What we are expecting from this presentation:

A We want to inform you on the most important highlights from this topic

B We need you to take the time to explore the presentation carefully and with a critical mind

C We would like you to write down every comment or idea that emerges while reading this presentation

D We exhort you to share with us a constructive feedback for further improvements

E We invite you to dialog with us if you have any doubt or want to dive into some specific aspects

Robotics

Content

- Intro to robots
- Operational advantages & benefits of robots
- Robots are made of a set of components of hardware & software
- Robotics roadmap: From an advantage to a commodity
- Total Robotics potential market & by industry
- Future main applications of robots
- Industrial robots: Types & Applications
- Industrial robots growth
- Robotics installations in the Manufacturing Industry
- Industrial robots in the Automotive Manufacturing Industry
- Automotive Suppliers initiatives in robotics
- Takeaways & Opportunities

Robots are smart machines that will define competitiveness in a near future

Robot Definition

- A robot is a machine designed to execute one or more tasks automatically with speed and precision. Robots have a movable physical structure, a motor of some sort, a sensor system, a power supply and a computer "brain" that controls all of these elements
- The term **robot** was conceived by the **Czech novelist** Karel Capek in a 1920 play titled Rassum's Universal Robots (RUR)
  - The word **robot** is derived from the Czech term ***robota*** that means **"forced labor"**
- There are as many different types of robots as there are tasks for them to perform:
  - Defense
  - Medical
  - Industry
  - Commercial
  - Security
  - Transport
  - Consumer

Advantages: Robots vs Humans

Productivity

- Produce more accurate and high quality work than humans
- Can work at a constant speed with no breaks

65%

Safety

- Increase worker safety by preventing accidents since humans are not performing risky tasks

31%

Savings

- Reduce wasted material used due to their accuracy
- Save time by being able to produce a greater amount of products

28%

Quality

- Work more precise and accurate
- Increase consistency and quality of the manufactured products

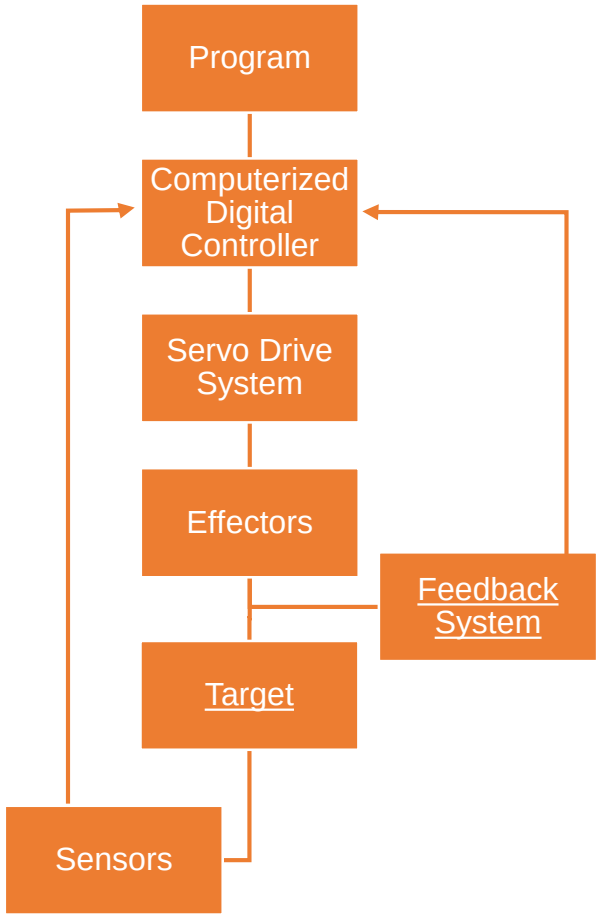
60%

Operational Efficiency
Efficiency/cost reduction
24 hour service
Flexibility/multi-tasking
Information Management

Source: BARCLAYS BANK (2015). Investment in Robotics

Looking more deeply most robotics systems are made up of a set of components of hardware & software

