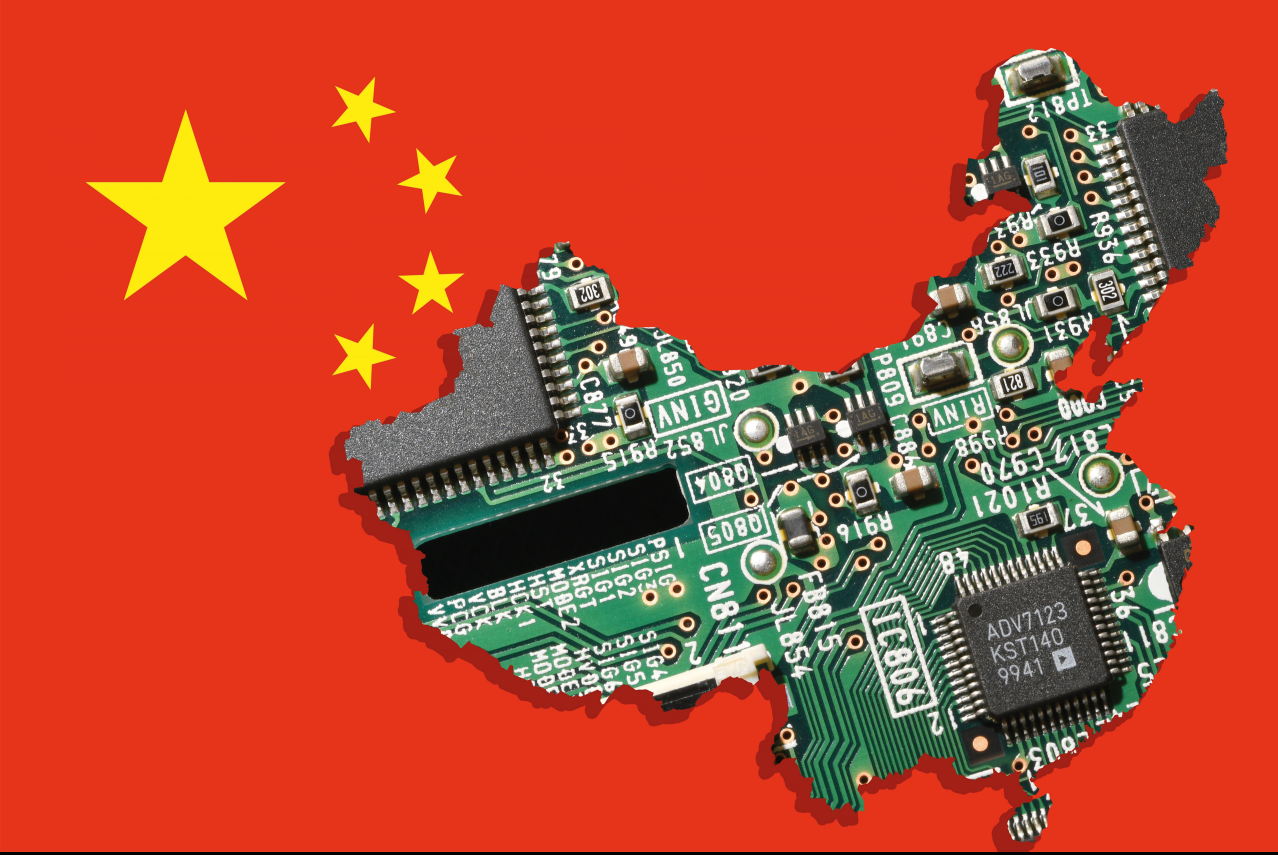

China's Technology Transfer Ecosystem

Key Actors and the Case of China Electronics Technology Group Corporation

Tobias Junerfält

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Sammanfattning

Kina har en lång historia av att nyttja utländska teknologier för att modernisera sin industri och militär, likt många andra länder. De medel som används för att få tillgång till utländska teknologier är både lagliga, olagliga och av gråzonskaraktär. Kinas ekosystem för utländsk teknologiöverföring kontrolleras i slutändan av det kinesiska kommunistpartiet. Involverade aktörer inkluderar diverse regeringsdepartement under Kinas statsråd, militären, akademiska institutioner, inklusive universitet, nationella akademier, och en mängd olika försvarsrelaterade laboratorier, Enhetsfrontsorganisationer i samverkan med kinesisk diaspora och Sinoutländska föreningar, samt kommersiella aktörer så som försvarsföretag, investeringsfonder och företag i industrier vars produkter har dubbla användningsområden. Försvarselektronikkonglomeratet China Electronics Technology Group Corporation, vars verksamhet sträcker sig till teknologiområden med civila och dubbla användningsområden så som halvledare, innefattar, kontrollerar eller interagerar med entiteter från både regering, akademi och näringsliv, och förkroppsligar på så vis de mångfacetterade banden mellan Kinas industriella och militära ambitioner.

Halvledarindustrin är en av de främsta måltavlorna för Kinas ansträngningar att tillskansa sig utländska teknologier, tillika ett av teknologiområdena i centrum för stormaktsrivaliteten mellan USA och Kina. Ökad geopolitisering av halvledarteknologi med dubbla användningsområden antyder att många lagliga medel för teknologiöverföring håller på att bli mindre tillgängliga för Kina. Samtidigt kan medel som är olagliga eller av gråzonskaraktär, samt de aktörer som tillämpar dessa medel, förväntas öka i betydelse.

Nyckelord: Kina, teknologiöverföring, ekosystem, nyckelaktörer, halvledarindustri, försvarselektronik, China Electronics Technology Group Corporation

Summary

China has a long history of utilising foreign technologies to modernise its industry and military, as have many other countries. The means employed to access foreign technologies are both legal, illegal, and grey zone. China's foreign-technology transfer ecosystem is ultimately controlled by the Chinese Communist Party. The actors involved include various government departments under the State Council; the military; academic institutions such as universities, national academies, and a range of different defence-related laboratories; United Front organisations alongside the overseas diaspora and Sino-foreign associations; and commercial actors, such as defence companies, investment funds and dual-use industry enterprises. The defence-electronics conglomerate, China Electronics Technology Group Corporation, which is also engaged in civilian and dual-use technologies, such as semiconductors, contains, controls, or interacts, with entities from both government, academia, and enterprise, and as such embodies the diverse ties between China's military and industrial ambitions.

The semiconductor industry is one of the primary targets of China's technology transfer efforts and one of the technology areas at the centre of US-China great-power rivalry. Increased geopoliticisation of dual-use semiconductor technology suggests that many of the legal means for technology transfer are becoming less available to China. Meanwhile, the use of illegal and grey-zone means, along with the actors who employ them, is expected to become increasingly important.

Keywords: China, technology transfer, ecosystem, key actors, semiconductor industry, defence electronics, China Electronics Technology Group Corporation

Preface

This report on China's technology-transfer ecosystem has been produced within the framework of the Asia Programme at the Swedish Defence Research Agency (FOI). The programme provides analyses for the Swedish Ministry of Defence and focusses on defence- and security-policy developments in and around East and South Asia. China's state-led efforts to acquire foreign technologies aim to benefit economic advancement and military modernisation. Against the background of increasing global geopolitical competition, to increase our understanding of how sensitive technology is transferred to China is important for Sweden's and Europe's economic security.

Oscar Almén

Project Manager for the Asia Programme, FOI.

Stockholm, September 2024.

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Tobias Junerfält, FOI.

Stockholm, September 2024.

Executive summary

Technology transfer takes many shapes and forms and is a daily phenomenon across the spheres of government, academia, and enterprise in all parts of the world. It is conducted by both legal and illegal means and for different purposes depending on the country and actor in question. China is an example of a country with a sophisticated, state-led ecosystem directed at foreign-technology transfer, which the Chinese Communist Party has developed top-down over the course of decades.

In the context of acquiring foreign technologies in service of state goals, modern-day China is not just one country among others, considering the combination of the far reach and ambitions of its party-state apparatus, the size of its economy and population, and the close ties between its civilian and defence industries and academic spheres, all of which are under extensive formal and informal state control. China has in many ways come far in its domestic innovation capabilities, but in a number of areas it is still reliant on foreign technology. Not only are overall industrial advancement and military modernisation closely interlinked in China, its ecosystem for foreign technology transfer is also characterised by a mix of transparent and non-transparent actors and behaviour.

China's technology transfer efforts have implications for Sweden and the EU, which have extensive commercial and academic ties to China. Sweden and the EU also maintain close ties to the US, which is currently embroiled in both geopolitical and geoeconomic rivalry with China. Semiconductor technology, as a major dual-use technology area, lies at the heart of this rivalry, both due to its contributions to the military capabilities of the US and China, not least in defence electronics and AI, and due to its importance in broader industrial and economic rivalry.

This study maps China's technology-transfer ecosystem by assembling scattered information into a comprehensive overview, detailing the actors involved, their roles, and the means they employ. Semiconductor technology receives special emphasis. The author's estimation is that this topic is inadequately studied in the European context and that a better grasp of the workings of China's technology-transfer ecosystem among European government, academic, and corporate personnel would contribute to better preconditions for both economic security and fruitful interaction with China.

The main findings of this report are as follows:

- China‘s ecosystem for foreign-technology transfer involves actors from all spheres of the Chinese system, ultimately controlled by the Chinese Communist Party. The different actors, which have different but over-lapping roles within the ecosystem, employ a great variety of legal, illegal, and grey-zone means to acquire foreign technologies.

- The first category of actors involves a variety of government departments that govern China's industrial and technological development, as well as the national security apparatus. The second category is the military, including military-affiliated universities and think tanks. The third category is academic institutions, including universities, national science academies, and various defence-related laboratories scattered across government, academia, enterprises, and the military. The fourth category includes organisations associated with the United Front, the CCP's strategy to spread its influence both domestically and abroad. This includes both organisations directly under the CCP and a plethora of overseas Chinese and Sino-foreign professional and academic associations. The fifth and last category comprises commercial actors, notably defence-industry companies, state-owned and private firms within dual-use industries, and financial intermediaries, such as investment funds and venture capital firms.
- Semiconductor technology is one of the prime targets for China's technology-transfer efforts and an excellent example of the ties between China's technological ambitions for its civilian and defence industries. Consequently, all of the different actors in China's foreign-technology transfer ecosystem have some interest in acquiring foreign semiconductor technology. However, some actors' profiles have particular relevance. A prominent example among the government departments is the Ministry of Industry and Information Technology. Other examples include academic institutions and United Front-affiliated diaspora organisations with a focus on semiconductor technology, defence electronics, or other semiconductor-dependent technology areas, such as artificial intelligence and telecommunications.
- This report features a case study that focusses on a particular commercial actor, the defence-industry conglomerate, China Electronics Technology Group Corporation (CETC). CETC symbolises the intersection between China's industrial and military ambitions in general and the dual-use semiconductor industry in particular. CETC is the arguably most significant actor within the Chinese defence-electronics sector and serves as an important supplier to the PLA. However, the conglomerate as a whole covers many different semiconductor-related business areas, including semiconductor-manufacturing equipment, telecommunications, AI, and solar power. CETC also supervises universities that have a defence-electronics profile and investment funds with a focus on dual-use semiconductor technology and the promotion of synergies between civilian and defence industries.
- The US-China great-power rivalry and Western economic-security initiatives have implications for China's technology-transfer ecosystem. There is now heightened emphasis among the US and its allies on the risks of industrial and academic interaction with China, an authoritarian state

and geopolitical rival. As a consequence, certain legal means for technology transfer, such as technology imports, company acquisitions, and academic collaboration, are becoming less available to China. Since China's ambitions for its domestic industry and military remain the same, these developments suggest that the illegal and grey-zone means within the technology-transfer toolbox, such as export-control circumvention, front organisations, and industrial espionage, may become increasingly important. However, some legal means, such as open-source intelligence-gathering and talent recruitment, will also remain useful to China.

- A partial shift from the use of legal to illegal and grey-zone means for technology transfer suggests a corresponding shift in the importance of certain actors. For instance, while the Ministry of State Security and United Front-affiliated overseas associations may increasingly emphasise espionage activities or coercive talent recruitment, China's regular industrial, commercial, and academic interaction with foreign partners may receive less attention in its technology-transfer efforts.

Glossary

English	Mandarin Chinese
Academy of Military Sciences	军事科学院
Artificial intelligence (AI)	人工智能
Association of Chinese Scientists and Engineers in Japan	在日中国科学技术者联盟
Central Military Commission (CMC)	中央军事委员会
Central Science and Technology Commission	中央科技委员会
China Association for International Exchange of Personnel	中国国际人才交流协会
China Electronics Technology Group Corporation (CETC)	中国电子科技集团公司
China Information Technology Security Evaluation Center	中国信息安全测评中心
China Institute of Contemporary International Relations	中国现代国际关系研究所
China Institute for International and Strategic Studies	中国国际战略学会
China International Talent Exchange Foundation	中国国际人才交流基金会
China International Culture Exchange Center	中国国际文化交流中心
China National Defence Science and Technology Information Society	中国国防科学技术信息学会
China Society for Scientific and Technical Information	中国科学技术情报学会
Chinese Academy of Engineering (CAE)	中国工程院
Chinese Academy of Sciences (CAS)	中国科学院
Chinese Association for Science and Technology (CAST)	中国科学技术协会
Chinese Communist Party (CCP)	中国共产党
Chinese People's Political Consultative Conference (CPPCC)	中国人民政治协商会议
Chunhui Plan	春晖计划
Civil-Military Integration (CMI)	军民结合
Defence Key Discipline Laboratory	国防重点学科实验室
Defence S&T Key Laboratory	国防科技重点实验室
Federation of Chinese Professional Associations in Europe	全欧华人专业协会联合会
Haizhi Plan	海智计划
Hikvision	海康威视
Hi-Tech Industry Development Zone	高新技术产业开发区
Hundred Talents Plan	百人计划

Innovation-Driven Development Strategy	国家创新驱动发展战略
Institute of Scientific and Technical Information of China	中国科学技术信息研究所
Introduction, digestion, absorption, and re-innovation (IDAR)	引进消化吸收再创新
Medium- and Long-Term Program for Science and Technology Development	中长期科学和技术发展规划纲要
Military-Civil Fusion (MCF)	军民融合
Military Science Information Research Centre	军事科学信息研究中心
Ministry of Commerce	商务部
Ministry of Education (MOE)	教育部
Ministry of Finance	财政部
Ministry of Foreign Affairs	外交部
Ministry of Human Resources and Social Security (MOHRSS)	人力资源社会保障部
Ministry of Industry and Information Technology (MIIT)	工业和信息化部
Ministry of Public Security	公安部
Ministry of Science and Technology (MOST)	科学技术部
Ministry of State Security (MSS)	国家安全部
National Defence Science, Technology and Industry MCF Industrial Investment Fund	国家国防科技工业军民融合产业投资基金
National Development and Reform Commission (NDRC)	国家发展和改革委员会
National Engineering Research Centre	国家工程研究中心
National Fund for Technology Transfer and Commercialization	国家科技成果转化引导基金
National Integrated Circuit Industry Investment Fund	国家集成电路产业投资基金
National Key R&D Program	国家重点研发计划
National MCF Industry Investment Fund	国家军民融合产业投资基金
National University of Defence Technology (NUDT)	中国人民解放军国防科学技术大学
Overseas Chinese Affairs Office (OCAO)	国务院侨务办公室
People's Bank of China	中国人民银行
People's Liberation Army (PLA)	人民解放军
People's Republic of China	中国人民共和国
People's Liberation Army Cyberspace Force	人民解放军网络空间部队
People's Liberation Army Strategic Support Force	人民解放军战略支援部队
Qiming Plan	启明计划

Research and development (R&D)	研究开发
Science and technology (S&T)	科学技术
Semiconductor Manufacturing International Corporation	中芯国际
Seven Sons of National Defence	国防七子
Seven Sons of the Arms Industry	兵工七子
Social Investigation Bureau	社会调查局
State Administration of Foreign Experts Affairs (SAFEA)	国家外国专家局
State Administration of Science, Technology, and Industry for National Defence (SASTIND)	国家国防科技工业局
State Key Laboratory	国家重点实验室
State-owned Assets Supervision and Administration Commission (SASAC)	国务院国有资产监督管委员会
Technology-transfer centre	技术转移中心
Thousand Talents Plan	千人计划
United Front Work Department (UFWD)	统一战线工作部
University of Electronic Science and Technology of China (UESTC)	电子科技大学
Xidian University	西安电子科技大学
Zhigong Party	中国致公党

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1 Introduction

Technology transfer is a daily phenomenon across the spheres of government, academia, and enterprise in all parts of the world. It takes place both within and outside the boundaries of the law. For instance, companies have their proprietary production technologies accessed by others both through paid licenses, company acquisitions, and cyberespionage. Similarly, valuable technology research is shared through both open conferences, joint research, targeted personnel recruitment, and breaches of non-disclosure agreements. Both legal and illegal technology transfers are initiated for various purposes: states seek to modernise domestic industries, companies aim to enhance productivity and competitiveness, and academic institutions strive to advance their research boundaries.

