The Training, Education, and Deployment of Semiconductor/IC Talent in China[1]

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"…the journey for professionals in the IC industry is an arduous one, and China hopes promising students can become a key pathway towards significant breakthroughs in the industry."

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Comments at the March 2021 Two Sessions Meeting

Overview

The global semiconductor industry grew 20% in 2021 with revenues rising to US$590 billion. That type of growth is expected to continue, albeit with a few bumps along the way, to make it a US$ 1 trillion industry. It is anticipated that the demand for semiconductors and integrated circuits will continue to rise as everything from 5G to artificial intelligence to advanced computing to electric and intelligent vehicles will require this technology to advance ahead. It is important to keep this global context in mind because it is against this backdrop that we can best understand China's evolving role today and in the future. In addition, it is important to recognize that as China continues to push ahead in its efforts to develop and advance its own indigenous semiconductor/IC industry, it is working against a moving target. It goes without saying that the key players in the global semiconductor industry are not standing still simply waiting for China to catch up. The leading international companies are engaged in an all-out effort to sustain their competitiveness by adopting AI technologies, improving their manufacturing processes, and hiring the best qualified talent. As a recent 2023 report by Deloitte suggests, the entire face of the semiconductor industry and the global supply chain for semiconductors are undergoing massive changes as a result of onshoring, re-shoring, nearshoring, and friend-shoring—driven by the continued legacy of the COVID pandemic as well as the new geo-political and national security environment.

In fact, it is safe to say that the entire global semiconductor industry basically is faced with the same challenge—namely to recruit and attract as well as develop and retain the qualified talent

[1] The information contained in this document has been drawn from a wide variety of Chinese and English language sources, including Chinese websites, social media, and government reports. The references have been omitted in the draft and will be inserted at a later time.

needed to support the industry in the years ahead. The search for talent, therefore, is a significant issue among all parts of the semiconductor industry. China's situation is particularly difficult because it is playing a catch-up role as it tries to respond to the increasing number of restrictions placed by the US government and its allies regarding PRC access to advanced semiconductor devices and the equipment and software needed to produce increasingly sophisticated semiconductor chips and integrated circuits. Recent events and efforts inside China may suggest, however, that this search for qualified talent is a relatively new phenomenon. Certainly, the intensity of the effort is of recent origin, but the recognition of the critical place of qualified talent at all levels of the industry is something that has roots going back to the onset of the 21st century. As China's S&T leaders as well as top officials in the electronics, telecommunications, and computer industry, (and the defense sector) have realized, building China into an innovation-driven nation will not occur without the effective harnessing of a talent pool able to meet the needs of all industries in the country. The priority given to the semiconductor and IC sectors has made this need for talent even more imperative. Without a sustainable pipeline of high caliber talent, China's goals for the semiconductor sector, especially in terms of further indigenizing the industry, will be not achievable. This leaves talent either as the potential Achilles heel of the industry or its key source of competitive advancement.

Today, China accounts for approximately 35% share of the global semiconductor market, making it the economy with the largest single share of the global semiconductor market—surpassing the US, EU, Japan, and Taiwan. Its efforts to develop more and more elements of the semiconductor value chain are being driven by not only significant internal demand, but also by the clear recognition that with the imposition of new stringent controls by the US on technology transfer, equipment sales, and advanced chip imports, the country's only hope to meet its growing demand for basic and advanced semiconductors must come from domestic sources. With American citizens prevented from working for Chinese entities engaged in the manufacture or research related to advanced semiconductors, the need for qualified, experienced talent has escalated sharply over the last 2-3 years.

Based on data from 2021, it was estimated that the Chinese semiconductor market was valued at approximately US$190 billion. China-based sources only were able to provide US$31.2 million or 16.7% of the demand. Moreover, only 6.6% of that supply came from PRC owned companies versus international firms operating in China. While there are over 30 major semiconductor projects in place, with many due to come online in 2024-2025, it is not likely that many of the new facilities will be working at the cutting edge defined by industry leaders such as Intel. China's stated goal is to reach 70% self-sufficiency by 2025—a goal that looks unlikely to be met given the present limits on China's access to the equipment and software needed to propel the industry forward at such a rapid pace.