Robot top-process

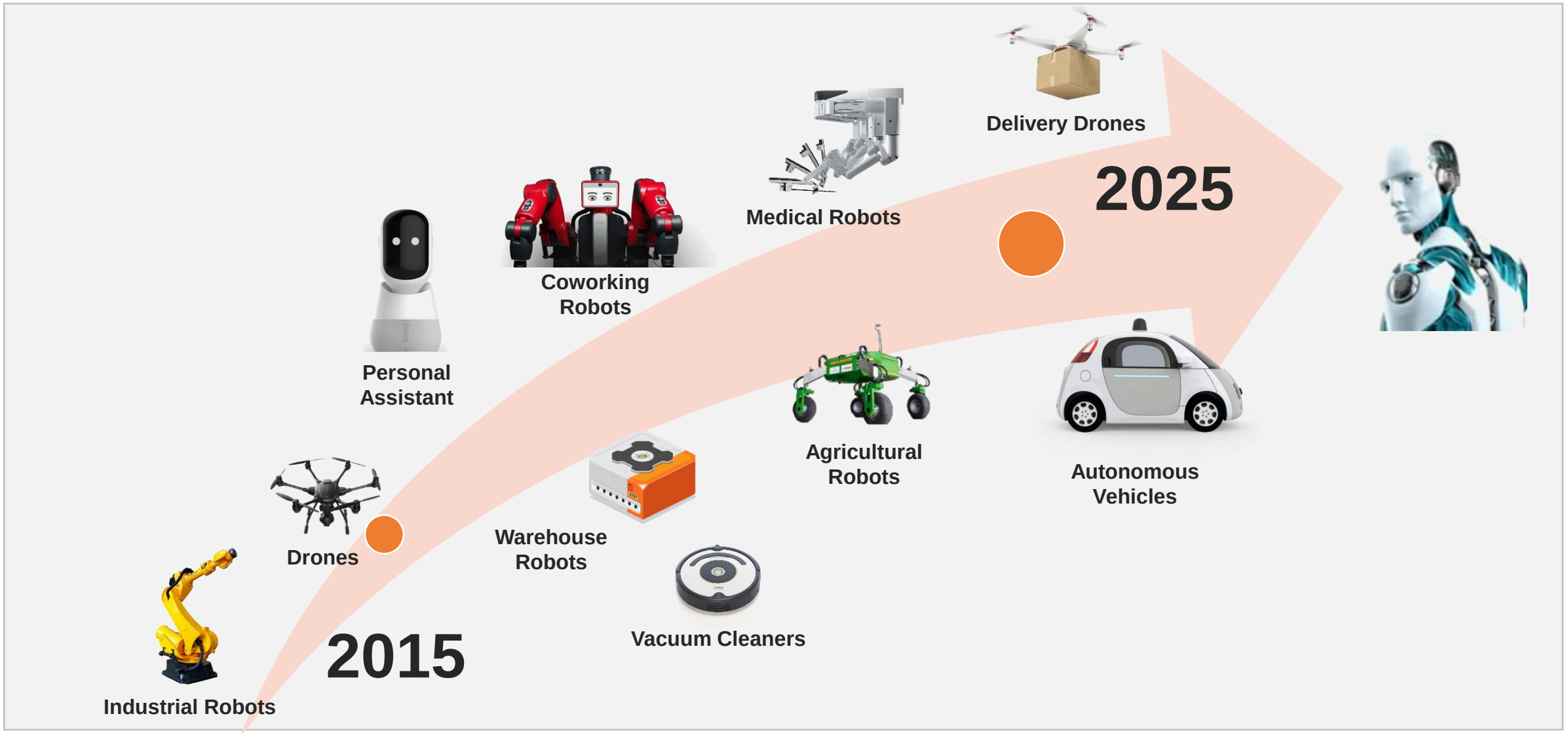


System	Description	% of Cost
Software	Set of coded commands or instructions that tell a mechanical device and electronic system, holistically what tasks to perform	**55%**
Sensors	Allow a robot to gather information about its environment. Measures attributes and interact with external events. Some of the items sensors measure include speed, orientation, and proximity of other objects	**5%**
Controller "Brain"	Determines the robot's behavior. This regulating device initiates one or more functions of operation in the robot arm, such as starting, stopping, reversing, and changing speeds	**5%**
Effectors	The parts of the robot that actually do the work. Effectors can be any sort of tool that you can mount on a robot and control with the robot's computer. For example a gripper, hammer and screwdrivers	**15%**
Servo Drive Systems	The drive is the engine or motor that moves the links into their designated positions. The links are the sections between the joints	**10%**
Structure/Frame	The body of a robot is related to the job it must perform. Industrial robots typically take the shape of a body less arm. The form of a robot needs to follow function	**10%**
~Industrial Robot Price		$50,000 USD