China is an interesting case of a country with a sophisticated state-led foreign technology transfer ecosystem that involves actors from across government, academia, and enterprise. This ecosystem has been deliberately developed through top-down state policies implemented by the Chinese Communist Party (CCP) over several decades. It is also closely tied to China's great-power ambitions and its official strategy for promoting synergies between its civilian and defence industries, Military-Civil Fusion (MCF; see Section 2.1.1).

China's state-led efforts to acquire foreign technologies to help economic advancement and military modernisation are not unique from an international or historical perspective. Nevertheless, China's modern history in this regard can be traced back to at least the 1800s, beginning with its defeat in the Opium Wars and later conflicts with Japan. Since the establishment of the People's Republic of China in 1949, the acquisition of foreign technology has continued to serve as a tool for the party-state to modernise domestic industry and the military. For instance, during the early period of the Cold War, until the Sino-Soviet split, the Soviet Union served as an important source of technology transfer. After the Cultural Revolution (1966–76), China under Deng Xiaoping started making renewed efforts to acquire technology from abroad. Efforts to promote studies overseas and research collaboration with foreign partners took off in the late 1970s, while diaspora networks emerged in the late 1980s, and programmes to recruit foreign talents were established in the 1990s. The 1990s and early 2000s also marked the beginning of institutionalised and widespread commercialisation of technology acquired from abroad through different commercialisation facilities. The toolbox for technology transfer, through legal, illegal, and grey-zone means, has continued to expand during the 21st century.[1]

[1] William C. Hannas and Huey-Meei Chang, "Chinese technology transfer—An introduction," in *China's Quest for Foreign Technology: Beyond Espionage*, ed. William C. Hannas and Didi Kirsten Tatlow (Routledge, 2021), 4–6. Mao's designated successor, Hua Guofeng, was also involved in promoting

Considering the combination of the extensive reach and ambitions of its party-state apparatus, the size of its economy and population, and the close ties between its civilian and defence industries and academic spheres, all of which are under broad formal and informal state control, modern-day China is not just one country among others when it comes to acquiring foreign technologies in service of state goals. China has in many ways come far in its domestic innovation capabilities, but in a number of areas it is still reliant on foreign technology. Not only are industrial advancement and military modernisation closely interlinked in China, its ecosystem for foreign technology transfer is also characterised by a mix of transparent and non-transparent actors and behaviour. The extremes abound: there are both legitimate actors and front organisations, clearly stated ambitions and obfuscation of defence ties. This dualism cuts across all different spheres of the ecosystem, including actors from both government, academia, and enterprise, examples of which are provided throughout this report.

China's technology transfer efforts have implications for Sweden and the EU, which have far-reaching commercial and academic ties to China. Sweden and the EU also maintain close ties to the US, which is currently embroiled in both geopolitical and geoeconomic rivalry with China. Semiconductor technology, as a major dual-use technology area, lies at the heart of this rivalry, both due to its contributions to military capability, especially in defence electronics and AI, and due to its importance for broader industrial and economic rivalry.

Despite the establishment of a diverse and sophisticated system for foreign technology transfer over decades, China is often treated as a monolithic entity. Outside the narrow community of China analysts with a special interest in the country's science and technology (S&T) development, sufficient understanding of the actors involved in its attempts to transfer foreign technology appears scarce. It seems to be an insufficiently studied topic, especially in a European context. Among European government, academic, and company personnel, a better grasp of the makeup of China's technology-transfer ecosystem would contribute to better preconditions for both economic security and fruitful interaction with China.

1.1 Purpose and research question

The purpose of this report is to map China's technology-transfer ecosystem. Scattered information, including thorough descriptions of the actors involved, the roles they play, and the means they employ, is pieced together to produce a comprehensive overview of the ecosystem. A special focus on the semiconductor industry is maintained, providing a prominent example of a dual-use industry that

renewed efforts for foreign technology acquisition at the end of and after the Cultural Revolution, including by resuscitating the open-source intelligence system, see Peter Mattis and Matthew Brazil, *Chinese Communist Espionage: An Intelligence Primer* (Annapolis, Maryland: Naval Institute Press, 2019), 72.

is at the core of China's ambitions to modernise its industry and military in parallel.

This study addresses the following research question:

1. Which actors are involved in China's foreign technology-transfer ecosystem, what roles do they play, and what are some examples of their activities related to the transfer of semiconductor technology?

A case study serves to illustrate the broader conclusions through a deep study of a specific actor, the defence-industry conglomerate, China Electronics Technology Group Corporation (CETC). As the arguably most significant actor within the Chinese defence-electronics sector, CETC symbolises both the intersection between China's industrial and military ambitions in general and the dual-use semiconductor industry in particular.

After addressing the research question, the report's content is discussed in the context of contemporary geopolitical developments, characterised by US-China great-power rivalry, the increasing geopoliticisation of the semiconductor industry, and Western economic-security initiatives. The implications for China's technology-transfer ecosystem and its efforts to acquire foreign technology are also explored.

1.2 Delimitations and definitions

Technology is here interpreted in a broad sense and used as an umbrella term for both tangible and intangible technology, including physical technological goods and technological expertise and know-how, as well as patents and other intellectual property. The purpose of this report is not to provide an exhaustive list of examples of technology-transfer attempts nor a quantitative assessment of the most common or efficient means used by each involved actor. It is important to note that far from all Chinese attempts to acquire foreign technology are successful. The intent here is rather to illustrate the pluralistic toolbox available for China's technology-transfer efforts. This is where another central concept, namely *ecosystem*, comes in. *China's technology-transfer ecosystem* refers to the variety of actors from different spheres within the Chinese system who engage in joint efforts, often state-led or supported, to acquire and utilise foreign technologies for the sake of the domestic industry. The CCP is ultimately in charge of this ecosystem, even though this does not preclude that the involved actors can exercise a degree of leeway for individual agency and self-serving or contradictory interests.

The intention in this study is to provide a representative and up-to-date overview of the ecosystem and to highlight key roles played by each actor. However, the interorganisational dependencies and interactions, as well as the roles played by each of the actors should not be considered exhaustive.

The study applies a special focus on semiconductor- and dual-use technology transfer, and semiconductor-based defence electronics.[2] To some extent, this also involves adjacent technology areas, notably artificial intelligence (AI), another major area of dual-use applications for semiconductor-based hardware. *Defence electronics* is a broad category of semiconductor-dependent military applications that includes, for example, systems for navigation, surveillance, detection, guidance, electronic warfare, and communication. Some specific and well-known military applications include radars, sonars, sensors, satellites, night-vision equipment, and autonomous vehicles. The military use of semiconductor technology is broad, however, as it lays the foundation for many dual-use electronics and IT applications, such as battery management and data processing. The delimitation towards semiconductor technology and its defence-related applications serves to narrow the scope of the report but is also relevant due to the significance of the semiconductor industry to contemporary geopolitical competition.

Lastly, it is difficult to disentangle the topics of technology transfer and semiconductor technology, the main research focusses of this report, from the concept of Military-Civil Fusion (MCF), China's official strategy to promote industrial synergy between its civilian and defence sectors. These three topics are interdependent components of China's broader strategic ambitions. However, MCF is addressed in detail only where it is deemed especially relevant.

1.3 Method and sources

The methodology for this report is qualitative and explorative, based on a bottom-up scientific approach. To use an analogy, the pieces of the puzzle have been examined one at a time, put into clusters, and gradually assembled into a somewhat complete picture. To map key actors involved in China's technology transfer ecosystem, the author conducted a literature review of both academic and "grey" literature, such as think-tank reports, news articles, and websites, on China and foreign-technology transfer. This includes monographies on, for instance, the defence industry, espionage, innovation, economic statecraft, and AI. Most of the referenced material is in English and from non-Chinese organisations. Chinese-language material has also been used to some degree, mostly derived from Chinese governmental, corporate, or academic websites.

Among the sources, a few monographies stand out for their importance to this report. Two of these are *China's Quest for Foreign Technologies: Beyond Espionage* and *Chinese Power and Artificial Intelligence: Perspectives and Challenges*, published in 2021 and 2023, respectively.[3] Many or most of the editors and

[2] "Microelectronics" is perhaps more accurate for describing integrated circuits and other tiny electronic devices made from semiconductor materials, but "semiconductors" is often used as a popular term. This is also the case in this report.

[3] Hannas and Tatlow, ed., *China's Quest* (see note 1); William C. Hannas and Huey-Meei Chang, ed.,

contributors to these two anthologies are affiliated with the US-based Center for Security and Emerging Technology and the Australian Strategic Policy Institute.

In addition to the anthologies, publications from both of these think tanks have provided much inspiration and data for this report. This includes inspiration for a loose framework on different means of technology transfer, illustrated in Table 1 below. It lists a number of different means included in China's technology-transfer toolbox, categorised by legality, type of target, and whether the means are employed within China's borders or abroad. Though the main focus of the report is actors, not means, the relevant actors and the roles they play are primarily identifiable through their actions. This motivates the use of the framework, which has been helpful for data-collection purposes when scouring the available physical literature and online content for information on the research topic.

Table 1. Different means used by China for technology transfer

	Legal	**Illegal**	**Grey-zone**[4]
Means	• *Overseas professional associations (O)* • *Start-up competitions (I, O)* • *Technology purchase and exchange (I, O)* • *Foreign-company acquisitions (I, O)* • *Venture-capital investments in foreign start-ups (I, O)* • *Regulations for foreign investments in China (I)* • **Studies at foreign universities (O)** • **Overseas academic associations (O)** • **Investments in foreign research (O)** • Talent recruitment (I, O) • Open-source information-gathering (e.g., academic journals, patent mining) (I, O) • Conferences (I, O) • Joint research agreements (I, O) • Joint research labs (I, O)	• *Export-control circumvention (O)* • *Reverse engineering (I, O)* • *Industrial espionage (e.g., insider operations) (I, O)* • Breach of contract, violation of NDAs (I, O) • Cyberespionage (e.g., computer-network exploitation) (I, O) • Patent/copyright infringement (I, O)	• Incentive programs for technology transfer (I, O) • Commercialisation facilities (e.g., technology-transfer centres) (I) • University-linked "innovation parks" (I) • Front organisations (I, O) • Non-transparent involvement by ministerial bureaus at different administrative levels (I), or by Chinese embassies (O)

Source: Hannas and Chang, "Chinese technology transfer," in *China's Quest* (see note 1), 7; author's adaptation and elaboration. Note: "I" and "O" indicate whether the means are employed inside (I) or outside (O) China's borders, or both. The text in *italics* indicates that commercial actors are the targets of technology transfer; **bold text** relates to academic targets while regular text refers to both.

Chinese Power and Artificial Intelligence: Perspectives and Challenges (Routledge, 2023).

[4] The means listed in this column, many of which are *prima facie* legal, are "grey-zone" in the sense that their purpose and implementation are characterised by non-transparency and/or the incentivisation of illegal technology transfer.

When mapping the key actors and their interactions, it is also helpful to have a framework to distinguish between different roles within the technology-transfer ecosystem. Luckily, in China, there is an official process, or strategy, dating back to the 1990s, for utilising foreign technologies for domestic, often defence industry, innovative purposes. Tai Ming Cheung, a California-based China scholar, has described this process in his monograph, *Innovate to Dominate: The Rise of the Chinese Techno-Security State*, published in 2022, as well as in previous work with colleagues. The process entails cooperation between the Chinese government, academic institutions, and industry. It can be divided into three steps, namely *introduction*, *digestion*, and *absorption*, with the end-result referred to as *reinnovation* (IDAR).[5]

The IDAR process *introduces* foreign technologies to China as a first step, for example, through imports, foreign direct investment, talent recruitment, open-source intelligence gathering, or other means listed in Table 1 above. This part of the process involves many different actors, depending on the specific means in question. Second, the Chinese system *digests*, that is, analyses and disseminates the technologies. Government actors and academic institutions, such as research institutes and laboratories (see Section 2.4.2) within both government agencies, universities, and defence companies, are involved at this stage. The PLA also plays a significant role, especially for military-grade intelligence. Third, the foreign technologies that have been introduced and digested need to be *absorbed* through the development of domestic products that combine foreign and domestic technology. This part of the process is output-orientated. The means involved are both legal, such as international joint ventures, and illegal, such as illicit imports or unauthorised reverse engineering. Commercialisation facilities, such as technology-transfer centres (see Section 2.2.2), or engineering-focused laboratories and research centres (see Section 2.2.5), housed by both commercial and academic entities, provide the necessary physical infrastructure for absorption. Staffing these commercialisation facilities with foreign talent who possess the adequate technical expertise is an important component (see Section 2.5.1). The intended result of the three steps in the IDAR process is *reinnovation*, that is, a domestic product whose utility goes beyond that of the acquired technology.[6]

The purpose of the IDAR process is to achieve so-called "creative adaptation" or "advanced imitation," that is, foreign technology that has been significantly improved upon, as opposed to more primitive imitation.[7] In a broader sense, the strategic, long-term goal for China is to become technologically self-sufficient and

[5] Tai Ming Cheung, *Innovate to Dominate: The Rise of the Chinese Techno-Security State* (Ithaca; London: Cornell University Press, 2022); Tai Ming Cheung, William Lucyshyn, and John Rigilano, *The Role of Technology Transfers in China's Defense Technological and Industrial Development and the Implications for the United States* (Monterey, California: Naval Postgraduate School, 2019), https://dair.nps.edu/bitstream/123456789/2756/1/UCSD-AM-19-028.pdf, 14.
[6] Cheung et al., *The Role of Technology Transfers*, 25–32.
[7] Cheung, *Innovate to Dominate*, 225.

self-reliant. In other words, China's ambitions for its indigenous innovation capabilities and its acquisition of foreign technology go hand in hand and do not just exist in parallel.

Furthermore, this report describes a number of organisations, not least government departments, which create plans, provide funding, and otherwise incentivise actions contributory to technology transfer, including through direct or indirect supervision of subordinate entities. A step preceding *introduction*, namely *enabling*, in the IDAR process has been added by the author to account for the role played by such entities. This results in four different, but partially overlapping, steps and roles: *enabling*, *introduction*, *digestion*, and *absorption*. This categorisation allows for differentiation between the different roles played by the various actors involved in China's technology-transfer ecosystem, as detailed throughout this report. An attempt is made in Chapters 2 and 3 to illustrate how the different actors involved in China's technology-transfer ecosystem interact and the roles played by each actor.

1.4 Structure of the report

Chapter 2 maps China's technology-transfer ecosystem, by describing key actors, their respective roles, and examples of the means they employ to acquire foreign technology. The chapter especially highlights semiconductor technology. Chapter 3 examines the case study of the defence-industry conglomerate, China Electronics Technology Group Corporation. Lastly, Chapter 4 presents the conclusions of the report and discusses the implications of increased geopoliticisation of the semiconductor industry for China's technology transfer ecosystem.

2 China's technology-transfer ecosystem

This chapter describes key actors in China's foreign technology-transfer ecosystem. Figure 1, below, summarises how the different categories of actors in China's ecosystem for technology transfer interact and their respective roles, based on the examples provided throughout the report.