To fully grasp the context in which the talent situation is evolving, it is important to consider five major events that have focused on Chinese semiconductor development. 1) In 2014, China issued its *National IC Promotion Guidelines*. It also established the *National IC Industry Development Investment Fund* (the Big Fund) with approximately US$21 billion in state-backed financing. In 2019, the Fund was renewed with another US$35 billion; 2) In August 2020, the State Council issued policy document *Guofa #8* that laid out important guidelines and tax policies for the development of the industry, including some key recommendations for talent policy (See Appendix). 3) The issuance of the State Council document is aimed at ensuring alignment between key parts of the *14th FYP (2021-2025)* that highlight not only China's broader innovation goals, but also specifically identifies the semiconductor industry as a key target for strong government support and attention; 4) The announcement by SASAC (State-owned Assets Supervision and Administration Commission) in September 2021 that strives to ensure that all SOEs involved in core electronics areas address their shortcomings and operational problems; and 5) The announcement by MoST that the National Key Labs will be expanding their involvement in basic frontier research and key technologies in the semiconductor industry. These five key developments have been complemented by the announced plans of several crucial provincial and municipal governments to put in place initiatives that will carry forward specific projects to support central government priorities for the semiconductor industry. A good example is the Beijing Municipal government, which announced its version of a 14^{th} FYP. In that plan, the Beijing Economic-Technological Area is identified as a base for IC equipment and for building an independent IC industry eco-system. Similar pronouncements were issued by Shanghai, Jiangsu, Zhejiang, and Hubei.

China's Semiconductor/IC Talent Situation

The situation regarding the supply and demand of talent for the PRC's semiconductor and IC sectors is rather complex because of the suddenness with which the pressures for indigenization have increased. With the new regulations imposed on the export of semiconductor technology, equipment and software to China, a range of obvious bottlenecks have emerged, many of which are proving to be extremely difficult to overcome. The situation regarding availability of relevant talent is proving to be one of the most arduous to fix; the answer is not simply to be found in graduating more students from China's colleges and universities, though this is indeed part of the solution to meeting China's growing talent needs. Currently, estimates range from 200-300,000 in terms of the existing and projected shortage of talents to staff the various technical positions in this critical sector. By 2021, it was believed that there were 541,000 persons employed in the semiconductor/IC sector; by the end of 2023, it is estimated that demand will reach 740-760,000 persons. An estimate for 2024 suggests that the demand side will reach 789,000 persons. In 2021, it was estimated there were more than 2800 chip design companies in China; that is a substantial increase over the last 5 years with the big increase occurring from 736 in 2015 to 1362 in 2016 and to 2218 in 2020. In addition, according to SIA in the US, there were nearly 15,000 firms registered as semiconductor enterprises in 2020. Last year, it was calculated that Chinese colleges and universities graduated over 200,000 students who had majored in some facet of semiconductor engineering. However, only about 15-20% of these graduates actually secured jobs in the industry. (In 2020, only 13.77% of the 210,000 graduates chose to enter the industry.)

There are many reasons for this situation. Many graduates simply do not possess the right sets of skills and experience needed by the industry. As noted, among the 100+ institutions with semiconductor related majors, only 42 actually qualify as "high end" institutions in terms of producing high caliber graduates. Among a large number of schools, the faculty don't have ample engagement with industry to understand the needs of the key companies. Many of the textbooks being used are not reflective of the prevailing state of the art. And, a large number of institutions do not have pilot research equipment or production lines for training students appropriately.

There also has been a major shift in the industry in terms of focus as China as gone from a lower end position in the semiconductor supply chain to greater emphasis on designing and producing its own semiconductors. In 2013, 44% of the companies were focused on testing and packaging, but that number has now decreased to 28%. In contrast, in 2013, 32% of the firms were focused on design but by 2020, that number increased to 43%. Manufacturing has remained relatively stable at 24-29% but the demand for qualified talent is projected to increase as China attempts to manufacture more advanced semiconductors and chips on its own.