Software is the most valuable element of the robot

Source: CSSI. Parts of a Robot. Christensen, Henrik. Georgia Tech. Stuttgart University

The number of applications for Robots is increasing, making them mainstream



Source: Yole Development (2016). Robots technology roadmap

There are 9 current & future main applications for robots

- BofA Merril Lynch Global Research estimates that by **2020** the robot market would be of **US $83B**

Industrials	Agricultural	Healthcare
 Industrial Robots $24B by 2025	 Agricultural Robots $16.3B by 2020	 Personal &Care $17.4B by 2020
Drones	**Medical**	**Service**
 Drones $14B by 2025	 Surgical $18B by 2022	 Service Robots $18B by 2020
Bionics	**Entertainment**	**Military**
 Exoskeletons $2.1B by 2021	 Entertainment $7.6B by 2022	 Military $7.5B by 2018

Applications	Companies/Startups
Industrial	FANUC ROBOTICS, ABB, DENSO, EPSON, YASKAWA, KUKA, NACHI, Kawasaki, omron, adept
Agricultural	BOSCH, JOHN DEERE, AGROBOT, HARVEST AUTOMATION, ATC
Healthcare	BLUE FROG THE ROBOT COMPANY, aesynt, AVATARMIND
Drones	dji, YUNEEC, 3D Robotics, Parrot, BLADE, UBSAN
Medical	VERB SURGICAL, INTUITIVE SURGICAL, THINK SURGICAL, auris, Medrobotics
Service	fellow ROBOTS, rethink robotics, fetch robotics, robosoft Services Robots, iRobot, savioke
Bionics	REX BIONICS, ReWalk Robotics, HONDA, RB 3D, LOCKHEED MARTIN
Entertainment	REACH ROBOTICS, SONY, SEGA, LEGO
Military	LOCKHEED MARTIN, BAE SYSTEMS, CLEARPATH ROBOTICS

Source: IFR. BofA Merril Lynch Global Research & Markets and Markets

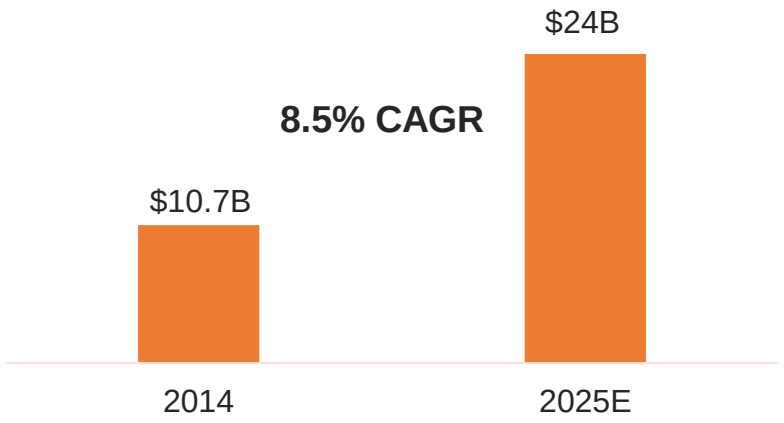
Industrial Robots are worth analyzing due to their expected market of $24B USD and their impact on manufacturing processes

Definition of Industrial Robots:

"Robots designed to move materials, parts and tools, and perform a variety of programmed tasks in manufacturing and production settings. Often used to perform duties that are dangerous or unsuitable for human workers. Ideal for situations that require high output and no errors"

Market Opportunity

- The global industrial robot market is expected to exponentially grow $13bn from 2014 to 2025



- Beyond traditional industrial robots, it is expected a fast growth in Collaborative Robots and a shift from hardware to software

