https://www.research.ed.ac.uk/portal/en/projects/future-ai-and-robotics-for-space-fairspace(c21ac17c-4c57-4c2c-ae88-65cce499a80f).html
[290] https://www.edinburgh-robotics.org/academics/zhibin-li
[291] https://unitracker.aspi.org.au/universities/harbin-institute-of-technology/
[292] https://www.groundai.com/project/analyzing-deep-neural-networks-with-symbolic-propagation-towards-higher-precision-and-faster-verification/1
[293] https://cgi.csc.liv.ac.uk/~xiaowei/
[294] https://orcahub.org/about-us/academic-partners/dr-sen-wang#:~:text=Heriot%2DWatt%20University-,Dr.,vision%20and%20machine%2Fdeep%20learning.
[295] https://orcahub.org/about-us/academic-partners/dr-sen-wang#:~:text=Heriot%2DWatt%20University-,Dr.,vision%20and%20machine%2Fdeep%20learning
[296] https://dl.acm.org/doi/10.1145/3161196

secrecy and information security engineering and whose employees have been charged with economic espionage (the paper speculates: 'in the wrong hands, Snoopy can potentially cause serious leaks of sensitive information'). For another piece of research, *UnDeep VO: Monocular Visual Odometry through Unsupervised Deep Learning*,[297] he joined two scholars from the PRC at the University of Essex and has worked with a researcher at the College of Mechatronics and Automation, NUDT.

Other researchers in Scotland have worked with PRC-based researchers on *Frustratingly easy person re-identification: generalising person re-ID in practice*.[298]

One researcher at Heriot-Watt's Institute of Sensors, Signals and Systems[299] has developed her own niche studying subjects around radar-jamming with researchers at the Chinese military-linked Key Laboratory of Radar Imaging and Microwave Photonics, Nanjing University of Aeronautics and Astronautics.[300] [301]

The abstract of one of her papers with the Key Laboratory, *Target Tracking While Jamming by Airborne Radar for Low Probability of Detection*,[302] reads:

> '[a]lthough radiation power minimization is the most important method for an advanced stealth aircraft to achieve the low probability of detection (LPD) performance against the opposite passive detection system (PDS), it is not always effective when the performance of PDS is advanced.'

She has received considerable UK taxpayer funding intended to improve the security of the United Kingdom and is affiliated with the University Defence Research Collaboration (UDRC) network ('the most prestigious signal processing activity in the UK')[303] [304] for work on 'Forward Looking RADAR', having been 'funded by DSTL through a National PhD studentship grant to work on Cognitive RADAR', receiving 'defence signal processing research grants from [QinetiQ] to work on MIMO RADAR and underwater communications.'[305] [306]

See technological themes:

8. Radars, antennae and related technologies.
10. Data science, AI, recognition and facial recognition.
11. Robotics (land, sea and space).

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[297] https://arxiv.org/abs/1709.06841
[298] https://arxiv.org/abs/1905.03422
[299] https://researchportal.hw.ac.uk/en/persons/mathini-sellathurai
[300] https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/iet-spr.2018.5212
[301] https://pureapps2.hw.ac.uk/ws/portalfiles/portal/23142810/sensors_18_02903.pdf
[302] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6165476/
[303] https://www.udrc.eng.ed.ac.uk/archive/phase-2/people/edinburgh-consortium/mathini-sellathurai
[304] https://www.ncl.ac.uk/engineering/research/eee/isc/udrc/
[305] https://www.udrc.eng.ed.ac.uk/archive/phase-2/people/edinburgh-consortium/mathini-sellathurai
[306] https://www.uscc.gov/sites/default/files/Research/DGI_China's%20Industrial%20and%20Military%20Robotics%20Development.pdf

Response from Heriot-Watt University

"Heriot-Watt University is a global university with an international academic community that takes part in world leading, multi-national research across many diverse areas. As with all universities, and as a charitable organisation, any research carried out, authored or co-authored by any member of Heriot-Watt University staff is publicly available and complies with all regulations and laws regarding national security and intellectual property. Having identified errors in the information given to us… we believe this report to be without merit."

University of Surrey and China Academy of Space Technology (CAST)

The University of Surrey has entered into an agreement with the China Academy of Space Technology (CAST), a subsidiary of CASC, to develop 5G technology.[307] In 2016, a delegation from Surrey's 5G Innovation Centre (5GIC) joined CAST at their Xi'an offices to discuss high-frequency transmission and satellite communication technology.[308] 5GIC's partners include Huawei. Surrey's Vice Chancellor is a graduate of Northeastern University in Shenyang who has defended Huawei's involvement in 5G in the UK. After joining Surrey, he was appointed to the Prime Minister's Council for Science and Technology and the Boards of UKRI and the National Physical Laboratory,[309] and has stated that he is making it a priority to increase links between Surrey and China.[310]

The China Academy of Space Technology (CAST, also known as the 5th Academy of CASC) appears on Japan's End User List,[311] and alleged proliferation activities include providing missile technology to Pakistan.[312] CAST's parent company, China Aerospace Science and Technology Corporation (CASC), is a major supplier of missiles, carrier rockets, military satellites and precision-guided weapons, and has been identified by the Nuclear Threat Initiative as a contributor to China's nuclear weapons programme.[313]

Response from the University of Surrey

"The University of Surrey's world-leading 5G Innovation Centre conducted this research into the role of satellites in maximising the potential of 5G service roll-out. The research was led by Professor Barry Evans, who is a leading authority on satellite-based technologies in telecommunications. We partner with many different companies, government agencies and

[307] https://web.archive.org/web/20190830051924/http:/www.cast.cn/Item/Show.asp?m=1&d=4278; https://unitracker.aspi.org.au/universities/china-aerospace-science-and-technology-corporation/
[308] *Ibid*.
[309] https://www.icheme.org/about-us/vision-and-strategy/icheme100/biographies/max-lu/
[310] https://www.timeshighereducation.com/news/new-university-of-surrey-vice-chancellor-g-q-max-lu-looks-to-china-for-industry-links
[311] https://unitracker.aspi.org.au/universities/china-aerospace-science-and-technology-corporation/
[312] https://www.nti.org/learn/facilities/56/
[313] https://www.uscc.gov/sites/default/files/Research/USCC_China-Space-Program-Report_April-2012.pdf ; https://www.nti.org/learn/facilities/64/ in https://unitracker.aspi.org.au/universities/china-aerospace-science-and-technology-corporation/

other bodies to drive this work to ensure the full potential of 5G technologies are realised. Telecommunications technologies are global in nature and scope, and our work contributes to defining and developing 5G standards and protocols internationally – and forms part of a large body of research on this topic publicly available worldwide.

The University of Surrey is dedicated to world-class research and innovation. By advancing our work in multiple fields through collaboration and international partnership with universities, businesses, governments and communities, and in compliance with all relevant British Government guidance and legislation, we are playing our part in both advancing the sum of human knowledge and delivering a global Britain."

University of Swansea, College of Engineering

One Professor of Aerospace Structures at Swansea became an Honorary Professor of Nanjing University of Aeronautics and Astronautics in 2010 and has researched with staff at Chinese military-linked universities for 15 years. He began working with researchers at the National University of Defence Technology while previously at Bristol (as well as staff at Beihang and NPU) on vibration analysis.[314] At Bristol, he has researched with staff at NUDT and NUAA especially,[315] and Harbin Institute of Technology (as well as Shiraz University, Iran).[316] Projects include wing technologies, flutter control, Control Momentum Gyroscopes (CGMs)[317] and trajectory optimisation (for advanced space stations), spacecraft tracking,[318] and control of rigid[319] and flexible spacecraft.[320] [321]

Response from the University of Swansea

The professor "will collaborate with partners if the research is open and published in the open literature. This is the approach he has adopted in all his collaborations with Chinese academics. All his research is concerned with very low technology readiness level that is not explicitly military."

[314] http://michael.friswell.com/PDF_Files/J135.html
[315] https://www.sciencedirect.com/science/article/abs/pii/S1270963820309615?via%3Dihub
[316] https://www.researchgate.net/publication/329441960_Flutter_Characteristics_of_Typical_Wing_Sections_of_a_Box_Wing_Aircraft_Configuration
[317] https://www.researchgate.net/publication/267340212_Multi-objective_Optimization_of_Zero_Propellant_Spacecraft_Attitude_Maneuvers
[318] http://michael.friswell.com/PDF_Files/J322.html
[319] http://michael.friswell.com/PDF_Files/J307.html
[320] http://michael.friswell.com/PDF_Files/J236.html
[321] http://michael.friswell.com/home_noframe.html

Chapter 3: Technological themes and discussion of potential risks

We find the following technological fields, which may include projects of potential dual use, being investigated at PRC-sponsored and linked centres in UK universities. Most fields cover a wide range of specific technologies.

NB: In the following, when we discuss some of the possible dual uses of technology types, we do not imply that any UK-based researcher working in a technological field is knowingly contributing to the potential military uses we outline here. We believe that all research carried out in the UK and/or by UK-based researchers is intended by parties within the UK for civil use only. The purpose is simply to discuss the potential risks that their research may be exploited for these types of ends. The aim is also not to show that any piece of research by a UK-based researcher is being put towards China's military development, but that some research may exist in a general area of potential dual use, and the way that universities are asked to assess the related risks may therefore need to change. None of the fields or projects discussed in this paper need directly contribute to a military programme, but they may improve the state of knowledge in general in a particular field in the PRC that may later help generate dual use outputs, or the business position of military-linked companies, or the capacities of military-linked universities.