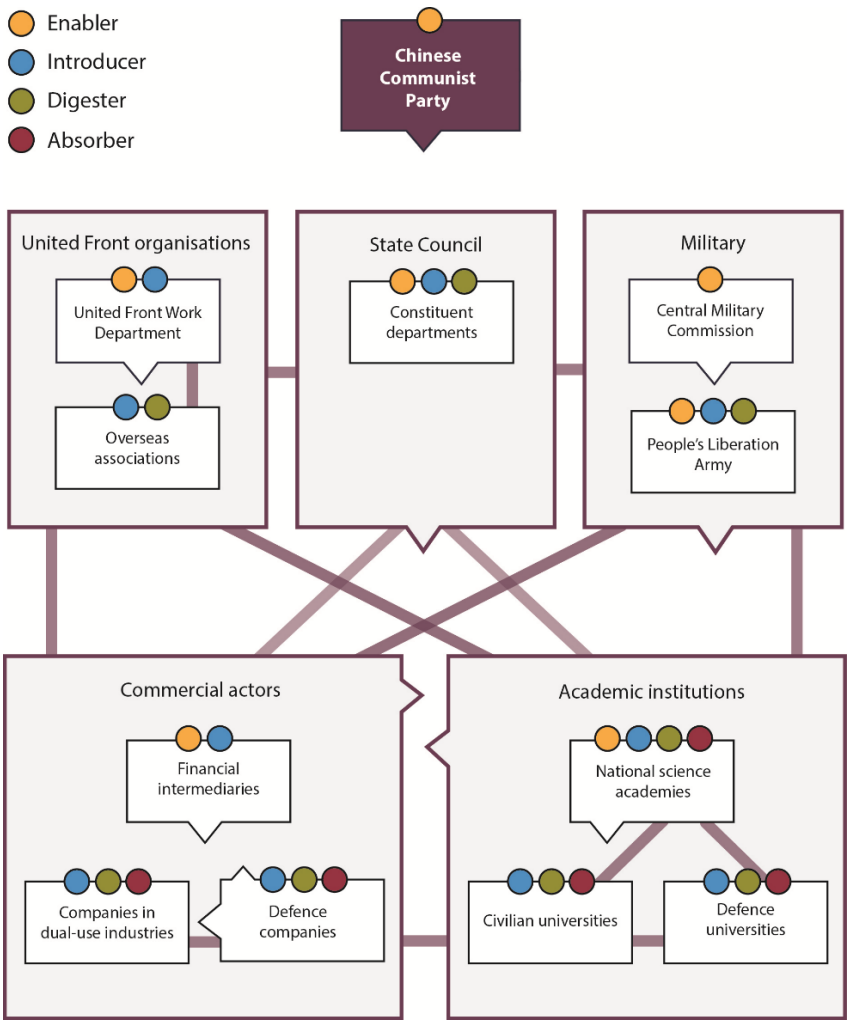

Figure 1. China's technology-transfer ecosystem

Note: The protruding arrowheads indicate control, whether hierarchical or financial, whereas solid lines indicate some kind of collaborative relationship.

China's collaborative technology-transfer efforts are a complex web of interaction between diverse actors. The CCP is the most high-ranking *enabler* within the ecosystem. Interaction between actors within the ecosystem takes the form of either control or collaboration, or both. For instance, the State Council both controls and collaborates with commercial actors through its different constituent departments. Moreover, the separation of tasks is not clear-cut, as many actors employ similar means, take on similar roles, and engage in joint efforts.

A prominent example is that of talent-recruitment programmes (see Section 2.5.1). Several ministries and national science academies under the State Council, as well as United Front organisations and overseas Chinese or Sino-foreign professional and academic associations, either *enable* or actively contribute to *introducing* foreign talent and technology to China through these programmes. Universities and companies also engage in the *introduction* of foreign talent, while simultaneously being among the primary beneficiaries, or *absorbers*. Another example is the diversity of commercial, academic, and governmental entities that host or supervise laboratories and research centres tied to both defence research and technology transfer (see Sections 2.2.5 and 2.4.2). These laboratories and research centres are major contributors to both *digestion* and *absorption* of foreign technologies within the MCF system.

It can also be difficult to separate commercial from academic actors. For example, there are defence-industry conglomerates that engage in collaborative research with foreign universities (see Section 3.2) and academic institutions with investment companies that are involved in Sino-foreign commercial joint ventures (see Section 2.4.3).

Some categories of actors represent several different roles simultaneously, as illustrated in Figure 1. However, a more granular illustration would also reveal internal differences, as some actors have a more prominent role in one stage of the technology-transfer process than others. For instance, the State Council's constituent departments and their different subdepartments represent both actors primarily engaged in *enabling* foreign technology transfer and those who play a more active role in *introducing* foreign technology to China.

2.1 The Chinese Communist Party

The CCP and its different suborgans, in terms of Central Committee departments, commissions, and leading small groups, are in ultimate charge of China's technology-transfer ecosystem. The Central Organisation Department is of overall importance, as it secures the CCP's hold over the party-state, including all categories of actors described in this report, through personnel appointments of party members.

Some CCP organs with special roles in China's technology-transfer ecosystem are the Central Military Commission (CMC), which governs the People's Liberation Army (PLA, see Section 2.3) and the United Front Work Department (see Section

2.5.1). CCP is also superordinate to the State Council and its constituent departments (see Section 2.2).

There is also the newly formed Central Science and Technology Commission. Since its founding in March 2023, it has ensured centralised party influence over China's S&T development and acts as the system's highest guiding body in this regard.[8]

2.1.1 Military-Civil Fusion

Several generations of prominent CCP leaders have encouraged the parallel modernisation of China's economy and its military. Long known as Civil-Military Integration (CMI), the concept is now better known as Military-Civil Fusion (MCF).[9] One can view MCF as an ambitious and far-reaching form of the broader concept of CMI. Under Deng Xiaoping, the emphasis was on the defence industry's contribution toward civilian production. A shifting focus over the years has meant that today, under Xi Jinping, the question is rather how innovation within the civilian industries can benefit defence production and the PLA.[10] Moreover, the degree of formal and informal state control over China's private sector is high, and Chinese industry should in general be considered to serve party-state interests when necessary.

MCF, or the promotion of synergies between civilian and defence industries, is a built-in feature of China's long-term strategies and plans for industrial development, science and technology (S&T), and innovation. The overarching strategy for these different focus areas is the Innovation-Driven Development Strategy, adopted in 2016. This umbrella strategy encompasses other prominent strategies, such as the Medium- and Long-Term Programme for Science and Technology Development, which is associated with the aforementioned IDAR process for foreign-technology transfer. Other examples include Made in China 2025 and the Science, Technology and Innovation 2030 Major Projects. Even though these are not defence strategies per se, they focus on a number of industries or technology areas with dual-use characteristics, including, for example, semiconductor and information technology, machinery, and aerospace.[11]

Acquiring foreign technologies is a crucial component of supporting MCF efforts. Much of these efforts are legal and openly stated, for example, in the plans listed above or in innovation and development programmes related to Five-Year Plans.[12]

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[8] Charles Mok, "The Party Rules: China's New Central Science and Technology Commission," *Diplomat*, August 23, 2023, https://thediplomat.com/2023/08/the-party-rules-chinas-new-central-science-and-technology-commission/.

[9] James Mulvenon and Chenny Zhang, "Targeting defense technologies," in *China's Quest* (see note 1), 94–6. Another Chinese name for CMI is 军民一体化.

[10] Cheung, *Innovate to Dominate*, 84–5.

[11] Cheung, *Innovate to Dominate*, 35–6, 239.

[12] 国务院关于印发"十三五"国家战略性新兴产业发展规划的通知, 国务院 ["State Council Notice on

There are also specific strategies put in place under the overarching Innovation-Driven Development Strategy to promote MCF and better leverage foreign technologies, together with the formation of committees and other organisational infrastructure, some of which include Xi Jinping himself. Furthermore, there are defence-specific strategies and Five-Year Plans, which also target dual-use technologies such as semiconductors, which exist in parallel to several of the major industrial and S&T policy programmes.[13] Actors across government, academia, and enterprise are all tasked with different technology-transfer responsibilities tied to China's S&T policy programmes and MCF ambitions.

2.2 The State Council

The National People's Congress, under the CCP's rule, delegates implementation of its policy decisions to the State Council, the country's national cabinet. It is comprised of 26 different departments, with several tasked with acquiring and disseminating foreign technologies.

2.2.1 The Ministry of Science and Technology

The Ministry of Science and Technology (MOST) develops and oversees some of the major plans for S&T development, including the National Key R&D Programme. The National Key R&D Programme is a high-level plan that integrates other national research and development (R&D) plans, such as the 863 Programme.[14] The 863 Programme was established in 1986 to guide joint civilian-military R&D and is, as such, important for Military-Civil Fusion (MCF).[15]

MOST also houses several departments and organisations with technology-transfer functions, including the Department of International Cooperation.[16] MOST has officials dispatched to Chinese embassies and consulates abroad, tasked with utilising foreign technology to further China's S&T goals.[17] MOST also hosts one of the foremost Chinese organisations for open-source S&T intelligence, the

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the Publication of the 13th Five-Year Plan National Strategic and Emerging Industries Development Program," State Council], November 29, 2016, https://www.gov.cn/zhengce/content/2016-12/19/content_5150090.htm.

[13] For an excellent overview and analysis of China's strategies and organisational infrastructure tied to the MCF system, see Cheung, *Innovate to Dominate*.

[14] "国家重点研发计划启动实施" 新闻发布会: 文字摘要, 科技部. ["Press Conference for 'Launch of National Key R&D Plan': Text Summary," MOST], February 16, 2016, https://www.most.gov.cn/xwzx/twzb/gjzdyfjh/twzbwzzy/201602/t20160216_124128.html.

[15] Sarah Kirchberger and Johannes Mohr, "China's defence industry," in *The Economics of the Global Defence Industry*, ed. Keith Hartley and Jean Belin (Routledge, 2020), 49–50.

[16] 组织机构, 科技部 ["Organisational Structure," MOST], accessed April 23, 2024, https://www.most.gov.cn/zzjg/index.html#z2; Hannas and Chang, "China's 'artificial' intelligence," 191.

[17] William C. Hannas, James Mulvenon, and Anna B. Puglisi, *Chinese Industrial Espionage: Technology acquisition and military modernization* (Routledge, 2013), 83.

Institute of Scientific and Technical Information of China. This institute not only collects information on foreign technology, but also analyses and disseminates it to relevant actors in China's technology-transfer ecosystem.[18]

MOST is also associated with being the State Council's chief organ for providing guidance on the establishment of industrial parks, in turn often managed by provincial and municipal authorities across China. These industrial parks are sometimes referred to as Hi-Tech Industry Development Zones and are put in place to promote local value-chain synergies.[19] These are attractive to foreign companies while providing China's high-tech industries new opportunities to obtain direct access to foreign technologies. They are also popular venues for start-up competitions, often initiated by MOST or other governmental entities, such as the Ministry for Industry and Information Technology (see Section 2.2.3) or the Ministry of Education (see Section 2.2.4). Start-up competitions, for instance, under the banner of "innovation and entrepreneurship," task local governments across the country to initiate campaigns to attract foreign companies to bring their business ideas to life in local industrial parks. Some of these competitions have also been held abroad, for example, in Silicon Valley.[20]

Finally, MOST is involved in establishing and overseeing commercialisation facilities for foreign technology, such as technology-transfer centres. Technology-transfer centres are set up with the explicit purpose of converting technologies, including foreign ones, into tangible goods and involve engagement by both academic and commercial actors in China. Technology-transfer centres and other commercialisation facilities are commonly found within industrial parks and at universities.[21]

[18] William C. Hannas and Huey-Meei Chang, *China's STI Operations: Monitoring Foreign Science and Technology Through Open Sources* (Center for Security and Emerging Technology, 2021), https://cset.georgetown.edu/wp-content/uploads/CSET-Chinas-STI-Operations.pdf, 19–23.

[19] 高新技术产业开发区, 科技部 ["Hi-Tech Industry Development Zones," MOST], accessed August 1, 2024, https://www.most.gov.cn/zxgz/gxjscykfq/index.html.

[20] Hannas and Chang, "China's 'artificial intelligence," 197–8.

[21] Hannas et al., *Chinese Industrial Espionage,* 93, 175. There are many different names for commercialisation facilities, including not only technology-transfer centres but also, for instance, "innovation service centres" (创业服务中心), and "overseas Chinese scholars pioneering parks" (海外学子创业园).

Focus on Semiconductor Technology

One of the subprogrammes of the 863 Programme is information technology, which includes semiconductor technology such as, for instance, optoelectronics.[22] The 863 Programme has also been associated with incentivising illicit foreign technology transfer. Over the past couple of decades, the 863 Programme has been identified as a beneficiary in both successful and failed attempts to illegally export semiconductor technology and defence electronics to China.[23]

Many industrial parks in China are home to semiconductor companies. For example, according to a Shaanxi government website, since its founding in 1991, a Xi'an industrial park has welcomed foreign investors representing a total of 939 companies, of which 90% belong to high-tech industries. Among these are many significant semiconductor and electronics companies, such as Applied Materials, Micron, and Intel from the US; Infineon from Germany; and NEC and Fujitsu from Japan. Naturally, Chinese companies have also been present, including Huawei, ZTE, and AVIC, one of the largest state-owned defence companies. Focussing over the years on both R&D and manufacturing, not least in semiconductors and electronics, the zone has brought about many thousands of patents and copyrights, while receiving plenty of government funding.[24]

2.2.2 The Ministry of Human Resources and Social Security

The Ministry of Human Resources and Social Security (MOHRSS) is also at the forefront of the technology-transfer ecosystem. It can be described as China's primary human resources department for foreign expertise, not least as it plays a major role in managing and funding talent-recruitment programmes (see Section 2.5.1).

Among its subentities, MOHRSS hosts the State Administration of Foreign Experts Affairs (SAFEA).[25] SAFEA in turn supervises several front organisations involved in recruiting foreign experts, such as the China Association for International Exchange of Personnel and the China International Talent Exchange Foundation.[26] The China Association for International Exchange of Personnel has local branches overseas that recruit foreign experts to work in China.[27] SAFEA

[22] Sarah Kirchberger and Johannes Mohr, "China's defence industry," in *The Economics of the Global Defence Industry*, ed. Keith Hartley and Jean Belin (Routledge, 2020), 49–50.

[23] Mattis and Brazil, *Chinese Communist Espionage*, 147–91.

[24] 西安高新技术产业开发区，陕西省地方志办公室 ["Xi'an Hi-Tech Industry Development Zone," Shaanxi Province Local Chronicles Office], accessed April 24, 2024, http://dfz.shaanxi.gov.cn/sqzlk/dqcs/dacswz/xas_16198/xatzlsns/201610/t20161028_807656.html.

[25] Hannas and Chang, "China's 'artificial intelligence," 191. SAFEA used to be China's most high-ranked administrative authority for foreign technology transfer, as its own government agency under the State Council. Following organisational reforms in the State Council, SAFEA was absorbed by MOST in 2018, and later on, in 2023, by MOHRSS, see 人力资源社会保障部举行加挂国家外国专家局牌子仪式, 人社部 ["The Ministry of Human Resources and Social Security held a ceremony for the addition of the State Administration of Foreign Experts Affairs," MOHRSS], August 1, 2023, http://www.mohrss.gov.cn/SYrlzyhshbzb/dongtaixinwen/buneiyaowen/hyhd/202309/t20230901_505569.html.

[26] Mattis and Brazil, *Chinese Communist Espionage*, 179. Another English name for the China Association for International Exchange of Personnel is the China International Talent Exchange Association.

[27] Didi Kirsten Tatlow, Hinnerk Feldwisch-Drentrup, and Ryan Fedasiuk, "Technology transfer from

was previously under the Ministry of Science and Technology, which continues to host the China Association for International Exchange of Personnel. Meanwhile, the China International Talent Exchange Foundation now also belongs to MOHRSS.[28] This would suggest that SAFEA's technology-transfer activities transect ministerial boundaries.

2.2.3 The Ministry of Industry and Information Technology

The Ministry of Industry and Information Technology (MIIT) has a managerial role in the MCF system and has a department dedicated to providing guidance on dual-use technology transfer, the Civil-Military Integration Promotion Department.[29]

Importantly, MIIT hosts the State Administration of Science, Technology, and Industry for National Defence (SASTIND). Among other things, SASTIND manages a number of universities and laboratories with close defence industry and military ties that also participate in technology-transfer efforts, including the so-called Seven Sons universities (see Section 2.3.1).[30] The defence industry's primary mediator for "technical targeting requirements," or requests for the acquisition of foreign technologies, is likely to be SASTIND.[31]

Focus on Semiconductor Technology

MIIT is in many ways the organisational incarnation of the ties between China's state ambitions for technology transfer, MCF, and the semiconductor industry. Besides the functions described above, MIIT is in charge of the development of several of the technology areas targeted by the Medium- and Long-Term Programme for Science and Technology Development, including semiconductors and electronics.[32] The MIIT is also in charge of the Qiming Plan, which is the latest iteration of the famous talent-recruitment plan, the Thousand Talents Plan, previously jointly run by a number of different ministries. The Qiming Plan is being implemented in light of the current US-China tech rivalry and focusses on "sensitive" areas such as semiconductor technology.[33]

Germany," in *China's Quest* (see note 1), 134–5.

[28] 基金会介绍, 中国国际人才交流基金会 ["Foundation Introduction," China International Talent Exchange Foundation], accessed April 23, 2024, https://www.citef.org.cn/CITEF/LEAP/citef/html/citef_authenty.html#0; 中心简介, 中国国际人才交流中心 ["Brief Centre Introduction," China International Talents Exchange Centre], accessed April 23, 2024, http://caiep.most.cn/portal/sub/1.

[29] Mulvenon and Zhang, "Targeting defense technologies," 96–7.

[30] James Mulvenon, "Espionage and trace secret theft cases," in *China's Quest* (see note 1), 303–4.

[31] Cheung, *Innovate to Dominate*, 219.

[32] Cheung, *Innovate to Dominate*, 206.