Industrial Robot Applications

Source: IFR. BofA Merril Lynch Global Research & Markets and Markets

There are 6 main types of industrial robots classified according to their type of movement and applications

Articulated

- Feature rotary joints* and can range from simple 2 joint structures to 10 or more joints
- The robotic arm is connected to the base with a twisting joint
- Applications: Welding, material handling, palletizing, painting

Polar

- Consist of a rotary base, an elevation pivot, a telescoping extension, and a retraction boom
- The axes form a polar coordinate system and create a spherical-shaped work envelope
- Applications: Spot welding, material handling, arc welding

Cartesian

- Have 3 linear joints that use the Cartesian coordinate system (X, Y, and Z)
- May have an attached wrist to allow for rotational movement
- Applications: Palletizing and assembly

SCARA

- Feature 2 parallel rotary joints that provide compliance in 1 selected plane
- Selectively compliant arm for robotic assembly is primarily cylindrical in design
- Applications: Assembly, palletizing, material handling

Cylindrical

- Operate within a cylindrical-shaped work envelope and has at least 1 rotary joint at the base and at least 1 prismatic joint to connect the links
- Applications: Assembly and welding

Delta

- Spider-like robots, built from jointed parallelograms connected to a common base
- Robot configuration capable of delicate, precise movement
- Applications: Assembly, picking, material handling

*Joint: The connection of different manipulators

Source: RobotWorx (2017). Main types of robots

The Industrial Robots market is expected to grow 10% annually over the coming decade

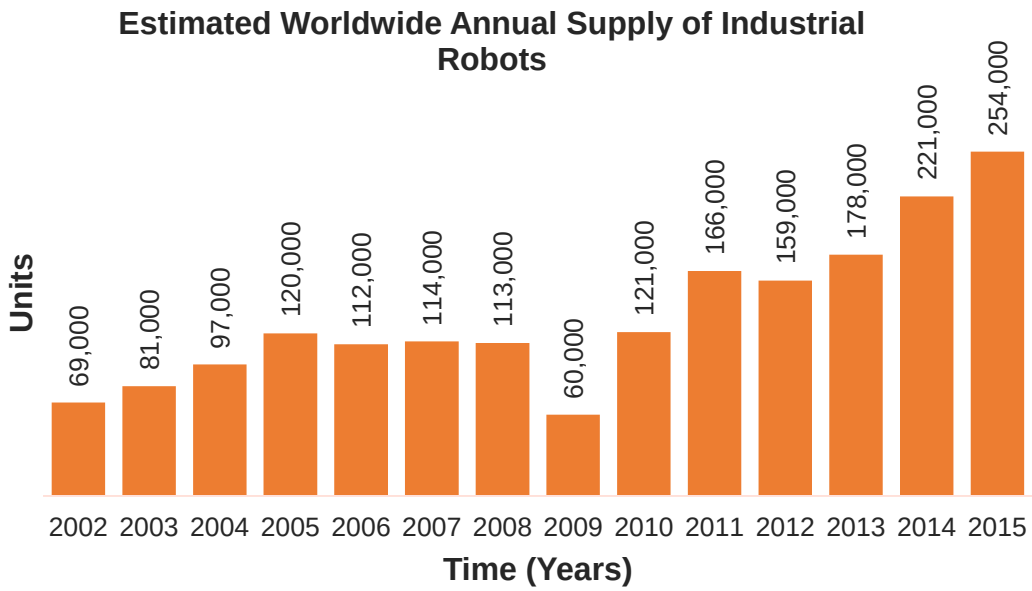
Industrial Robots

- Since **2010**, the **demand** for **industrial robots has accelerated** due to the ongoing trend toward automation. Between this year and 2015, the average robot sales increase was of:

16%

CAGR

- Just in **2015 robot sales** were of **254,000 units**

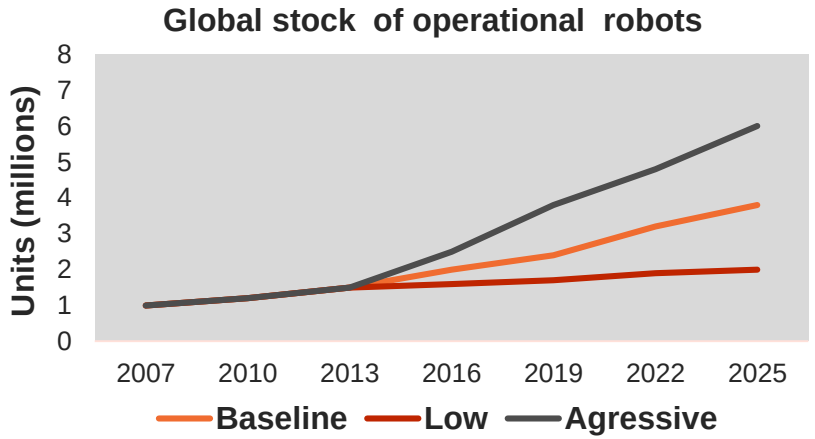


The automotive parts suppliers and the electrical/electronics industry were the main drivers of the growth

Source: IFR. Industrial Robotic Statistics

Robot Installations

- **10% performance improvement each year.** We are reaching the inflection point where companies replace human workers with robotics in many sectors
- **Point to replace human workers with robots is reached when the cost of human labor becomes 15% higher than the cost of robotics labor**
- **Companies** in **China** are **installing robots** in new factories to anticipate the rapid rise in wages for the foreseeable future
- **Industries concentrated in a low cost economy**, such as India; **will be less likely to adopt automation than those based in a high economy**, such as Australia, United Kingdom or United States



Robots are becoming a commodity in the manufacturing industry

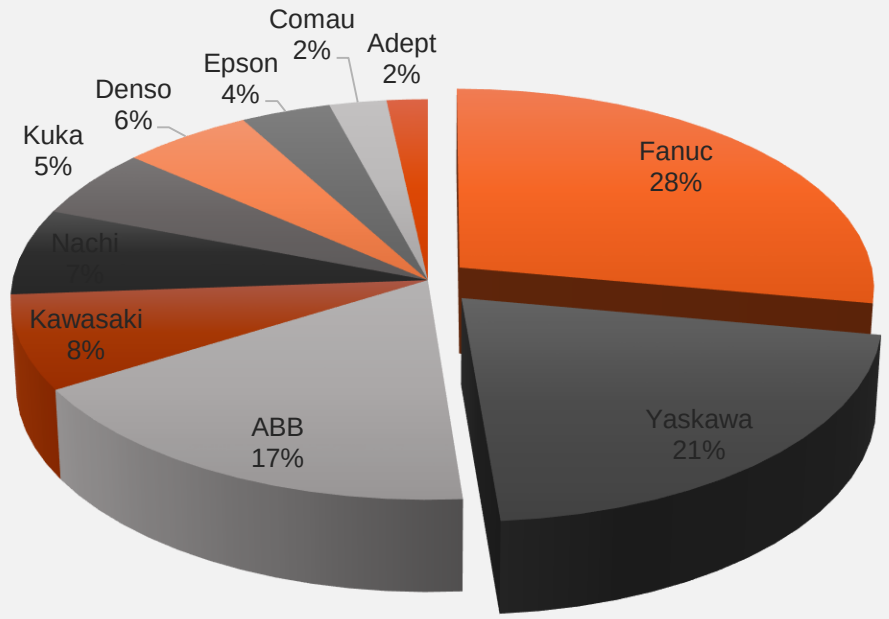
Source: BCG (2016). The Robotics Revolution

Fanuc & Yaskawa are the market leaders in the industrial robot installations

Global Industrial Robots Install Base

- Industrial robots installations are increasing and it will continue, robots will become crucial for every manufacturing plant

Total = 1.43 M units*



Fanuc & Yaskawa account for almost 50% of robot installations worldwide

Leading Industrial Robots Companies

FANUC ROBOTICS

- Only company in its sector that develops and manufactures every single major component, both hardware and software, in-house
- Wide variety of robots and packaged robot cells
  - Arc welding
  - Palletizing
  - Painting
  - Product handling
- From lightweight robots to enormous robots on rails
- New robotics application
  - First heavy duty collaborative robot, it can lift up to 35 kg