It must be remembered in considering the learning environment in many of these institutions that universities are not only educating and training future graduates, but they also are engaged in advanced research related to semiconductors, integrated circuits, etc. As the Chinese say, they are "walking on two legs." However, if the research activities are leaning in the theoretical direction for purposes of academic publication rather than practical application, the results do not contribute much to preparing students for their job assignments post-graduation.

Since the big push for educating more graduates specializing in semiconductor engineering and integrated circuit design began, there has been a massive curriculum restructuring among many universities. In 2003, China established integrated circuit design and integrated systems as a major. It became a special major in 2012. Today it is estimated, as suggested earlier, that over 100 colleges and universities have this major. In 2020, China separated integrated circuit science and engineering from electronic science and technology, and established IC science and engineering as a first level discipline. It became one of the 14 key disciplines classified among "interdisciplinary disciplines" that included IC science and engineering and national security studies (12+2=14). This happened through an announcement by the Academic Degree Committee of the State Council and the Ministry of Education. The first level disciplines reflect the high priority fields designated by the Chinese government; through this designation, universities have an approved framework to set up courses and a whole curriculum, recruit professors, recruit students—all to meet the economic and social development objectives stated by the central leadership.   The top ten schools with the highest ranking are: Chengdian

(Chengdu), Xidian (Xian), Peking Univ, Tsinghua Univ, Southeast Univ, Fudan, Shanghai Jiaotong, Nanjing, Zhejiang, Xijiao, and Beijing Post & Telecommunications Univ.

Along with raising the status of the IC science and engineering discipline, 26 colleges and universities were chosen by the Ministry of Education and several other ministerial departments in July 2015 to build national demonstration microelectronics colleges. A group of 9 institutions were selected to be among the first batch of schools to get national level financial support. It was indicated that the remaining 17 would receive funding to move forward at a later time. Two more schools were added (Xiamen University School of Electronic Science and Technology (September 2018) and the Shenzhen-HK School of Microelectronics at the South China University of Science and Technology (February 2-19). Taken together, these 28 schools represent the strongest, highest caliber schools of microelectronics—including semiconductors and integrated circuits—in China (see Appendix).

These demonstration microelectronics colleges were complemented by the establishment of 20 national integrated circuit talent training bases. The roots of these training bases goes back to 2003 when the Ministry of Education first approved the construction of so-called "national IC training bases" at seven universities (later expanded): Peking Univ, Tsinghua, Zhejiang, Fudan, Xian Univ of Electronic Science and Technology, Shanghai Jiaotong, Southeast Univ, Univ of Electronic Science and Technology, and Huazhong Univ of Science and Technology in Wuhan. In August 2004, the Ministry of Education approved six more institutions: Beijing Univ of Aeronautics and Astronautics, Xian Jiaotong, Harbin University of Technology, Tongji Univ, South China Univ of Technology, and Northwest University of Technology. In June 2009, five more universities were approved by the Ministry of Education, including Beijing Univ of Technology, Dalian Univ of Technology, Tianjin Univ, Sun Yat-sen Univ, and Fuzhou Univ. Among these twenty institutions, two are located in the northeast, three are in the northwest, two are located in the south, five are in Beijing/Tianjin, and the remainder are located the Yangtze River Delta.

This buildout of training capabilities has continued to grow. In October 2020, the NDRC and the Ministry of Education held a joint conference about the development of "national integrated circuit industry-education integrated innovation platforms." This initiative is part of the Double First Class project under the Ministry of Education in which the government has designated not only individual universities for special support to become world class, but also specific disciplines within a broader range of universities that may not be qualified as whole for world class status but have selected disciplines that are top notch. Eight universities were identified as active players in the first round: Peking, Tsinghua, Fudan, Xiamen, Nanjing, Huazhong, Univ of Electronic Science and Technology, and Xian University of Electronic Science and Technology. Four of the platforms were under construction and four had feasibility studies under review as of late 2020. The key element of these platforms (as their name suggests) is to enhance the cooperation between universities and specific companies. The level of support ranges from 470 million yuan for Fudan to 200 million yuan for Xiamen University. Each one has a specialized mandate, e.g. Tsinghua is focused on CMOS logic devices and circuits, memory, and sensors. Data regarding the second batch of four schools has emerged with Huazhong in Wuhan getting about 341 million yuan and Xidian in Xian receiving 354 million yuan. According to the Tencent News report, Chengdian and Xidian are the most attractive for potential applicants because they remain in the "A+" category even though they require lower gaokao scores for entrance.