[33] Julie Zhu, Fanny Potkin, Eduardo Baptista, and Michael Martina, "Insight: China quietly recruits overseas chip talent as US tightens curbs," *Reuters*, August 24, 2023, https://www.reuters.com/technology/china-quietly-recruits-overseas-chip-talent-us-tightens-curbs-2023-08-24/.

2.2.4 The Ministry of Education

The Ministry of Education (MOE) is responsible for overseeing the development of China's universities and promoting domestic R&D. Among its key roles for China's technology transfer ecosystem is the promotion of overseas studies for Chinese students, directed by its International Cooperation and Exchange Department.[34] The MOE also promotes foreign technology transfer, such as foreign-talent recruitment and international academic exchange.[35] Moreover, the MOE supervises defence-related laboratories within civilian universities (see Section 2.4.2), which are of importance to both indigenous innovation, the MCF system, and technology-transfer efforts.

MOE's foreign talent-recruitment efforts overlap with its parallel role in commercial start-up competitions. Notably, MOE is in charge of the Chunhui Plan, an initiative that aims to incentivise Chinese scholars overseas to contribute to China's technological and industrial development. The start-up competition, Chunhui Cup, under the auspices of the Chunhui Plan, connects overseas Chinese with domestic academic and commercial actors to encourage start-ups in China.[36]

Focus on Semiconductor Technology

The MOE has emphasised foreign talent recruitment and international academic exchange as key strategies to address gaps in China's AI development, notably in basic research and advanced microchips.[37]

2.2.5 The National Development and Reform Commission

The National Development and Reform Commission (NDRC) is in charge of developing industrial strategies, such as the aforementioned Innovation-Driven Development Strategy, which includes foreign-technology transfer among its means of fulfilment.[38]

The NDRC also supervises National Engineering Research Centres, which contribute to turning acquired foreign technology into tangible output, thus acting as an important bridge between research organisations and industry. The majority of these research centres concentrate on civilian technologies, although there are instances of dual-use or defence-industry affiliation (see Chapter 3). Moreover, the NDRC is one of the most high-ranking government organs within the MCF system. In this context, it has close cooperation with the Central Military Commission, the PLA's supervisory organ.[39]

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[34] Hannas et al., *Chinese Industrial Espionage*, 86.
[35] Huey-Meei Chang and William C. Hannas, "Foreign support," in *Chinese Power* (see note 9), 41.
[36] Andrew Spear, "Serve the motherland while working overseas," in *China's Quest* (see note 1), 29.
[37] Chang and Hannas, "Foreign support," 41.
[38] Ngor Luong and Ryan Fedasiuk, "State plans, research, and funding," in *Chinese Power* (see note 9), 6.
[39] Cheung, *Innovate to Dominate*, 105, 222.

2.2.6 The Ministry of State Security

The Ministry of State Security (MSS) spearheads China's security and foreign intelligence apparatus. It is represented at all administrative levels, including national headquarters and provincial, municipal, and county bureaus.[40] The national headquarters in Beijing is believed to consist of 18 different bureaus, several of which are involved in acquiring foreign technology, often through front organisations. The 11th Bureau of the MSS supervises the China Institute of Contemporary International Relations, a think tank engaged in international academic exchange. The 12th Bureau, also known as the Social Investigation Bureau or by its cover name as the China International Culture Exchange Centre, coordinates MSS interaction with the United Front, which is the CCP's strategy to spread the party's influence at home and overseas in all spheres of society.[41] The 12th Bureau "is the MSS's custom-made organ for meeting, covertly influencing and recruiting elites from around the world" and manages a number of different front organisations abroad, for instance, publishing houses, think tanks, university alumni associations, and international conferences. Needless to say, front-organisation involvement implies economic espionage rather than regular intellectual exchange.[42]

The 13th bureau, also known as the China Information Technology Security Evaluation Centre, is the ministry's main body for cyberespionage.[43] Industrial trade theft through cyberespionage was previously associated with the PLA and its Unit 61398, but, in later years, the MSS seems to be leading these illegal technology transfer efforts. It does this by supervising a decentralised network of hackers, which includes both front companies and universities.[44]

The MSS's provincial bureaus, known for their specific regional foci, are responsible for conducting foreign espionage. For example, the Zhejiang provincial bureau is associated with espionage operations in Europe.[45] Aside from its different bureaus, the MSS also uses other organisations as cover in its foreign espionage efforts. The MSS is highly intertwined with all sorts of actors in China in its covert operations, including United Front associations, commercial actors, and academic institutions, such as universities.[46] Moreover, the MSS recruits not

[40] Mattis and Brazil, *Chinese Communist Espionage*, 54, 91.
[41] Mattis and Brazil, *Chinese Communist Espionage*, 56.
[42] Alex Joske, *Spies and Lies: How China's Greatest Covert Operations Fooled the World* (Melbourne; London: Hardie Grant Books, 2022), 26, 28, 33.
[43] Dakota Cary, *Academics, AI, and APTs: How Six Advanced Persistent Threat-Connected Chinese Universities are Advancing AI Research* (Center for Security and Emerging Technology, 2021), https://cset.georgetown.edu/wp-content/uploads/CSET-Academics-AI-and-APTs.pdf, 28.
[44] Nicole Perlroth, "How China Transformed Into a Prime Cyber Threat to the U.S.," *New York Times*, July 20, 2021, https://www.nytimes.com/2021/07/19/technology/china-hacking-us.html.
[45] Demetri Sevastopulo, Henry Foy, John Paul Rathbone, and Joe Leahy, "Chinese spies recruited European politician in operation to divide west," *Financial Times*, December 15, 2023, https://www.ft.com/content/601df41f-8393-46ad-9f74-fe64f8ea1a3f.
[46] Joske, *Spies and Lies*, 7.

only Chinese citizens or people with Chinese heritage for espionage purposes but also foreigners. There are documented cases of foreigners being co-opted during their stay in China. For example, a US citizen was approached by MSS officers while studying language in China, after which he received payments to return home and attempt to infiltrate US government agencies, including the CIA.[47]

Focus on Semiconductor Technology

To acquire semiconductor technology, the MSS has engaged in both traditional espionage, or human intelligence, and cyberespionage. For instance, semiconductor technology has been one of the foci of international conferences held by the China International Culture Exchange Centre and other MSS front organisations.[48] The MSS is also thought to have overseen the hacker group APT10/Red Apollo, which engaged in multisector cyberespionage, including targeting the electronics industry, worldwide in the mid-2010s.[49]

Moreover, in a case from the 1990s, an alleged MSS officer, at the time posing as a US-based Chinese businesswoman, brokered a joint venture between Canadian former telecom giant Nortel and China's State Planning Commission, now known as the National Development and Reform Commission, for the manufacture of Nortel's advanced telecom equipment, wiretapping-compliant digital switches, in Guangdong, China. Later on, during the late 1990s and early 2000s, Nortel suffered IP theft through cyberespionage by Chinese state-sponsored hackers. This served to undermine Nortel's competitiveness while coinciding with the rise of Huawei. Whether the Chinese state, or Huawei itself, intentionally acquired and utilised Nortel's IP as a way to pave the path for Huawei's success or not remains uncertain. Meanwhile, reports from China claimed that Huawei was commercialising products that were identical to Nortel's. Nortel eventually sold its telecom and semiconductor patents, divesting what remained of its business. Ironically, Huawei recruited some of its former employees.[50]

2.2.7 The Ministry of Public Security

The Ministry of Public Security, as its name implies, is in charge of law enforcement and domestic security, including counterintelligence. In the context of China's technology transfer ecosystem, its responsibilities seem minor compared to those of the MSS. However, among its various duties, the Ministry of Public Security is tasked with monitoring foreigners in China.

Focus on Semiconductor Technology

The Ministry of Public Security's monitoring of foreigners includes foreign businesses, particularly "sensitive units," such as foreign semiconductor companies possessing valuable technologies.[51]

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[47] Clive Hamilton, *Silent Invasion: China's Influence in Australia* (Hardie Grant Books, 2018), 181.
[48] Joske, *Spies and Lies*, 33.
[49] Johan Englund, *Kinas industriella cyberspionage*, FOI Memo 6698 (Swedish Defence Research Agency—FOI, 2019), https://www.foi.se/rapportsammanfattning?reportNo=FOI%20MEMO%206698, 5, 12–3.
[50] Didi Kirsten Tatlow, Greg Walton, and Anna B. Puglisi, "The impact of China's policies," in *China's Quest* (see note 1), 207–11.
[51] Mattis and Brazil, *Chinese Communist Espionage*, 40, 250.

2.2.8 Other government departments

There are other State Council departments that have a more indirect or overarching role in the technology-transfer ecosystem. For instance, the Ministry of Finance and the People's Bank of China channel funds to financial actors such as investment banks and investment funds that target specific sectors of priority, such as the semiconductor industry, for investments.[52]

There is also the Ministry of Commerce, which, together with the NDRC, regulates the Chinese economy to facilitate foreign technology transfer in line with industrial-policy goals. This includes creating and enforcing requirements for joint ventures and technology transfer for foreign investments in priority sectors, such as the semiconductor industry, and providing preferential corporate tax rates for companies that comply. The Ministry of Commerce's technology-transfer contributions also include the regulation of Chinese companies, such as steering overseas investments towards prioritised sectors.[53] The Ministries of Finance and Commerce, as well as the NDRC, were all involved in drafting the IDAR technology-transfer strategy, further exemplifying their significance to China's technology transfer ecosystem.[54]

The Ministry of Foreign Affairs is one last example of a government department relevant to China's technology-transfer ecosystem. Not only does it provide the Chinese system with input from international developments, but it is also at the head of implementing foreign policy.[55] China's foreign policy oftentimes overlaps with domestic industrial policies and contributes to technology-transfer efforts. For example, the Belt and Road Initiative, China's vast, continent-spanning infrastructure project, includes the establishment of joint laboratories abroad.[56]

2.3 The People's Liberation Army

The PLA is governed by the Central Military Commission (CMC), a CCP organ. It is among the foremost beneficiaries of the fruits of Military-Civil Fusion (MCF) and China's technology-transfer ecosystem. Moreover, the PLA has itself been involved in technology transfer. Until recently, the PLA's Strategic Support Force held the military's cyberattack, data exfiltration, and signals-intelligence functions. The Strategic Support Force was dissolved into its separate branches in April

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[52] Barry Naughton and Briana Boland, *CCP Inc.: The Reshaping of China's State Capitalist System* (Washington, DC: Center for Strategic and International Studies, 2023), https://www.csis.org/analysis/ccp-inc-reshaping-chinas-state-capitalist-system, 14.

[53] Karen M. Sutter, "Foreign technology transfer through commerce," in *China's Quest* (see note 1), 61–2, 67.

[54] Cheung, *Innovate to Dominate*, 215.

[55] James Reilly, *Orchestration: China's Economic Statecraft Across Asia and Europe* (New York, NY: Oxford University Press, 2021), 39. An exhaustive list of State Council-controlled institutions contributory to China's technology-transfer ecosystem would be even longer, and could include, for example, the State Administration of Market Regulation and the China National Intellectual Property Administration.

[56] Elsa Kania and Peter Wood, "The PLA and foreign technology," in *China's Quest* (see note 1), 234.

2024. Since then, cyberespionage responsibilities within the PLA have now likely been inherited by the PLA Cyberspace Force.[57]

The Second Department, sometimes abbreviated as 2PLA and also known as the Intelligence Bureau of the Joint Staff Department, is involved in more traditional espionage, such as spies tasked with organisational infiltration and intelligence-gathering abroad.[58] The Intelligence Bureau also controls think tanks, for instance the China Institute for International and Strategic Studies, which engage in international academic exchange.[59] This think tank has been known to co-host conferences with another think tank, the China Institute of Contemporary International Relations, controlled by the Ministry of State Security's 11th Bureau.[60]

Some defence universities are under the CMC's direct supervision. Notable among these is the National University of Defence Technology (NUDT). Because of its especially close ties to the PLA, the NUDT greatly contributes to the technology transfer ecosystem and the MCF through international research collaboration. The flow of personnel is in both directions; many researchers from the NUDT have been active at leading universities abroad, and the NUDT has received foreign researchers as well as Chinese returnees to work in military or dual-use research fields.[61] The Army Engineering University, key to the PLA ground forces, also has a history of extensive international research collaboration.[62]

Moreover, the PLA's Academy of Military Sciences hosts one of the major open-source S&T intelligence-gathering organisations, the Military Science Information Research Centre. This centre complements the Institute of Scientific and Technical Information of China, affiliated with the Ministry of Science and Technology, by focussing on military S&T for the CMC and the defence industry. Both organisations act as hubs for China's broader open-source S&T intelligence system. The CMC also manages the China National Defense Science and Technology Information Society, which is a professional group that educates defence-related open-source S&T intelligence workers and disseminates information within the Chinese system. It is complemented by a civilian counterpart (see Section 2.5.2).[63] The PLA and its General Armament Department are important actors for China's arms import, a significant venue for foreign technology transfer. Other key government actors in this regard are the Ministry of Industry and Information Technology, the Ministry of Commerce, and the State-owned Assets Supervision

[57] Joe McReynolds and John Costello, "Planned Obsolescence: The Strategic Support Force In Memoriam (2015–2024)," Jamestown Foundation, April 26, 2024, https://jamestown.org/program/planned-obsolescence-the-strategic-support-force-in-memoriam-2015-2024/.
[58] Hamilton, *Silent Invasion*, 180.
[59] Peter Mattis, "China's 'Three Warfares' in Perspective," *War on the Rocks*, January 30, 2018, https://warontherocks.com/2018/01/chinas-three-warfares-perspective/.
[60] Clive Hamilton and Mareike Ohlberg, *Hidden Hand: Exposing How the Chinese Communist Party is Reshaping the World* (Oneworld Publications, 2020), 149.
[61] Kania and Wood, "The PLA and foreign technology," 233.
[62] Alex Joske, *Picking flowers, making honey: The Chinese military's collaboration with foreign universities* (Australian Strategic Policy Institute, 2018), https://www.aspi.org.au/report/picking-flowers-making-honey, 5.
[63] Hannas and Chang, *China's STI Operations,* 23–8, 39.

and Administration Commission (see Section 2.6).[64]

2.4 Academic institutions

China's ecosystem for technology also involves a number of academic institutions, including universities, research laboratories, and national S&T academies. This section describes a subset of these institutions, with a focus on those especially tied to defence research and the Military-Civil Fusion (MCF) system.

2.4.1 Defence-related universities

The State Administration of Science, Technology, and Industry for National Defence (SASTIND), under the Ministry of Industry and Information Technology (MIIT), supervises a number of nominally civilian universities with close ties to the defence industry and the military, exemplified by their prominence in defence research and the large shares of their graduates that end up as defence sector employees. These universities include, but are not limited to, the "Seven Sons of National Defence" and the "Seven Sons of the Arms Industry."[65] Some of the Seven Sons of National Defence have been linked to illegal technology transfer, such as espionage and export-control violations. They are also venues for legal and grey-zone technology transfers. For instance, some talent-recruitment plans, such as Program 111, involve the creation of university-based "innovation bases" that focus on international research collaboration and recruiting foreign talent.[66] SASTIND has sought to deepen the ties between universities and the defence sector for decades through agreements with other government agencies, such as the Ministry of Education (MOE). This includes defence-related laboratories spread out across both civilian and military research institutions (see Section 2.4.2). Some universities are also supervised by defence companies.[67]

There are many known cases from the US and beyond of Sino-foreign academic-research collaborations where the Chinese counterpart has turned out to have ties to the People's Liberation Army (PLA). It is often the case that the researchers' PLA associations are omitted in English but included in Chinese-language descriptions of their affiliated research laboratories, articles, CVs, etc. Many cases involve researchers from defence-related universities such as the Seven Sons of

[64] Cheung et al., *The Role of Technology Transfers*, 26–7.

[65] These two groups of a total of 12 universities partially overlap, as Beijing Institute of Technology and Nanjing University of Science and Technology figure in both. The Seven Sons of National Defence include Beijing Institute of Technology, Beihang University, Harbin Engineering University, Harbin Institute of Technology, Nanjing University of Aeronautics and Astronautics, Nanjing University of Science and Technology, and Northwestern Polytechnical University. On the other hand, the Seven Sons of the Arms Industry include Beijing Institute of Technology, Changchun University of Science and Technology, Chongqing University of Technology, Nanjing University of Science and Technology, North University of China, Shenyang Ligong University, and Xi'an Technological University.

[66] Emily Weinstein and Jeffrey Stoff, "China's quest for AI talent," in *Chinese Power* (see note 9), 63.

[67] Alex Joske, *The China Defence Universities Tracker*: *Exploring the military and security links of China's universities*, Policy brief Report No. 23 (Australian Strategic Policy Institute, 2019), https://www.aspi.org.au/report/china-defence-universities-tracker, 6–8.