1. Alloys of aluminium, titanium and other metals

Progress in aluminium has long been tied to aviation and defence. In 1903, the Wright brothers made an aluminium engine crankcase for the first wood-frame biplane. Today, aluminium alloys are 'the overwhelming choice for the fuselage, wing, and supporting structures of commercial airliners and military cargo/transport aircraft.'[322]

A number of aluminium alloys are commonly used in military aircraft. Aluminium-yttrium-nickel alloys have been developed to enable F-35 Joint Strike Fighters to fly 'farther and faster.'[323] Aluminium alloy 7050 has high corrosion resistance, strength in wide sections, and is resistant to fractures, often used for wing skins and fuselages in military aircraft. 7068 is especially commonly used in military planes, as is Al-Zn-Mg alloy 7075 for fatigue resistance:[324] 'AA7050 is one of the few alloys of aluminium which is used in almost all alloy related products in defense and aviation sector.'[325]

Research is also focusing on aluminium-lithium alloys, including for weight reduction;[326] recent studies have also highlighted the need for research into aluminium-titanium alloys,

[322] https://aluminum.org/product-markets/aircraft-aerospace
[323] https://www.airforcemag.com/1100jsf/
[324] https://www.aerospacemanufacturinganddesign.com/article/aluminum-alloys-for-aerospace/
[325] https://www.sciencedirect.com/science/article/pii/S2214785320351920
[326] https://www.aerospacemanufacturinganddesign.com/article/aluminum-alloys-for-aerospace/

as used in the F/A-18 (structural aluminium alloy AA7050-T7451).[327] India's Defence Metallurgical Research Laboratory lists, in particular, 'AA2219, AA6082, AA6061 and AA5086' for 'sheets, plates and rods as required for Army, Navy, Air Force and DRDO's missile programmes.'[328] In manufacturing research, hot stamping is a high priority due to the small formability and large springback of cold stamped high-strength aluminium alloys, like A6061.[329]

Analysing the work of the sponsored scholars we discuss in this report demonstrates that among the most common areas of research are:

- AA7000 series, a preferred material group in the military sector due to their high strength.[330][331]Aluminium-Copper alloys (of particular interest for military uses[332]), including AA2050, an Al-Cu-Li alloy which is one of most attractive for military applications;[333]
- Researchers at one of the Imperial centres have researched AA7B04 for aeronautics use.[334] Researchers at NPU and the Airforce Engineering University, Xian, have also researched this alloy.[335]

One of the Imperial centres also publishes on Aluminium-Zinc-Magnesium alloys with researchers from the (AVIC) Aeronautical Key Lab for Plastic Forming Techs, who in turn publish regularly with researchers at NPU.[336]

Other priority fields are titanium alloys and nickel-based superalloys. Titanium alloys are crucial for military research: '[t]he military has, for decades, been the real push behind the developing titanium industry', the metal being vital for 'aircraft, spacecrafts, missiles, and other military purposes'.[337] Its saltwater resistance makes it ideal for submarines, and given its resistance to extreme temperatures, '[m]ilitary aircrafts tend to use even more titanium alloy in their components than are found in commercial aircraft. In some models, up to 25% of the jet may be comprised of titanium', while it is also being tested for use in armour and

[327] https://www.dst.defence.gov.au/publication/equivalent-crack-size-modelling-corrosion-pitting-aa7050-t7451-aluminium-alloy-and-its
[328] https://www.drdo.gov.in/development-wrought-al-alloys-defence-applications
[329] https://coek.info/pdf-hot-stamping-of-high-strength-aluminium-alloy-aircraft-parts-using-quick-heating.html
[330] https://www.sciencedirect.com/topics/engineering/7000-series-alloy
[331] https://www.researchgate.net/publication/321583778_Properties_of_AA7075_aluminum_alloy_in_aging_and_retrogression_and_reaging_process
[332] https://link.springer.com/article/10.1007/s11665-009-9554-z
[333] https://iopscience.iop.org/article/10.1088/1742-6596/382/1/012034/pdf
[334] https://spiral.imperial.ac.uk/bitstream/10044/1/65123/2/Manuscript-accepted%20version.pdf
[335] https://www.researchgate.net/publication/301706779_Effect_of_pre-corrosion_on_the_fatigue_behavior_of_AA7B04_and_life_forecast_Fatigue_behavior_of_AA7B04
[336] https://www.sciencedirect.com/science/article/abs/pii/S0921509319316405?via%3Dihub
[337] https://titaniumprocessingcenter.com/supplying-titanium-for-military-and-aerospace-industries/

ordnance. Military grades include, but are not limited to, Titanium 6-4 ELI, 6Al-6V-2Sn Ti, and Grade 5.[338] [339]

We have discussed Ti-6Al-4V research at UK-China Advanced Structure Manufacturing Technology Laboratory, for example (this has excellent ballistic penetration potential).[340] Nickel-based superalloys, as discussed in breakthroughs at Imperial, are also used in both civil and military aircraft engines and rotors (including but not limited to 708 and 716).[341]

2. Steels

Stainless steel was invented in Sheffield to address the problem of erosion in gun barrels, but now has thousands of civil uses.[342] Military-grade steels remain probably the most important metal for military equipment, including tanks, ships and aeroplanes, and tend to be higher-strength, generally being tested for hardness and ballistic properties.[343]

Areas of interest include martensitic steels, ultra-high strength steels (UHSS), and coatings to allow steels to be used in extreme environments. Martensitic steels tend to be extremely strong and are especially useful for firearms and gun barrel manufacture,[344] however their main drawback for aerospace applications is difficulty in sculpting complex components. Fast light Alloy Stamping Technology (FAST) is a process that enables such components to be formed.[345]

In the UK, the UK-China Advanced Structure Manufacturing Technology Laboratory (a partnership of Imperial and China's main ICBM manufacturer the China Academy of Launch Vehicle Technology (CALT)) has published on the fast light alloys stamping technology (FAST) process for martensitic steel and ultra-high strength steels (as well as aluminium alloys) (above), including with Imperial's AVIC Centre for Structural Design and Manufacturing.

Researchers in China have analysed the potential of UHSS for rocket shells and other military applications.[346] A Chinese national is alleged to have supplied Iran's ballistic missile

[338] https://titaniumprocessingcenter.com/supplying-titanium-for-military-and-aerospace-industries/
[339] https://www.researchgate.net/figure/Military-applications-of-titanium-alloy-42_fig3_271764073

[340] https://www.researchgate.net/publication/292311265_Ballistic_Penetration_of_Titanium_Alloy_Ti-6Al-4V

[341] https://niobium.tech/-/media/niobiumtech/attachments-biblioteca-tecnica/nt_nickel-base-superalloy-materials-technology-for-advanced-igt-applications.pdf

[342] https://www.azom.com/article.aspx?ArticleID=17076
[343] https://www.azom.com/article.aspx?ArticleID=17291
[344] https://www.azom.com/article.aspx?ArticleID=17076
[345] https://www.mdpi.com/2504-4494/4/2/57/htm
[346] https://www.sciencedirect.com/science/article/pii/S1000936114000570

programme with maraging steel (an age-treated high-strength martensitic steel) and aluminium alloy.[347] The field of Shipbuilding (below) also includes steels research.

3. Aerospace physics

While transonic flutter, 3D printing and gust alleviation (at Imperial's COMAC Centre) can all be used in civil aviation, all appear to have possible dual use aircraft applications;[348] [349] [350] so do adaptive control systems and cooperative and consensus control, researched at Manchester's Sino-British Joint Advanced Laboratory on Control System Technology, backed by the China Aerospace Science and Technology Corporation (CASC), for UAV formation flying. Staff at one of the Manchester centres (below) have researched in this field with the Beijing Institute of Technology, listed by ASPI as a very high-risk institution and a centre of military aircraft and missile research with a formal partnership with Norinco.[351] [352]

Vibration control and disturbance rejection, studied at Imperial, are also a focus for NUDT staff, in papers such as *Real time visual tracking of moving targets using a low-cost unmanned aerial vehicle with a three axis stablised gymbal system* (an 'extension' of 'disturbance rejection-based control methodologies').[353]

4. Hypersonic technology

Hypersonic technology is a dominant area of research in the UK centres. Some hypersonic missiles under development will travel at up to 15 times the speed of sound. A new arms race appears to be underway between the US and other western countries, and China: winning this hypersonic race has been called 'the first priority' in western defence security.

While ICBMs may already travel at hypersonic speeds (over Mach 5) on descent, hypersonic missiles broadly refer to those which can manoeuvre at these speeds. These missiles are potentially massively destabilising, constituting not simply an evolutionary development but a 'revolutionary new type of weapon [that would] strike almost any target in the world within a matter of minutes.'[354] In theory, able to carry nuclear warheads, they can be manoeuvred to arrive potentially without warning, allowing first strike capacity. According to a recent study by *The New York Times* and the Center for Public Integrity, '[during] flight,

[347] https://www.kcl.ac.uk/news/case-study-li-fang-wei-limmt. There is no suggestion that anyone mentioned in this paper is connected to these activities.
[348] http://www.diva-portal.se/smash/get/diva2:1244326/FULLTEXT01.pdf
[349] https://www.wired.com/story/air-force-3d-printing-parts-manufacturing-olympics/
[350] https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1172&context=mae_etds

[351] https://www.researchgate.net/publication/343724317_Cascade_structure_predictive_observer_design_for_consensus_control_with_applications_to_UAVs_formation_flying
[352] https://unitracker.aspi.org.au/universities/beijing-institute-of-technology/
[353] https://www.mdpi.com/2076-3417/10/15/5064
[354] https://www.nytimes.com/2019/06/19/magazine/hypersonic-missiles.html

the perimeter of their potential landing zone could be about as big as Rhode Island.'[355] That they are only 5-10 feet long will also allow 'instant leader-killer' capacity, according to a former Obama administration White House official.

China 'has flight-tested its own hypersonic missiles at speeds fast enough to reach Guam from the Chinese coastline within minutes', and a Chinese space programme contractor has claimed to have successfully flight-tested a hypersonic missile for over six minutes.[356] Current research includes 'waverider' missiles, hypersonic missiles of such power that they 'ride' on their own shock waves.[357] Gen. John E. Hyten, commander of United States Strategic Command, told the Senate Armed Services Committee in March 2018: 'We don't have any defense that could deny the employment of such a weapon against us.'[358]

One of the major challenges in hypersonic development is creating coatings to protect missile bodies from the extreme heat created by flying at such speeds. Research has included ceramics, carbon-fibre composites and superalloys like nickel-chromium. Others include manoeuvring and tracking control.[359]

One Laboratory's publications include air-breathing hypersonic vehicles. These are hypersonic missiles that breathe air to feed their engines, and an area of urgent military competition between China and the United States especially, with DARPA due to carry out flight tests of such missiles in 2021.[360] In November 2020, images emerged of what appeared to be a Chinese H-6N missile carrier aircraft carrying a missile whose 'features… point to a hypersonic design, which could potentially be air-breathing and nuclear-capable.'[361] Its shape was similar to a DF-17, known to be a developmental Chinese hypersonic missile.[362]

An example of Manchester hypersonic research, *Modeling and nonlinear control for air-breathing hypersonic vehicle with variable geometry inlet*, was aimed at generating more powerful thrust. Carried out with defence-funded Tianjin University, it reads: 'this extends the velocity range, which is favourable to the acceleration and manoeuvring flight.'[363] Elsewhere, variable geometry inlets are the subject of US missile jet engine patents that have been cited by arms firms for the manufacture of hypersonic missiles.[364]

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[355] https://www.nytimes.com/2019/06/19/magazine/hypersonic-missiles.html
[356] https://www.nytimes.com/2019/06/19/magazine/hypersonic-missiles.html
[357] *Ibid*.
[358] *Ibid*.
[359] *Ibid*.
[360] https://newatlas.com/military/darpa-us-air-force-hypersonic-weapon-captive-carry-flight-test/
[361] https://www.thedrive.com/the-war-zone/37465/new-images-of-chinese-bomber-carrying-huge-mystery-missile-point-to-hypersonic-capability
[362] https://www.thedrive.com/the-war-zone/30119/four-of-the-biggest-revelations-from-chinas-massive-70th-anniversary-military-parade
[363] https://www.research.manchester.ac.uk/portal/files/57550117/2017AESCTE_Preprint.pdf
[364] https://patents.google.com/patent/US4620679A/en

Graphene is a potentially revolutionary nanomaterial, a single layer of atoms in an effectively two-dimensional lattice, with potential in hypersonics and many other areas. On his visit to Manchester in 2015, Xi Jinping was given a tour of Manchester's graphene laboratories by Chancellor George Osborne to welcome the new 'Golden Era' in UK-China relations.