According to a recent article from 191it.com, the China Integrated Circuit Industry and Talent Development Report (2020-21), in 2020, indicated there were approximately 210,000 IC-related graduates; currently, it is expected in 2023 actual demand will reach 76,500. Given the small percentage of how many students chose to enter the industry and the small percentage who meet the requirements of the hiring firms, the report suggests the most current estimate of the overall shortfall (multiyear) will be over 200,000. The problem is that the industry is growing so fast that companies cannot wait for the 4-5 year cycle for students to graduate; in 2021, 106,000 new IC chip-related enterprises were registered, a 33.5% increase from the previous year. This has created the impetus for the emergence of an additional component in the overall training system; a new group of auxiliary training organizations has emerged to cut the time for preparing students for jobs in the semiconductor and IC industry. Since 2020, their numbers have been growing rapidly. The main specializations include chip verification and chip design—initially at a 2:1 ratio. These training firms provide a very intense education to qualified applicants; most applicants have some background in the subject matter to allow them to get a quick jump start. In general, the primary goal of the applicants is to land a job in a big chip firm with lots of upside potential. Competition for jobs is extremely intense; these days many of the applicants are willing to forgo higher salaries in new startup firms for more stable employment in established companies.

With the problem of demand exceeding supply in terms of qualified graduates from universities and training schools, the salaries in the IC sector have started to increase. According to the White Paper on Talent in the IC Industry (2020-21), the average salary in the semiconductor industry increased by 4.75% in 2020 and the growth rate in the IC industry was 8.0%. Estimates are that it reached 9.0% in 2021. Tuition at the training schools is between 20,000-30,000 yuan for a multi-month course. There is a great deal of skepticism among potential applicants as to whether these schools can really secure for them a well-paying job. On the other hand, according to multiple reports, the graduates from the training program often don't meet the expectations of the companies. The key problem in this regard is finding competent teachers who have the type of knowledge and experience required by potential employers. With the number of teachers also in short supply, their salary demands also have increased. All in all, this has created a rather chaotic situation with lots of poaching of employees, poaching of teachers, and even poaching by schools of potential applicants. Perhaps this quote from a co-founder of the IC Xiuzhen Academy captures the situation best:

> *"We are short of people now, and many companies will "dig" each other if they cannot supply talent in the short term. A person*

is in this company today and goes to that company tomorrow. Their salary has tripled as they have changed three companies. This is actually. a great waste of resources. The money has been lost and it has not created much value for the company."

In terms of overall employment, based on the 2021 report on semiconductor talent issued by 51job, a talent search firm, the volume of employees recruited from the market was 236,000 versus 67,000 that were recruited from campuses. Private enterprises in China recruit primarily from the market; private enterprises accounted for 81.3% of the recruitment efforts and provided 79.6% of the jobs from the market. Campus recruitment for private enterprises occurred in only 53.5% of the cases. SOEs recruit primarily from campuses. In 2021, however, they accounted for only 7.2% of the employers, but provided 35% of the jobs for graduates.

The situation regarding talent training and employment mirrors some of the overall problems in the semiconductor industry as it has sought to ramp up in response to US restrictions. In October 2020, the NDRC got involved in addressing what it called "the chaotic situation" facing the industry. The NDRC specifically noted that while "the enthusiasm for domestic investment in the IC industry is constantly rising," too many companies "with insufficient knowledge of IC development have blindly entered into projects." This affects the employment situation as unqualified companies are trying to attract talent without much prospect of business success. The candidates end up in unproductive situations and many leave the sector because they are simply uncomfortable with the uncertainties and problems.

