U.S. – China Economic and Security Review Commission
China's Pursuit of Next Frontier Tech: Computing, Robotics, and Biotechnology
Panel II: Industrial and Military Robotics

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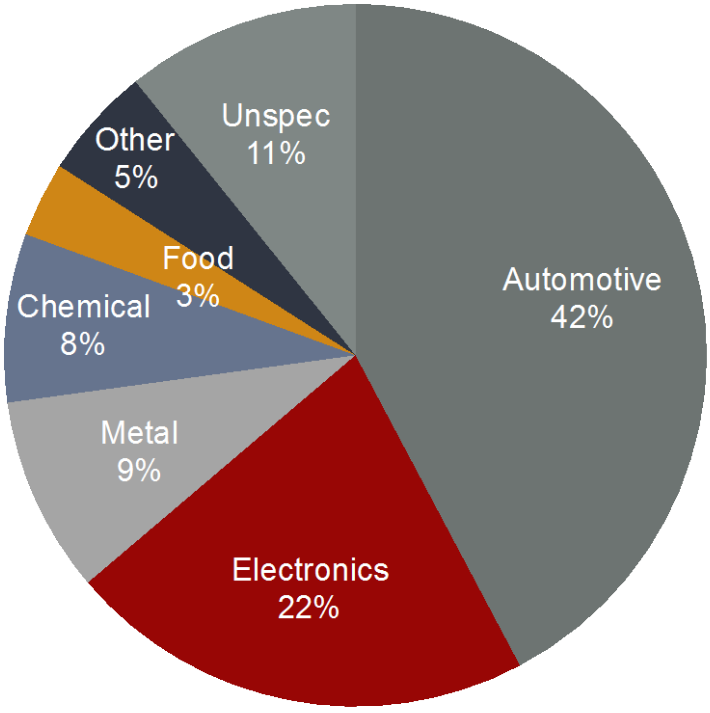
1. Introduction

Robots as a technology was invented in United States about 55 years ago. The initial application was in the automotive sector, which is still the dominant application of industrial robot technology today. Present applications are typically divided into industry, service and defense/security applications. For the service domain, we further subdivide into professional and domestic applications.

The use and sale of robotics is captured in the publication "World Robotics" which is published annually by the International Federation for Robotics (IFR)[1]. The statistics is gathered by the German VDMA through survey data obtained from robotics companies worldwide. The publication is considered a trusted source by the industry. The numbers used throughout this report are adopted from the 2015 edition of the report, unless otherwise noted.

The distribution across application domains of industrial robots is shown in Figure 1. The statistics represent use of robots by 2015.



[1] http://www.worldrobotics.org

Figure 1: Application domains for industrial robots by 2015, according to World Robotics

China is seeing major growth in manufacturing of cars. During 2015 they saw a 6% growth. Close to 31% of all cars manufactured worldwide are made in China[2]. In comparison about 6% of cars are manufactured in USA.

The prototypical view of an auto-manufacturing facility is shown in Figure 2. It is important to note that even the most highly automated factories still have 8 workers for every robot. The factory will utilize a high degree of automation in the plate, the welding and the paint-shop, but the rest of the factory, which includes the main assembly line will have limited automation.

Figure 2. The prototypical image of automotive manufacturing.

Recently there has also been a pickup of robot technology for aerospace manufacturing. The two main applications have been layup of composite material and drilling of holes and insertion of rivets. The motivation has been a need to increase manufacturing volume and reduce backlog.

The industrial robotics industry has an annual turnover of ~$30.5B of which $20B are in systems integration and approximate $10.8B are from direct sales of robot units.

The entire industry has a consolidated annual growth rate (CAGR) of 17% since 2009. The Asia region saw a 41% annual growth 2014-2015 and is by far the fastest growing region worldwide. A total of 254,000 industrial robots were sold during 2015. The predicted growth rate for 2017-2020 is expected to be at the same level.

[2] www.oica.net - 2015 production statistics

In terms of defense / security applications the most obvious area of interest is Unmanned Aerial Vehicles (UAVs). The largest commercial provider of UAVs is DJI which is based in China. The biggest providers of UAV for military applications are General Atomics, General Dynamics and Northrup Grumman Corporation, all of whom are US based. UAV technology will soon find a much broader user-base for inspection, crop dusting, … but also for use in asymmetric warfare. In Syria, there were news reports during February 2017 that a majority of (improvised) aerial bombs were delivered using low-tech UAV systems.

