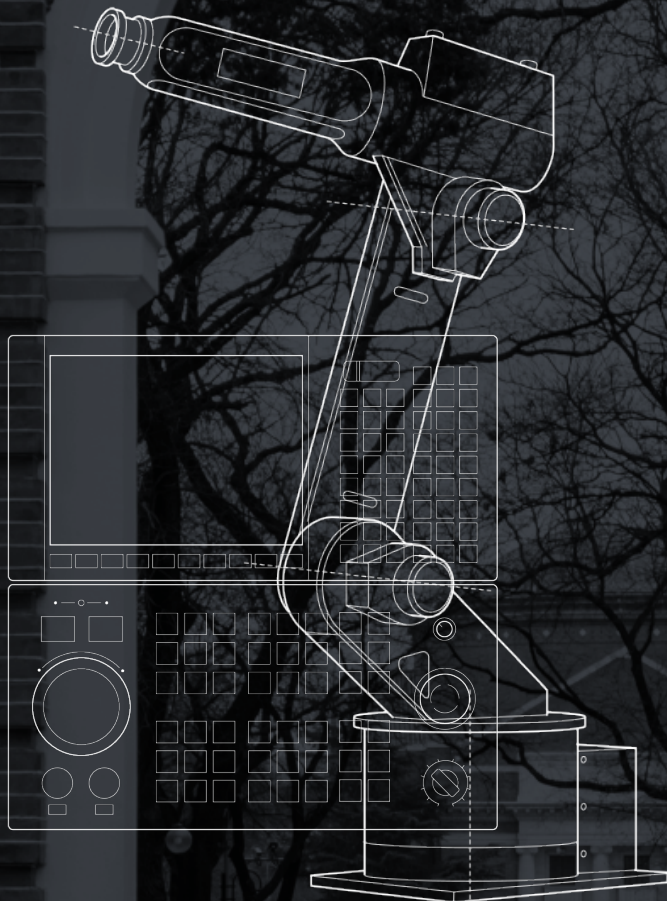


C4ADS
innovation for peace

Open Gates:

**Technology Transfer from Chinese Universities to the
Defense Industry Through Joint Ventures**



ABOUT C4ADS

C4ADS (www.c4ads.org) is a 501(c)(3) nonprofit organization dedicated to data-driven analysis and evidence-based reporting of conflict and security issues worldwide. Our approach leverages nontraditional investigative techniques and emerging analytical technologies. We recognize the value of working on the ground in the field, capturing local knowledge, and collecting original data to inform our analysis. At the same time, we employ cutting edge technology to manage and analyze that data. The result is an innovative analytical approach to conflict prevention and mitigation.

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ABOUT THE AUTHOR

Coby Goldberg is an Analyst at C4ADS on the Counterproliferation Cell, where he specializes in China's technology strategy and defense industry. His writing has been published in Foreign Policy, the Los Angeles Review of Books, and by the Center for a New American Security. He holds a BA in East Asian Studies from Princeton University.

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ANALYSIS POWERED BY



WINDWARD°



EXECUTIVE SUMMARY

Chinese universities operate dozens of joint ventures with Chinese defense conglomerates, which defense conglomerates use to obtain university intellectual property and the services of university faculty. Academics who continue to access domestic and global research networks through their university positions work for these companies. Ostensibly civilian universities that maintain global research collaborations transfer hundreds of patents to these companies. Yet the end-users of these companies' products, and in many cases their primary funders, are defense conglomerates. Because they are openly recorded in corporate records, these joint ventures can be used to identify national security risks within Chinese university networks.

In recent years, a growing body of national security literature has highlighted the role that Chinese universities play in the Chinese military-industrial complex. Past research has explored the role universities play in technology transfer into China, and has shed light on which Chinese universities have the most labs sponsored by defense conglomerates or the most graduates working for them.^{1 2 3} This report builds on that research by developing a methodology for identifying specific individuals at universities with ties to the defense industry, in order to provide a tool for differentiating academics and labs at civilian universities who have ties to the defense industry from those at the same universities who have no such ties.

To do so, this report takes a novel approach by using bulk publicly available information to conduct replicable analysis of university investment networks. We began with access to Chinese corporate records, showing investment relationships between companies and their subsidiaries. Next, we took a sample list of 79 universities and mapped out over 20,000 of their subsidiaries. Finally, we looked for instances of overlap in equity stakes between these 20,000 companies and a select list of seven well-known Chinese defense conglomerates and their subsidiaries, yielding a list of dozens of joint ventures which analysts then reviewed for relevance to U.S. national security interests. The results helped identify specific labs and professors within given universities that partner with defense conglomerates. This approach captures of course only one part of the risk picture within university investment networks, and risks outside of joint ventures are assessed in section four of the report. Still, it is one means of crafting more nuanced policy approaches to China's defense universities than those that characterize universities' relationships with China's military-civil fusion strategy in a binary.

Incentives in China's political economy are structured such that a growing number of prominent universities have some degree of tightening ties with the defense industry. Moving forward, it will be important for researchers to develop methodologies for identifying precisely where within university networks those ties exist. By identifying the connective tissue of joint ventures between universities and the defense ecosystem, this report provides a tool to enable foreign universities, corporate entities, and governments to mitigate their exposure to China's defense ecosystem while maintaining engagement with China's academic institutions.

¹ Fedasiuk, Ryan and Emily Weinstein. "Overseas Professionals and Technology Transfer to China." Center for Security and Emerging Technology, 21 July 2020, <https://cset.georgetown.edu/research/overseas-professionals-and-technology-transfer-to-china/>.

² Joske, Alex. "The China Defence Universities Tracker." Australian Strategic Policy Institute, 25 Nov. 2019, <https://www.aspi.org.au/report/china-defence-universities-tracker>.

³ Fedasiuk, Ryan and Emily Weinstein. "Universities and the Chinese Defense Technology Workforce." Center for Security and Emerging Technology, Dec. 2020, <https://live-cset-georgetown.pantheonsite.io/research/universities-and-the-chinese-defense-technology-workforce/>.

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BREAKING DOWN UNIVERSITY INVESTMENT NETWORKS

Chinese technology transfer can be geographically divided into two parts: the transfer of technology from foreign entities to Chinese entities, and the transfer of technology between Chinese entities. The former is the more widely studied technology transfer process, and occurs through Chinese investment in foreign enterprises, China's partnership with foreign universities, and espionage.⁴

But technology transfer does not end when technology crosses into China from abroad. In order to fulfill the Chinese state's policy ambitions in economic development and national security, technology must also successfully transfer from universities and other public research organizations into the commercial sector. As China's indigenous innovation capabilities continue to improve and new restrictions on research collaboration abroad limit its access to critical foreign technologies, this second form of technology transfer will grow in significance to Chinese policymakers. However, while a comparatively high portion of Chinese innovation occurs at universities,⁵ Chinese universities commercialize less than 5 percent of their patents on average, compared to an equivalent rate of around 37 percent for the top 58 universities in the United States.⁶ ⁷ Because this prevents China's economy from benefiting from the fruits of university research, Chinese policymakers have sought to encourage universities to transfer research and technology to industry by investing in companies founded by university faculty members and built on university patents.

Universities first began to build corporate networks in the late 1980s as part of a broader effort to diversify revenue streams away from government funds.⁸ ⁹ Universities took equity stakes in their professors' commercial ventures alongside co-investors like private companies, local governments, and state-owned enterprises. These investments provided universities with new private sector funding for research, while the ventures also created future revenue streams for universities.¹⁰ ¹¹ More recently, Chinese policymakers have sought to accelerate the growth of these corporate networks through policy changes at both the national and local level that have encouraged universities to give their faculty a larger stake in the post-transfer income

⁴ For an account of these strategies of technology transfer, see Hannas, William, James Mulvenon, and Anna Puglisi. *Chinese Industrial Espionage: Technology Acquisition and Military Modernisation*. Routledge, May 2013.