China's University Sector

While the establishment of an array of training schools specializing in semiconductor-related training is valuable, the important role of Chinese universities should not be underestimated. In recent years, China's Ministry of Education, with advice and counsel from the PRC leadership, has put in place a variety of reforms and policy changes to help strengthen the quality of both education and research in both national level and local level higher learning institutions. These efforts have resulted in dramatic improvements in the academic and administrative operations of a large number of institutions. One of the outcomes is that an increasing number of PRC universities are now listed among the top universities in the world.

Of the top 1499 universities ranked in the world, the US has 255 institutions on the list accounting for 17% of the total, while China has 176 institutions on the list, accounting for almost 12%--putting China in the number two spot ahead of the UK, Canada, Germany and France. In the QS 2022 rankings of higher education institutions, Tsinghua was ranked 17th, Beijing University was ranked 18th, and Fudan University was ranked 31st—not a bad result for a country whose higher education system was basically decimated as a result of the turbulence of the Cultural Revolution (1966-1976).

Given these newest rankings and considering the tremendous progress that has been made especially in China's top tier institutions, it should not be surprising to find that universities such as Tsinghua and Beijing University have been asked to play a strategic role in supplying qualified talent. Before engaging in a discussions of the various new initiatives underway, it is important to remember that the ability to create long term competitive advantage in semiconductors derives from three main sources: First, and most obvious, is the ability to master the technological improvements that are occurring across the industry at home and abroad; second, and no less important, is to develop a talent pipeline that can provide the intellectual creativity and ingenuity to push the frontiers of knowledge; and third, is the ability to understand and leverage knowledge and understanding of the economics of the industry and associated managerial requirements at the factory and R&D levels. This last area is often given little, if any, attention, especially in terms of education and training in China. To the best of my understanding, for example, despite the huge growth of MBA education in China, there are few, if any, specialized degree programs in China for preparing future managers and analysts who are trained to understand the specifics of semiconductor business cycles, pricing dynamics, and related issues.

When Intel first opened up its massive 65-nanometer semiconductor facility in Dalian in 2007, it held discussions with the Dalian University of Technology about launching a program to train semiconductor engineering talent for the city, but when it tried to develop interest in a program in the management school about economics and management in the semiconductor industry, there was little to no receptivity. This is not a small problem because taken more broadly it is linked to the dearth of qualified senior managers who have an in-depth understanding of the dynamics of the industry domestically and on a global scale.

Returning to the on-going semiconductor-related initiatives occurring at China's major universities, several seem worthy of attention because of their rapid progress. The configuration of the curriculum and pedagogical approach for educating future semiconductor engineers reflects a key difference with US counterparts. Those being groomed for careers in semiconductors in the US come from a broader array of disciplines, including electrical engineering, chemical engineering, mechanical engineering, physics, chemistry, and information engineering. In China, especially with the heightened focus on meeting specific industry needs, there is greater emphasis on microelectronics as a whole with a dose of physics involved. With some recent exceptions, depth is emphasized over breadth. As the technologies being deployed get more and more complex <u>and</u> the need for a broader perspective becomes more essential to drive new technological advances, the PRC education approach, while yielding short term benefits, may not be pointed in the right direction to solve the bigger problems that lie around the corner.

Another issue is the mix of undergraduate (UG), masters, and PhD students. According to one source, as the semiconductor industry becomes more and more research intensive, and comes to depend more on new knowledge breakthroughs, China's emphasis on UG students also may turn out to be productive in the short term but inadequate to keep China competitive in the future. At present, 80% of the graduates securing jobs have UG degrees, 15%-18% have masters degrees, and less than 5% hold doctoral degrees. This mix will have to change over time so that the R&D side of the equation can be given more support.

One of the most strategic developments associated with the big push on enhancing semiconductor education involves strengthening the ties between industry and universities. In May 2021, the Talent Exchange Center of MIIT and the Industry-Education Integration Research Association of the China Higher Education Society jointly hosted a major conference in Chongqing that included a keynote speech by Li Ning, a director of the MIIT Talent Research Center. The speech emphasized three key points: a) universities need to do a better job of working with companies so that graduates are better positioned to address the problems and issues actually occurring within the companies; b) do a better job of translating research results into solutions applicable to the needs of the IC enterprises; and c) develop effective curriculum that necessarily involves a greater voice from industry so that universities can adjust and adapt their curriculum in the right directions. This call for improved connectivity reverberated across the entire education community and semiconductor/IC industry and has reset the tone for enhancing collaboration in multiple areas.