Graphene's many potential military uses include in semiconductors, batteries and composite materials for improved aerodynamics and reduced drag and weight. China's military is interested in graphene coatings for uses from artillery and installations on artificial islands in the South China Sea, potentially to clothing for soldiers along the disputed border with India.[365] [366] Recent Chinese reports suggest China's Z-10 attack helicopter has been equipped with graphene armour that may have been developed at the Beijing Institute of Aeronautical Materials (BIAM).[367]

The Manchester Graphene Aerospace Materials Centre (with BIAM) researches graphene in aerospace materials, including composites and ceramics.

Meanwhile in 2017, *The Economist* covered work by a researcher at the Graphene Aerospace Materials Centre from China with Xiang Xiong of Central South University in an article entitled 'Hot stuff: A new ceramic could help hypersonic planes take off – Surviving the searing heat of Mach 5 and above'.[368]. It notes: 'The lure of hypersonic flight is such, though, [that] the world's air forces would love such planes.' It describes how 'Among those lured' are the researcher at Manchester and 'Xiang Xiong at South Central University in Changsha, China, and their colleagues. And they have come up with a new material that might provide the answer.' Manchester has also reported on the development: 'Researchers from the University of Manchester have created a new kind of ceramic coating that… could be the future for hypersonic aerospace vehicles.'[369] Central South University is a major military aviation research base (see Chapter 1).

In fact, Manchester seems to suggest a possible military or dual-use result of the cooperation with CSU:

> 'Researchers at The University of Manchester in collaboration with Central South University (CSU), China, have created a new kind of ceramic coating that could revolutionise hypersonic travel for air, space and defence purposes… [with] temperatures [of] 2,000 to 3,000 °C [the] structural problems are primarily caused by processes called oxidation and ablation… when extremely hot air and gas remove surface layers from the metallic materials of the aircraft or object travelling at such

[365] https://www.scmp.com/news/china/science/article/3016480/can-new-graphene-coating-save-chinese-military-rusting-away
[366] https://www.hindustantimes.com/world-news/chinese-military-to-buy-graphene-clothing-chopper-drones-from-pvt-cos-for-india-border/story-Ddrzp2oFawwBxIwrMsFjoJ.html
[367] https://www.defenseworld.net/news/23505/China_Flies_Graphene_armored_Z_10_Attack_Helicopter
[368] https://www.economist.com/science-and-technology/2017/08/12/a-new-ceramic-could-help-hypersonic-planes-take-off
[369] https://www.research.manchester.ac.uk/portal/en/media/business-news-network-researchers-create-new-ceramic-coating-to-help-with-hypersonic-travel(1d816953-24de-4cb5-a4f1-2e8ee835e520).html

> high speeds. To combat the problem materials called ultra-high temperature ceramics (UHTCs) are needed in aero-engines and hypersonic vehicles such as rockets, re-entry spacecraft and defence projectiles.'

It adds:

> 'researchers at The University of Manchester… in collaboration with the Central South University of China, have designed and fabricated a new carbide coating that is vastly superior in resisting temperatures up to 3,000°C, when compared to existing UHTCs… [The professor] who led the study in University of Manchester explains: 'Current candidate UHTCs for use in extreme environments are limited and it is worthwhile exploring the potential of new single-phase ceramics.''[370]

According to Manchester, its new material was partially manufactured as CSU's 'Powder Metallurgy Institute'. CSU's 'State Key Laboratory for Powder Metallurgy' is a designated major defence laboratory.[371]

The research appears to be that presented in the paper *Ablation-resistant carbide Zr0.8Ti0.2C0.74B0.26 for oxidizing environments up to 3,000°C*, which states: 'Ultra-high temperature ceramics are desirable for applications in the hypersonic vehicle, rockets, re-entry spacecraft and defence sectors… potential uses may include the hot section components in re-entry spacecraft, defence army, gas turbines and nuclear areas and so on.' One of its authors has listed his affiliations as both the State Key Lab and the School of Materials at Manchester.[372]

5. Composites, nanocomposites, polymers, laminates and related technologies

The main UK centres for this broad area are the AVIC Centre for Structural Design and Manufacturing, the COMAC-Imperial Research Centre for Wing Technology of Commercial Aircraft (both at Imperial), the University Innovation Centre at Nottingham, WMG, and the Queen Mary University of London-NPU partnership.

Composites are an area of cutting-edge dual use research. Composites like carbon fibre reinforced plastic (CFRP) are being developed as radar-absorbing materials (RAMs) for stealth, and its light weight is leading to 'ever more attention from the arms industry', while

[370] https://www.manchester.ac.uk/discover/news/chances-of-hypersonic-travel-heat-up-with-new-materials-discovery/
[371] https://unitracker.aspi.org.au/universities/central-south-university/
[372] https://www.nature.com/articles/ncomms15836

it is emerging as an alternative to aluminium alloys in a number of military applications.[373] [374] [375]

In composite laminates, joint research at Imperial's AVIC Centre for Structural Design, the AVIC First Aircraft Institute and the Department of Naval Architecture of Wuhan University of Technology (supported MTI and ASRI) has investigated 'the effects of projectile hardness on the impact response of fibre-reinforced composite laminates', in which 'high-density polyethylene (HDPE) projectiles… impact against woven carbon-fibre reinforced poly (ether-ether ketone) (CF/PEEK) composite specimens'.[376] PEEK is a promising dual-use material, including for stealth, and researchers in the PRC are investigating its applications in 'aerospace and weapons'.[377] Separately, it is reported that in 2018, Imperial's sponsor AVIC-MTI founded a group codenamed 'J.J.' to develop China's next stealth fighter.[378]

Joint research on fibre-metal laminates (FMLs) between Imperial and Shougang Research Institute of Technology has focused on forming technologies for FMLs, which are lightweight structural materials. FMLs have also been used for military transport aircraft since the early 1990s[379] and remain a subject of military research, including to improve the adhesive strength of CFRPs.[380]

3D composites and carbon composites have been used for space technology as well as in missile systems.[381] A project involving BAE Systems that includes Manchester, Bristol and Nottingham universities is researching 3D woven textile composites for structural light-weighting in aerospace.[382]

According to a 2019 report for the US-China Economic and Security Review Commission,[383] China '[could] gain the upper hand in the composites marketplace, and by extension… key… defense technologies.'

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[373] https://www.army-technology.com/downloads/whitepapers/manufacture/the-major-reasons-why-cfrp-is-proving-victorious-in-defence-technology/

[374] https://www.infona.pl/resource/bwmeta1.element.ieee-art-000004720745

[375] https://www.researchgate.net/publication/278329718_COMPARATIVE_STUDY_ON_ALUMINIUM_ALLOY_AND_CARBON_FIBER_REINFORCED_POLYMER_CFRP_FOR_MILITARY_BRIDGES

[376] https://www.sciencedirect.com/science/article/pii/S258884041930112X

[377] https://pubs.rsc.org/en/content/articlelanding/2018/ra/c7ra11675f#!divAbstract

[378] https://news.yahoo.com/not-again-china-building-another-182500796.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAABDsMGb8uWFtqkJzijYUCDtqiW3wYhiMiONE7CQknsUuHKBjTw1ON-nD5QtFpzZBYVNplHw7y8672tD-TOYbcQoXibKK9Vd4WR9uQPvJz28aZh5Pf6jTqKRwz4qpDaKQJ2T6Chry0ZmqIIHMlfghB3qtNr0C7VvT_kJzYEv0X7wf

[379] https://link.springer.com/book/10.1007/978-94-010-0995-9#about

[380] https://www.sciencedirect.com/science/article/abs/pii/S1359836818331937

[381] https://gameon.nasa.gov/2016/03/30/first-3d-woven-composite-for-nasa-thermal-protection-systems/

[382] https://www.insidecomposites.com/new-project-to-drive-development-of-3d-woven-textile-composites-in-uk-aerospace-industry/

[383] https://www.uscc.gov/sites/default/files/June%207%20Hearing_Panel%202_Dan%20Coughlin_New%20Materials.pdf

A WMG researcher has researched with military-linked CSU in high energy density polymer nanocomposites,[384] her research stating that 'functional polymer composites are attracting interest [in] polymer based dielectric capacitors which are [among other uses] employed [in] high power weapons.'[385]

Polymer nanocomposites have been described as showing 'staggering potential' for military applications – including UAVs, aircraft and ships.[386] [387] One of the most promising applications of high energy density polymer nanocomposites is in high energy density capacitors. One PRC paper says: 'Polymer nanocomposites incorporated with high-dielectric-constant nanoparticles are widely studied as… materials for high-energy-density electrostatic capacitors.'[388] The highest energy density, high voltage capacitors 'typically have short lifetimes [and] are designed for military applications.'[389]

Thermoplastic elastomer composites and nanocomposites are studied in ballistic missile material research, including to protect the components of missile launching systems and solid rocket motors, with thermoplastic polyurethane elastomer nanocomposites (TPUNs) 'developed mainly for military application'.[390] [391] Separately, energetic thermoplastic elastomers (ETPEs) are being researched for propellants and explosives.[392]

6. Ceramics, piezoelectrics and rare earth coatings

The QMUL-NPU partnership is a major centre of research into ceramics, piezoelectrics and rare earth coatings, especially under the Research Centre in which NPU's Chief Scientists are Prof Feng Gao and Prof Kong Jie (guest professor of QMUL, Dean of QMES and Party Branch Secretary, whose research includes aero engines and gas turbines and has been funded by the National Defense Technology Foundation for Scientific Research of China).