⁵ 18 percent of Chinese patent applications come from universities, compared to about 2 percent in the United States. See "Zhejiang daxue he qinghua daxue gaoju 2018 nian shouquan faming zhuanli guonei wai gaoxiao shenqing ren paiming qian liang ming" [Zhejiang University and Tsinghua University are among the top two domestic and foreign university applicants for authorized invention patents in 2018]. Sohu, 21 Feb. 2019, <https://archive.ph/5FeLX>.

⁶ Zhang, Xiaoyu. "Gaoxiao zhuanli jishu chanye hua buzhi 5%, daodi gai ruhe bimian ziyuan langfei" [The industrialization of patented technology in universities is less than 5%, how can we avoid waste of resources]. Huahuize Intellectual Property Wechat, 21 Nov. 2018, <https://web.archive.org/web/20210330133524/https://mp.weixin.qq.com/s/k4HdSq4bYm1sBOBHGHGXJw>.

⁷ Caviggiola, Federico, Antonio De Marco, Fabio Montobbio, and Elisa Ughetto. "The licensing and selling of inventions by US universities." *Technological Forecasting and Social Change*, vol. 159, Oct. 2020, <https://doi.org/10.1016/j.techfore.2020.120189>.

⁸ Li, Wenli and Liu Qiang. "Chinese Higher Education Finance: Changes over Time and Perspectives to the Future." *Procedia - Social and Behavioral Sciences*, vol. 77, 22 Apr. 2013, <https://doi.org/10.1016/j.sbspro.2013.03.095>.

⁹ Zou, Yonghua and Wanxia Zhao. "Anatomy of Tsinghua University Science Park in China: institutional evolution and assessment." *The Journal of Technology Transfer*, vol. 39, issue 5, May 2012, <https://doi.org/10.1007/s10961-013-9314-y>.

¹⁰ Li, Wenli and Liu Qiang. "Chinese Higher Education Finance: Changes over Time and Perspectives to the Future." *Procedia - Social and Behavioral Sciences*, vol. 77, 22 Apr. 2013, <https://doi.org/10.1016/j.sbspro.2013.03.095>.

¹¹ Zou, Yonghua and Wanxia Zhao. "Anatomy of Tsinghua University Science Park in China: institutional evolution and assessment." *The Journal of Technology Transfer*, vol. 39, issue 5, May 2012, <https://doi.org/10.1007/s10961-013-9314-y>.

generated through these companies, further incentivizing faculty to research technology that can be commercialized.^{12 13 14 15} With these policy changes, universities have invested in a growing number of companies over the past decade. (See Figure 1).

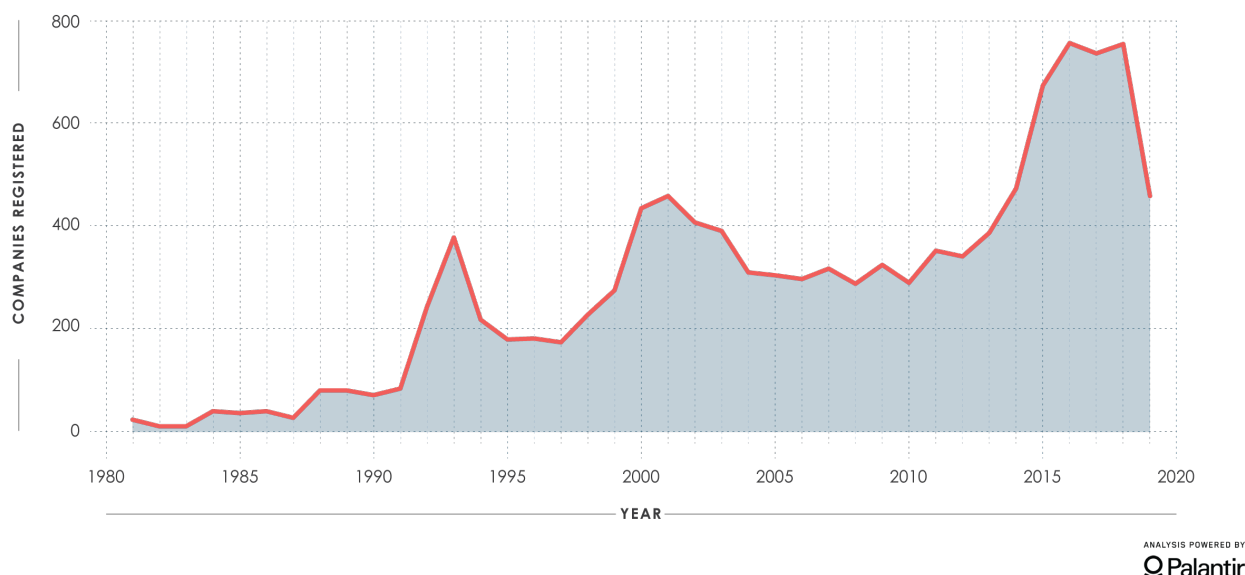


Figure 1: Thanks in part to policy changes meant to encourage greater technology transfer from universities to industry, the number of companies registered per year across the 79 university investment networks analyzed in this paper rose from around 190 per year between 1990 and 1999 to a high of 756 registered in 2016 alone.

These university-invested companies play an increasingly important role in inducing academic research towards the Chinese state's policy goals, and in some cases toward the needs of the Chinese military. Through some of these companies, universities sell patents to military end-users, and professors take on positions in the defense industry while holding concurrent positions as university faculty. Of course, only a small portion of these companies play such a role. The challenge, then, is identifying those university-invested companies that transfer technology to the defense industry, in order to differentiate them from the large majority of university-invested companies that operate in non-risky fields.

¹² Ren, Xiaozhang. "Keyan chengguo zhuanhua yi da nan ti zhong bei jie jue: Zhuanrang dingjia bu zai yaoqiu zichen pinggu" [A big problem in the transformation of scientific research results was finally solved: transfer pricing no longer requires asset evaluation]. Yicai, 8 Apr. 2019, <https://archive.ph/TTezY>.

¹³ "Jiaoyu bu guojia zhishi chanquan ju keji bu guanyu tisheng gaodeng xuexiao zhuanli zhiliang cujin zhuanhua yunying de ruogan yijian" [Several Opinions of the Ministry of Education and the State Intellectual Property Office of the Ministry of Science and Technology on Improving the Quality of Patent in Higher Education and Promoting Transformation and Application]. Ministry of Education of the People's Republic of China, 19 Feb. 2020, <https://archive.ph/ztd5>.

¹⁴ "Announcement of the Standing Committee of Shanghai Municipal People's Congress No. 53." The Standing Committee of Shanghai Municipal People's Congress, 20 Apr. 2017, <https://archive.ph/cXRQO>.

¹⁵ "Zhonghua renmin gongheguo cujin keji chengguo zhuanhua fa" [People's Republic of China Notice on Several Provisions of the Law on Promoting the Transformation of Scientific and Technological Achievements]. State Council, 2 March 2016, <https://archive.ph/w57VI>.

As connective tissue between universities and defense conglomerates, joint ventures provide a window into which specific research labs and professors at a given university are materially supporting China's defense industry, and can therefore be useful to the international community in understanding where university partnerships may create inadvertent exposure to China's military-industrial complex. These joint ventures do not present a complete picture of the risks posed by university investment networks. Some university-affiliated companies with no investment links to defense conglomerates also facilitate the transfer of technology to the defense industry, as demonstrated in the fourth section of this report. Still, joint ventures are a useful risk signal that can be used to identify researchers and university labs that are contributing to China's military development.

We used Chinese corporate registry filings to identify these joint ventures. To do so, we first compiled a list of seven state-owned defense conglomerates and 79 mostly civilian universities with purported ties to China's military.¹⁶ The 79 universities were chosen for their ties to China's military-industrial complex as previously identified in research by the Australian Strategic Policy Institute, but they also represent some of China's leading research institutions, accounting for sixteen of the top twenty Chinese universities as measured by quantity of patents held.^{17 18}

We then used corporate records to identify more than 60,000 companies in which the defense conglomerates and universities are invested, which were integrated and standardized using Palantir Foundry. We mapped out the companies within two degrees of the defense conglomerates and within three degrees of the universities using Palantir Gotham, which provides social network and other data analysis capabilities.¹⁹ (See Figure 2).