Five Case Examples

1.Shanghai has become a leader in supporting the central government's big push to meet the semiconductor industry's talent needs today and in the future. It has now set up three campuses in the city to focus on developing talent for the chip industry. One campus is in Jiading district, one in Zhangjiang district, and one in Lingang district. These three campuses are part of the municipal government's plan to make Shanghai into a leading base for the semiconductor industry. In January 2022, an ambitious training program was announced to produce talent to meet the need for qualified employees across the entire semiconductor supply chain. The Lingang project involves Shanghai University and the city's Integrated Circuit Industry Association.

2. Beijing, led by both Tsinghua University and Beijing University, has responded in a comprehensive fashion to the central government's admonishments. In April 2021, Tsinghua formally established a School of Integrated Circuits, which is aimed at development of a world class curriculum for semiconductor education. Their plan is to invite established experts to teach some classes and provide some lectures to establish a strong connection with industry. Tsinghua has been involved in teaching about semiconductors since 1956! Over the last several decades, it has sent 4,000 UG students, 3,000 masters students, and 500 doctoral students to work in the field of integrated circuits. The creation of the school has been accompanied by lots of political fanfare linked to China's push for greater technological self-reliance. Peking University is known as the originator of microelectronics in China. It too has established a School of Integrated Circuits. According to press reports, the unique aspect of the school at Peking University is its multidisciplinary orientation; the curriculum will strengthen the integration of computer science, mathematics, physics, chemistry, material science, and other related fields. Like in most other instances, the launch of the IC school at Peking University was accompanied by lots of fanfare related to serving the national interest as well as making technological breakthroughs.

3. Another interesting example from Beijing involves the case of Beihang University, which is one of the seven sister universities under the MIIT. In 2020, Beihang changed the official name of its microelectronics school to the "School of Integrated Circuit Science and Engineering." Beihang has been involved in a high priority project called "the Excellent Engineer Training Summit Forum," which was held in September 2022. The forum involved the Ministry of Education and SASAC as key organizers. The summit builds on the "spirit" of the Central Talent Work Conference held in 2021 and was focused on strategies in the education and training of engineers as well as ways to promote more in-depth cooperation between universities, enterprises, and research institutes. Other key players in the forum were Tsinghua University, Zhejiang University, Huawei, China Electronic Technology Group, China Aviation Industry Group, and Zhongguancun laboratory. Along with discussions and presentations regarding general engineering, there were at least two important sub-forum on integrated circuits and engineering training. The meeting also provided an opportunity for the China Semiconductor Industry Association and the Ministry of Education to introduce the "Core Star Plan." Developed in April 2022, the plan focuses on key improvements in two areas of education for integrated circuits: 1) improving the skills of college graduates in IC engineering; and 2) enhancing the pre-job training of future employees, which would include developing better internship linkages. The ultimate goal of the entire program is to put in place an "excellent engineer training system" with Chinese characteristics that is of world class quality.

4. In Shenzhen, in June 2021, the Shenzhen Technological University also launched a new school focused on integrated circuits named "the College of New Materials and New Energies." The founding of the school was accomplished in conjunction with the signing of a memorandum of strategic cooperation with the Chinese company SMIC. School officials have indicated their intention to forge close ties with other Chinese firms including Huawei and BYD. Connecting with industry will be a key part of the school's overall strategic positioning.

5. Finally, a different approach to addressing the need for talent in the semiconductor/IC sector is highlighted by the example of Nanjing Integrated Circuit University in Jiangsu province. It falls neither under the jurisdiction of the Ministry of Education or the local provincial government. Instead, it is under the oversight of the Jiangbei New Area Management Committee. Its principal purpose is to work with local industry to solve existing or emerging problems. Founded in October 2020, it will not award degrees; it will provide certificates and its faculty will be drawn from among senior engineers working in local industry. It will not have a traditional faculty.