YASKAWA

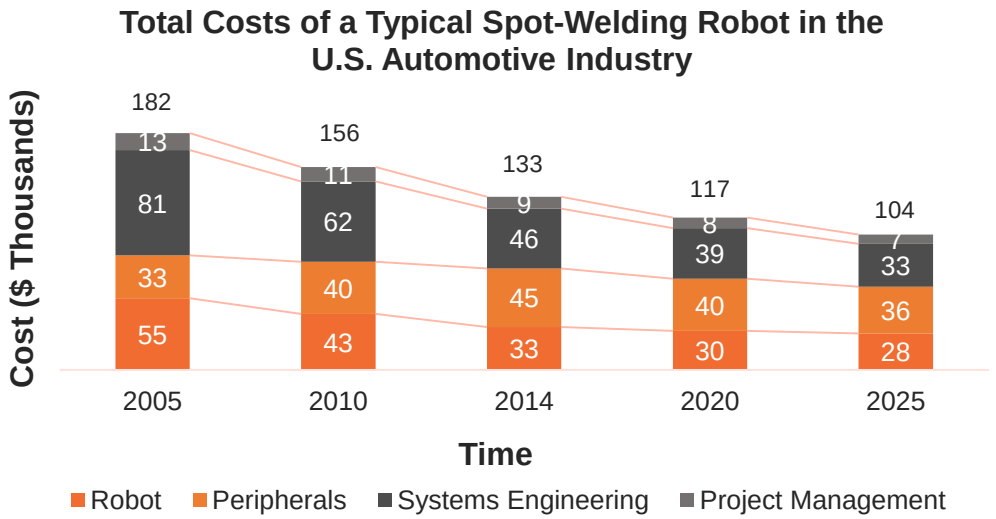
- Provides automation products and solutions for virtually every industry and robotic application
- Product line includes more than 150 distinct industrial robotic arm
- Huge history in robotic welding
- Produce a wide variety of arc welding robots (total = 15)
- Provides integrated robotic welding cells that include Kinetiq Teaching

*Industrial robots install base until August 2016

Source: Robotics & Automation News

Given the cost benefits that robotics bring to production, OEMs around the world place Industrial Robots at the forefront of modern Manufacturing

- For many organizations, the biggest reason for not replacing manual labor with robots is purely economic
- Most organizations begin to ramp up their investment in automation when the cost of employing human labor rises high enough above the cost of owning and operating robotics systems

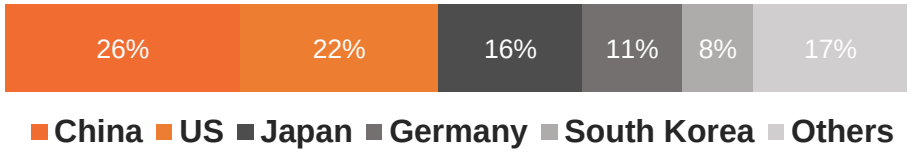


While the costs of advanced industrial robots fall, their performance is steadily improving

- With the use of robots, production lines have become more efficient, flexible, and precise

Industrial Robots → **Auto Industry**

- Over the next decade, **China, United States, Japan, Germany**, and **South Korea** will account for around **80% of robot shipments**
  - By 2025 China and United States alone will account for half of those shipments:



- According to a study made by BCG one of the four industry groups with the **highest number of robots use** its **automotive**

All countries with the top number of industrial robots shipments are manufacturers of auto parts & automobiles

Source: BCG (2016). The Robotics Revolution

OEMs are in the pole position of implementing new industrial robotic solutions in production lines

New Robot Applications

Robotic Vision

- Used for identification and navigation
- Deal with finding a part and orienting it for robotic handling or inspection before an application is performed

Collaborative Robots

- Designed to assist human beings as a guide or assistant in a specific task
- Helps enhance productivity

Robotic Hand

- Helps reduce the stress produced by repetitive movements, increasing productivity and safety

Vision Guided Vehicles (VGV)

- Automated forklifts that transforms the way materials move throughout manufacturing and distribution facilities
- Allows companies to optimize workflow processes