Piezoelectricity is the electric charge that accumulates in some solids, including some crystals and ceramics, in response to applied mechanical pressure, or refers to the ability of materials to change shape when an electric charge is applied. Some reports state that China's military is interested in piezoelectric ceramics for uses including ignition detonation and gyroscopes.[393]

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[384] https://pubmed.ncbi.nlm.nih.gov/31270524/
[385] https://pubs.rsc.org/en/content/articlelanding/2019/cs/c9cs00043g#!divAbstract
[386] https://www.academia.edu/35443282/Defence_Applications_of_Polymer_Nanocomposites
[387] https://www.igi-global.com/chapter/the-use-of-polymer-nanocomposites-in-the-aerospace-and-the-militarydefence-industries/224401
[388] https://pubs.rsc.org/en/content/articlelanding/2020/ta/d0ta01380c#!divAbstract
[389] https://www.ga.com/capacitors/high-energy-density-capacitors
[390] https://www.hindawi.com/journals/jnm/2010/583234/
[391] https://www.researchgate.net/publication/43808064_Thermoplastic_Polyurethane_Elastomer_Nanocomposites_Morphology_Thermophysical_and_Flammability_Properties
[392] https://www.onlinelibrary.wiley.com/doi/10.1002/prep.201200002
[393] https://www.piezohannas.com/Piezoelectric-ceramics-used-for-military-id537031.html

In piezoelectric ceramics, QMUL-NPU research includes the effect of MnO2 on the microstructure and electrical properties of piezoelectric ceramics (specifically PZNNT, a form of lead zirconate titanate (PZT) containing niobium and nickel). China-based researchers within the QMUL-NPU partnership have researched the same PZNNT material.[394] Like all other universities we discuss, QMUL's research into these materials is intended for civil use only, in this case to make piezoelectric ceramics more environmentally friendly.

Elsewhere, a study by the US Army Research Laboratory described PZT generally as 'a smart material… for both sensors and actuators… In missile applications that require the use of a guidance and control systems, it can act as a backup inertial measurement unit (IMU). PZT is also gaining attention in the field of power MEMS for applications in energy storage and power reclamation. Insertion of smart material MEMS sensors into projectiles will [help] develop more precise and lethal projectiles'.[395]

Separately, some forms of lead zirconate titanate are suitable for other high-sensitivity uses, such as hydrophones[396] (underwater listening devices) that in some contexts are used to track adversaries' submarines.

High entropy and ultra-high temperature ceramics are another focus for QMUL researchers within the partnership, including "(Hf-Ta-Zr-Nb)C" (hafnium tantalum zirconium niobium carbide).[397] Hafnium carbide (HfC) has the highest melting point of any known two-element compound (almost 3,890 degrees Celsius) (hafnium is so similar to zirconium that separating the two elements is difficult); zirconium carbide is an extremely hard ultra-high temperature ceramic (UHTC).[398] Elsewhere, some Hafnium-based UHTCs have also been reported as having potential for ICBM re-entry heat shields.[399]

Rare earths are another focus for QMUL and NPU researchers. This is an area of intensifying strategic competition. China is the leading producer of all of the rare earths that we find being researched by QMUL-NPU.[400] [401] [402] [403]

[394] https://www.researchgate.net/publication/337204508_Effect_of_different_MnO2_phases_b-_g-_and_e-_on_the_microstructure_and_piezoelectric_properties_of_PbZr12Ti12O3-PbZn13Nb23O3-PbNi13Nb23O3_ceramics_for_energy_harvesting

[395] https://apps.dtic.mil/dtic/tr/fulltext/u2/a433154.pdf

[396] https://www.globalspec.com/learnmore/materials_chemicals_adhesives/ceramics_glass_materials/electroceramics/piezoelectric_ceramics

[397] https://www.sems.qmul.ac.uk/staff/publications/m.j.reece

[398] https://www.livescience.com/38591-hafnium.html

[399] https://www.researchgate.net/publication/330530302_Hafnium_Diboride_as_a_saturable_absorber_for_Q-switched_lasers

[400] https://duckduckgo.com/?q=dysprosium+producers&ia=web

[401] https://www.newtondesk.com/holmium-element/

[402] https://www.rsc.org/periodic-table/element/68/erbium

[403] https://www.statista.com/statistics/277643/yttrium-production-worldwide-by-country/

Many of these rare earths have become strategic concerns for the UK and US on various levels (which have little or no production of Lanthanum or Yttrium, for example).[404] [405] [406] This research may also more generally help grant China strategic advantages.

7. Drones and lithium-ion batteries

Drones are the subject of major R&D investments by the Chinese and western militaries, expected to 'fundamentally change' the nature of warfare.

China's 'military UAV industry is robust and growing rapidly.' Many of the advantages a lead in drone technology will provide are non-obvious: '[Chinese] unmanned systems will likely [provide] intelligence, surveillance, and reconnaissance support to long-range precision strikes and anti-submarine warfare capabilities.' For example, its Soar Dragon UAV could provide guidance for the DF-21D anti-ship ballistic missile.[407]

Drones are also a repeated focus for research in the centres studied, where, as in the other technological fields, dual use appears to be a risk. One researcher at the SMeSTech Laboratory at Strathclyde researched 'UAV swarming technology' (for oil and gas facility inspection). While at Imperial's Department of Aeronautics (now at the QMUL School of Engineering and Materials Science (SMES)), one researcher published *Fully autonomous micro air vehicle flight and landing on a moving target using visual–inertial estimation and model-predictive control*.[408]

Related to drones, lithium-ion batteries are a focus of the Imperial Centre for Materials Characterisation, Processing and Modelling. Core projects include lithium-ion battery thermal runaway modelling, modelling of solid-state lithium batteries, and 'characterisation and degradation of all solid-state thin film lithium battery' [sic]. At WMG, technological areas include lithium-ion batteries.

Lithium-ion batteries are seen as central to the development of drones,[409] giving long life cycles and potentially allowing hundreds of missions on a single battery, while tolerating extreme conditions.[410] Research into different types of lithium batteries is also fundamental to drone development. Solid-state batteries are more compact than li-ion cells but remain

[404] https://www.livescience.com/34564-yttrium.html#:~:text=China%2C%20Russia%2C%20India%2C%20Malaysia,the%20leading%20producers%20of%20yttrium

[405] http://avalonadvancedmaterials.com/rare_metals/lanthanum/#:~:text=Most%20lanthanum%20is%20mostly%20sourced,some%20is%20produced%20in%20India.

[406] https://fas.org/sgp/crs/natsec/R41744.pdf

[407] https://www.uscc.gov/sites/default/files/Research/DGI_China's%20Industrial%20and%20Military%20Robotics%20Development.pdf

[408] https://www.onlinelibrary.wiley.com/doi/10.1002/rob.21821

[409] https://www.dataweek.co.za/11731r

[410] https://www.epsilor.com/sections/blog/Blog20122017/

expensive. However, they have promise for drones, for which they have entered trials.[411][412] Meanwhile, thin-film li-ion batteries are seen as candidates for use in radio frequency identification (RFID) tracking devices.[413] Some of the UK's allies and partners are changing their approach to China and drone technology, with Japan reportedly preparing to 'freeze China from its drone supply chain'.[414]

8. Radars, antennae and related technologies

Since their inception in allied military research in WWII, radar (or 'radio detection and ranging', a detection system employing radio waves to ascertain objects' velocity, range, angle and nature) and antenna technologies have been of uninterrupted strategic value to militaries across land, sea, air and space. Research priorities include the following fields.

Synthetic-aperture radar (SAR). This extends the effective size of a radar system by using time-varying data from the radar as it moves relative to a fixed target, creating high-resolution images. These are used for satellite imaging using microwave frequencies which can see through the atmosphere. Calculations based on materials' reflective properties allow images of targets of interest.[415]

Phased array radar. Radar determines target direction and distance by scanning a narrow beam over a range of angles by rotating the antenna or controlling the phase distribution of a multi-element antenna array ('phased array'). The latter remains complex and expensive, but sees military and civilian use.[416]. Millimetre wave circuits are important components in 5G and other radar.[417]

Ultra-wide band (UWB). Using a wide bandwidth for communication has advantages for radio connections. These use similar power, but being spread over a wide bandwidth, power per Hz is low, for less interference with other systems. UWB allows accurate distancing, is difficult to detect, and data algorithms allow high encryption.[418]

High frequency radar. This operates at frequencies 2-30MHz and can monitor ocean currents and waves because although the antennas are electrically small, the target is large. Multiple coastal sites can cooperate to produce data using sophisticated signal

[411] https://www.androidauthority.com/lithium-ion-vs-solid-state-battery-726142/
[412] https://www.slashgear.com/first-solid-state-lithium-batteries-to-be-used-in-drones-this-year-02536298/
[413] https://en.wikipedia.org/wiki/Thin_film_lithium-ion_battery#Applications
[414] https://www.scmp.com/news/asia/east-asia/article/3107735/japan-prepares-freeze-china-out-its-drone-supply-chain-due

[415] https://earthdata.nasa.gov/learn/backgrounders/what-is-sar
[416] https://www.microwavejournal.com/articles/21278-phased-array-radar-at-the-intersection-of-military-and-commercial-innovation
[417] https://www.radartutorial.eu/06.antennas/Phased%20Array%20Antenna.en.html
[418] https://insights.samsung.com/2020/08/21/what-is-ultra-wideband-and-how-does-it-work/

processing.[419] [420] China has installed high frequency communications facilities on seven of the Spratley Islands in the South China Sea.[421]

Multiple Input Multiple Output (MIMO). Describes a radio which uses multiple antennas that reduce fade for transmission and reception. In 5G the concept is taken further, maximising signal-to-noise, and therefore data rates, while reducing interference. For advances in antenna technology, MIMO improves link reliability while its multiple streams boost data-rate.[422]