Final Thoughts

> *"…semiconductors [are] as important for manufacturing as hearts for humans. When your heart isn't strong, no matter how big you are, you're not really strong,"*
>
> Xi Jinping
> April 2018, Visit to YMTC
> (From NYTimes August 29, 2022)

There is little doubt that China has made a comprehensive commitment to developing an array of viable solutions to address its talent shortage across the entire value chain of the semiconductor and IC industry. Over the last 2-3 years in particular, the PRC leadership has not missed a chance to create new momentum and provide substantial financial resources (and incentives) to address the talent needs of this strategically important industry. Achieving greater self-reliance in all aspects of the semiconductor industry is not simply desirable under current circumstances; it has become a top national priority. The Ministry of Education, the MIIT, the NDRC, SASAC, and the MoST all have strengthened their collaboration to enhance the chances for success moving forward. As suggested earlier, however, the difficulty of enhancing China's overall competitive position in semiconductors and ICs is compounded by the fact that the technology and expertise required for success continues to evolve and change at an accelerated pace. The challenge is to see whether China can combine the power of its universities, think tanks like the Chinese Academy of Sciences, National Key Labs, and enterprises to identify breakthrough opportunities.

That said, there still are some very practical problems that must be overcome. It has become clear from the Chinese own assessments of the evolving situation that not every job in this sector requires applicants with advanced degrees. Vocational schools, community colleges, and even the types of specialized schools noted earlier can help to provide solutions to the demand for talent. However, there also is evidence that there are some basic problems that must be addressed, including replacing outdated textbooks, identifying new faculty who are better connected to industry, legal protections so that companies that share their know-how are not putting their IP at risk, increasing the availability of experimental equipment inside schools at all levels, and stabilizing the labor markets so that talent mobility is an asset rather than a liability as it is under the current fluid situation.

Will China come up with a grand solution to meet its talent needs for developing an advanced semiconductor/IC industry? China has sought to utilize the same type of solution that South Korea employed to catch up with Japan in the semiconductor industry; it has tried to hire retired or part-time engineers from South Korea and Japan as well as Taiwan to meet the need for experienced talent. This has partially yielded some positive results, though most recently several former Samsung personnel were charged with violating the company's IP regulations. Taiwan has stepped up its efforts to limit PRC firms from poaching employees from the island's semiconductor and IC firms; there already are a large number of engineers from Taiwan working for mainland companies. This number is being reduced daily. And, any Americans working in China for local Chinese firms have had a leave as noted previously, China's talent recruitment programs also don't seem to offer a comprehensive solution, even though there has been an increase in the number of STEM professionals returning to China over the last 2+ years; the best and the brightest among Chinese-American scientists and engineers still chose to remain in the US in their current jobs.

So, in the final analysis, the burden of solving China's semiconductor talent challenge falls squarely on the domestic education system. In some respects, we can see ample evidence that progress is being made. The five examples cited above highlight how thinking about curriculum and university-industry connectivity have changed for the better. Nonetheless, given the speed of technological advance and the growing need for import substitution to become effective, it is likely that China's talent dilemma in semiconductors and ICs will remain a significant problem for some time into the future. There are many moving pieces involved in achieving the level of self-reliance in semiconductors and IC technology that is needed to remain competitive on a global level. While it is never a good idea to write off China's potential for catching up, there promise to be a plethora of hurdles still out there over the next few years—with the shortage of qualified talent being one of the most serious and consequential.

Appendix

Talent Provisions of the August 2020 State Council Guofa #8

"Several Policies to Promote the High-Quality Development of the Integrated Circuits Industry and the Software Industry in the New Era"

V. Talent Policy

(22) Further strengthen the construction of integrated circuits and software majors in colleges and universities, accelerate the establishment of first-class disciplines for integrated circuits, closely adjust the curriculum, teaching plans and teaching methods in time in line with the needs of industrial development, and strive to cultivate compound and practical high-level talents. Strengthen the construction of integrated circuit and software teachers, teaching laboratories and internship training bases. The Ministry of Education, together with relevant departments, strengthens supervision and guidance.