National Defence or Xidian University (see Chapter 3), researchers working under Chinese state-funded defence programmes, or from the People's Armed Police.[68] There have also been several cases of joint research with military-affiliated Chinese researchers in Sweden.[69] Moreover, government departments are involved in facilitating Sino-foreign research through their front organisations. For example, the China International Culture Exchange Centre, which acts as a cover for the Ministry of State Security's 12th Bureau, has helped put partnerships into place between Australian and Chinese universities, as have the front organisations associated with the State Administration of Foreign Experts Affairs under the Ministry of Human Resources and Social Security.[70]

Focus on Semiconductor Technology

Many of the defence-related universities have subdivisions focused on electrical engineering, computer science, and other disciplines related to semiconductor technology. However, there are a few universities of particular importance for China's defence-electronics sector. Among these are Xidian University and the University of Electronic Science and Technology of China, which are described in more detail in Chapter 3.

As an example of "innovation bases," Northwestern Polytechnical University, a Seven Sons university, has a Program 111 base with a focus on dual-use sensing technology staffed with both Chinese and foreign researchers, e.g., from the US, the UK, and Singapore.[71] The National University of Defence Technology (NUDT), the PLA's primary source of defence research, has done collaborative research with several Australian universities as well as an Australian governmental research agency in fields such as AI and satellite-navigation technology, both of which have dual-use applications.[72] Moreover, a number of NUDT experts on, for example, radars, drone swarms, and supercomputers, the latter of which is associated with nuclear-weapon development, have benefitted from studies abroad.[73]

2.4.2 Defence Key Laboratories

As part of its national innovation infrastructure, China has a complex system of laboratories that spans several administrative levels: state, provincial/ministerial, municipal, and university/institute. At the state level, there is both a state-laboratory system administrated by the Ministry of Science and Technology (MOST) and a defence-research laboratory system overseen by SASTIND under

[68] Jeffrey Stoff, "Sino-foreign research collaboration," in *China's Quest* (see note 1), 172–9. The People's Armed Police is a paramilitary police force that performs domestic security and surveillance, including in the Xinjiang region, which is associated with large-scale human rights abuses.

[69] Jani Sallinen and Amanda Lindholm, "Militärforskare från Kina på svenska universitet," *Svenska Dagbladet*, February 18, 2023, https://www.svd.se/a/O8WALV/militarforskare-fran-kina-pa-svenska-universitet.

[70] Hamilton, *Silent Invasion*, 183–4; Joske, *Spies and Lies*, 33.

[71] Weinstein and Stoff, "China's quest for AI talent," 63.

[72] Hamilton, *Silent Invasion*, 190–3, 208. China's system for satellite navigation, corresponding to the GPS system initiated by the US government, is known as Beidou (北斗).

[73] "National University of Defence Technology," Australian Strategic Policy Institute, last updated November 23, 2019, https://unitracker.aspi.org.au/universities/national-university-of-defense-technology/.

the MIIT. At the provincial and ministerial levels, there are, for example, laboratories supervised by the MOE.[74] Moreover, as a result of deepened ties between universities and the defence sector, there are now defence-research laboratories within universities with an otherwise strong civilian research focus, such as Tsinghua University and Peking University.[75]

There are several different categories of "key laboratories" worth mentioning in the context of China's technology-transfer ecosystem. Within the state laboratory system, State Key Laboratories play an important role. Most of these are located at universities or institutes run by government bodies, notably the MOE and the Chinese Academy of Sciences (see Section 2.4.3), and to some extent the MIIT. Some are also established and operated by private and state-owned enterprises, albeit ultimately under MOST control.[76]

The most prestigious key laboratories within the defence-research laboratory system are called Defence S&T Key Laboratories, under joint supervision by SASTIND and the PLA. These are found within both universities, major defence companies, and the PLA itself.[77] There are also Defence Key Discipline Laboratories at the state level, focussed on defence-related basic research and concentrated among top universities, often those with strong defence ties, such as the SASTIND-managed Seven Sons universities.[78] Moreover, there are defence-related laboratories at the provincial and ministerial levels. Besides hosting prestigious State Key Laboratories, the MOE and the MIIT have their own key laboratories, some of which are focussed on defence research. It should be noted that the official English translations of the descriptions of various defence key laboratories often do not reveal their ties to defence-related research, e.g., by omitting the word "defence."[79]

While the aforementioned State Key Laboratories are civilian-branded, some of them were especially established to further the MCF system. Moreover, even though many of them do not necessarily have a defence-research focus, it can oftentimes be difficult to distinguish them from the defence laboratories noted

[74] Alex Stone and Ma Xiu, *The PRC State & Defense Laboratory System: An Overview* (China Aerospace Studies Institute, 2022), https://www.airuniversity.af.edu/CASI/Display/Article/2987660/the-prc-state-defense-laboratory-system/, 1, 3–4. The defense-research laboratory system under SASTIND is likely under joint supervision by the CMC. Apart from the different types of state-level laboratories described herein, there are also National Laboratories (国家实验室) and Defense S&T National Laboratories (国防科技国家实验室). These still appear to be undergoing significant reforms or implementation, even though there are examples of existing National Laboratories.

[75] Joske, *The China Defence Universities Tracker*, 9–12.

[76] Emily Weinstein, Channing Lee, Ryan Fedasiuk, and Anna Puglisi, *China's State Key Laboratory System: A View into China's Innovation System* (Center for Security and Emerging Technology, 2022), https://cset.georgetown.edu/publication/chinas-state-key-laboratory-system/, 12–17.

[77] Joske, *The China Defence Universities Tracker*, 9–12.

[78] Stone and Xiu, *The PRC State & Defense Laboratory System*, 5. The Defence Key Discipline Laboratories are not necessarily state-level, but could also be managed at a provincial/ministerial level.

[79] Joske, *The China Defence Universities Tracker*, 9–12. For a list of MIIT key laboratories hosted among, for instance, Seven Sons universities, see Weinstein et al., *China's State Key Laboratory System*, 31–33.

above. Apart from the issue of English-language names obfuscating defence ties, the different names for civilian and defence key laboratories are often used interchangeably even in Chinese. SASTIND, together with the National Development and Reform Commission, MOST, and the Central Military Commission, have also promoted symbiotic relationships between the different key laboratories, exacerbating issues with differentiating between civilian and defence-related research institutions.[80] Thus, it could be argued that State Key Laboratories should be considered defence-related until proven otherwise.

Apart from being tied to ministries, universities, enterprises, and military units within China's technology-transfer ecosystem, the defence-research laboratories themselves engage in foreign technology transfer activities. For instance, there are numerous examples of academic collaboration between Defence S&T Key Laboratories and US top universities, including in dual-use research topics.[81] As for State Key Laboratories, apart from their role in furthering breakthroughs in basic research, they also have technology-transfer responsibilities, including through foreign talent recruitment and promoting international academic exchange.[82] Moreover, some laboratories may engage in illegal activities. For example, a MOE key laboratory at Wuhan University was previously accused of serving the PLA by performing cyberattacks to collect defence-related intelligence across the US.[83]

Focus on Semiconductor Technology

There is a great variety of key laboratories, scattered among governmental, commercial, and academic entities, with research profiles related to semiconductor technology and adjacent technology areas, such as defence electronics, AI, and telecommunications. Chapter 3 provides some examples.

[80] Stone and Xiu, *The PRC State & Defense Laboratory System,* 3, 7–8.
[81] Stone and Xiu, *The PRC State & Defense Laboratory System,* 8–9.
[82] Weinstein et al., *China's State Key Laboratory System*, 12–7.
[83] Bill Gertz, "Network Effects: Chinese university lab linked to PLA cyber attacks," *Washington Free Beacon,* May 14, 2023, https://freebeacon.com/national-security/network-effects/.

2.4.3 The national science academies

China's foremost science academy, the Chinese Academy of Sciences (CAS), is directly subordinate to the State Council. It consists of more than 100 research institutes.[84] CAS is a central actor among China's government research organisations, and has partaken in several S&T-related policy programmes such as Five-Year Plans and Made in China 2025.[85]

Another important national academy is the Chinese Academy of Engineering (CAE), also directly subordinate to the State Council. CAE leads the China Standards 2035 initiative, under the Made in China 2025 programme. Among other things, this sets standards that foreign companies are required to adhere to in order to access the Chinese market, including through mandatory technology-sharing.[86]

Apart from international academic exchange, Chinese national academies engage in foreign technology transfer through a variety of means. For instance, CAS supervises one of the major talent-recruitment programmes, the Hundred Talents Plan, aimed at bringing foreign scholars to China.[87] CAS is also at the core of China's system for open-source S&T intelligence-gathering.[88] Besides legal means of technology transfer, there have been examples of CAS being used by the Ministry of State Security as a front to coopt foreign academics.[89] Moreover, CAS and its provincial branches manage technology-transfer centres. For example, one major centre in Shanghai dates back to the 1950s and is associated with multiple successes in the conversion of foreign technology.[90]

[84] 国务院关于机构设置的通知, 国务院 ["State Council Notice on Organisational Set-up," State Council], March 16, 2023, https://www.gov.cn/zhengce/content/2023-03/20/content_5747309.htm.
[85] Sarah Harting, Daniel Gonzales, Michael J. Mazarr, and Jon Schmid, *Comparative Analysis of U.S. and PRC Efforts to Advance Critical Military Technology*: *Volume 1, Analytic Approach for Conducting Comparative Technology Assessments* (Santa Monica, California: RAND Corporation, 2024), https://www.rand.org/content/dam/rand/pubs/research_reports/RRA2100/RRA2197-1/RAND_RRA2197-1.pdf, 41.
[86] Sutter, "Foreign technology transfer," 66.
[87] Hannas and Chang, "China's 'artificial intelligence," 193.
[88] Hannas and Chang, *China's STI Operations*, 15–6.
[89] Hamilton, *Silent Invasion*, 162.
[90] Hannas et al., *Chinese Industrial Espionage*, 94.

Focus on Semiconductor Technology

Two of CAS' institutes are the Institute of Semiconductors and the Institute of Optics and Electronics. These in turn host a number of different key laboratories, which, as suggested above, contribute to both the introduction and dissemination of foreign technologies.[91] Moreover, CAS has invested in semiconductor technology through its commercial spinoffs. For instance, in 2016, a CAS investment company entered a joint venture with US company AMD for the licensed manufacture of x86 CPUs.[92] CAS has also, through both commercial and academic subsidiary entities, namely CAS Sugon and CAS Institute of Computing Technologies, had partnerships with US chip-design giant Nvidia, with a focus on deep learning, i.e., AI. Through this partnership, CAS has had access to Nvidia's GPU technology, which is otherwise under US export controls to China. This is also occurring in the context of CAS Sugon's support for the PLA's MCF efforts.[93]

CAE has been at the forefront of formulating Chinese policy goals for the semiconductor industry. It was in fact CAE, together with MIIT, that paved the way for the industrial policy programme, Made in China 2025, through a joint research project on Chinese manufacturing capabilities.[94]

2.5 The United Front, the Chinese diaspora, and foreign talents

The CCP's United Front strategy is intended to spread the party's influence both domestically and abroad. This section describes actors associated with the United Front whose activities relate to China's technology-transfer efforts.

2.5.1 The United Front Work Department

The United Front Work Department (UFWD) is another key actor within China's technology-transfer ecosystem. The UFWD reports to the Central Committee of the CCP and coordinates United Front activities. This includes facilitating technology transfer through aiding China's foreign talent-recruitment programmes.

There is a great variety of state-led talent-recruitment programmes that are sponsored at multiple administrative levels to target foreign professionals and academics. Some examples are provided in Sections 2.2 and 2.4. The basic concept is to invite foreign experts, whether of Chinese descent or not, to come to China and spread

[91] 机构简介, 中国科学院光电技术研究所 ["Brief Organisational Introduction," Chinese Academy of Sciences Institute of Optics and Electronics], accessed May 24, 2024, https://ioe.cas.cn/2019jgjj/2019jgjs/;机构简介, 中国科学院半导体研究所 ["Brief Organisational Introduction," Chinese Academy of Sciences Institute of Semiconductors], accessed May 24, 2024, http://www.semi.cas.cn/sqgk/jgjj/201404/t20140410_4088027.html.

[92] Ryan Smith, "China Calling: AMD Forms Joint Venture for x86 Server SoCs in China," *AnandTech*, April 21, 2016, https://www.anandtech.com/show/10268/china-calling-amd-forms-joint-venture-for-x86-server-socs-in-china.

[93] Kania and Wood, "The PLA and foreign technology," 231.

[94] Cheung, *Innovate to Dominate*, 238.

their knowledge while receiving generous remuneration. Many different state actors are involved, and information about the talent programmes is spread on the websites of Chinese ministries, foreign consulates, and among Sino-foreign professional associations abroad. Foreign talents who have been successfully recruited end up in positions among many different actors within China's technology-transfer ecosystem, for instance in government departments, academia, state-run laboratories, existing companies or start-ups, or in some kind of commercialisation facility, such as technology-transfer centres situated in industrial parks.[95] In addition to talent-recruitment plans, United Front activities abroad frequently involve overseas associations, as described below.

The UFWD manages a number of different organisations, not least the Overseas Chinese Affairs Office (OCAO). OCAO is the central organisation for managing China's relations with the Chinese diaspora and organising overseas United Front activities.[96] Having previously been sorted under the State Council, the shift to UFWD supervision in 2018 entailed increased party-control over OCAO and the diaspora.[97] In practice, OCAO is now used as a front organisation for the UFWD. OCAO focusses on overseas ethnic Chinese, whether Chinese citizens or not. This differs from the State Administration of Foreign Expert Affairs, under the Ministry of Human Resources and Social Security, which aims to coopt and obtain knowledge from foreign citizens in general. While attracting Chinese nationals or foreigners with valuable expertise to come to China is crucial for China's technology-transfer policies, individuals can also contribute to technology transfer while remaining abroad. As an example, in 2017, the OCAO's director paid a visit to Sydney. Among other things, she used her time in Australia to hold a speech for Chinese academics at the University of Technology Sydney, presenting OCAO's latest policy for encouraging "overseas countrymen" to contribute to innovation in China, also noting their importance as a key resource.[98]

2.5.2 The Chinese People's Political Consultative Conference

The Chinese People's Political Consultative Conference (CPPCC) is a body for political consultation constituted by political parties and other organisations, subservient to the CCP. It is part of the CCP's United Front system and also engages in technology-transfer efforts abroad. Among other things, its subordinate organ, the China Association for Science and Technology (CAST), initiated the Haizhi Plan, a key talent-recruitment plan, together with a number of overseas

[95] William C. Hannas and Huey-Meei Chang, "China's 'artificial' intelligence," in *China's Quest* (see note 1), 193–4.
[96] Alex Joske and Jeffrey Stoff, "The United Front and technology transfer," in *China's Quest* (see note 1), 258–9.
[97] Bethany Allen, *Beijing Rules: China's Quest for Global Influence* (London, UK: John Murray Press, 2023), 43.
[98] Hamilton, *Silent Invasion*, 38, 153, 178–9.

Chinese S&T associations.[99] CAST also manages the China Society for Scientific and Technical Information, a professional organisation that plays an important role in disseminating open-source S&T intelligence within the Chinese system.[100]

2.5.3 Overseas professional and academic associations

There are large numbers of associations abroad that bring together Chinese academics and professionals. These are often sincere in their strive to provide opportunities for overseas Chinese to expand their academic and professional networks to their own benefit. However, it is also often the case that the Chinese state, for instance, represented by the local Chinese embassy, is involved in both establishing and managing such associations, one purpose being to contribute to technology transfer. For example, the Federation of Chinese Scientists in Australia, an umbrella organisation for local professional Chinese associations, hosted meetings at the Chinese embassy and was lauded by the Ministry of Education (MOE) in Beijing for its success in talent recruitment. It also had two leaders engaged in nanotechnology research at Australian universities, one of whom kept ties to Chinese defence-related universities such as Harbin Institute of Technology, and one of whom was a member of a State Council expert committee.[101]

Another important umbrella organisation for talent recruitment and technology transfer is the Federation of Chinese Professional Associations in Europe, which among other things has cooperated with CAST under the banner of the Haizhi Plan, the aforementioned talent-recruitment plan. It has also collaborated with the Zhigong Party, one of the CCP-subservient political parties represented in the CPPCC. The Zhigong Party's involvement in technology-transfer efforts is further exemplified by the fact that its previous leader simultaneously served as the Minister of Science and Technology.[102]

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Among the diaspora organisations affiliated with the United Front, there are numerous examples of academic and professional associations whose activities pertain to semiconductor technology. One of these is the Association of Chinese Scientists and Engineers in Japan. It is another of the many associations affiliated with the Haizhi Plan.[103] Microelectronics is among the fields of expertise represented by its members, many of whom have founded companies in Japan or become prominent academics. The association has also repeatedly assisted the Chinese government and other Sino-Japanese associations in arranging S&T exhibitions promoting returnees to create start-ups in China, among other means of "serving the country." The Ministry of Science and Technology, the Chinese Academy of Sciences, MOE, and OCAO, among others, have recognised the association's contributions to China since its founding in 1993.[104]

[99] Didi Kirsten Tatlow, Hinnerk Feldwisch-Drentrup, and Ryan Fedasiuk, "Europe: A technology transfer mosaic," in *China's Quest* (see note 1), 116.
[100] Hannas et al., *Chinese Industrial Espionage*, 44–5.
[101] Hamilton, *Silent Invasion*, 182, 184–6.
[102] Tatlow et al., "Europe," 116–8.
[103] Hannas and Chang, "Japan and South Korea," 155.
[104] 关于科盟，在日中科学技术者联盟 ["About the Science Alliance," Association of Chinese Scientists

2.6 Commercial actors

Commercial actors are another crucial category of actors in China's technology-transfer ecosystem. This section especially focusses on a subset of commercial actors, including defence companies, subcontractors within dual-use industries, and financial intermediaries, related to the semiconductor industry and the Military-Civil Fusion (MCF) system.