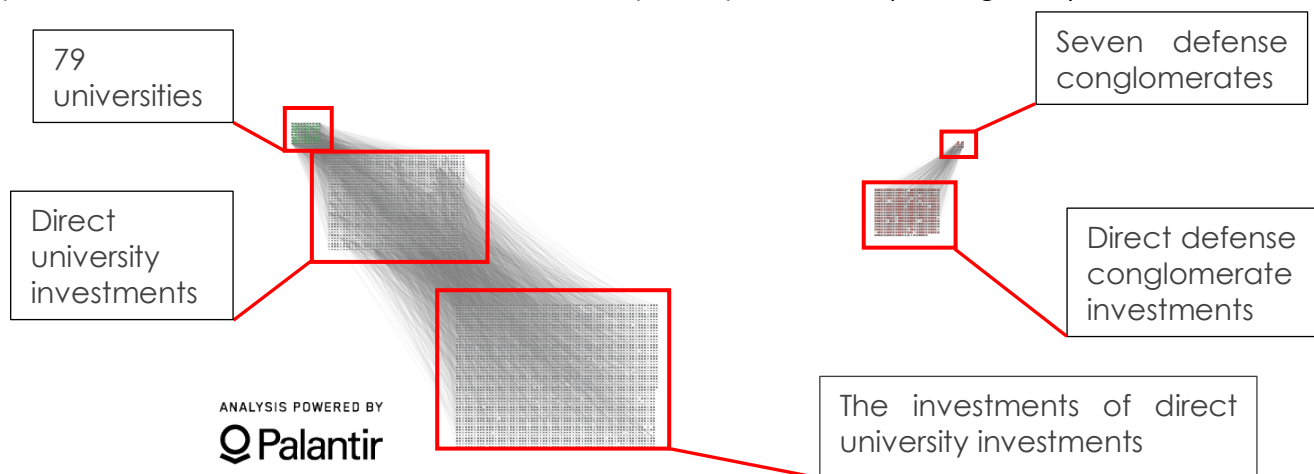


Figure 2: Using Palantir Gotham, we mapped the networks of our chosen of defense conglomerates and universities

¹⁶ Full lists of the defense conglomerates and universities used in this analysis are available in the appendices.

¹⁷ Joske, Alex. "The China Defence Universities Tracker." Australian Strategic Policy Institute, 25 Nov. 2019, <https://www.aspi.org.au/report/china-defence-universities-tracker>.

¹⁸ "Faming zhuanli zuixin 50 qiang gaoxiao chulu" [The latest top 50 universities for invention patents are released]. China National Intellectual Property Administration, 23 Mar. 2017, <https://archive.ph/Szgqa>.

¹⁹ This degree of analysis still captures some companies that operate outside of the defense domain. For example, our research found joint ventures between universities and defense conglomerates in a car company and a healthcare firm. But this analysis is conservative by other measures: if expanded to reach two levels further in the subsidiary chain of both SOEs and universities, 45 of the 79 Chinese universities in the dataset share investments with a defense conglomerate. Given the extensive use of shell companies as investment holding companies in the Chinese corporate environment, this broader analysis of corporate networks would also yield valuable analysis. The analytical boundaries were therefore set to balance these competing considerations.

We next used Palantir Gotham to identify companies with direct or indirect investments from both state-owned defense conglomerates and universities, which analysts then reviewed for relevance to U.S. national security interests. (See Figure 3). The next section outlines the structure and function of the joint ventures identified in this process.

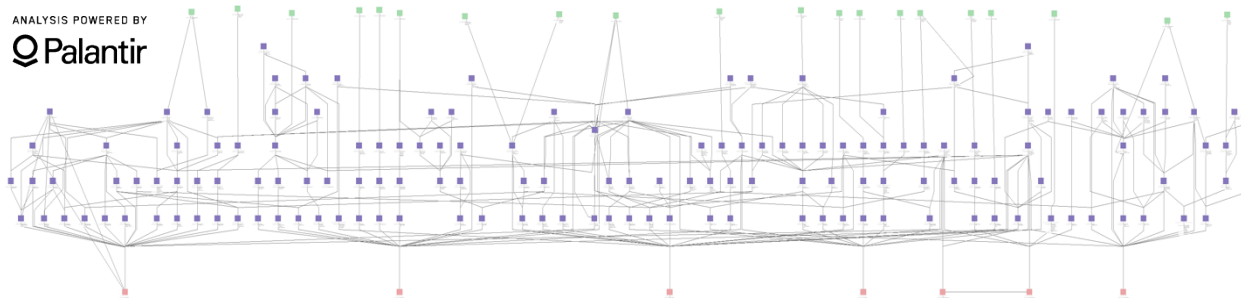


Figure 3: Using Palantir Gotham, we identified the joint ventures between defense conglomerates (in red) and universities (in green)

HOW JOINT VENTURES CONNECT DEFENSE COMPANIES AND UNIVERSITIES

Through joint ventures, university faculty are put to work for defense conglomerates and university patents are transferred to defense conglomerates.

In working for these enterprises, professors can wear two hats: one as an executive or researcher for a corporate affiliate of a Chinese defense conglomerate and one as an academic researcher at a university. As executives or researchers, professors can earn significant salaries and equity while contributing directly to China's defense industry.²⁰ As academics, they maintain a place in domestic and sometimes global research networks, and may inadvertently expose foreign universities to China's defense conglomerates.

These joint ventures also enable defense conglomerates to obtain licenses to patents originally held by the universities. C4ADS reviewed more than 1,000 patents licensed to twenty joint ventures and found nearly 40% had originally been filed by the partner university.^{21 22} In other words, research conducted at universities is transferred to the Chinese defense sector through these companies.

The following case studies illustrate these points in greater detail.

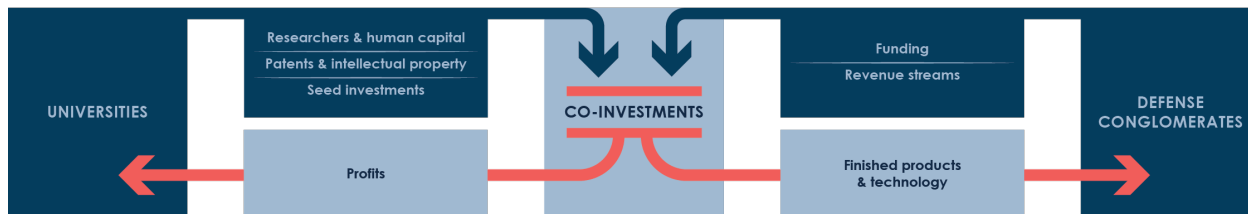


Figure 4: Joint ventures between universities and defense conglomerates enable defense conglomerates to access university research talent and intellectual property, while providing universities and their researchers with funding and potential future revenue streams.

²⁰ See Beijing Global Safety Technology below

²¹ Chinese corporate registry third-party aggregator

²² In other cases, universities license patents out directly to defense conglomerates, rather than through investee companies. The reasons for licensing patents out through investee companies range from profit motives for the university to professors' desire to remain in some control of their intellectual property. For a discussion of this latter phenomenon, see "Bupobuli: Zhongguo gaoxiao ji shu zhuonong zhong chuangye qiye de zichan fen chai yu 'jiaoshou nanti'" [Unbreakable and unreliable: the separation of assets of entrepreneurial enterprises and the "professor problem" in technology transfer of Chinese universities]. China Intellectual Property, July 2016, <https://archive.ph/T1yZy>.

Joint ventures are a source of human capital for defense conglomerates, putting university faculty and students to work on technologies that the defense industry needs.