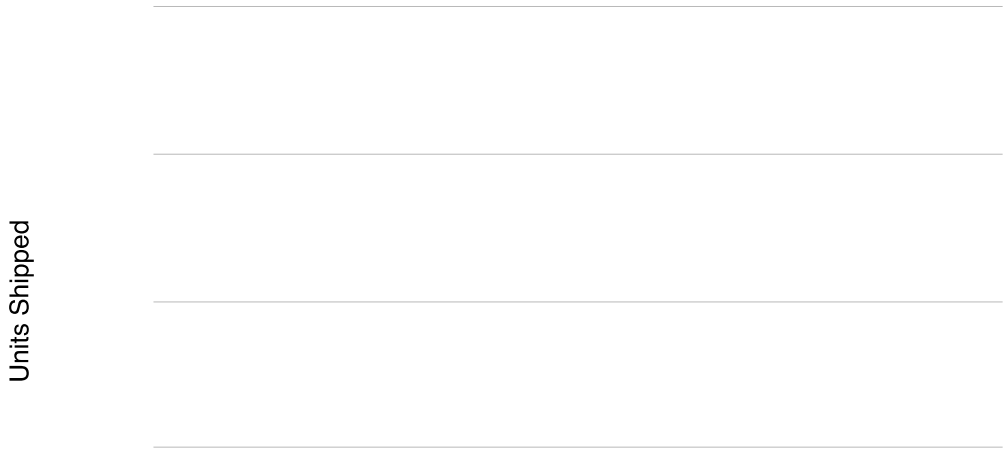


Figure 3: The number of robot units shipped worldwide [World Robotics 2015].

2. Robot use in US and China

Until recently the main market for industrial robots was USA across all segments. USA was the leader in utilization of industrial robotics technology until 2013, where China took over as the main market for robotics and automation. By now Japan and Germany have also overtaken USA in terms of number of robots sold per year. During 2015 China purchased 27% of all robots worldwide.

Typically, the market maturity is determined by the number of robots deployed per 10,000 workers. The highest use of robots is in Republic of Korea where more than 500 robots are used per 10,000 workers or about 1 robot for every 20 workers. Singapore is second and Japan third with 395 and 305 robots / 10,000 workers, respectively. USA has 176 robots / 10,000 workers. The world average is 64 robots / 10,000 workers. China is utilizing 49 robots / 10,000 workers and is significantly below average in adoption of robots for manufacturing.

If the comparison only considers the automotive market, Japan has the highest with 1,400 robots / 10,000 workers. Germany, USA and S. Korea have equal penetration ~1,150 robots / 10,000 workers. China is at 392 robots / 10,000 workers. To match the others for the automotive market China would have to triple its acquisition of robots.