OEMs employing new robotic solutions in their production lines

Human-Robot cooperation in BMW Group Production

- US Spartanburg plant is the first BMW production facility implementing direct human-robot cooperation in series production
- In door assembly, people and robots work side by side without a safety fence

Collaborative Robot in Volkswagen Production Plant

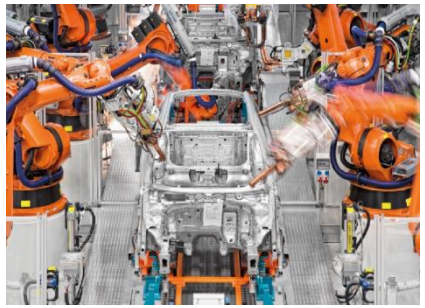
- Volkswagen started up its first "collaborative robot" at its production plant in Salzgitter, Germany
- The robotic arm works in close vicinity of humans and with its collaborative gripper is responsible for handling fragile components

Source: ROBOTIC (2014)

Tier 1 suppliers are bringing on new robot applications into their manufacturing plants to increase efficiency, quality & flexibility

MAGNA

- "The automotive plant of the future will likely include robots that interact with humans and are able to sense when they are near humans"
- A new wave of collaborative robots will likely be introduced at its plants over the next five to 10 years
- There is going to come a time in the future where robots are going to become more intelligent, they are going to become user friendly



– Ian Simmons, Vice President of Business Development of Magna

voestalpine
ONE STEP AHEAD.

- Voestalpine is working on creating future smart factories
- These smart factories will have a significant amount of intelligent robots that will increase:
  - Efficiency
  - Quality
  - Flexibility

Gestamp

- Production has doubled as a result of the use of robots
- "We employ half the amount of people that would have been needed for manual welding. We also use 75 percent less space, and we waste less"

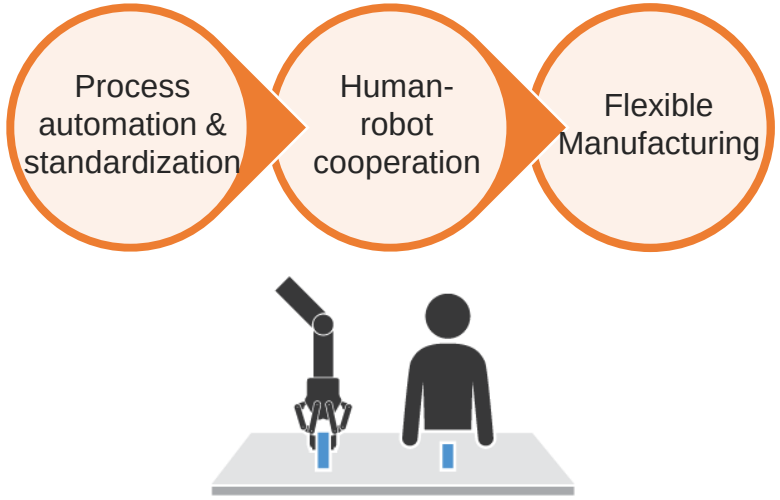
– Mustafa Boga, Mechanical Engineer of Gestamp

The versatility of Collaborative Robots makes them a perfect fit for a wide range of applications in the factory floor

COBOTs

- The **industry is now witnessing the arrival of Collaborative Robots (COBOTs)**
- **Robots that can operate safely alongside** their **human** counterparts on the factory floor
- Can relieve workers from ergonomically unfavorable, repetitive work
- Completely cage free robots equipped with sensors to ensure they stop if they bump into a human

Advantages of working with COBOTs



COBOT Applications

Palletizing

- Great solution for monotonous, but critically important jobs of moving parts to/from tables, conveyors, and fixtures
- Ability to maintain counts, re-orient parts and place them into a specific position

Assembly

- Automation of assembly for products that utilizes fastening methods such as driving of screws, application of glue or other adhesive, welding
- Improve speed and process quality while reducing the risk of injury associated with working in close proximity to heavy machinery

Packing and Packaging

- Can mimic a motion such as packing, moving similarly to a human
- Ability to repeat the action over and over
- Packing and packaging of raw materials, finished goods and multi-pack cases for different types of products and containers