The case of AVIC Gyro Beijing Photoelectricity Technology Co., Ltd. (中航捷锐北京光电技术有限公司) illustrates how joint ventures serve as vectors to transfer technology from Chinese universities to the defense sector. AVIC Gyro is a manufacturer of high precision fiber-optic gyroscopes, a technology needed for guidance and control systems in aircrafts and spaceships. China's largest aerospace manufacturer, AVIC, owns 77% of the company's equity through an affiliated research institute and a publicly traded affiliate according to corporate registry records, while the remaining shares are held by the Beihang University Asset Management Company and by Beihang University Professor of Engineering Zhang Chunxi (张春熹).²³ In its own words, the company "relies on the first-class technology and talents of Beihang University, combined with the advanced military product engineering production management experience and capital resource advantages of the AVIC platform."²⁴ AVIC Gyro "relies on...talents of Beihang University" in that it is staffed, at least in part, by Beihang University faculty—AVIC Gyro's chief engineer and minority shareholder, Zhang Chunxi, continues to work as a professor at Beihang University.²⁵ He teaches classes to undergraduates and graduate students, publishes patents through Beihang University, and gives talks at other universities, where he is introduced as a professor.^{26 27} He also has co-authored research with an Italian professor and sat on committees sponsored by British universities alongside professors from all across the world.^{28 29}

The company leverages this relationship with Beihang University—"relying on Beihang's solid theoretical foundation under the difficult conditions of foreign technology blockade," as one article about the company puts it³⁰—to develop technology that services the needs of the military. The company holds third level military industry production safety standardization accreditation (军工体系安全生产标准化三级), and won third place at a competition in Beijing for dual-use military equipment.³¹ It also counts companies like AVIC subsidiary Shaanxi Huayan Aviation Instrument and defense industry supplier Beijing Sanchi Inertial Technology among its customers.^{32 33}

Joint ventures enable defense conglomerates to access university patents.

Some university faculty who do not work for a joint venture still see intellectual property that they helped create transferred to the joint ventures. Xidian University, for example, is home to several major labs affiliated with the Chinese military, including the National Lab of Radar Signal

²³ Chinese corporate registry third-party aggregator

²⁴ "Zhonghang jie rui (beijing) guangdian jishu youxian gongsi" [AVIC Gyro (Beijing) Photoelectricity Technology Co., Ltd.]. AVIC Gyro (Beijing) Photoelectricity Technology, 20 Dec. 2017, <https://archive.ph/s2ZTc>.

²⁵ "Zhang Chunxi." Beijing University of Aeronautics and Astronautics, <https://archive.ph/t5ETT>.

²⁶ Ibid.

²⁷ "Beijing hangkong hangtian daxue bodao zhangchunxi jiaoshou lai xiao xueshu jiaoliu" [Professor Chunxi Zhang, PhD Supervisor of Beijing University of Aeronautics and Astronautics, came to the school for academic exchanges]. School of Physics and Electronic Science, Changsha University of Science and Technology, 2018, <https://archive.ph/EgJkO>.

²⁸ Liu, Yang, Zheng Li, Lianjie Fu, Jinling Wang, Sandro Radicella, and Chunxi Zhang. "Analyzing Ionosphere TEC and ROTI Responses on 2010 August High Speed Solar Winds." IEEE Access, vol. 7, 2019, <https://doi.org/10.1109/access.2019.2897793>.

²⁹ "Organizers." The 8th IEEE International Symposium on Instrumentation and Control Technology, 2012, <http://isict.ieee-ims.org/isict/2012/organizers>.

³⁰ "Bu wang chuxin, yong pan hangye zui gaofeng pijingzhanji, keji chuangxin xu huihuang" [Don't forget your original aspiration, always climb the highest peak of the industry], ST Daily, 12 Sep. 2017, <https://archive.ph/iN2Ye>.

³¹ "Qiyue Zizhi" [Company Qualifications]. AVIC Gyro (Beijing) Photoelectricity Technology, 20 Dec. 2017, <https://web.archive.org/web/20190716165845/http://avic-gyro.com/Portal.do?method=detailView&contentID=1>.

³² Chinese corporate registry third-party aggregator

³³ "Beijing san chi guanxing keji gufen youxian gongsi gongkai zhuanrang shuomingshu" [Beijing Sanchi Inertial Technology Co., Ltd. Public Transfer Manual]. China Dragons Securities Co., Ltd, July 2017, http://pdf.dfcfw.com/pdf/H2_AN201707310758655354_1.pdf.

Processing³⁴ and the National Key Laboratory of Antennas and Microwave Technology.³⁵ Drawing on the work done in these two labs, Xidian University partnered with China Electronics Technology Group Corporation (CETC), one of China's leading military electronics manufacturers, to establish a radar company, Xi'an Zhongdian Kexi Electric University Radar Technology Cooperative Innovation Research Institute Co., Ltd.^{36 37 38}

The company, led by CETC Chairman Xiong Qunli (熊群力) and Xidian University professor Shi Guangming (石光明), was founded in order to "raise the efficiency of transformation of scientific and technological achievements," according to a Xidian University website.³⁹ This transformation is made material in the form of patent licenses: of 348 patents held by the company according to corporate registry records, 200 were transferred from Xidian University.⁴⁰ Using these patents, the company strives "to develop new systems of radar, signal processing, information transmission, electronic devices and other related fields of radar technology" for the military market, the same Xidian University website specifies.⁴¹ As a result, the work of more than 60 Xidian University professors is being used, indirectly, to develop military technology. This includes professors who, for example, have taught in and collaborated with colleagues from the United Kingdom according to online research profiles.^{42 43 44 45} Though most of those professors do not work for the company, their research is "making a contribution to the construction of national defense informatization," as a corporate biography describes its work.⁴⁶

Joint ventures shape the direction of academic research through the provision of funding.

Joint ventures help researchers access new funding, while bending the focus of their research towards the needs of the funder. In 2001, Beijing University Physics Professor Yang Yingchang (杨应昌), then one of China's leading physicists, started a business with investment from China National Nuclear Corporation (CNNC), the leading state-owned enterprise for China's civilian and military nuclear programs.⁴⁷ Yang had seen his research into neodymium magnets⁴⁸ slowed by funding constraints, and reportedly had high hopes that the partnership would be a means to access the funding he needed while contributing to CNNC's mission and to the development

³⁴ 雷达信号处理国家重点实验室/雷达信号处理国防科技重点实验室

³⁵ 天线与微波技术国防科技重点实验室/天线与微波技术重点实验室

³⁶ 西安中电科西电科大雷达技术协同创新研究院有限公司

³⁷ "Xi'an zhong dian ke xi dian keda leida jishu xietong chuangxin yan jiu yuan youxian gongsi" [Xi'an Zhongdian Kexi Electric University Radar Technology Cooperative Innovation Research Institute Co., Ltd.]. Xidian University, 2018, <https://archive.ph/LjOJE>.

³⁸ Joske, Alex. "The China Defence Universities Tracker." Australian Strategic Policy Institute, 25 Nov. 2019, <https://www.aspi.org.au/report/china-defence-universities-tracker>.

³⁹ "Gongsi qingkuang" [Company Overview]. Xi'an Zhongdian Kexi Electric University Radar Technology Cooperative Innovation Research Institute Co., Ltd, 2018, <https://archive.ph/etfQj>.

⁴⁰ Chinese corporate registry third-party aggregator

⁴¹ "Gongsi qingkuang" [Company Overview]. Xi'an Zhongdian Kexi Electric University Radar Technology Cooperative Innovation Research Institute Co., Ltd, 2018, <https://archive.ph/etfQj>.

⁴² Ding, Jianshan, et al., inventors. Millimeter wave video imaging system and method based on synthetic aperture technique. 21 May 2019. Chinese Patent 107238866A, Google Patents, <https://patents.google.com/patent/CN107238866A/en>.

⁴³ "Geren Jianjie" [Personal profile]. Xidian University, https://faculty.xidian.edu.cn/DJS/zh_CN/index/358627/list/index.htm.

⁴⁴ Xu, Le, et al., inventors. Array aerial direction figure approximating method based on the weighting normal direction Return Law. 10 May 2019. Chinese Patent 106126836B, Google Patents, <https://patents.google.com/patent/CN106126836B/en>.

⁴⁵ Wen, Le-Hu, et. al. "A Wideband Series-Fed Circularly Polarized Differential Antenna by Using Crossed Open Slot-Pairs." IEEE Transactions on Antennas and Propagation, 18 Dec. 2019, https://www.researchgate.net/publication/338035584_A_Wideband_Series-Fed_Circularly_Polarized_Differential_Antenna_by_Using_Crossed_Open_Slot-Pairs.