2.6.1 Defence companies

The State-owned Assets Supervision and Administration Commission (SASAC), which reports to the State Council, is the main organ tasked with managing state-owned enterprises in both the civilian and defence industries.[105] SASAC thus plays a key role in the technology-transfer ecosystem for facilitating the dissemination of dual-use technologies among state-owned enterprises and their domestic and foreign subsidiaries.

Eight state-owned industry groups or conglomerates, each of which in turn represents an array of subsidiaries, including wholly or partly state-owned companies as well as research institutes, dominate the Chinese defence industry. As of 2019, the defence giants were distributed across aerospace (2), shipbuilding (1), ordnance (2), aviation (1), nuclear technologies (1), and defence electronics (1).[106] In 2022, all of these were among the global top 100 defence industry companies, and all but one were in the top 20, according to SIPRI statistics.[107] Several of these conglomerates, not least in the aerospace segment, contain entities engaged in semiconductor technology and defence electronics, but for present purposes, the China Electronics Technology Group Corporation (CETC) deserves special attention. Chapter 3 provides a detailed description of CETC and its contributions to China's technology-transfer ecosystem.

2.6.2 Financial intermediaries

Financial intermediaries play an important supportive role among the commercial actors. Notable among these are investment funds, especially so-called "government guidance funds," established and managed by the State Council and its departments to further China's industrial policy and technology-transfer efforts. Government guidance funds, as their name implies, direct private capital and state-provided funds towards investments in strategic industries, both domestically and

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and Engineers in Japan], accessed April 26, 2024, http://www.npo-ohp.com/acsej/cn/page.php?id=1.

[105] Mulvenon, "Espionage and trade secret theft cases," 302.

[106] Kirchberger and Mohr, "China's defence industry," 45. The merger between China's two shipbuilding giants in 2019 makes eight the official number of Chinese defence-industrial champions.

[107] "The SIPRI Top 100 arms-producing and military services companies in the world, 2022," SIPRI, December 2023, www.sipri.org/visualizations/2023/sipri-top-100-arms-producing-and-military-services-companies-world-2022. The two shipbuilding giants, CSSC and CSIC, merged in 2019.

overseas. They are also an important tool for the MCF system, and some are even organised by defence companies (see also Section 3.1). The most significant fund in this context is the National Defence Science, Technology, and Industry MCF Industrial Investment Fund, commonly known as the Defence S&T MCF Investment Fund.[108]

The foremost government guidance fund focused on the semiconductor industry is the National Integrated Circuit Industry Investment Fund, also known as the National IC Fund, or the Big Fund. There is also, for instance, the National Fund for Technology Transfer and Commercialisation; it is managed by the Ministry of Science and Technology, which together with the Ministry of Finance established it in 2011. Among other things, it provides venture capital for high-tech sectors such as information technology, distributed through a number of different sub-funds.[109]

Beside investment funds, there are also venture-capital firms and investment-management companies. Many of these are government-backed and can provide an easy way for the Chinese government to indirectly, but with limited involvement, gain access to foreign start-ups and innovative technologies.[110]

2.6.3 Dual-use industry subcontractors

The Chinese semiconductor industry is a key upstream supplier of dual-use goods to the Chinese defence industry and defence electronics. Examples of major companies include Semiconductor Manufacturing International Corporation, Yangtze Memory Technologies Corporation, and ChangXin Memory Technologies. The degree of direct or indirect state involvement in the semiconductor industry is high. There are also nominally private companies within adjacent industries that serve as important subcontractors to the defence-electronics segment of China's defence industry. This includes large telecommunications companies such as Huawei, Great Dragon Telecommunications Equipment, ZTE, and Datang Telecom. Huawei, which was founded by ex-militaries and enjoys significant state funding, has had particular importance in procurements to the People's Liberation Army (PLA).[111] In 2020, about 25,000 different private enterprises acted as suppliers to the PLA, approximately a fifth of which dealt in various electronic equipment.[112]

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[108] Cheung, *Innovate to Dominate*, 32–3, 124–5, 133.

[109] 推进科技成果转化快速发展国家科技成果转化基金 2.5 亿落地陕西, 人民网 ["250 million from the National Fund for Technology Transfer and Commercialization has been delivered to Shaanxi for the promotion of quick developments within commercialisation of S&T achievements," People's Daily Online], January 26, 2022, http://sn.people.com.cn/n2/2022/0126/c347857-35113785.html.

[110] Chang and Hannas, "Foreign support," 43–4.

[111] Kirchberger and Mohr, "China's defence industry," 45, 48.

[112] Ryan Fedasiuk and Emily Weinstein, "AI in the Chinese military," in *Chinese Power* (see note 9), 182.

Moreover, tech giants such as Baidu, Alibaba, and Tencent are heavily engaged in China's efforts to become world-leading in AI, a semiconductor-dependent technology that has many dual-use applications, for example, in autonomous weapon systems and military surveillance.[113] Baidu, Alibaba, and Tencent have all enjoyed the benefits of international collaboration, not least with the US, as can be seen by the large representation of foreigners or Chinese nationals with foreign university degrees in their workforces. They also have AI labs abroad, such as in Silicon Valley, where they recruit foreign talent to serve China's industrial development.[114] Also, the well-known rivals, Alibaba and Tencent, have semiconductor-industry subsidiaries, as their competition has diversified from software to hardware.[115] As is the case with many other nominally private companies in China, AI companies enjoy various kinds of state support and are subject to both formal and informal government control.[116] However, it should also be noted that despite their similarities, Baidu, Alibaba, and Tencent are three separate companies, each with its own distinct relationship to the Chinese state.

Through their interaction with foreign companies and professionals in China and overseas, both state-owned and private companies in the semiconductor industry and adjacent industries, as well as the aforementioned financial intermediaries, contribute to technology transfer and, by extension, the MCF system. Table 2 below provides examples of different commercial means for foreign semiconductor-related technology transfer.

[113] Kirchberger and Mohr, "China's defence industry," 59–60.
[114] Hannas and Chang, "China's 'artificial intelligence," 196.
[115] Lulu Yilun Chen, *Influence Empire: The Story of Tencent & China's Tech Ambition* (Hodder & Stoughton, 2022), 207.
[116] Karen. M. Sutter and Zachary Arnold, "China's AI companies: Hybrid players," in *Chinese Power* (see note 9), 21.

Table 2. Examples of commercial means for foreign technology transfer

Means	Chinese entity	Foreign entity	Business activity
Joint venture	San'an Optoelectronics	STMicroelectronics (Netherlands)	Manufacturing in China of silicon-carbide semiconductors for automotives, using STMicroelectronics' IP, since 2023[117]
Overseas research laboratory	Baidu, Alibaba, Tencent	-	Chinese-owned AI laboratories in the US, which recruit foreign talent, since the 2010s[118]
Sino-foreign research laboratory	Huawei	STMicroelectronics (Netherlands)	R&D in sensors and software in Grenoble, France, since 2018[119]
Company acquisition abroad	GAE, with funding from National IC Fund	Silex Microsystems (Sweden)	Front-end manufacturing of micro-electromechanical systems, acquisition took place in 2015[120]
Company acquisition in China	Equity firm Hopu Investment, and others	Arm China (subsidiary to UK-based Arm)	Chip design IP, majority stake acquired in 2018[121]
Talent recruitment	Bitmain Technologies	TSMC, MediaTek (Taiwan)	Recruitment of engineers for AI chip development, including allegedly illegal front companies, since 2018[122]

[117] John Lee and Jan-Peter Kleinhans, "Automotive Chips: a European Chokepoint?" in *Reverse Dependency: Making Europe's Digital Technological Strengths Indispensable to China*, ed. Tim Rühlig (Digital Power China, 2024), https://dgap.org/system/files/article_pdfs/DPC%20-%20GESAMT_Final.pdf, 120.

[118] Hannas and Chang, "China's 'artificial intelligence,'" 196.

[119] Mu Xuequan, "China's tech giant Huawei opens new research center in France," *Xinhua*, November 29, 2018, http://www.xinhuanet.com/english/2018-11/29/c_137637940.htm.

[120] Tobias Junerfält and Emil Wannheden, *Manufacturing Vulnerabilities: Chinese Minerals, Semiconductors and Green Technologies in the EU*, FOI-R--5524--SE (Swedish Defence Research Agency—FOI, 2024), https://www.foi.se/rest-api/report/FOI-R--5524--SE, 32–3. Following the acquisition, the National IC Fund has also funded a Silex plant in an industrial park in Beijing.

[121] Yelin Mo, Max A. Cherny, and Stephen Nellis, "Arm's China relationship complicates IPO," *Reuters*, August 23, 2023, https://www.reuters.com/markets/deals/arms-china-relationship-complicates-ipo-2023-08-22/.

[122] Debby Wu, "Taiwan Probe Spurs Fears of China Poaching Top Chip Talent," *Bloomberg*, March 10, 2021, https://www.bloomberg.com/news/articles/2021-03-10/bitmain-probe-spurs-fears-of-china-poaching-taiwan-chip-talent.

3 Case study: China Electronics Technology Group Corporation

This chapter discusses the defence-industry conglomerate, China Electronics Technology Group Corporation (CETC), in detail. First, an overview of CETC's organisation, its commercial scope, and contributions to China's Military-Civil Fusion (MCF) system are provided. This includes an overview of two CETC-supervised universities and examples of defence-related laboratories and engineering research centres affiliated with CETC. CETC's technology-transfer activities involve many different subentities and means; this chapter provides examples of both legal and illegal activities affiliated with CETC. Figure 2 provides an overview of how CETC interacts with other actors within China's technology-transfer ecosystem.

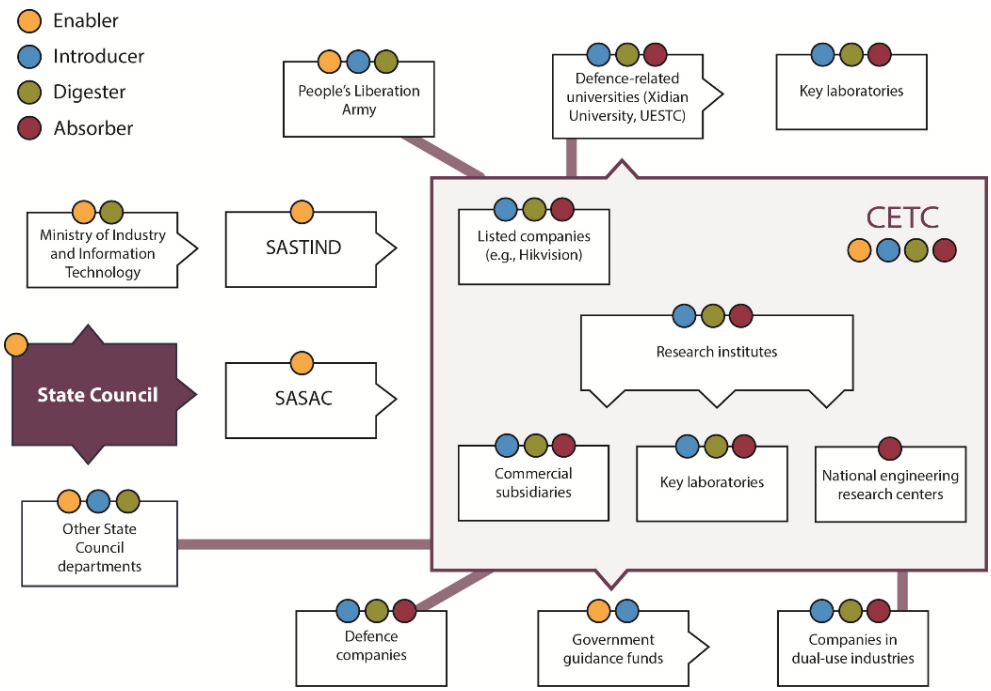

Figure 2. CETC within China's technology-transfer ecosystem

Note: The figure focusses on CETC's interaction with external actors and excludes the interactions between the different external actors themselves. The protruding arrowheads indicate control, whether hierarchical or financial, whereas solid lines indicate some kind of collaborative relationship.

3.1 Organisational overview

Founded in 2002, CETC is an industry group that originally sprung out of various research institutes and companies organised under the now-defunct Ministry of Information Industry, succeeded by the Ministry of Industry and Information Technology (MIIT). In addition to being a state-owned enterprise under the State-owned Assets Supervision and Administration Commission (SASAC), CETC is also supervised by the State Administration of Science, Technology, and Industry for National Defense (SASTIND) under the MIIT.[123] According to its own website, CETC has more than 700 subsidiaries, including 47 state-level research institutes and 17 listed companies, representing more than 200,000 personnel.[124]

As a corporate group, CETC leverages its industrial advancement in technology areas such as semiconductor technology, electronics, and telecommunications to benefit the People's Liberation Army (PLA). Listed as number 11 in SIPRI's top 100 list of major defence-industry actors in 2021–2, CETC derives 27 percent of its revenue from arms sales.[125] The majority of CETC's revenues are thus derived from civilian or dual-use goods, for instance semiconductor-manufacturing equipment.[126] CETC, in fact, is a significant international supplier of chemical-mechanical planarisation tools, used for front-end semiconductor manufacturing.[127] Its military product portfolio includes early-warning systems, communication and navigation technology, electronic warfare, integrated electronic information systems, UAVs, and radar.[128]

The research institutes that comprise CETC are associated with historical contributions to China's nuclear weapon and missile capabilities, as well as satellite technology.[129] In its corporate introduction, CETC is transparent about its ties to

[123] "China Electronics Technology Group Corporation," Australian Strategic Policy Institute, last updated August 31, 2020, https://unitracker.aspi.org.au/universities/china-electronics-technology-group-corporation/.

[124] 集团简介, 中国电子科技集团有限公司 ["Brief Corporate Introduction," China Electronics Technology Group Corporation], accessed May 23, 2024, cetc.com.cn/zgdk/1593037/jtjj/index.html. Another major state-owned defence electronics producer, easily confused with CETC, is China Electronics Corporation (中国电子信息产业集团); see, for example, "China Electronics Corporation," Australian Strategic Policy Institute, last updated October 29, 2019, https://unitracker.aspi.org.au/universities/china-electronics-corporation/.

[125] "The SIPRI Top 100 arms-producing and military services companies in the world, 2022," SIPRI, December 2023, www.sipri.org/visualizations/2023/sipri-top-100-arms-producing-and-military-services-companies-world-2022.

[126] 集成电路装备, 中国电科 ["Integrated Circuit Manufacturing Equipment," CETC], accessed 23 April, 2024, http://www.cetczb.com/product/5/.

[127] "Supply Chain Explorer," Emerging Technology Observatory, last updated 16 October, 2022, https://chipexplorer.eto.tech/?filter-choose=organization&organization=P85&parentNode=N57&selectedNode=N86.

[128] Australian Strategic Policy Institute, "China Electronics Technology Group Corporation."

[129] Matthew Luce, "A Model Company: CETC Celebrates 10 Years of Civil-Military Integration," Jamestown Foundation, February 21, 2012, https://jamestown.org/program/a-model-company-cetc-celebrates-10-years-of-civil-military-integration/.

the military; it states that it is "the main force in military electronics," and working to "carry out the PLA's 100th anniversary goals for year 2027."[130]

CETC also supports China's MCF system. Together with SASTIND and a Fujian provincial commission, it was behind the establishment of the foremost MCF fund, the Defence S&T MCF Investment Fund (see Section 2.5.2). CETC also has stakes in at least two other major MCF-related funds, the National IC Fund, (see Section 2.5.2), and the National MCF Industry Investment Fund.[131] CETC is today also closely associated with China's "smart cities" and social-credit system through its role in providing the technical equipment and big-data analytics for mass surveillance, including in Xinjiang.[132] The latter is an example of how CETC's dual-use products not only have both civilian and military applications, but also have uses for the domestic security apparatus.