The Kent Communications Research Group's research includes space antennas, smart antennas, space-borne radars, phased arrays, MIMO, antenna and radio propagation for 4G/5G/6G mobile communications, base station antennas, antennas for satellite communications, RF/microwave/millimetre-wave circuits and RF front ends, mobile communication systems, satellite communications, inter-satellite links, UWB radars, GNSS [global navigation satellite system] reflectometry, synthetic-aperture radars, small satellites and intelligent antenna technologies for 6G. Huawei has sponsored 5G antenna technologies including millimetre-wave antenna designs for 5G and adaptive multi-band small MIMO antennas, both for smartphones.[423]

Among the areas that may risk leading to dual use include SAR, an interest in the development of surveillance and attack drones;[424] and phased array antennas, which are the subject of increasing competition as the US Space Force expands.[425] In 2016, reports claimed that a Chinese JY-26 UWB (phased array) radar tracked US F-22 stealth fighters over South Korea.[426]

CETC has launched the YLC-8B Ultra High Frequency (UHF) anti-stealth aircraft radar.[427] The Type 052C destroyers and the PLA Navy's first highly capable destroyer class both feature a multifunctional active phased array radar.[428]

The development of 5G in China is connected to civil-military fusion and will require 'specialised communications equipment [e.g.] antennas and microwave equipment, that the China Electronics Technology Group Corporation (CETC), a state-owned defense conglomerate, has established particular proficiency in developing.' 5G could also provide 'the rapid transmission and bandwidth required to realize the potential of the Internet of

[419] https://marine.rutgers.edu/cool/education/class/josh/hf_radar.html
[420] https://cordc.ucsd.edu/projects/mapping/documents/principles.php
[421] https://www.jhuapl.edu/Content/documents/High-FrequencyCommunications.pdf
[422] https://www.electronicdesign.com/communiqu/article/21135305/its-all-about-the-antennas-for-5g
[423] https://research.kent.ac.uk/communications/
[424] https://brandessenceresearch.com/aviation/synthetic-aperture-radar-sar-market-size
[425] https://spacenews.com/space-force-weighing-options-to-modernize-ground-antennas-for-military-satellites/
[426] https://www.china-arms.com/tag/chinas-anti-stealth-radars/
[427] http://www.defense-aerospace.com/articles-view/release/3/188617/china-talks-up-new-military-radars.html
[428] https://sinodefence.wordpress.com/2017/05/25/type-052c-luyang-ii-class/

Things and artificial intelligence (AI) on the battlefield.'[429] While 6G technology is still being developed, the PLA 'is already planning use on the battlefield.'[430]

A researcher at Heriot-Watt University (above) has researched radar-jamming with staff at the military-linked Nanjing University of Aeronautics and Astronautics (on target tracking while jamming by airborne radar).

9. Shipbuilding

Shipbuilding and navy-related research mainly falls into the categories of metals for shipbuilding, ship parts (such as propellors), and other naval structures.

Metals research includes as-welded steels, including S690, and their fracture toughness requirements. These are high-strength structural steels (HSSS) and of increasing military interest.[431] Many western defence researchers have moved into this field, including in the US and Sweden.[432] [433]

Component research includes torsional-longitudinal vibrations of ship propeller shafts; propeller-shaft vibration is an area of interest to Chinese military institutions, such as the Ordnance Engineering College.[434]

Navy-applicable structures include very large floating structures (VLFS) and their hinge connectors. A VLFS can be used as an offshore base, potentially allowing sea and air power projection into disputed waters. China is developing a 'Very Large Floating Platform', apparently a version of the US 'Mobile Offshore Base' concept, which could allow a mobile military base near, theoretically, any coastline within weeks. The China Jidong Development Group has designed a specifically military VLFS which could hold more aircraft than a traditional carrier. [435] [436] A researcher at Southampton (above) has carried out research with at least two Chinese military-affiliated institutions on VLFS.

[429] https://www.defenseone.com/ideas/2019/01/why-chinas-military-wants-beat-us-next-gen-cell-network/154009/
[430] https://www.scmp.com/news/china/military/article/3080235/chinas-military-draws-6g-dream-modernise-fighting-forces-and
[431] http://midra.uni-miskolc.hu/document/35455/32439.pdf
[432] http://www.shipstructure.org/pdf/466.pdf
[433] https://www.researchgate.net/profile/Anders_Blom3
[434] https://www.jvejournals.com/article/17889
[435] https://www.navyrecognition.com/index.php/news/defence-news/year-2015-news/august-2015-navy-naval-forces-defense-industry-technology-maritime-security-global-news/2973-china-unveiled-its-first-vlfs-project-similar-to-the-us-military-mobile-offshore-base-concept.html#:~:text=China%20unveiled%20its%20first%20%22Very,exhibition%20held%20recently%20in%20Beijing
[436] https://finance.yahoo.com/news/china-wants-build-giant-floating-203010806.html

10. Data science, AI, recognition and facial recognition

The creation of a high-tech surveillance state is one of the most disturbing trends to emerge from China in recent years, a threat not just to the liberties of the Chinese people, including its ethnic minorities, but increasingly to the preservation of liberties elsewhere.

The CCP intends to use big data and artificial intelligence to create, as the writer John Lanchester, drawing on work by Kai Strittmatter,[437] has put it,[438] 'the most perfect surveillance state the world has ever seen.'[439] An early example is facial recognition, where increased computing power 'has been transformational', turning the hundreds of thousands of cameras in cities into 'a connected network offering real-time surveillance and supervision'. Already a street crossing in Fujian projects jaywalkers' faces, names and addresses onto a video screen beside the road: China's state surveillance network is becoming capable of identifying any one of China's 1.4 billion citizens within a second, with its 'police cloud' being upgraded to synthesise citizens' 'medical histories, takeaway orders, courier deliveries, supermarket loyalty card numbers, methods of birth control, religious affiliations, online behaviour, flights and train journeys, GPS movement co-ordinates and biometric data, face, voice, fingerprints – plus the DNA of some forty million Chinese people'.

This combination of facial recognition and data capture is facilitating the next phase of the digital surveillance state: the social credit system, in which citizens are awarded points for state-approved behaviour (like 'offering use of their basement for a CCP singalong') and lose points for undesirable behaviour (in some pilots, social credit falls when people socialise with those with low credit). As Lanchester has described,[440] the ultimate purpose of this system 'is to make people internalise their sense of the state: to make people self-censor, self-monitor, self-supervise'.

The Uighurs of Xinjiang already appear to live in a *de facto* AI police state, in which the disappearance of over 1 million into prison camps and ongoing population replacement by Han Chinese is enforced by state-backed firms using facial recognition technology through a vast network of surveillance cameras. Here, 'algorithmic policing' is taking on new forms, with Uighurs facing arrest for publishing textbooks that contain over 30 per cent Uighur words (one man was seized because his book contained the word 'China' only four times).[441]

Uighurs now constitute 'the most intensely surveilled population on Earth'.[442] Beijing is moving Han 'big brothers and sisters' into Uighur homes to monitor forced assimilation: some Han big brothers share the beds of the wives of detained Uighur men. Police force

[437] Strittmatter, K. (2019). *We Have Been Harmonised: Life in China's Surveillance State*. Old Street.
[438] https://www.lrb.co.uk/the-paper/v41/n19/john-lanchester/document-number-nine
[439] https://www.lrb.co.uk/the-paper/v41/n19/john-lanchester/document-number-nine
[440] See also Strittmatter, K. (2019). *We Have Been Harmonised: Life in China's Surveillance State*. Old Street.

[441] Christian Shepherd in the *Financial Times*, in https://www.lrb.co.uk/the-paper/v41/n19/john-lanchester/document-number-nine
[442] https://www.theatlantic.com/magazine/archive/2020/09/china-ai-surveillance/614197/

Uighurs to install monitoring apps on their phones. AI-powered sensors 'lurk everywhere, including in Uighurs' purses and pants pockets.'[443] Other programmes scan Uighurs' digital communications, looking for suspect patterns like lack of fervour in using Mandarin.[444]

Every few blocks Uighurs may encounter a checkpoint with a surveillance camera that compares faces with pictures taken at a 'health check' (these checks also see Uighurs forced to donate genetic data for studies of 'how DNA [produces] Uighurlike chins and ears'; Uighur women are forced to have abortions or be sterilised).[445] The system notes their arrival at the edge of their neighbourhood. In this new 'AI-powered techno-totalitarian state', people will have 'fully internalised the demands of the state and [complete] its surveillance and control.'[446]

A recent research output with Harbin Engineering University was *Snoopy: Sniffing your smartwatch passwords via deep sequence learning;*[447] *UnDeep VO: Monocular* [single camera] *Visual Odometry through Unsupervised Deep Learning*[448] was a project with the College of Mechatronics and Automation, NUDT. (Odometry is the use of data to estimate change in position of an object or target and visual odometry has applications in robotics and surveillance cameras.)

In Scotland, researchers worked with the Institute of Information Science of Beijing Jiaotong University on *Frustratingly easy person re-identification: generalising person re-ID in practice;* [449] Birmingham's research has collecting internet user data to predict online behaviour; Cranfield University at Shrivenham has studied real time people tracking in multiple CCTV networks using colour constancy and tone compression, and a researcher produced *Detection of psychological stress using a hyperspectral imaging technique*,[450] which developed automated human surveillance techniques.

11. Robotics (land, sea and space)

A recent Brookings study placed robotics at the centre of future battlefields and military capacity generally,[451] describing robots taking on:

> 'a wider set of battlefield roles. Battlefield robots are being developed to target snipers and carry a full range of weapons. Unmanned surface vessels (USVs) and

[443] *Ibid*.
[444] https://www.theguardian.com/news/2019/apr/11/china-hi-tech-war-on-muslim-minority-xinjiang-uighurs-surveillance-face-recognition
[445] https://foreignpolicy.com/2020/07/01/china-documents-uighur-genocidal-sterilization-xinjiang/
[446] https://www.lrb.co.uk/the-paper/v41/n19/john-lanchester/document-number-nine
[447] https://arxiv.org/pdf/1912.04836v2.pdf
[448] https://arxiv.org/pdf/1709.06841.pdf
[449] https://arxiv.org/abs/1905.03422
[450] https://ieeexplore.ieee.org/document/6919328
[451] Like this section of the paper, the Brookings study discussed both robotics and UUV-related technologies.