⁴⁶ "Gongsi qingkuang" [Company Overview]. Xi'an Zhongdian Kexi Electric University Radar Technology Cooperative Innovation Research Institute Co., Ltd, 2018, <https://archive.ph/etfQj>.

⁴⁷ The company is called Shenzhen PKU Magpoles HI-TECH Co. (深圳北大双极高科技股份有限公司)

⁴⁸ Neodymium magnets are a rare earth-based magnet often described as the strongest magnets in the world. They have a range of applications, from door locks to electrical motors.

of China's rare earth industry.⁴⁹ Soon after the company was established, he was quoted in a Chinese media article as saying that, "for the researchers of Peking University, this means going out of the laboratory on campus and investing in the overall battlefield of the national economy, making direct contributions to strengthening our country's strength."⁵⁰ Through their joint ventures with universities, defense conglomerates can shape the research done within university walls, aligning it with national objectives.

Joint ventures form training pipelines that direct university students towards the defense industry.

Shared investments not only contribute to the technology needs of the stakeholder state-owned enterprise but also provide development and career pipelines that funnel university students towards the defense industry. Suzhou CNNC Huadong Radiation Co. (苏州中核华东辐照有限公司), a joint venture between Suzhou University and CNNC's publicly traded affiliate China Isotope & Radiation Corporation, represents this trend.⁵¹ Suzhou CNNC Huadong Radiation, like many companies within the CNNC corporate network, operates in a dual-use industry, conducting research into irradiation technology for medical applications while also holding accreditation from the China National Defense Technology Industry Laboratory Accreditation Committee (中国国防科技工业实验室认可委员会).⁵²

The company is a training ground for Suzhou University students, providing space for student research as well as offering internships to undergraduate and graduate students according to a post on the university website.⁵³ Through its shared investment with CNNC, Suzhou University has built a new pipeline for its students to research and work for a defense conglomerate.

As the above case studies demonstrate, joint ventures are publicly identifiable nodes in university networks that link Chinese academics to the Chinese military-industrial complex.

Defense conglomerates use joint ventures to obtain university intellectual property and the services of university faculty. These joint ventures are also funding pipelines that shape the nature of academic research, and training pipelines that shape the careers of university students. Because they are openly recorded in corporate records, joint ventures can be used to identify national security risks within Chinese university networks. In the next section, equity centric analysis is used to identify risk vectors within Tsinghua University, which controls the largest corporate network of any Chinese university.

⁴⁹ "Beida jiaoshou 20 nian yanjiu chengguo 'chenfeng' shiyan shi 5 nian zhihou" [Peking University professor's 20-year research results "dust-covered" the laboratory 5 years later]. Sina Finance, 8 Oct. 2001, <https://web.archive.org/web/20050208155458/http://finance.sina.com.cn/o/20011008/113811.html>.

⁵⁰ Ibid.

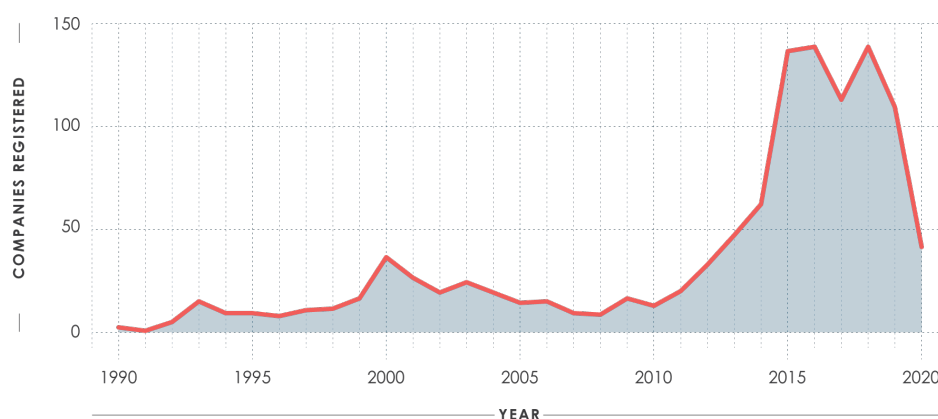
⁵¹ Chinese corporate registry third-party aggregator

⁵² "Suzhou zhonghe huadong fu zhao youxian gongsi (suzhou daxue fu zhao jishu yanjiu suo) jiance zhongxin zhaopin jianzhang" [Recruitment Guide for Testing Center of Suzhou China Nuclear East China Irradiation Co., Ltd.]. Graduate School of Suzhou University, 10 July 2015, <https://archive.ph/bcGO1>.

⁵³ Ibid.

USING JOINT VENTURES TO IDENTIFY RISK WITHIN TSINGHUA UNIVERSITY'S NETWORK

Tsinghua University, China's premier research institution, controls China's largest university investment network.⁵⁴ That network has grown rapidly in the past decade, accounting for one in seven of the companies established in the dataset of 79 universities between 2016 and 2018. (See Figure 5). Within a university network of Tsinghua's size and prestige, some degree of connection to the military-industrial complex is inevitable. The difficulty, though, is in pinpointing precisely where within the university network those ties exist, and which Tsinghua professors and labs are most enmeshed in the defense industry. Using shared equity analysis, C4ADS identified several Tsinghua affiliated companies and professors who are connected to defense conglomerates. Though this does not provide an exhaustive picture of points of risk within Tsinghua's corporate network, it is a useful tool for developing an initial picture of risk in the network at scale.



ANALYSIS POWERED BY
 Palantir

Figure 5: Tsinghua's corporate network has expanded rapidly in the past decade, with nearly 150 companies registered per year between 2015 and 2018.

⁵⁴ Chinese corporate registry third-party aggregator

One joint venture between Tsinghua and the defense industry is Tsinghua Tongfang (同方股份有限公司), a publicly traded company that started as a joint venture between CNNC and Tsinghua. Tsinghua Tongfang is deeply involved in China's military-civil fusion ecosystem, managing some of its investments through a military division that is dedicated to "realizing the corporate pursuit of serving national defense through practical actions," as Tsinghua Tongfang's 2017 annual report puts it.^{55 56} Through its military division, Tsinghua Tongfang is invested in two laser companies,^{57 58} a satellite technology company,⁵⁹ and a marine technology company.⁶⁰ Tsinghua Tongfang remains in active control of these investments through the general manager of the company's military division,⁶¹ Zhang Xinghu (张兴虎), who is chairman of 14 of Tsinghua Tongfang's investments according to Chinese corporate registry records.⁶²

In some cases, Tsinghua Tongfang turns the research of Tsinghua professors into products for the military, while those professors access global academic networks in their roles as professors. Beijing Tongfang Huaguang System Technology (北京同方华光系统科技有限公司), for example, designs, develops, and produces high-powered lasers for China's army, navy, and air force, and has received weapons equipment quality certification.^{63 64} The company's founder, Tsinghua Professor Gong Mali (巩马理), comes from a defense industry background, having worked for the Chinese arms manufacturer NORINCO for ten years prior to becoming a researcher at Tsinghua in 1998.⁶⁵

In addition to running Beijing Tongfang Huaguang System Technology, Professor Gong is also part of global research networks. As of 2012, Gong reportedly ran the Tsinghua-Hitachi Via Laser Laboratory, which is sponsored by Japanese conglomerate Hitachi.⁶⁶ Gong also collaborated with Japanese engineers at Mitsubishi, working on at least one patent filed by the company according to public patent records.⁶⁷ Other professors associated with Beijing Tongfang Huaguang System Technology maintain international networks, too. Tsinghua professor Huang Lei (黄磊), whose name appears alongside Gong's on five patents belonging to the company, was a visiting professor at University of Arizona in 2016 and has co-authored with professors from the University of Arizona since then.^{68 69 70}

⁵⁵ "Tongfang gufen youxian gongsi er ling yi qi nian niandu baogao" [Tongfang Co., Ltd. Annual Report 2017]. Tsinghua Tongfang, <http://www.thtf.com.cn/uploadfiles/file/201804/13.pdf>.