Moreover, CETC's commercial ties with China's private sector are extensive. For example, CETC has a long history of business relations with Huawei.[133] Also, as an example of the synergy between China's AI development, spearheaded by civilian tech companies, and the defence industry, CETC has previously made claims about the world-leading capabilities of its military drone swarms.[134]

Together with the Ministry of Education and SASTIND, CETC also jointly supervises two universities with a defence-electronics research focus, Xidian University and the University of Electronic Science and Technology of China (UESTC). Since 2011, Xidian University and CETC have developed a joint innovation centre, which also involves the PLA and other defence-industrial actors.[135] Xidian University has its roots in a PLA engineering institute and maintains close military ties. For instance, it hosts a State Key Laboratory of Integrated Services Networks engaged in IT research for the PLA.[136] UESTC is a major defence-research institute, particularly in defence electronics. UESTC's research has been utilised across China's defence industry and military. UESTC's ties to the defence industry are further exemplified by its acting as a recruitment base for CETC.[137] Both Xidian University and UESTC are at the leading edge of research in radar and electronic warfare.[138]

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[130] CETC, "Brief Corporate Introduction."
[131] Cheung, *Innovate to Dominate*, 126, 130.
[132] Hamilton, *Silent Invasion*, 251.
[133] Luce, "A Model Company."
[134] Kirchberger and Mohr, "China's defence industry," 59–60.
[135] "Xidian University," Australian Strategic Policy Institute, last updated May 13, 2021, https://unitracker.aspi.org.au/universities/xidian-university/. The complete Chinese name of Xidian University literally translates to "Xi'an Electronics Science and Technology University."
[136] Hamilton, *Silent Invasion*, 174, 206.
[137] "The University of Electronic Science and Technology of China," Australian Strategic Policy Institute, last updated November 19, 2019, https://unitracker.aspi.org.au/universities/university-of-electronic-science-and-technology-of-china/.
[138] "Critical Technology Tracker," Australian Strategic Policy Institute, accessed May 25, 2024, http://techtracker.aspi.org.au.

In addition to its many research institutes, CETC hosts a total of 41 "state-level key laboratories."[139] Xidian University and UESTC also host their own key laboratories.[140] Table 3 below lists examples of the various key laboratories, many of which are defence-related, affiliated with CETC.

Table 3. CETC-affiliated key laboratories and engineering research centres

Controlling entity	Research institution
7th Research Institute	National Engineering Research Centre for Mobile Communications
18th Research Institute	National Engineering Research Centre of New Power Supply
54th Research Institute	State Key Laboratory of Satellite Navigation Systems National Engineering Research Centre for Communication Software and Special Integrated Circuit Design
55th Research Institute	State Key Laboratory of Wide Bandgap Semiconductor Power Electronic Devices
Xidian University	State Key Laboratory of Integrated Services Networks Defence S&T Key Laboratories on 1) Radar Signal Processing and 2) Antennas and Microwave Technology Defence Key Discipline Laboratory of Wide Bandgap Semiconductors Ministry of Education Defence Key Laboratory of Electronic Information Countermeasures and Simulation Technology
UESTC	State Key Laboratory of Electronic Thin Films and Integrated Devices Defence S&T Key Laboratories on 1) Vacuum Electronics and 2) Communication Anti-Interference Technology Defence Key Discipline Laboratory on Extremely High Frequencies Ministry of Education Defence Key Laboratory of Integrated Electronic Systems

Sources: Cheung, *Innovate to Dominate*, 223; Weinstein et al., *China's State Key Laboratory System*, 35, 37; Australian Strategic Policy Institute, "Defence laboratories." Note: Xidian University's laboratory on antennas and microwave technology and UESTC's laboratory on vacuum electronics are jointly run with CETC's 14th and 12th research institutes, respectively.

[139] China Electronics Technology Group Corporation, "Brief Corporate Introduction."
[140] "Defence laboratories," Australian Strategic Policy Institute, accessed May 24, 2024, https://unitracker.aspi.org.au/defence-laboratories/.

3.2 Technology-transfer activities

This section provides examples of how CETC and its subsidiaries engage in activities that relate to both legal and illegal technology transfer, including diverse international commercial ventures, but also export control violations and other illicit activities.

3.2.1 International commercial ventures

CETC has, or has had, many different international commercial collaborations with foreign suppliers and partners in both research and development. For instance, US companies have been heavily involved with CETC subsidiary Hikvision, a major global provider of surveillance equipment, which is also infamous for its involvement in mass surveillance and human rights abuses in China's Xinjiang province.[141] CETC's deep learning and AI surveillance capabilities have benefitted from partnerships with US semiconductor giants Intel and Nvidia, which have provided Hikvision and Dahua, another Chinese AI surveillance company, with hardware such as graphics processing units and field-programmable gate arrays, examples of so-called "AI chips." There are examples from 2018–19 of the Ministry of Public Security explicitly seeking to obtain hardware from Nvidia and Intel in their efforts to track Uyghurs across China. Hikvision and Dahua have also relied on partnerships with US companies Seagate and Western Digital for supplies and joint development of special hard drives for managing the vast amount of data-processing involved in AI surveillance. This is reflective of China's continued dependence on certain semiconductor technology from abroad, as the foremost domestic AI chip companies, such as Hikvision, as well as Cambricon and Huawei subsidiary HiSilicon, cannot cover all hardware needs. Another example of partnerships with US companies includes a joint venture between CETC and Microsoft, which jointly developed "Windows 10 China Government Edition," launched in 2017.[142] Besides the examples provided above, CETC has historically also been both a partner and supplier to major US companies such as IBM, HP, and Cisco.[143]

CETC and its subsidiaries are also active abroad. There are many examples from Europe. For instance, since 2012, the CETC Avionics Company has had a joint venture with French aerospace company Thales to research and produce avionics for Chinese commercial aircraft.[144] Another example is from Austria, where CETC founded a local research centre after collaborating with Austria's Technical University Graz in 2015.[145] In 2018, CETC and German company Siemens signed

[141] "Hikvision," Australian Strategic Policy Institute, last updated June 2021, https://chinatechmap.aspi.org.au/#/company/hikvision.
[142] Peterson, "Technology and the surveillance state," 244–6, 248.
[143] Luce, "A Model Company."
[144] Kania and Wood, "The PLA and foreign technology," 229–30.
[145] Peterson, "Technology and the surveillance state," 248.

an agreement for joint R&D in intelligent manufacturing. The following year, in 2019, CETC, through its subsidiary CETC Network & Communication Group, signed a 20-month joint research project with the University of Birmingham on antennas for 5G communication. Since 2020, CETC Electronic Equipment Group has collaborated with a Turkish construction company on a photovoltaic industrial park, producing components for solar-power panels.[146]

CETC has also collaborated on defence-related projects in Europe. This includes a defence-industry cooperation agreement with the Serbian Ministry of Defence in 2016; alleged participation in AI and data-processing research in a Sino-Belorussian industrial park in Minsk since 2017; and a commercial partnership with Russian defence company Rostec for the development and production of electronics since 2019.[147]

Beyond the US and Europe, CETC has, for example, signed deals for the establishment of an air-traffic management laboratory in Kenya in 2016; the construction of a large-scale solar-power station in Papua New Guinea in 2017; collaboration on smart city technology with Tehran's Municipal Government in 2018; and a greenfield investment in solar-cell production in India, also in 2018.[148] In Australia, CETC and its research institutes previously collaborated with the University of Technology Sydney, including the establishment of a joint research centre in 2017 that focussed on various dual-use technology areas, such as advanced electronics, big data analytics, and communications technology.[149] However, after CETC's involvement in providing mass surveillance equipment in Xinjiang was revealed, the university eventually had to review its partnership with the Chinese tech giant.[150]

3.2.2 Export-control violations

At least twenty of CETC's research institutes are on the US Bureau of Industry and Security Entity List, which lists foreign entities subject to special scrutiny for export licenses. There are usually multiple aliases identified for each institute. For example, the 7th, 54th, and 55th research institutes, which host key laboratories and engineering research centres, are on the list. CETC's presence on the list also includes a number of commercial and academic entities subordinate to its research institutes, as well as listed companies, such as Hikvision.[151]

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[146] "Mapping China's Tech Giants," Australian Strategic Policy Institute, last updated June 2021, https://chinatechmap.aspi.org.au/#/map/f2-CETC.
[147] Australian Strategic Policy Institute, "Mapping China's Tech Giants."
[148] Australian Strategic Policy Institute, "Mapping China's Tech Giants."
[149] Hamilton, *Silent Invasion*, 204–5.
[150] Sophie McNeill, Jeanavive McGregor, Meredith Griffiths, Michael Walsh, and Echo Hui, "UTS, Curtin unis announce reviews over links to surveillance tech used by Chinese Government," *ABC News*, July 16, 2019, https://www.abc.net.au/news/2019-07-16/australian-unis-to-review-links-to-chinese-surveillance-tech/11309598.
[151] "Supplement No. 4 to Part 744-Entity List," Code of Federal Regulations, accessed May 23, 2024, https://www.ecfr.gov/current/title-15/subtitle-B/chapter-VII/subchapter-C/part-744/appendix-

CETC company subsidiaries are often controlled by the research institutes, albeit not always openly. The US has seen several cases linking CETC research institutes to export control violations. One such case, from 2003/2004, involved military-grade electronics, including gallium-arsenide monolithic microwave integrated circuits, which are used in military applications such as radars, electronic warfare, and missiles. The perpetrators were naturalised US citizens born in China, who acted on behalf of the CETC's 20th and 41st research institutes, which were then formally part of the Ministry of Information Industry. The successful exports involved the use of a shell company and falsification of shipping documents.[152]

Other examples include Chinese nationals illegally exporting electronic components to various CETC research institutes and subsidiaries by transshipments via Hong Kong in 2004–7, and a Chinese-born US naturalised citizen attempting to design and illegally export high-performance analogue-to-digital converters to CETC's 24th research institute in 2009.[153]

3.2.3 Xidian University and UESTC

The CETC-affiliated defence-electronics universities are also associated with technology-transfer activities. For instance, researchers from Xidian University's Defence S&T Key Laboratory of Radar Signal Processing have been engaged in Sino-US joint research on radar technology with the University of Delaware and the University of Florida, while obfuscating the lab's defence ties.[154] Xidian University is also tied to the PLA's signal intelligence organisation and allegedly supports military hacker training. Moreover, Xidian University has had some success in foreign talent recruitment, hiring foreign experts to its PLA-managed Mobile Internet Security Talent Recruitment Base.[155] In addition to its military and defence-industrial ties, Xidian University maintains connections with the national security apparatus. This includes arranging joint graduate programs and research laboratories with the provincial chapters of the Ministry of State Security's (MSS) 13th bureau, one of which manages the APT3 cyberespionage group.[156]

Like Xidian University, UESTC is also associated with PLA signals-intelligence operations and military hacker training. Furthermore, UESTC is renowned for its AI research, which has ties to human rights abuse. For instance, UESTC was

Supplement%20No.%204%20to%20Part%20744.

[152] Mattis and Brazil, *Chinese Communist Espionage*, 147; "Manten Complaint," United States District Court: District of New Jersey, June 30, 2004, https://www.justice.gov/archive/usao/nj/Press/files/pdffiles/Older/Mantencomplaint.pdf, 7.

[153] Mattis and Brazil, *Chinese Communist Espionage*, 148, 182–3; "Two Chinese Nationals Convicted of Illegally Exporting Electronics Components Used in Military Radar & Electronic Warfare," US Department of Justice (press release), May 17, 2010, https://www.justice.gov/opa/pr/two-chinese-nationals-convicted-illegally-exporting-electronics-components-used-military.

[154] Stoff, "Sino-foreign research collaboration," 171, 178.

[155] Australian Strategic Policy Institute, "Xidian University."

[156] Cary, *Academics, AI, and APTs*, 16–7.

involved in the talent recruitment that led to the founding of AI surveillance company Koala AI. This was an example of successful talent acquisition under the Thousand Talents Plan in the early 2010s, where Chinese nationals developing their academic careers in Australia were recruited back to China and subsequently founded Koala AI. In addition, UESTC has collaborated with foreign academics. It runs a joint research centre in fibre optics with the University of New South Wales and a joint college in electronics with the University of Glasgow.[157]

3.3 Conclusion

As a state-owned defence-industry champion ultimately under State Council and CCP control, CETC's military-use technologies, including its defence research, provide important contributions to the PLA's military capabilities. At the same time, CETC's civilian and dual-use products, exemplified by solar panels and semiconductor-manufacturing equipment, also benefit the broader Chinese industry, some of which in turn provides supplies to the defence sector and the military.

The international commercial activities of CETC and its subsidiaries suggest that CETC has a history of (mutually) beneficial business relationships with foreign partners, not least from the US. This has potentially also entailed technology transfers for CETC, including in dual-use technology areas such as AI, 5G communications technology, and intelligent manufacturing. Illegal imports involving CETC research institutes have granted CETC access to foreign dual-use technologies. This activity has also contributed to the blacklisting of many of its constituent research institutes by the US and other countries.

At the same time, much of CETC's international activity relates to civilian technologies. Also, many of CETC's international commercial ventures, such as solar-panel production, seem to entail CETC bringing its technologies abroad, rather than the opposite. Nevertheless, projects that sound harmless or irrelevant from a technology-transfer perspective could potentially contribute to the overall competitiveness, international collaboration opportunities, and future industrial development potential of CETC, its subsidiaries, and other Chinese companies with whom it cooperates. However, some of the CETC conglomerate's subsidiaries, such as those focused on solar-power technology, will likely also face difficulties in finding international partners, despite their civilian production focus, due to the defence industry and military ties of the conglomerate as a whole.

CETC's overseas commercial activities involve research, development, and production. Despite the engagement of CETC's research institutes in both basic and applied research, only a few appear to be purely research-focused. However, this is not surprising. In fact, CETC is perhaps best regarded as a number of decentralised sub-conglomerates within the overarching corporate group. Many or

[157] Australian Strategic Policy Institute, "The University of Electronic Science and Technology of China."

most of the individual CETC research institutes have their own subsidiaries and commercial networks, often characterised by opaque organisational ties and pseudonyms. CETC's historical roots, having sprung out of a ministry and its separate constituent entities, likely still have bearing on the corporate group's organisational behaviour today. That is, each research institute acts more or less autonomously, focussing on its own core activity, until top-down enforcement demands otherwise. Through the corporate entities, research done in China or abroad is commercialised with both civilian and military end-users, through a mix of commercial and MCF motives. Furthermore, CETC teams up with other Chinese actors within the MCF system, such as the PLA, universities, and companies, while also acting as a "middleman" and providing them access to foreign partners.[158]

CETC is not only a state-owned enterprise but also a quasi-governmental actor. For example, it has been involved in establishing and financing major MCF government-guidance funds. These investment funds act as CETC's extended arm through their investments domestically and abroad and are as such part of CETC's technology transfer and MCF contributions. Additionally, CETC oversees two major defence-related universities, Xidian University and UESTC, as part of CETC's defence-electronics ecosystem. Most of their foreign technology-transfer contributions likely stem from international academic exchange, such as research collaboration with foreign universities and hosting foreign researchers in their key laboratories. However, Xidian University and UESTC also engage in insidious activities, such as cyberespionage, which includes joint efforts with the MSS.

CETC, as a whole, fulfils all the different roles of the technology-transfer process. It acts as an *enabler* of technology transfer and MCF efforts through its management of government guidance funds and defence-related universities; as an *introducer* of foreign technology through its many constituent entities that engage in various international commercial and academic ventures; as a *digester* of acquired technologies, notably by hosting a number of key laboratories; and as an *absorber*, represented by a multitude of sub-entities with the capacity to turn foreign technologies into tangible output, notably commercial subsidiaries, listed companies, various key laboratories, and National Engineering Research Centres.

In summary, CETC is a prominent example of an actor that unites the different spheres of government, academia, and enterprise that together constitute China's technology-transfer ecosystem. Through the many different entities represented by the CETC conglomerate, it is both a major governmental, commercial, and academic actor and the epitome of a dual-use industrial actor. CETC collaborates in technology-transfer efforts with most of the different types of actors in China's technology-transfer ecosystem. Based on the examples in this report, the exception is United Front organisations. However, it is characteristic of the United Front strategy, as well as most MSS operations, that any potential connections to CETC's business activities are not openly admitted.

[158] Luce, "A Model Company."

4 Conclusion and discussion

This chapter presents the conclusions drawn from addressing the report's research question. Moreover, it discusses the implications of increased geopoliticisation of the semiconductor industry for China's efforts to acquire foreign technology. Lastly, it provides suggestions for future research to complement the findings of this report.