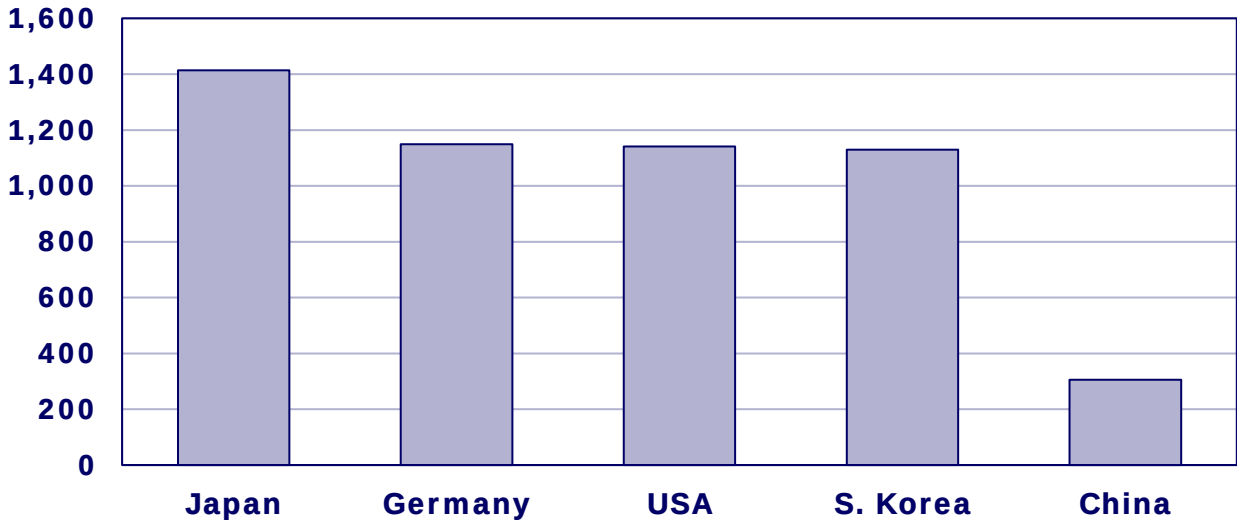


Figure 4: Number of robots in use per `10,000 workers in the automotive sector [WR 2015]

The adoption of robots in the automotive sector has primarily been to ensure consistent quality.

Foreign manufactured cars are typically twice as expensive as domestically manufactured cars in China. Today none of the cars manufactured in China are exported. In comparison BMW is the largest exporter of cars in USA.

A big driver in China has been increasing salaries that have required innovation to bring down / maintain production costs.

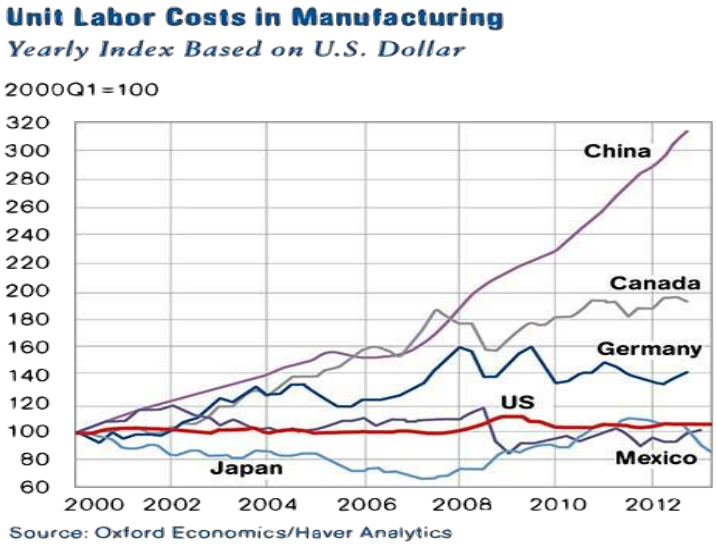


Figure 5 Changes in labor cost over time across several key nations.

3. The growth of a Chinese robot supply base

Today, the main robotics providers in China are FANUC, ABB, KUKA, and Yaskawa. These companies operate in China as joint venture subsidiaries. Already 2001 ABB chose to move their robotics R&D headquarter from Västerås, Sweden to Shanghai.

About 80% of all robots in China are provided by joint venture companies. In parallel several Chinese owned companies have emerged.

The biggest Chinese company is Siasun. The company is a spin-off from the Chinese Academy of Science. They were initially a systems integrator that purchased foreign manufacturing components and integrated them into complete systems. As they got more experience they have launched their own series of robots. Today about 20% of the robots sold in China are manufacturing by Chinese companies. The overall partition of the market is shown in Figure 6.

A challenge for Chinese companies have been access to high quality reduction / precision gears. These gears have almost exclusively been manufactured by the companies Nabtesco and Harmonic Drives in Japan. More recently, a Chinese company has emerged named Harmonious Drives and they produce gears that have a close resemblance to those made by Harmonic Drives.