⁵⁶ "Geren jianjie" [Personal profile]. Sina Finance, <https://archive.is/oPVZy>.

⁵⁷ Tongfang Yixu Laser Tech (北京同方亿讯激光科技有限责任公司)

⁵⁸ Chaoguang Tech (同方中科超光科技有限公司)

⁵⁹ Beijing Tongfang Zhike Technology Co., Ltd. (北京同方智科科技有限公司)

⁶⁰ Harbin Shipbuilding Special Equipment Technology Development Co., Ltd. (哈尔滨哈船特装科技发展有限公司)

⁶¹ "Geren jianjie" [Personal profile]. Sina Finance, <https://archive.is/oPVZy>.

⁶² Chinese corporate registry third-party aggregator

⁶³ "Beijing tongfang hua guang xitong keji youxian gongsi" [Beijing Tongfang Huaguang System Technology Co., Ltd.]. Zhongguancun Science Park Management Committee, <https://web.archive.org/web/20210325000647/http://www.zgcnwth.com/qiyefuwu/companyInfo/detail?id=2382>.

⁶⁴ "Tongfang hua guang huode shuang gaoxin shuang zhiliang tixi zizhi rending" [Tongfang Huaguang obtained double high-tech double quality system qualification certification]. THSystems, 26 Feb. 2021, <https://archive.ph/9LHuL>.

⁶⁵ "Gong Mali." X-Mol, <https://archive.ph/0IYVq>.

⁶⁶ "Tsinghua-Hitachi Via Laser Laboratory." Department of Precision Instrument, Tsinghua University, 3 Sep. 2012, <https://archive.ph/4dTTQ>.

⁶⁷ Akatsuka, Masakazu, et al., inventors. High-speed-contactless measurement data communication system and communication method thereof. 13 Dec. 2009. Japanese Patent 2009282965A, Google Patents, <https://patents.google.com/patent/JP2009282965A/en>.

⁶⁸ "Huang Lei." X-Mol, <https://archive.ph/gq6XO>.

⁶⁹ Aftab, Ahab, et al. "Dynamic metrology and data processing for precision freeform optics fabrication and testing." Fourth European Seminar on Precision Optics Manufacturing, 15 June 2017, <https://doi.org/10.1117/12.2272353>.

⁷⁰ "Prof. Lei Huang." LOFT, Large Optics Fabrication and Testing group with OEFF & RFCML, <https://web.archive.org/web/20210415134959/http://www.loft.optics.arizona.edu/members/researcher/dr-lei-huang-%E2%80%8B/>.

In other cases, Tsinghua Tongfang investments have turned the work of Tsinghua professors into successful surveillance exports. Beijing Global Safety Technology (北京辰安科技股份有限公司), which Tsinghua Tongfang helped establish and from which it has since divested, has been behind notable global surveillance projects. After getting its start domestically, the company has helped take China's surveillance apparatus to Latin America according to reports in Chinese and foreign media. In Ecuador, it helped build a police surveillance system that local critics fear is enabling democratic backsliding.^{71 72 73} In Venezuela, it built the VEN 911 system, designed to "speed up the response capacity of the police and military agencies" according to a story in a Chinese newspaper.⁷⁴ The system was featured in Freedom House's 2020 report on Venezuela's growing surveillance state.⁷⁵

Public records indicate that Beijing Global Safety Tech was founded by two Tsinghua professors who have continued to work both at the company and at Tsinghua: Yuan Hongyong (袁宏永), a professor of Public Safety Research and Chairman of Beijing Global Safety Technology, and Fan Weicheng (范维澄), a researcher at the Tsinghua University-Hefei Public Safety Research Institute and a director at Beijing Global Safety Technology.^{76 77} As professors, Yuan and Fan are active in global research networks. Yuan was a visiting professor at Loughborough University in the United Kingdom in 2012, where Fan holds an honorary degree.^{78 79} Fan was also reportedly put in charge of a Boeing-Tsinghua joint lab established in 2010.⁸⁰ As the reported founders of one of China's most successful exporters of surveillance technology, Yuan and Fan have profited considerably. Corporate registry records show that both individuals draw salaries upwards of one million RMB (150,000 USD) per year from the company, in addition to owning about 18 million RMB (2.75 million USD) worth of shares between the two of them.⁸¹

Beyond Tsinghua Tongfang, another Tsinghua joint venture with CNNC, Chinergy Co., Ltd. (中核能源科技有限公司), uses Tsinghua researchers and Tsinghua patents to design nuclear reactor technology for CNNC according to corporate registry records. Two of Chinergy's directors, Tang Yaping (唐亚平) and Wang Gehua (王革华), work concurrently at the Tsinghua Institute of Nuclear and New Energy Technology as Secretary of the Party Committee and a researcher, respectively, according to Tsinghua websites.^{82 83} Wang also continues to advise doctoral candidates there.⁸⁴ Through Tang, Wang, and its relationship with the institute as a whole,

⁷¹ "Qinghua keyan guanlian ci: Gaige.chuangxin.yinling" [Key words of Tsinghua's scientific research: reform, innovation and leading]. Tsinghua University, <https://archive.ph/3jm8V>.

⁷² "President Xi praises emergency monitoring system highly." China Daily, 23 Nov. 2016, https://web.archive.org/web/20210415144454/https://www.chinadaily.com.cn/business/2016-11/23/content_27471565.htm.

⁷³ Mozur, Paul, Jonah M. Kessel and Melissa Chan. "Made in China, Exported to the World: The Surveillance State." New York Times, 24 Apr. 2019, <https://www.nytimes.com/2019/04/24/technology/ecuador-surveillance-cameras-police-government.html>.

⁷⁴ "Mingmen zhihou chen an keji: Shexian yinman guanlian jiaoyi" [Mingmen Chenan Technology: Suspected of concealing related transactions]. Time Weekly, <https://archive.ph/SIRi7>.

⁷⁵ "Freedom on the Net 2020: Venezuela." Freedom House, <https://freedomhouse.org/country/venezuela/freedom-net/2020>.

⁷⁶ Li Zhengwei. "Chen'an keji: Cong shiyan shi dao quanqiu shichang de chuangxin yangban" [Chenan Technology: Innovative samples from laboratory to global market]. GSafety, 30 Sep. 2016, <https://archive.ph/NIXmH#selection-1319.30-1319.33>.

⁷⁷ Chinese corporate registry third-party aggregator

⁷⁸ "Yuan Hongyong." Department of Engineering Physics, Tsinghua University, <https://archive.ph/NtreH>.

⁷⁹ "Fan Weicheng." Tsinghua University, <https://archive.ph/x2WJm>.

⁸⁰ Wang Zhuoqiong. "Companies Boeing, Tsinghua open research center." China Daily, 21 Oct. 2010.

https://web.archive.org/web/20200720005259/https://www.chinadaily.com.cn/business/2010-10/21/content_11440455.htm.

⁸¹ Chinese corporate registry third-party aggregator

⁸² "He yan yuan dangwei shuji tangyaping" [Tang Yaping, Secretary of the Party Committee of the Nuclear Research Institute]. Tsinghua University Party Committee Propaganda Department, <https://archive.ph/gfO3w>.

⁸³ "Wanggehua, he yan yuan yanjiuyuan" [Wang Gehua, Researcher, Institute of Nuclear Research]. Tsinghua University Master of Engineering Management (MEM) Education Center, <https://archive.ph/6Mu6e>.

⁸⁴ Ibid.

Chinergy gains access to Tsinghua's research, according to patent records. In total, 162 of 238 patents licensed to the company were transferred from Tsinghua.⁸⁵

Joint ventures with defense conglomerates, of course, only capture part of the risk picture within Tsinghua's investment networks. Beyond the military context, Tsinghua's investment network plays an active role in China's efforts to advance domestic capabilities in critical technology sectors. Many of these investments are made by Tsinghua Holdings Technology Transfer (华控技术转移有限公司), which has backed the ventures of prominent Tsinghua professors like Andrew Yao (姚期智), a Turing Award-winning computer scientist who renounced his U.S. citizenship in 2015 through a Chinese Academy of Sciences program for the return of foreign scholars to China.⁸⁶ Policymakers may determine that these sorts of investments also pose a risk that must be considered when evaluating a partnership. The following section examines a case in which the primary risk within a university corporate network comes from companies in which defense conglomerates are not invested.