4.1 Conclusion

This report provides a comprehensive overview of the diversity of actors involved in China's technology-transfer ecosystem, the roles they play, and the means they employ. The case study in Chapter 3 concretises the bird's-eye view provided in Chapter 2 by taking a closer look at a specific actor within the ecosystem.

Figures 1 and 2, found at the beginning of Chapters 2 and 3, respectively, illustrate not only the different categories of actors and how they interact, whether in terms of hierarchical relationships or collaborative efforts, but also the different roles they play in China's official IDAR technology-transfer process. This report especially highlights the role of *enablers*, notably government actors, not least various departments under the State Council, which create plans, provide funding, or otherwise serve as controlling entities in efforts to leverage foreign technologies for China's domestic industry. *Introducers* of foreign technology to China are found within every category of actors described in this report, whereas *digesters* and *absorbers* are primarily concentrated in the spheres of academia and enterprise.

However, this report demonstrates that there is a lack of task separation within China's technology-transfer ecosystem, making it difficult to simply pair each respective role within the IDAR process with a corresponding category of actors within the technology-transfer ecosystem. This is perhaps in part a reflection of the overall tight links within China's military-academic-industrial complex, intentionally shaped by the CCP-controlled state apparatus to further the party's strategic ambitions. The proliferation of key laboratories scattered across government, academia, enterprise, and the military serves as an illustration.

Overlapping responsibilities within the ecosystem suggest not only synergies but also the potential for intra-state "turf wars." For instance, the Ministry of State Security (MSS) and the Ministry of Public Security are known to have been rivals ever since the former was founded in 1983 and absorbed foreign intelligence functions from the latter.[159] Diverse involvement in similar technology-transfer activities also suggests inefficiencies and difficulties in identifying accountability for failed efforts.

[159] Cheung, *Innovate to Dominate*, 79.

In addition to turf wars, each actor has their own set of priorities that may not always overlap. For example, consider the question of trade and foreign imports. Trade agreements implemented by the Ministry of Commerce that grant foreign companies beneficial access to the Chinese market can simultaneously serve as an important diplomatic tool for the Ministry of Foreign Affairs and pose a threat to the competitiveness of domestic industry, according to the National Development and Reform Commission.[160] Though this is just one example, it illustrates that there needs to be continuous centralised control over the different actors in China's technology-transfer ecosystem to prevent differing interests from harming collaborative efforts.

This report places special focus on semiconductor technology as a prominent example of a dual-use technology area that symbolises the ties between China's technology-transfer efforts and its Military-Civil Fusion ambitions. Semiconductor technology is a prime target for China's technology transfer efforts. Consequently, all of the different actors in China's ecosystem for foreign technology transfer have some interest in the successful acquisition of foreign semiconductor technology. However, some actors have a profile of particular relevance. Among the government departments under the State Council, the Ministry of Industry and Information Technology deserves special mention, considering its particular importance for the development of China's semiconductor industry. Its subentity, the State Administration of Science, Technology, and Industry for National Defence, acts as an important bridge between defence-related research institutions and the defence industry and thus has a unique opportunity to promote the proliferation of dual-use semiconductor technology within the MCF system.

The subject of Chapter 3's case study, China Electronics Technology Group Corporation, and its affiliated entities provide numerous examples of other actors with a profile of particular relevance, whether due to their focus on semiconductor technology or on applications such as, for instance, defence electronics and telecommunications. This includes research institutes, commercial subsidiaries, key laboratories, and National Engineering Research Centres under the CETC umbrella, as well as CETC-affiliated defence-related universities and investment funds.

4.2 Discussion

This section places the report's content into the current geopolitical context, characterised by US-China great-power rivalry, the increasing geopoliticisation of the semiconductor industry, and Western economic-security initiatives. It also explores the implications for China's technology-transfer ecosystem and its efforts to acquire foreign technology.

[160] Reilly, *Orchestration*, 40.

4.2.1 Waning access to legal technology transfer for China

Attempts to acquire foreign technologies by the different actors within China's technology-transfer ecosystem described herein naturally vary in their success rate. There is a plethora of legal, illegal, and grey-zone means for China to acquire foreign technologies from both commercial and academic targets, as illustrated in Table 1 in Section 1.3 and throughout the preceding two chapters. Some actors and means will be more efficient than others, depending on the specific context. There are as many, or more, tales of failure as there are success stories.

This report does not set out to assess what means for technology transfer are currently the most common or efficient for China or what actors are the most successful. However, the author estimates that geopolitical developments suggest that legal means for technology transfer are becoming less available to China, whereas illegal and grey-zone means may become increasingly important. Not least, since the late 2010s, China has had a more difficult time to import both advanced semiconductors and important inputs for advanced semiconductor manufacturing, following a US-led export control regime against it.

Export controls targeting the Chinese high-tech industry, enforced by the US and its allies, such as the Netherlands and Japan, limit China's legal access to foreign semiconductor technology, including both advanced semiconductors and crucial manufacturing inputs. For instance, US semiconductor companies, such as Intel, Qualcomm, Nvidia, and AMD, can no longer export advanced semiconductors to China the way they used to, and commercial relationships with Chinese companies such as Hikvision are thus less likely to develop moving forward. In fact, export controls target many different actors within the Chinese semiconductor-dependent high-tech industry, including emerging technologies with dual-use applications such as AI and quantum computing. Targeted actors include not only companies such as Huawei, ZTE, and Semiconductor Manufacturing International Corporation but also, for instance, universities and CAS-associated research institutes.[161]

At the same time, US-led export controls against China risk backfiring in the long run, in so far as the controlled technologies and associated companies end up losing market share and competitiveness, while China might successfully develop new technologies and reduce its dependence on foreign suppliers. For example, China's continued access to foreign suppliers for many of the necessary subcomponents of crucial semiconductor-manufacturing equipment might help it develop its own domestic alternatives.[162] Moreover, export controls are never watertight, and China will likely continue to have access to certain prohibited goods through various circumvention schemes.

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[161] "China's Premier Li Qiang in Anhui: Enhancing capability for innovation-driven development and accelerating tech self-reliance," *Geopolitechs* (blog), May 11, 2024, https://www.geopolitechs.org/p/chinas-premier-li-qiang-in-anhui?r=2d0s7n&utm_campaign=post&utm_medium=web.

[162] Jan-Peter Kleinhans and John Lee, "Is the EU's Semiconductor Manufacturing Equipment a Strategic Chokepoint?" in *Reverse Dependency* (see note 124), 39.

Nevertheless, China's legal means to access foreign technology are being limited not only by export-control regimes but also by inbound foreign-investment screening, which has become tougher in the US, EU, and beyond. This includes Taiwan, a major semiconductor-industry nation, which has recently toughened its legislation to prevent the leakage of critical technologies to China. This includes measures against talent poaching, economic espionage, and illegal investments.

Taiwan has also long had investment screening for outbound investments in place; this is an area in which both the US and EU are also currently contemplating new legislation. Altogether, these trends suggest that China is increasingly facing restrictions on technology transfer through legal commercial means such as imports, company acquisitions, joint ventures, and, to some extent, talent recruitment. However, China is also contributing to this partial decoupling of legal commercial interaction, for instance, through recent initiatives to phase out US-made processors among domestic telecommunication providers.

China is also facing growing restrictions on its access to academic exchange, another important source of foreign technology. The risks involved in conducting collaborative research with China have gained increased attention, in part due to the many cases of non-transparency regarding the Chinese counterpart's military and defence ties. It seems likely that the US and many of its allies will increasingly aim to circumscribe academic ties with China, particularly within dual-use technology areas such as semiconductor technology.

At the same time, there are numerous benefits associated with international research collaboration, and many Western academic institutions will likely be reluctant to go far in breaking ties with their Chinese counterparts. Moreover, researchers may not perceive the national-security risks associated with sharing information on their research activities with China.[163]

4.2.2 Illicit technology transfers growing more likely?

Whereas legal means for foreign technology transfer from the West are becoming less useful for China, state-led goals for the domestic semiconductor industry and S&T in general are likely to remain the same. If the legal options for accessing desired technologies from abroad are becoming restricted, it seems plausible that the employment of illegal or grey-zone means will become increasingly important tools in China's technology-transfer toolbox. This includes, for instance, export control circumvention, the use of front organisations, and industrial espionage.

The advanced lithography machines produced by the Dutch company ASML, of crucial importance for advanced front-end semiconductor manufacturing, provide an interesting scenario in this regard. There have already been instances of ASML

[163] Fiona Quimbre, "Educating Academics Will Ease UK Universities' Foreign Influence Crisis," RAND Corporation, October 19, 2023, https://www.rand.org/pubs/commentary/2023/10/educating-academics-will-ease-uk-universities-foreign.html.

accusing China of exploiting former ASML employees to access trade secrets.[164] Following US-initiated export controls that prevent China from legally procuring ASML's most advanced equipment, the incentive for China now appears to be to seek access through other means. For instance, this can involve accessing ASML's technical blueprints through industrial or cyber espionage, combined with targeted talent recruitment to acquire the right expertise, and a combination of legal and illegal imports of the necessary lithography-machine subcomponents from ASML's extensive supplier network.

If China has to increasingly resort to illegal means to access its desired technologies, especially in dual-use areas such as semiconductors, certain actors within China's technology-transfer ecosystem will become increasingly important, not least the MSS, but also, for instance, the patriotic diaspora with valuable academic and commercial networks overseas. Meanwhile, other actors within the ecosystem, such as companies that engage in commercial ventures with foreign industry or academics who engage in international academic exchange, will become less important.

Also, to the extent that illegal means take precedence over legal means, tracking China's technology-transfer efforts will likely also become increasingly difficult. There are already signs that the Chinese state is making efforts to obscure its strategies and actions tied to its industrial ambitions in relation to dual-use industries. Some examples include the cessation of transparent reporting of Military-Civil Fusion activities and the toning down and rebranding of Made in China 2025 ambitions. To some extent, foreign scrutiny, not least from the US, of China's civil-military ambitions has been counterproductive, as it has incentivised China to shroud its intentions and activities, which were previously quite transparent.[165]

This has also made external analysis of China's ambitions more difficult, illustrated by the fact that updated versions of long-term strategies such as the new Medium- and Long-Term Program for Science and Technology Development (for 2021–35) or sectoral strategies, such as the one for critical raw materials, are classified or otherwise made unavailable to foreign observers.[166] In other words, not only is clandestine technology-transfer activity by actors such as the MSS likely to increase, but otherwise legal or grey-zone technology-transfer activities by government departments, academic institutions, and commercial entities may also become increasingly shrouded in fog.

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[164] Cagan Koc and Debby Wu, "ASML Says Ex-Employee in China Stole Chip Data," *Bloomberg*, February 15, 2023, https://www.bloomberg.com/news/articles/2023-02-15/asml-says-ex-employee-in-china-misappropriated-chip-data.

[165] Cheung, *Innovate to Dominate*, 102–3, 139–40.

[166] See, for instance, Patrik Andersson, "The growing secrecy around China's mineral resource planning: implications for the EU," Swedish National China Centre, May 16, 2024, https://kinacentrum.se/publikationer/the-growing-secrecy-around-chinas-mineral-resource-planning-implications-for-the-eu/.

4.2.3 Continued importance of talent recruitment and OSINT

Foreign talent recruitment is an example of a means of technology transfer that could gain increasing importance as many other avenues become restricted for China. While much of China's foreign talent recruitment is entirely legal, some cases involve coercive methods or the illegal disclosure of classified or proprietary information. The importance of foreign talent recruitment for China is already apparent, judging by the breadth of actors involved, including governmental, commercial, and academic entities. China does not necessarily have the proper infrastructure in place to successfully absorb and utilise technologies acquired from abroad, and part of the problem is a lack of adequate personnel with the appropriate know-how.

Another aspect of having insufficient infrastructure to absorb foreign technologies is a persistent lack of efficient collaboration between different spheres of the Chinese system. As a consequence, foreign technologies introduced to China have oftentimes ended up being improperly digested, absorbed, and reinnovated.[167] The Chinese state's awareness of this issue is reflected in its continued efforts to deepen ties between academia and enterprise. This is exemplified by the institutionalisation of key laboratories that transect sectoral boundaries, encompassing government departments, civilian and defence universities, private and state-owned enterprises, and the military. Foreign talent recruitment plays a crucial role in supporting these key laboratories, particularly in their efforts to digest and absorb foreign technology.

Talent recruitment also remains a venue for Chinese companies, including in dual-use industries, to acquire foreign technology otherwise prohibited by export controls and investment-screening mechanisms. It is harder to prohibit people from sharing their knowledge, in China or while remaining abroad, than it is to prevent the flow of tangible goods. Not all countries have as strict talent recruitment legislation as, for instance, Taiwan. Actors from all spheres of the Chinese system will likely remain willing to provide generous remuneration in order to attract foreign expertise.

The importance of the United Front Work Department's overseas activities pertaining to talent recruitment might also have increased in importance for China's technology-transfer efforts during the past decade, following a statement in 2015 by Xi Jinping that emphasised this aspect of United Front work.[168] At thesame time, foreign recruitees will have to balance the benefits with the risks of being scrutinised and losing access to lucrative career opportunities outside of China.

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[167] 乔为国, 陈芳, 引进消化吸收再创新的政策体系与实施问题研究, 科技促进发展 [Qiao Weiguo and Chen Fang, "Research on the Policy System and Implementation of Technology Import, Absorption and Re-innovation," *Science & Technology for Development*] 6, no. 11 (December 2010): 37, https://www.chinastd.net/thesisDetails#10.11842/chips.2010.11.005&lang=zh.

[168] Joske and Stoff, "The United Front and technology transfer," 260.

Open-source intelligence-gathering is another important legal means for China to acquire foreign technology that remains useful. This may be one of the primary avenues for technology transfer to China, besides other means that understandably garner more attention, such as, for example, industrial and cyber espionage.[169] In fact, China has had a dedicated system for open-source intelligence-gathering since the 1950s, perhaps employing as many as 100,000 people with a budget exceeding that of state-funded R&D.[170] This system is not only significant in quantitative terms, as it employs both advanced technology and highly skilled personnel.[171]

In the semiconductor industry, not only basic and intermediate research, but also certain mature technology, is openly accessible. Notably, RISC-V is an open-source chip-design architecture with potential to help China reduce its reliance on foreign IP, dominated by Intel in the US and Arm in the UK.[172] For example, Alibaba's chip-design subsidiary T-Head/Pingtouge has used RISC-V to design processors, e.g., for use in AI.[173] It would be difficult both in principle and in practice to prevent China from utilising openly accessible technology, such as RISC-V or know-how provided by academic journals.

4.3 Future studies

Using this study as a starting point, there is plenty of opportunity to conduct case studies, whether focusing on specific actors, means, or technology areas. It might even be urgent to do so, considering that much of China's efforts to acquire foreign technology are still legal and openly reported, for instance on the websites of government departments, universities, and companies. To illustrate, there is plenty of information available on international research conferences, business expos, and foreign-talent recruitment. As is the case for most countries, the available information is more abundant on websites in the national language, namely, Mandarin Chinese. Case studies on individual government, academic, or commercial actors could focus, for example, on identifying changing patterns in technology transfer activity, or analysing gaps between openly reported activities and those that are likely to take place unreported.

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[169] Cheung, *Innovate to Dominate*, 217; Mattis and Brazil, *Chinese Communist Espionage*, 145.
[170] Chang and Hannas, "Foreign support," 39.
[171] William C. Hannas and Huey-Meey Chang, "Measuring risk," in *Chinese Power* (see note 9), 266.
[172] Jacob Feldgoise, "RISC-V: What it is and Why it Matters," Center for Security and Emerging Technology, January 22, 2024, https://cset.georgetown.edu/article/risc-v-what-it-is-and-why-it-matters/.
[173] Jeffrey Burt, "Alibaba on the bleeding edge of RISC-V with XT910," *Next Platform*, August 21, 2020, https://www.nextplatform.com/2020/08/21/alibaba-on-the-bleeding-edge-of-risc-v-with-xt910/; Che Pan, "Alibaba's chip design subsidiary launches RISC-V chip to boost performance of its cloud data centres," *South China Morning Post*, November 2, 2023, https://www.scmp.com/tech/tech-trends/article/3240096/alibabas-chip-design-subsidiary-launches-risc-v-chip-boost-performance-its-cloud-data-centres.

This study largely describes the principal actors within China's technology-transfer ecosystem from a bird's-eye view. However, it is apparent in much of the studied material that the personal ties between members of government, academia, and enterprise are significant, exemplified by high-level personnel who have key positions within multiple organisations from different spheres at once. For example, government officials can simultaneously hold chairs in key laboratories, United Front organisations, or enterprises. Future studies could focus more on granular analysis of the importance of personal ties, for example, for decision-making and information dissemination, within China's technology transfer eco-system.

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