(23) Encourage qualified universities to adopt cooperation with integrated circuit enterprises to accelerate the construction of demonstration microelectronics colleges. Priority should be given to building and cultivating integrated industry-education enterprises in the field of integrated circuits. For pilot enterprises included in the construction and cultivation of integrated industries and education enterprises, if the investment in the establishment of vocational education meets the regulations, the education surcharge and local education surcharge payable by the enterprise in the current year may be deducted in proportion to 30% of the investment amount. Encourage social-related industry investment funds to increase investment and support college joint ventures to carry out the construction of a special resource pool for the training of integrated circuit talents. Support the School of Demonstrative Microelectronics and the School of Characteristic Demonstration Software to cooperate with internationally renowned universities and multinational companies to introduce foreign teachers and high-quality resources, and jointly train integrated circuits and software talents.

(24) Encourage local governments to commend and reward high-end talents who have made outstanding contributions in the field of integrated circuits and software, as well as high-level engineers and R&D designers, in accordance with relevant regulations of the State, and improve the equity incentive mechanism. Through relevant talent projects, we will strengthen efforts to introduce top experts and outstanding talents and teams. Give priority to exploring relevant policies to introduce integrated circuit and software talents in industrial agglomeration areas or related industrial clusters. Formulate and implement the annual plan for the introduction and training of integrated circuit and software talents, promote the construction of the national integrated circuit and software talent international training base, and focus on strengthening the medium- and long-term training of urgently needed professionals.

(25) Strengthen industry self-discipline, guide the rational and orderly flow of integrated circuit and software talents, and avoid vicious competition.

28 Top Microelectronics Academic Institutions

Number	Name	Number	Name
1	Beijing University	15	Tongji University
2	Tsinghua University	16	Nanjing University
3	Univ of Chinese Academy of Sciences	17	China Univ of S&T in Hefei
4	Fudan University	18	Harbin Inst of Tech
5	Xian Elec S&T Univ	19	Fuzhou University
6	Shanghai Jiaotong	20	Shandong University
7	Southeast University	21	Huazhong S&T Univ
8	Zhejiang University	22	National Defense S&T University
9	Electronics S&T Univ	23	Huanan Polytechnic
10	BUAA	24	Zhongshan Univ
11	Beijing Inst of Tech	25	Xian Jiaotong Univ
12	Beijing Univ of Technology	26	Northwest Polytechnic Univ
13	Tianjin University	27	Xiamen University
14	Dalian Univ of Tech	28	South China Univ of Technology
Source: Ministry of Education			

Ranking of the 42 Top Universities in Electronics Science and Technology

University	Rating	University	Rating
Electronics S&T Univ	A+	Harbin Inst of Tech	B
Xian Electronics S&T	A+	Xiamen Univ	B
Beijing Univ	A	Wuhan Univ	B
Tsinghua Univ	A	Zhongshan Univ	B
Southeast Univ	A	Southeast Polytech	B
Fudan Univ	A-	East China Normal	B
Shanghai Jiaotong	A-	China S&T University	B
Nanjing Univ	A-	Nankai Univ	B
Zhejiang Univ	A-	Beijing Univ of Tech	B
Xian Jiaotong Univ	A-	Nanjing Polytechnic	B
Beijing Posts & Telec	A-	Shandong Univ	B-
BUAA	B+	Hunan Univ	B-
Beijing Inst of Tech	B+	Chongqing Univ	B-
Tianjin Univ	B+	Dalian Univ of Tech	B-
Jilin Univ	B+	Xinan Jiaotong Univ	B-
Defense S&T Univ	B+	Beijing Jiaotong Univ	B-
Huazhong S&T Univ	B+	Hefei Univ of Tech	B-
Northwest Polytechnic Univ	B+	Anhui University	B-
Nanjing Posts & Telec	B+	Fuzhou Univ	B-
Air Force Engineering University of PLA	B+	Army Engineering University of PLA	B-
Hangzhou Electronics S&T University	B+	Xian Polytechnic Univ	B-