⁸⁵ Chinese corporate registry third-party aggregator

⁸⁶ "'Duihua' yangzhenning, yaoqizhi: Wo weisheme fangqi waiguo guoji?" ["Dialogue" Yang Zhenning and Yao Qizhi: Why did I give up my foreign nationality?]. Xinhua, 21 Feb. 2017, <https://archive.ph/OKwP5>.

BEYOND SHARED EQUITY: HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Shared equity analysis does not provide an exhaustive picture of the risks that emanate from university corporate networks. C4ADS investigated Huazhong University of Science and Technology's (HUST) corporate network because it shared an investment with a defense conglomerate, but found that the defense industry ties of other companies within the HUST network were more significant than those of the joint venture. Namely, though these other HUST investments are not joint ventures with defense conglomerates, they are key suppliers of defense conglomerates, using HUST technology to meet the needs of military end-users according to corporate registry records and online reports.

HUST, which ranked eleventh among Chinese universities for patent strength as of 2016,⁸⁷ is a shareholder in Wuhan KaiMu Information Technology Co., Ltd. (武汉开目信息技术股份有限公司), a smart manufacturing company in which CASIC, a Chinese missile manufacturer, also has stake.⁸⁸ The company lists the aviation, aerospace, and weapons industries as its top three industries, and counts CASIC, AVIC, CASC, NORINCO, CSGC, CSSC, and CETC—the full roster of China's most prominent defense conglomerates—among its customers.⁸⁹ But this shared investment is only one of HUST's points of exposure to China's military-industrial complex.

HUST participates in a broad range of defense procurement activities through its wholly-owned subsidiary, a laser technology company called Wuhan HUST High-Tech Group Co., Ltd. (武汉华中科技大学大产业集团有限公司). Wuhan HUST High-Tech Group “holds a leading market share in important industries such as shipbuilding, telecommunications, and national defense and military production” according to its corporate website.⁹⁰ Chinese corporate records indicate that it is invested in 66 different companies.⁹¹

One of Wuhan HUST High-Tech Group's investments, Wuhan Focunergy Laser Co., Ltd. (武汉飞能达激光技术有限公司), counts many of the PLA's prominent defense conglomerates among its partners, including AVIC, CASIC, NORINCO, and now sanctioned entities like the Three Gorges Corporation and China Communications Construction Company.⁹² ⁹³ Wuhan Focunergy Laser Co. uses HUST research to partner with those companies: of 69 patents licensed to the company according to corporate registry records, 57 were originally filed by HUST.⁹⁴

⁸⁷ “Faming zhuanli zuixin 50 qiang gaoxiao chulu” [The latest top 50 universities for invention patents are released]. China National Intellectual Property Administration, 23 Mar. 2017, <https://archive.ph/Szgqa>.

⁸⁸ Chinese corporate registry third-party aggregator

⁸⁹ Chinese corporate registry third-party aggregator

⁹⁰ “Huagong keji chanye gufen youxian gongsi 2000 nian zai shenzhen zhengquan jiaoyi suo shangshi” [Huagong Technology Industry Co., Ltd. was listed on the Shenzhen Stock Exchange in 2000]. HUST High-Tech Group, 26 Sep. 2019, <https://web.archive.org/web/20210406142104/http://cyjt.hust.edu.cn/info/1076/1251.htm>.

⁹¹ Chinese corporate registry third-party aggregator

⁹² Chinese corporate registry third-party aggregator

⁹³ “Hezuo huoban” [Partners]. Wuhan Focunergy Laser Co., Ltd., <https://archive.ph/WISZi>.

⁹⁴ Chinese corporate registry third-party aggregator

Through another Wuhan HUST High-Tech Group investment, Wuhan Huazhong Numerical Control Co., Ltd. (also known as Huazhong CNC 武汉华中数控股份有限公司), HUST has played a pivotal role in China's development of computer numerical control (CNC) technology, an important tool for creating aerospace, weapons, and radar technologies.⁹⁵ ⁹⁶ The company was the brainchild of HUST Professor Zhou Ji (周济), who would go on to become mayor of the city of Wuhan and then Vice Minister of Education.⁹⁷ ⁹⁸ Zhou "realized the extreme importance of CNC technology to China's national defense security and economic security," according to an article linked on the company website.⁹⁹

The company's development was hampered when it was designated by the U.S. Department of State from 2008 and 2010 for alleged violations of the Iran, North Korea, and Syria Nonproliferation Act.¹⁰⁰ But with the assistance of a domestic government program designed to spur domestic CNC technology development, the company invested in a massive R&D program, spending between 20 and 30 percent of operating revenues on R&D for three years.¹⁰¹ In the cases assessed earlier, it was defense industry investments that helped fuel the growth of university-backed companies; Wuhan Huazhong Numerical Control Co., Ltd., meanwhile, drew on government subsidies to support its growth according to an article on the corporate website.¹⁰²

While Huazhong CNC's funding came from generous state programs, much of its intellectual property came directly from HUST. Of 244 patents obtained by Huazhong CNC between 2008 and 2019, 121 (49.6%) had originally been applied for by HUST. Nearly 200 different HUST faculty members, researchers, and graduate students worked on patents that were licensed to Huazhong CNC, among them academics who studied in Australia and the United States.¹⁰³ ¹⁰⁴ ¹⁰⁵ ¹⁰⁶ The company's chairman, one of its directors, and one of its supervisors all continue to work as HUST professors.¹⁰⁷

The technology developed through the Huazhong CNC-HUST partnership, in turn, is reportedly deployed by the military. As early as 2008, the company had become the first domestic CNC

⁹⁵ Chinese corporate registry third-party aggregator

⁹⁶ Ye, Ronan. "CNC Machining Use Cases in the Military and Defense Industries." 3ERP, 6 July 2020, <https://www.3erp.com/blog/cnc-machining-use-cases-in-the-military-and-defense-industries/>.

⁹⁷ "Chule xinpian, qia bo zi huan you gaodang shukong xitong" [In addition to the chip, the card neck also has a high-end CNC system]. Huazhong CNC, 8 Aug. 2019, <https://archive.ph/l4vNW>.

⁹⁸ Zheng, Xinrong. "Jiaoshou pouxu zhouji congzheng zhi lu cheng shi 'lingdao xue jingdian anli'" [The professor analyzes Zhou Ji's political career and calls it a "classic case of leadership"]. Changjiang Daily, 12 June 2010, <https://archive.ph/UgyXU>.

⁹⁹ "Chule xinpian, qia bo zi huan you gaodang shukong xitong" [In addition to the chip, the card neck also has a high-end CNC system]. Huazhong CNC, 8 Aug. 2019, <https://archive.ph/l4vNW>.

¹⁰⁰ "Bureau of Verification, Compliance and Implementation: Imposition of Measures Against Foreign Persons, Including a Ban on U.S. Government Procurement." The United States Department of State, 23 Oct. 2008, <https://www.federalregister.gov/documents/2008/10/23/E8-25316/bureau-of-verification-compliance-and-implementation-imposition-of-measures-against-foreign-persons>.

¹⁰¹ "Chule xinpian, qia bo zi huan you gaodang shukong xitong" [In addition to the chip, the card neck also has a high-end CNC system]. Huazhong CNC, 8 Aug. 2019, <https://archive.ph/l4vNW>.

¹⁰² "Chule xinpian, qia bo zi huan you gaodang shukong xitong" [In addition to the chip, the card neck also has a high-end CNC system]. Huazhong CNC, 8 Aug. 2019, <https://archive.ph/l4vNW>.

¹⁰³ "Songping He." GovSalaries, 2016, <https://govsalaries.com/he-songping-29699319>.

¹⁰⁴ Liu, Hongqi, et al., inventors. *Online monitoring method for turning stability of digital control machine tool*. 2 January 2013. Chinese Patent 102284888B, Google Patents, <https://patents.google.com/patent/CN102284888B/it>.