> unmanned underwater vehicles (UUVs) are in development for unseen attacks against navy ships. Space is being opened as "a new unmanned battleground".'[452]

Reports state that China is deploying underwater listening drones in the Indian Ocean, which it claims, like many military technologies, have peaceful purposes, in this case oceanography.[453]

Australian media report that Indonesian fishermen captured a Chinese UUV in waters of strategic importance to Australia, a maritime route linking the South China Sea to the city of Darwin. One navy expert stated that this sends a signal that:

> 'the Chinese navy is getting ready to deploy submarines closer to our maritime approaches north of Darwin and we need to be ready for the prospect of submarine activity much closer to Australia's northern coast than we have been experiencing in the past.'[454]

China is investing in research on robotics for land, sea and space warfare. A study at Harbin Institute of Technology outlines considerable resources being invested in future space robot vehicles and robot astronauts.[455] This is happening in the context of an emerging space arms-race. China has begun testing anti-satellite missiles; the *Financial Times* has quoted one European military official, 'In space, we [in the West] still collectively maintain the edge… that edge is a target.' As an example, a prototype robotic arm that China has demonstrated for 'debris removal' could be used to grab satellites. Space may become 'the next battlefield'.[456]

China is 'determined' to become 'the dominant power in space'. A recent report stated: 'China has developed and fielded ground- and space-based anti-satellite, directed-energy, and electronic warfare capabilities that place the peaceful use of international space at risk… China… launched its first successful ground-based direct ascent anti-satellite missile, the SC-19, in 2007… In 2018 [PLA] units [began] training with anti-satellite missiles.'[457]

On land, Chinese conglomerates are now producing lethal military robots. Norinco's Sharp Claw is equipped to carry a submachine gun; and the Mule-200 transports ammunition and can be equipped with firearms.[458] At sea, 'Chinese advances in [UUVs]' are liable to erode Western nations' advantages in undersea warfare.[459]

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[452] https://www.brookings.edu/opinions/wired-for-war-the-future-of-military-robots/
[453] https://www.livemint.com/news/india/china-deploying-en-masse-underwater-drones-in-indian-ocean-report-11609373452869.html
[454] Malcom Davis, quoted by ASPI, in: https://www.abc.net.au/news/2020-12-31/suspected-chinese-submarine-drone-found-by-indonesian-fishermen/13022488
[455] http://robotics.estec.esa.int/i-SAIRAS/isairas2014/Data/Plenaries/ISAIRAS_FinalPaper_0152.pdf
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[457] https://www.defensenews.com/opinion/commentary/2020/06/23/china-wants-to-dominate-space-and-the-us-must-take-countermeasures/
[458] https://nationalinterest.org/blog/buzz/chinas-army-now-has-killer-robots-meet-sharp-claw-145302
[459] https://www.uscc.gov/sites/default/files/Research/DGI_China's%20Industrial%20and%20Military%20Robotics%20Development.pdf

Chapter 4: UK commitments and current guidelines

Main relevant treaties and regimes

We begin by discussing two central counter-proliferation regimes on which the UK's national export controls (below) are based: the Wassenaar Arrangement (WA) and the Missile Technology Control Regime (MTCR). These should be understood in light of the UK's arms embargo on the PRC (which now includes Hong Kong), a partial arms embargo, covering:[460]

> 'lethal weapons, such as machine guns, large-calibre weapons, bombs, torpedoes, rockets and missiles; specially designed components of the above and ammunition; military aircraft and helicopters, vessels of war, armoured fighting vehicles and other weapons platforms; any equipment which might be used for internal repression. This embargo covers the export of these items from the UK. It is implemented through the Export Control Order 2008.'

The UK's military and dual-use lists (below) provide more coverage however.

The Wassenaar Arrangement (WA) on Export Controls for Conventional Arms and Dual-Use Goods and Technologies

The WA is a non-legally binding regime (non-treaty) asking its 42 member states to be accountable for exports of conventional arms and dual-use goods and technologies to countries outside the WA.[461] The UK is a signatory; the PRC is not.

Volume 2 of the WA details the dual-use goods and technologies member states must consider when exporting or sharing such items. Dual-use goods and technologies to be controlled are 'major or key elements for the indigenous development, production, use or enhancement of military capabilities'.[462] Dual-use items are evaluated for:

- Foreign availability outside member states;
- The ability to effectively control the export of the goods;
- The ability to make a clear and objective specification of the item; and
- Controlled by another regime.

There are three categories in the dual-use list which will apply to most of the research centres above:[463]

[460] https://www.gov.uk/government/collections/uk-arms-embargo-on-mainland-china-and-hong-kong#:~:text=Since%201989%2C%20following%20Chinese%20military,was%20extended%20to%20Hong%20Kong

[461] https://www.wassenaar.org/

[462] https://www.wassenaar.org/app/uploads/2019/consolidated/Criteria_for_selection_du_sl_vsl.pdf

[463] https://www.wassenaar.org/app/uploads/2020/12/Public-Docs-Vol-II-2020-List-of-DU-Goods-and-Technologies-and-Munitions-List-Dec-20-3.pdf

- Category 1 Special Materials and Related Equipment;
- Category 2 Materials Processing; and
- Category 9 Aerospace and Propulsion.

The US Commerce Department's Bureau of Industrial Security announced in October 2020 that six technologies related to chip manufacturing would be included in its new export control under the WA.[464]

Missile Technology Control Regime (MTCR)

The MTCR is an informal arrangement between its 35 member states to limit the proliferation of missiles and missile technology. One of its aims is vigilance over the transfer of missile equipment, material, and related technologies for systems capable of delivering weapons of mass destruction (WMD).[465] The MTCR seeks to limit the risks of WMD proliferation by controlling exports of goods and technologies that could contribute to delivery systems (other than manned aircraft) for such weapons, with particular focus on rockets capable of delivering a payload of at least 500kg over at least 300km and equipment, software, and technology for these.[466] The following passages are derived from MTCR text.

The MTCR does this with export controls applied to a common list of items (the MTCR Equipment, Software, and Technology Annex), a list of controlled items – including much of the equipment, materials, software, and technology needed for missile development, production, and operation controlled by MTCR members. The Annex has two parts: Category I and Category II items. MTCR members require license authorisation requirements before listed items may be exported.[467]

Category I items include complete rocket and unmanned aerial vehicle systems (such as ballistic missiles, space launch vehicles, sounding rockets, cruise missiles, target drones, and reconnaissance drones), capable of delivering a payload of at least 500kg to a range of at least 300km, their major complete subsystems (such as rocket stages, engines, guidance sets, and re-entry vehicles), and related software and technology, and specially designed production facilities for these items.[468] Category I exports are subject to an unconditional strong presumption of denial, regardless of the purpose of the export, and are licensed for export only on rare occasions. Category II items include less-sensitive and dual-use missile-related components. Exports judged by the exporting country to be intended for use in WMD delivery are to be subjected to a strong presumption of denial.[469]

[464] https://www.gibsondunn.com/new-controls-on-emerging-technologies-released-while-us-commerce-department-comes-under-fire-for-delay/
[465] https://mtcr.info/frequently-asked-questions-faqs/
[466] https://mtcr.info/frequently-asked-questions-faqs/
[467] *Ibid*.
[468] https://fas.org/nuke/control/mtcr/text/mtcr_handbook_item1.pdf
[469] https://mtcr.info/frequently-asked-questions-faqs/

UK commitment to the Missile Technology Control Regime (MTCR)

Each member state implements the MTCR Guidelines in accordance with national legislation on the basis of sovereign discretion. UK compliance is maintained through the UK Strategic Exports Control List,[470] including a military and a dual-use list, plus EU compliance legislation. The UK Strategic Exports Control List also complies with the Wassenaar Arrangement. It was last updated December 2020.

UK export controls including Military and Dual-Use Lists

The Military and Dual-Use Lists are drawn especially from the Export Control Order 2008 Schedule 3: The UK National Dual-Use Control List (including the explosive-related list); Annexes 2 and 3 of Council Regulation (EC) No. 1236/2005 (as amended) (the EU Human Rights List); and Annex 1 of Council Regulation (EC) No. 428/2009 (as amended) (the EU Dual-Use List).[471]

Controlled dual-use goods cover thousands of items controlled, *but not necessarily designed*, for dual-use, having benign civil applications but significant potential for military use, including for WMD, and potential for human rights abuses.

According to DIT, the item of concern will have some utility 'in a weapons manufacture programme'. This can 'control key components, accessories, technology and software, in addition to actual goods.'[472] Importantly, under the lists, 'technology' means 'information' necessary for the 'development', 'production', or 'use' of goods or software (which are subject to controls).[473] There are some exceptions for information 'in the public domain'. Exports can take the form of physical or electronic transfers. The dual use categories are as follows:[474]

0 Nuclear materials, facilities and equipment.
1 Special materials and related equipment.
2 Materials processing.
3 Electronics.
4 Computers.

[470] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/944003/UK_strategic_export_control_lists_20201215.pdf
[471] The Trade Controls are set out in Articles 20 to 25 of the Export Control Order 2008 (following the Export Control Act 2002) and Schedule 1 Part 1 – Category A goods; Schedule 2 (the Military list (items 'specifically designed or modified for military use')) Part 2 – Category B goods; Schedule 3 – the UK dual use list.
[472] Sometimes technical parameters must be met, such as purity, accuracy, and so on.
[473] See also: Research Services, University of Sheffield (2021). *Guidance on Export Control Legislation*. https://www.sheffield.ac.uk/rs/export
[474] Dual-use lists are drawn from the Wassenaar Agreement and MTCR, as well as the Nuclear Suppliers Group, Australia Group, and Chemical Weapons Convention.

5 Telecommunications and information security.
6 Sensors and lasers.
7 Navigation and avionics.
8 Marine.
9 Aerospace and propulsion.

On WMD and End Use Controls, in its briefings DIT states: 'WMD and End-Use Controls: The end-use control can be applied to ANYTHING (e.g. main equipment or components) or ANY activities (e.g. training or helplines), if potentially connected to a WMD programme.' According to DIT, 'Most of the goods or technology required for WMD or missile delivery systems may not be on any control list', meaning it is incumbent on the party supplying the technology to contact the authorities to check whether its activities may be proscribed.

This does not mean that any researchers have personally broken UK rules, because we assume that university centres and their research focuses have been approved. However it may suggest that individual research projects which risk falling under dual use areas may need prior approval on a case by case basis, as the products manufactured by companies also would, which appears to mean reforms are needed to university rules.