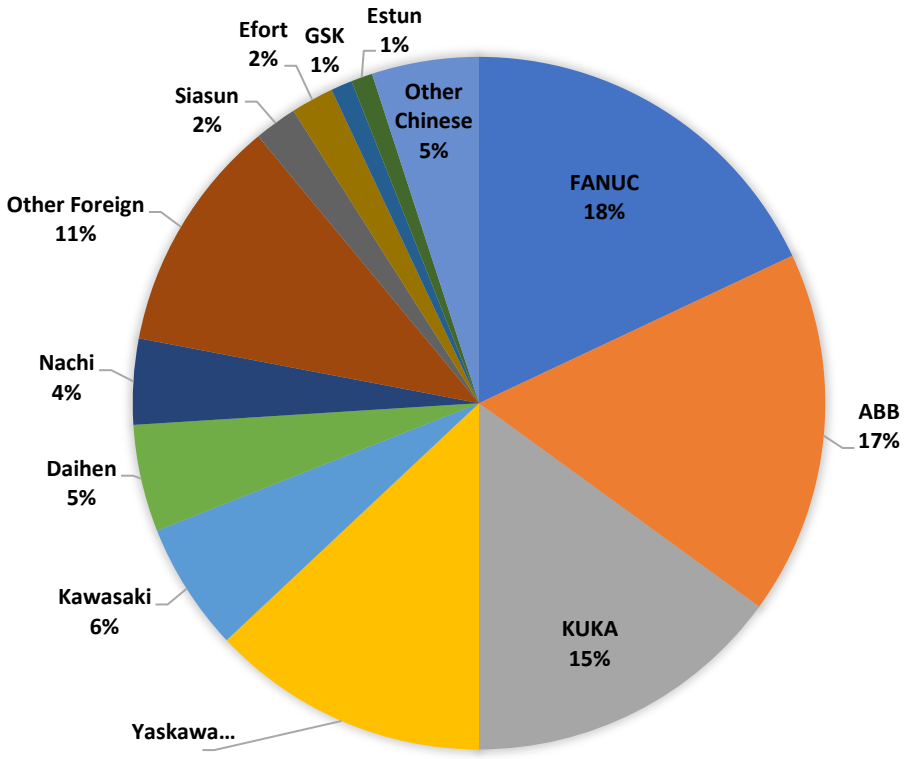


Figure 6: Division of sales across foreign and domestic companies in China for industrial robotics

The Chinese companies have had a reduced accuracy and repeatability compared to foreign manufactured products. A modern US / EU manufactured robot has a repeatability of 0.1 mm (~1/250") and an overall accuracy of about 0.3-0.8 mm. The average lifetime for an industrial robot is 10 years of operation. In comparison, a typical Chinese robot has a repeatability of 0.35mm and an accuracy of 1 mm (1/25") and the lifetime is 3 years.

An obvious question has been – how can China catch up? There are two obvious opportunities: i) accelerate R&D in China and/or international partnering or ii) acquire foreign owned IP and expertise. One such examples that took place during 2016 was the Chinese company Midea acquiring the 2nd largest robotics company KUKA AG (German) at a cost of $4.5B. The acquisition will be finalized during March 2017. No doubt more acquisitions will happen over the next few years.

4. A Chinese ambition for industrial robotics

China has a 3-stage strategy for robotics and manufacturing according to Mr. Wang Weiming, Vice Department Head of Industry Equipment Department of the Ministry of Industry and Information Technology (MIIT): i) a short-term strategy, ii) a 2025 strategy and iii) a long-term 2049 strategy. The first decade 2006-2016 has been devoted to establishing China as a modern manufacturing nation. By 2025 the country wants to be a manufacturing world-power. By 2049 China wants to be the world leader in manufacturing. The overall ambition is outlined in the strategy document "Made in China 2025". By 2025 China would like to have a penetration of robots corresponding to 150 robots / 10,000 workers. It is anticipated that by 2019 40% of the worldwide supply will be installed in China [World Robotics 2016]. To reach the target of 150 robots / 10,000 workers more than 600,000 new robots must be installed within the next 8 years. The worldwide supply during 2016 was 258,000 so it would require a major growth in manufacturing and installation of robots. Consequently, it is obvious why the big market for industrial robots today is China. The US market in comparison is only about 10% of the world supply and the growth rate is predicted to be around 15% per year.

5. The Chinese UAV industry

While most industrial robot manufacturing today is taking place outside of USA the same is not true for the Aerospace Sector where companies such as The Boeing Company, Northrup Grumman Corporation, General Dynamics, Lockheed Martin and General Atomics are significant providers of airplanes and unmanned aerial vehicles (UAVs). Traditionally Boeing and Airbus have been the big providers of commercial airplanes and only now is the Commercial Aircraft Corporation of China, Ltd. (Comac) introducing airplanes that are expected to compete with single aisle airplanes such as the Boeing 737.