Machine Tending

- Can be used to tend machines and relieve employees of repetitive work
- Ability to integrate with machines for coordinating with the varied cycle times, loading and unloading parts, and supporting finishing operations

Source: COBOTs Guide (2017)

COBOTs for Assembly are expected to succeed in the future due to their flexibility and their impact in production cycles, but first there are some challenges that needs to be solved

COBOTs for Assembly

- **Assembly tasks are becoming more and more automated**
- With the introduction of robots that can work alongside workers, the human robot collaboration is truly a step up. It is now easier, less risky and a lot faster to use a robot on the assembly line
- A **COBOT** act as **"third hand" assistant** on assembly lines by delivering kits, tools, parts, and holding work pieces while the operator works on it
- Nowadays COBOTs can handle assembly of plastics, wood, metals but are venturing on other materials also

Benefits of using COBOTs for Assembly

- Share workspace with employees →Optimization of layout
- Relatively simple to program and integrate
- Flexible assembly manufacturing practices
- Reduce assembly times, increase production, speed, and quality

Challenges

Using COBOTs for time-critical and safety-critical domains, such as assembly of auto parts, brings about several multi-disciplinary challenges

Navigating Automotive Assembly Lines

- COBOTs should be able to operate safely with due consideration of humans in its surrounding

Anticipating Human Motion

- COBOTs should be able to efficiently plan and execute its path in a dynamic and uncertain environment designed for humans

Robot Saliency and Fluency

- Since COBOTs have to operate in automotive assembly lines, which include moving floors, the robots should be able to execute the path on surfaces and not only in obstacles which are not static

Limitations

Payload

- Payload similar to what a human can carry
- 35 kg is the maximum payload COBOTs can handle

Speed

- COBOTs carry out tasks at similar or lower speed than humans
- COBOT speed: ~1.5m/s

The rise of COBOTs for assembly is coming. The major industrial robot companies & startups are competing for being the biggest disruptor

Traditional Companies

FANUC

- Can operate in cooperation with or alongside humans in a shared workspace
- Force sensing and iRVision sensors integrated
- Speed: 0.75 m/s
- Payload: 35 kg

Price/Unit: Not disclosed

YASKAWA

- Safe & flexible interaction
- Force/torque sensor in every axis
- Will be available until the end of 2017
- Speed: Not disclosed
- Payload: 10 kg

Price/Unit: Not disclosed

ABB

- Ideal for human-robot collaboration in small parts assembly
- Ease of use: Lead-through programming
- Speed: 1.5 m/s
- Payload: 0.5 kg

Price/Unit: ~40,000 USD

Startups

rethink robotics

- Like a human arm, allowing them to maneuver around obstacles
- Ideal for environments with line turnover
- Speed: 1.5 m/s
- Payload:4 kg

Price/Unit: ~$30,000 USD

FRANKA EMIKA

- More dynamic than a typical robotic arm due to its torque-control
- Visually intuitive programming
- Speed: 2 m/s
- Payload: 3 kg

Price/Unit: ~$10,500 USD

UNIVERSAL ROBOTS

- Ideal to optimize low-weight collaborative processes
- Ultra flexible table-top robot
- Speed: 1 m/s
- Payload: 3-10 kg (Different models)

Price/Unit: ~$35,000 USD

In a near future, Robots will redefine competitiveness and we need to make sure we are ready for the blue ocean of opportunities

Takeaways

- Cost of robotic equipment is falling sharply, making them mainstream

- The evolution of technology has influenced in the creation of robots in new application fields

- Industrial robots are becoming driving forces behind automotive manufacturing

- Industrial robots are shifting to COBOTs in some applications. MLAB believe COBOTs will be key for flexible manufacturing processes

- In the future what will prove valuable are the applications around robots, not robots themselves. Robot machines will become a commodity

Opportunities

- Robotics is enabling the introduction of new technology to manufacturing plants to become more adaptable & agile
- The automotive industry is being disrupted by the arrival of COBOTs into the manufacturing plants
- COBOTs can impact on workers performance by relieving them of repetitive tasks, so they can handle activities that generate value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