For WMD End-Use Controls in the UK, Article 6 of the Export Control Order 2008 contains 'additional controls on transfer of technology by any means and provision of technical assistance in relation to WMD.' DIT states:

> 'If you know or suspect an export will be used in connection with a WMD programme you have a legal obligation to contact [the authorities] and ask for a licence.' 'WMD purposes' mean 'use in connection with the development, production, handling, operation, maintenance, storage, detection, identification or dissemination of chemical, biological or nuclear weapons or other nuclear explosive devices, or the development, production, maintenance or missiles capable of delivering such weapons.'

DIT also defines 'in connection with' as 'includ[ing] exports which may be used directly in a weapon or missile *or indirectly in WMD development*'. Indirect uses include 'infrastructure projects; *research programmes at universities or government laboratories*; un-safeguarded nuclear activities; civil space programmes' [our italics].

A licence is required if the exporter 'knows', has been 'informed', or even 'suspects' the goods software or technology are intended for 'any relevant use'. Parties are advised to consult the Consolidated list of strategic military and dual-use items that require export authorisation,[475] only a few of whose categories are listed below.

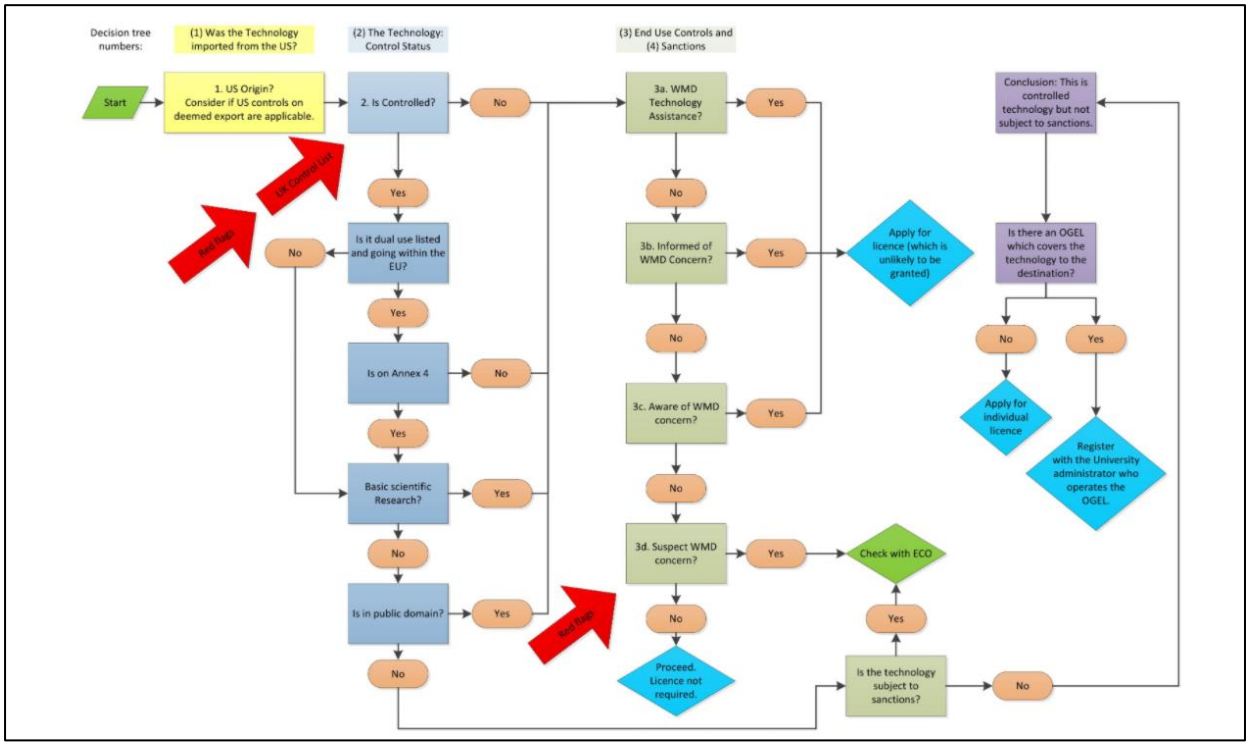
[475] https://www.gov.uk/government/publications/uk-strategic-export-control-lists-the-consolidated-list-of-strategic-military-and-dual-use-items-that-require-export-authorisation

While controls exclude some basic scientific research or findings that will be or are in the public domain, this will not exclude all such research[476] (again, this also implies the need for government to analyse the need for possible revision of what is meant by basic scientific research). According to guidance issued for academics by Project Alpha at King's College London with the support of the Foreign and Commonwealth Office,[477] '[e]ven if the item, technology or software is not listed in the UK Consolidated Lists, a licence could also be required if the exporter knows, has been informed or suspects there is a WMD end use.'

It adds: 'Additional restrictions can apply when dealing with countries that are subject to sanction… which often have the effect of broadening the UK Consolidated Lists to include items which would not normally be included in the UK Consolidated List.'

Project Alpha's flowchart (below) shows why this research may still be proscribed even if the research funding in general has been approved (for a broader research centre). If we begin from Question 2 ('Is it controlled?') at the top, the possible responses for cooperation with China all lead to 3a ('WMD technology assistance?'). Where this is deemed possible, the advice is 'Apply for licence (which is unlikely to be granted)'.

Export Control Flowchart



Source: Project Alpha, King's College London (2015) [478]

[476] Research Services, University of Sheffield (2021). *Guidance on Export Control Legislation*. https://www.sheffield.ac.uk/rs/export

[477] King's College London News Centre, 19 July 2015. *Project Alpha and association of university legal practitioners issue export control guidance for academia*. https://www.kcl.ac.uk/news/project-alpha-and-association-of-university-legal-practitioners-issue-export-control-guidance-for-academia

[478] *Ibid*.

Current UK control lists

The following are examples of goods and technologies on UK control lists,[479] intended only to be indicative of some of the areas covered.

- **The UK Military List**

This includes:

- Electronic guidance and navigation equipment;
- Vessels (surface or underwater);
- 'Aircraft', 'lighter-than-air vehicles', 'Unmanned Aerial Vehicles' ('UAVs'), aero-engines and 'aircraft' equipment, related goods, and components as follows, specially designed or modified for military use:
    - 'UAVs', Remotely Piloted Air Vehicles (RPVs), autonomous programmable vehicles and unmanned 'lighter-than-air vehicles';
- Launchers, recovery equipment and ground support equipment;
- Equipment designed for command or control; Propulsion aero-engines and specially designed components therefor; and
- Electronic equipment, 'spacecraft' and components, not specified elsewhere in [this]Schedule [including] Global Navigation Satellite Systems (GNSS) jamming equipment and specially designed components therefor.

The list also 'controls all electronic guidance and navigation equipment Goods and material, coated, treated or prepared to provide signature suppression, specially designed for military use'.

- **The UK Dual-Use List**

This includes the products listed below and the 'technology' for many of these:

- Remotely operated vehicles;
- [Various] metal alloys, metal alloy powder and alloyed materials;
- Metals in particle sizes of less than 60 µm whether spherical, atomised, spheroidal, flaked or ground, manufactured from material consisting of 99 per cent or more of zirconium, magnesium and alloys thereof;
- Materials and devices for reduced observables, such as radar reflectivity, ultraviolet/infrared;
- [Various] signatures and acoustic signatures [usable] in 'missiles', 'missile' subsystems or unmanned aerial vehicles (specified; includes: a. Structural materials and coatings specially designed for reduced radar reflectivity; b. Coatings, including paints, specially designed for reduced or tailored reflectivity or emissivity in the microwave, infrared or ultraviolet regions of the electromagnetic spectrum);

[479] https://www.gov.uk/guidance/uk-strategic-export-control-lists-the-consolidated-list-of-strategic-military-and-dual-use-items

- A range of graphite, ceramic, and ultra-high temperature ceramic materials – including Hafnium carbide (HfC) (including usable for missile components (such as nose-tips, re-entry vehicles, leading edges, jet vanes, control surfaces or rocket motor throat inserts) in ‘missiles’, [some] space launch vehicles, [some] sounding rockets [or] 'missiles');
- Hafnium metal and alloys (with certain properties);
- Maraging steels useable in 'missiles' (with certain properties);
- Certain single or complex oxides of zirconium and complex oxides of silicon or aluminium; and
- Robots designed to comply with national safety standards applicable to potentially explosive munitions environments, to operate at high altitudes or withstand high radiation.

Under the Category of Telecommunications and Information Security:

- Mobile telecommunications interception or jamming equipment;
- Telemetry and telecontrol equipment (including ground equipment, designed or modified for ‘missiles’);
- ‘Information security’ systems and components for the control of ‘satellite navigation system’ receiving equipment containing or employing decryption;
- ‘Cryptography for data confidentiality’ having a ‘described security algorithm’ in some conditions; and
- Certain systems, equipment and components for defeating, weakening or bypassing ‘information [W] security’ (including ‘functions designed to defeat cryptographic mechanisms in order to derive confidential variables or sensitive data, including clear text, passwords or cryptographic keys’).

The dual list also includes:

- Hydrophones (including ‘Flexible piezoelectric composites’);
- Gyros usable in missiles; and
- Certain 'integrated navigation systems', designed or modified for 'missiles'.

Under the Marine category:

- Submersible vehicles and surface vessels;
- Unmanned submersible vehicles;
- ‘Robots’ specially designed for underwater use, controlled by using a dedicated computer; and
- Propellers, power transmission systems, power generation systems and certain noise reduction systems.

Under Aerospace:

- Aero gas turbine engines with various technologies;
- Ramjet, scramjet or 'combined cycle engines', and specially designed components therefor;

- ‘Unmanned aerial vehicles’ (‘UAVs’), unmanned ‘airships’, related equipment [and] components [including] Air breathing reciprocating or rotary internal combustion type engines, specially designed or modified to propel ‘UAVs’ or unmanned ‘airships’, at altitudes above 15,240 metres (50,000 feet);
- Vehicles for transport, handling, control, activation or launching, designed or modified for space launch vehicles (specified elsewhere), sounding rockets (specified elsewhere) or ‘missiles’;
- Other ‘technology’ ‘required’ for the ‘development’ or ‘production’ of any of the following gas turbine blades, vanes or ‘tip shrouds’, made from directionally solidified (DS) or single crystal (SC) alloys; and
- Components [manufactured] from organic ‘composite’ materials designed to operate above 588K (315°C).