¹⁰⁵ "Jianjie" [Resume]. ORCID, https://orcid.org/0000-0002-2404-9971?lang=zh_CN.

¹⁰⁶ Li, Bin, et al., inventors. *Numerical control machine tool wear monitoring method*. 5 June 2013. Chinese Patent 102091972B, Google Patents, <https://patents.google.com/patent/CN102091972B/en>.

¹⁰⁷ "Huazhong shukong: 2020 Nian niandu baogao" [Huazhong CNC: 2020 Annual Report]. Sina Finance, 1 April 2021, <https://archive.ph/es9EJ>.

provider for China's military.¹⁰⁸ This was technology "urgently needed by the national defense, military, and shipbuilding industries," according to an article on Huazhong CNC's website, a case of "China's 'brain' equipping the Republic."¹⁰⁹ It continues to spend lavishly in the area, and in 2020 its second highest development expenditure was for a "Military-use High-power Servo Driver."¹¹⁰ It also has invested in robotics subsidiaries that manufacture for the military and are considered of growing importance to PLA officials, according to posts on their corporate websites.¹¹¹ ¹¹²In 2017, China's ten leading defense conglomerates selected Wuhan Huazhong as their bulk CNC provider.¹¹³

The case of HUST demonstrates the role university-backed companies can play in connecting university research to the military-industrial complex even when there is no equity-based financial connection.

¹⁰⁸ "Zhongyang lingdao guanzhu huazhong shukong de fazhan" [Central leaders pay attention to the development of Huazhong CNC]. Huazhong CNC, 25 Aug. 2006, <https://archive.ph/P5UU8>.

¹⁰⁹ "Huazhong shukong: Rang zhongguo 'danao' wuzhuang zhongguo zhuangbei" [Huazhong CNC: Let China's "brain" arm China's equipment]. Huazhong CNC, 11 Nov. 2008, <https://archive.ph/CeAHL>.

¹¹⁰ "Huazhong shukong: 2020 Nian niandu baogao" [Huazhong CNC: 2020 Annual Report]. Sina Finance, 1 April 2021, <https://archive.ph/es9EJ>.

¹¹¹ "Zhongguo weisheme yao fazhan gongye jiqiren?" [Why should China develop industrial robots?]. Huazhong Industrial Robot, 29 Sep. 2020, <https://archive.ph/4Mtt8>.

¹¹² "Junmin ronghe cu fazhan | 95112 budui zhengzhi gongzuo bu yang fuqiang shangxiao lu jiceng dangwei, zhibu shuji lilin hua shu jiqiren shen guan xuexi" [Military-civilian integration promotes development | Colonel Yang Fuqiang of the Political Work Department of the 95112 Army leads the grassroots party committee and branch secretary to visit Huashu Robotics]. Huazhong Industrial Robot, 14 Sep. 2018, <https://archive.ph/lg76R>.

¹¹³ "Huazhong shukong: Daguo zhong qi de xiyu you" [Huazhong CNC: The joys and worries of the big country heavy equipment]. Huazhong CNC, 6 Aug. 2018, <https://archive.ph/N0ATK>.

CONCLUSION

China's military-civil fusion strategy aspires to better integrate the country's key innovators with China's military-industrial complex. University investment networks are one means of achieving this goal. Through companies in these networks, university faculty and university patents can flow to the defense industry, as defense money in turn shapes the research direction of academics.

While defense conglomerates use university-invested companies to obtain key technologies, foreign universities and policymakers can use these companies as a means of identifying Chinese university researchers and labs with ties to the Chinese military. Future research should aim to develop more tools for honing understanding of networks of risk within Chinese academia and China's political economy, in order to enable foreign decision makers to continue to engage Chinese academia and Chinese businesses without inadvertently engaging the Chinese military.

APPENDIX I: LIST OF DEFENSE CONGLOMERATES USED IN ANALYSIS

Conglomerate Name (English)	Conglomerate Name (Chinese)
China Aerospace Science and Industry Corporation (CASIC)	中国航天科工集团有限公司
Aviation Industry Corporation of China (AVIC)	中国航空工业集团有限公司
China Electronics Technology Group Corporation (CETC)	中国电子科技集团公司
China National Nuclear Corporation (CNNC)	中国核工业集团有限公司
China North Industries Group (NORINCO)	中国兵器工业集团公司
China State Shipbuilding Corporation (CSSC)	中国船舶工业集团有限公司
Commercial Aircraft Corporation of China (COMAC)	中国商用飞机有限责任公司

APPENDIX II: LIST OF UNIVERSITIES USED IN ANALYSIS

University Name (English)	University Name (Chinese)
Anhui University	安徽大学
Beijing Institute of Technology	北京理工大学
Beijing University	北京大学
Beijing University of Aeronautics and Astronautics (Beihang University)	北京航空航天大学
Beijing University of Chemical Technology	北京化工大学
Beijing University of Posts and Telecommunications	北京邮电大学
Central South University	中南大学
Changchun University of Science and Technology	长春理工大学
Chongqing University	重庆大学
Chongqing University of Posts and Telecommunications	重庆邮电大学
Chongqing University of Technology	重庆理工大学
Dalian Minzu University	大连民族大学
Dalian University of Technology	大连理工大学
Donghua University	东华大学
East China University of Technology	东华理工大学
Fuzhou University	福州大学
Guilin University of Electronic Science and Technology	桂林电子科技大学
Hangzhou Dianzi University	杭州电子科技大学
Hangzhou Normal University	杭州师范大学
Harbin Engineering University	哈尔滨工程大学
Harbin Institute of Technology	哈尔滨工业大学
Harbin University of Science and Technology	哈尔滨理工大学
Hebei University	河北大学
Hebei University of Science and Technology	河北科技大学
Hefei University of Technology	合肥工业大学
Heilongjiang Institute of Technology	黑龙江工程学院
Heilongjiang University	黑龙江大学
Henan University of Science and Technology	河南科技大学
Huazhong University of Science and Technology	华中科技大学
Hunan University	湖南大学
Hunan University of Science and Technology	湖南科技大学
Jiangsu University of Science and Technology	江苏科技大学
Jilin University	吉林大学

Kunming University of Science and Technology	昆明理工大学
Lanzhou University	兰州大学
Lanzhou University of Technology	兰州理工大学
Nanchang Aviation University (Nanchang Hangkong University)	南昌航空大学
Nanchang University	南昌大学
Nanjing Normal University	南京师范大学
Nanjing Tech University	南京工业大学
Nanjing University	南京大学
Nanjing University of Aeronautics and Astronautics	南京航空航天大学
Nanjing University of Posts and Telecommunications	南京邮电大学
Nanjing University of Science and Technology	南京理工大学
North University of China	中北大学
Northwestern Polytechnical University	西北工业大学
Shandong University	山东大学
Shandong University of Technology	山东理工大学
Shanghai Jiaotong University	上海交通大学
Shanghai University	上海大学
Shenyang Ligong University	沈阳理工大学
Shenzhen University	深圳大学
Shijiazhuang Tiedao University	石家庄铁道大学
Sichuan University	四川大学
South China University of Technology	华南理工大学
Southeast University	东南大学
Southwest University of Science and Technology	西南科技大学
Sun Yat-Sen University	中山大学
Suzhou University	苏州大学
Tianjin Polytechnic University	天津工业大学
Tianjin University	天津大学
Tongji University	同济大学
Tsinghua University	清华大学
University of Electronic Science and Technology	电子科技大学
University of Science and Technology Beijing	北京科技大学
University of Science and Technology of China	中国科学技术大学
University of Shanghai for Science and Technology	上海理工大学
University of South China	南华大学
Wuhan University	武汉大学
Wuhan University of Technology	武汉理工大学
Xiamen University	厦门大学
Xiangtan University	湘潭大学

Xidian University	西安电子科技大学
Xi'an Technological University	西安工业大学
Xi'an Jiaotong University	西安交通大学
Xi'an University of Posts and Telecommunications	西安邮电大学
Yanshan University	燕山大学
Yunnan Normal University	云南师范大学
Zhejiang University	浙江大学