In the area of unmanned aerial vehicles the military space has been dominated by companies such as General Atomics, Northrup Grumman and General Dynamics. For non-military

applications companies such as DJI and 3D robotics have been market leaders. Today the biggest provider of drones for the commercial space is DJI. In the US 48% of the FAA registered UAVs are from DJI.

DJI has had a hard time convincing people to move to China to participate in their R&D and they have consequently setup research centers in USA and in Europe. This has been an effective strategy to have basic research carried out in USA and Europe while commercialization and manufacturing is taking place in China. The US company 3D robotics is moving away from the low-end commercial space and Chinese companies such as Ehang and Yuneec are quickly joining DJI to be the leaders in this space. The applications are abundant from infrastructure inspection over environmental monitoring to package delivery. Companies such as UPS and Amazon have announced that they are ready for short-range package delivery and both companies have reported early testing.

The UAV market is about to take off big time for assistance in the logistics space. The platforms will have numerous dual-use opportunities. Is this a space USA can afford to give away?

6. The long-term Chinese strategy

As mentioned earlier the “Made in China 2025” document outlines a clear ambition for robotics in China. The current investments are close to $10B / year. The portfolio of funding is across setup of strong research groups in China, transition of technology for production in China and acquisition of core IP from international companies.

China needs access to core technology to allow them to be the manufacturing leader not only in terms of mass manufacturing products such as cell phones, textile, but also for mass customized products such as cars and airplanes. To this end there is a need to build a strong industrial robotics industry anchored in China, but ideally connection to innovation centers worldwide.

For the defense industry and for unmanned aerial vehicles there is an opportunity for China to be the world-leader not only for low-cost commercial systems, but also for defense applications. Right now the backlog for delivery of commercial airplanes is 5-8 years. COMAC is testing an airplane that may be delivered significantly faster. The fastest growing market for air-traffic is in Asia. Boeing is now delivering 31% of their production to Asia and expect the numbers to grow to 29% by 2035. COMACs creation of a competitive single aisle airplane could challenge this economic growth. The same technologies are not only used for commercial airplanes but also for larger UAV systems as manufactured in the US by General Atomics, Northrup Grumman and General Dynamics. Clearly the commercial UAV industry will also provide core technologies for defense application. No doubt USA is the leader on large scale UAV technology today, but given that more than 50% of the commercial UAV industry is in China today this balance could change quickly.

7. Policy implications?

By far the biggest industrial robotics market today is China. Today market is already 240% larger than the US market and that number is expected to grow over the next decade. The investment in China is at least $10B / year. The corresponding number in the USA is likely around $2B. It is hard to accurately estimate these numbers as big commercial players such as Amazon, UPS, United Technologies, Google, Qualcomm are making major investments and the numbers are in most cases not public. For industrial robots non-US companies are today more likely to invest in China than in USA as the big growth opportunity is in South Eastern Asia. The US market is already relatively mature whereas the Chinese market is still emerging.

For industrial robotics the big companies FANUC, KUKA, ABB, and Yaskawa are already foreign. An emerging market for industrial robotics is collaborative systems, where the two market leaders ReThink Robotics and Universal Robots are controlled by USA investors, but their biggest markets are in Asia.

From a policy point of view there are some obvious opportunities

1. Investment into manufacturing robotics to make USA a competitive market for the future of manufacturing. Next generation manufacturing is in many cases focused on mass customized products rather than mass manufactured products. The single biggest market today is still in the United States. Ensuring that the US market is attractive for manufacturing opens new opportunities to also do the R&D and commercialization domestically.
2. Chinese companies are setting up R&D laboratories in USA as the movement of the best people to China still poses a challenge due to language and cultural barriers. There are regulations in place for Export Control and ITAR, but in many cases these regulations are too slowly adapting to limit broader dissemination of new technology. In addition, it is not clear that these mechanisms are particularly effective. Ensuring that technology is adopted and utilized in USA appears to be a more effective strategy
3. Today adoption of new legal frameworks for UAVs, driverless cars etc appears to be slower in USA than other nations. In addition, in some cases testing of new technology is faster / less restricted in other areas which encourages new research to be performed outside of USA.
4. Traditionally USA has been an innovation leader and attracted the smartest people to do R&D across academia, research laboratories and industry. To compete it will be essential to continue to promote USA as an innovation economy and the best place to innovate.