Under stealth technology:

- Materials specially designed for absorbing electromagnetic radiations, or intrinsically conductive polymers (and some materials and devices for reduced observables, such as radar reflectivity, ultraviolet/infrared signatures and acoustic signatures, or usable in some 'missiles', ‘missile’ subsystems or unmanned aerial vehicles, unless formulated solely for civil applications);
- ‘Software’ for analysis of reduced observables, such as radar reflectivity, ultraviolet/infrared signatures and acoustic signatures; and
- Some pulse radar cross-section measurement systems and components.

Academic Technology Approval Scheme

The Academic Technology Approval Scheme (ATAS) applies to all international students (apart from exempt nationalities) who are subject to UK immigration control and are intending to study at postgraduate level in certain sensitive subjects. Its subjects are those where students’ knowledge could be used in programmes to develop Advanced Conventional Military Technology (ACMT), WMDs, or their means of delivery.[480] These students must apply for an Academic Technology Approval Scheme (ATAS) certificate before they can study in the UK.

In this area, ministers at the National Security Committee in 2020 signed off plans for stricter controls over the ATAS for Chinese post-graduate students from research institutions with links to the PLA.[481] This includes within cyber security and aviation.

[480] https://www.gov.uk/guidance/academic-technology-approval-scheme
[481] https://www.thetimes.co.uk/article/chinese-students-face-ban-amid-security-fears-nmp7plwch

US and Japanese sanctions on Chinese defence-linked universities and companies

The US now bans US investment in or by a large number of Chinese companies, having added dozens of Chinese companies to the Entity List in 2020.

These lists apply different types of sanctions depending on whether companies have military ties or whether they are, for example, telecoms firms whose involvement in US infrastructure is deemed undesirable, who may be banned from involvement and from receiving certain exports of goods.

The previous US Administration's Commerce Secretary, Wilbur Ross, stated that the US will 'not allow advanced US technology to help build the military of an increasingly belligerent adversary.'[482] The inclusion of China's leading chipmaker Semiconductor Manufacturing International Corporation (SMIC), for example, despite less direct military involvement than other firms, was motivated by 'China's military-civil fusion (MCF) doctrine and evidence of activities between SMIC and entities of concern in the Chinese military industrial complex.'

In June 2020, the US Department of Commerce Bureau of Industry and Security (BIS) added 33 Chinese firms and institutions to the list of entities banned from receiving various exports, re-exports or transfers.[483] Its full entity list[484] and military end-user list[485] includes many companies and institutions discussed in this report. On 18 December 2020, the US government added 59 companies to the entity list for a combination of human rights abuses, including for the use of surveillance technology, IP theft, and activities that generally undermine national security.

The Department of Defense maintains a list of PRC companies sanctioned due to Chinese military backing pursuant the National Defense Authorization Act. These sanctions involve asset blocking and visa restrictions, and are the equivalent of inclusion on the Specially Designated Nationals and Blocked Persons List (SDN), typically prohibiting financial transactions with US individuals.[486] The DOD states:

> 'The Department is determined to highlight and counter the People's Republic of China's (PRC) Military-Civil Fusion development strategy, which supports the modernization goals of the People's Liberation Army (PLA) by ensuring its access to advanced technologies and expertise acquired and developed by even those PRC companies, universities, and research programs that appear to be civilian entities.'[487]

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[482] https://www.cnbc.com/2020/12/18/us-adds-chinese-drone-company-dji-to-economic-blacklist-.html
[483] https://www.pillsburylaw.com/en/news-and-insights/updated-list-of-us-national-security-actions-impacting-supply-chains.html
[484] https://www.bis.doc.gov/index.php/documents/regulations-docs/2326-supplement-no-4-to-part-744-entity-list-4/file
[485] https://www.bis.doc.gov/index.php/policy-guidance/lists-of-parties-of-concern/1770
[486] *Ibid*.
[487] https://www.defense.gov/Newsroom/Releases/Release/Article/2328894/dod-releases-list-of-additional-companies-in-accordance-with-section-1237-of-fy/

The DOD lists the following as 'Chinese military companies':[488] [489] [490]

- Aviation Industry Corporation of China (AVIC);
- China Aerospace Science and Technology Corporation (CASC);
- China Aerospace Science and Industry Corp.;
- China Electronics Technology Group Corp.;
- China South Industries Group Corp.;
- China Shipbuilding Industry Corp.;
- China State Shipbuilding Corp.;
- China North Industries Group (Norinco);
- Hangzhou Hikvision Digital Technology Co.;
- Huawei Technologies Co.;
- Inspur Group Co.;
- Aero Engine Corporation of China (AECC);
- China Railway Construction Corp.;
- CRRC Corp.;
- Panda Electronics Group Co.;
- Dawning Information Industry Co.;
- China Mobile Communications Group Co.;
- China General Nuclear Power Corp.;
- China National Nuclear Corp.;
- China Telecommunications Corp.;
- China Communications Construction Co.;
- China Academy of Launch Vehicle Technology;
- China Spacesat Co.;
- China United Network Communications Group Co.;
- China Electronics Corp.;
- China National Chemical Engineering Group Corp.;
- China National Chemical Corp.;
- Sinochem Group Co.;
- China State Construction Group Co.;
- China Three Gorges Corp.;
- China Nuclear Engineering & Construction Corp.;
- Xiaomi; and
- Commercial Aircraft Corporation of China (COMAC).

[488] https://media.defense.gov/2020/Aug/28/2002486659/-1/-1/1/LINK_2_1237_TRANCHE_1_QUALIFIYING_ENTITIES.PDF
[489] https://media.defense.gov/2020/Aug/28/2002486689/-1/-1/1/LINK_1_1237_TRANCHE-23_QUALIFYING_ENTITIES.PDF
[490] https://www.bloomberg.com/news/articles/2020-11-18/here-s-a-list-of-31-chinese-firms-named-in-u-s-investment-ban

In June 2020, BIS added a licence requirement for certain US exports to PRC military end users – even if the export itself is for a purely civilian application.[491] Most of the Chinese universities discussed in this report are subject to full licence requirements.[492]

In what might also be seen as a form of 'modern slavery' policy, the US Departments of State, Commerce, Homeland Security and Treasury have also issued an advisory describing supply chain risks linked to firms or institutions connected to human rights abuses in China (in this case in Xinjiang), including forced labour and other abuses.[493] Despite the UK's arms-related sanctions regimes and military and dual-use requirements (discussed above), the closest UK document, the Consolidated List, contains no equivalent sanctions or controls for specific Chinese companies.[494]

[491] *Ibid*.
[492] https://www.bis.doc.gov/index.php/documents/regulations-docs/2326-supplement-no-4-to-part-744-entity-list-4/file
[493] *Ibid*.
[494] https://ofsistorage.blob.core.windows.net/publishlive/ConList.pdf

Conclusions and recommendations

China has a long history of weapons sales to countries that carry out grievous human rights abuses, including Iran, Syria, Burma and North Korea (Introduction).

In addition, China's development of a surveillance state is already leading to systematic human rights abuses. Its treatment of the Uighur minority is being described as genocide. Its new security law for Hong Kong is leading to the systematic arrest of protesters and has made a mockery of the city's autonomy (subjects not covered in this report).

The methods by which the UK monitors and controls Chinese involvement in UK university research appear to be inadequate. **However, none of the researchers whose work is mentioned in this report are being accused of intentionally assisting the development of China's military, let alone of any rule-breaking or of any criminal activity; still less are their ties and work alleged to have been recklessly entered into or undertaken.**

The companies sponsoring these UK-based research centres include China's largest weapons manufacturers and military suppliers. These include the leading state-owned enterprises (SOEs) in strike fighter engine production, ICBMs, nuclear warheads, stealth aircraft, military drones, tanks, military-use metals and materials, navy ships, and other fields. There must, therefore, be a risk of research intended for civilian purposes and benefits being co-opted and misused for Chinese military and political ends, although at times this will mean simply improving the general commercial or research position of a Chinese military-linked sponsor whose expansion is liable not to be in the UK national interest in general.

At its simplest, for the UK government and taxpayer to risk funding and assisting the technological development and capabilities of the military of the People's Republic of China is not in the British national interest.

This is a picture of 'strategic incoherence'. China's civil-military fusion, rapid technological-military development and force-projection capabilities threaten the national interests of the United Kingdom. To risk financing the companies at the centre of this strategy through our leading universities and research institutions points to ill-considered research policies at the level of the UK universities themselves, but also a lack of strategic coordination.

This points to the need for a strategic reassessment leading to new rules for scientific research with PRC universities and companies, some of which should be applied directly to the UK's research councils and universities, while some may require legislation. Other rules are necessary for any scientific research on sensitive technological fields generally, and in universities in particular.

Recommendations

The UK government should:

- List all those Chinese military-linked companies and institutions that it wants to bar from sponsoring scientific research in UK universities and from research collaboration in general and consider the same for graduates and staff;
- List those entities it wishes to prevent making inward investments generally into the UK. This has been the practice of the US government and looks set to continue with the new administration;
- Initiate a public audit of UK universities' sponsorship relationships and policies, with the aim of establishing the total level of Chinese funding of UK technology research and establishing new rules for universities themselves, as well as for UKRI, Innovate UK, the Royal Society, and research councils such as the EPSRC. Combined with an 'entities list', this may be best placed in new legislation, covering UK scientific research and Chinese military-linked organisations specifically, or authoritarian states generally;
- Set up a new government organisation similar to the Committee on Foreign Investment in the United States (CFIUS) within the National Security and Investment Bill,[495] whose role would include the monitoring and assessment of proposed and ongoing university sponsorship;
- While it is important to preserve academic freedom, the government should assess whether some of what is currently deemed 'basic scientific research' or research whose findings enter the public domain may still have possible dual-use, in sanctioned countries including China, and where overall approval for a research centre may be allowing specific inadvertently dual use projects to be carried out;
- Further review the Academic Technology Approval Scheme (ATAS), to better control entry to the UK of international students (apart from exempt nationalities) whose research may create risks in certain sensitive subjects; and
- Reassess the fields of scientific research that can be carried out by public research institutions and/or where research findings can be publicly released.

That British universities have cause to re-examine their relationships with and funding from the People's Republic of China is, we believe, already apparent. On the basis of facts in the public domain, we believe that this report demonstrates that their sponsorship by China's military-linked companies and universities has become a dangerous aspect of these relationships.

Finally, the measures we recommend should form part of the urgent reassessment by the UK government of the security implications of the so-called 'Golden Era' policies of the UK towards China, and of the strategic assumptions that underpinned them.

[495] https://www.natlawreview.com/article/cfius-uk-uk-government-announces-new-foreign-investment-measures

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